

**89. Jahrestagung und DPG-Frühjahrstagung 2026  
der Sektion Materie und Kosmos (SMuK)**

89<sup>th</sup> Annual Meeting and DPG Spring Meeting 2026  
of the Matter and Cosmos Section (SMuK)

*with its Divisions and the further DPG Division*

*History of Physics,*

*as well as the Working Groups*

Equal Opportunities, Energy; Physics, Modern IT and Artificial Intelligence, Information;  
Physics and Disarmament, Young DPG



Schloss Quelle: FAU

**15 – 20 March 2026**

**Friedrich-Alexander-Universität Erlangen-Nürnberg**

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Verhandlungen der Deutschen Physikalischen Gesellschaft (ISSN 2751-0522 [Online])

Reihe VI, Band 61 (2026)

Zitertitel: Verhandl. DPG (VI) 61, 3/2026

Erscheinungsweise: Jährlich 3 - 6 Online-Hefte, je nach Bedarf

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Dear Conference Guests,

On behalf of the German Physical Society (DPG), I would like to warmly welcome you to the 89. Annual Conference of the DPG and DPG Spring Meeting of the Matter and Cosmos Section (SMuK) at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU).

The fact that the DPG can meet in such a compact setting at FAU, an outstanding institution for science and research, is of inestimable importance for scientific exchange and the public visibility of physics. The FAU will be “occupied” by physics for a week, making the university an international beacon of physics. I would therefore like to express my special thanks to the university for making this conference possible on their premises.

Our DPG Spring Meetings, which attract more than eight thousand participants each year, have been very successful for decades – and they are also regularly among the largest physics conferences in Europe! That alone is a great achievement by all those involved. This year’s outstanding conference programme in Erlangen, with its wide range of topics, comprises various events aiming at strengthening the perception and appreciation of physics in our society: it impressively demonstrates the strength of physics research and the special social responsibility that comes with it, namely to contribute to solutions for major global challenges through scientific findings from basic research.

I would also like to point out that the DPG’s communication focus for 2026 is artificial intelligence in the context of physics. Our goal is to promote discussion within physics and raise public awareness of the relevance of physics to AI research and development – and, last but not least, of the importance of AI in physics studies. Our DPG Spring Meeting in Erlangen, with the participation of the Working Group on “Physics, Modern IT, and Artificial Intelligence” (AKPIK), offers ideal opportunities for promoting these aspects as well.

The success of this Spring Meeting is only possible with the greatest commitment of many persons. I would like to express my sincere thanks to everyone involved. First of all, I would like to thank the Friedrich-Alexander-Universität Erlangen-Nürnberg for their hospitality and support. Many thanks also to the Wilhelm und Else Heraeus-Stiftung for generously supporting all DPG Spring Meetings. I would also like to thank the spokespersons of the DPG Matter and Cosmos Section, Prof. Anna Bakenecker and Prof. Johannes Haller, and the chairpersons of participating DPG divisions and Working Groups for organising the excellent scientific programme.

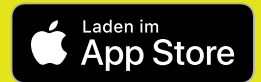
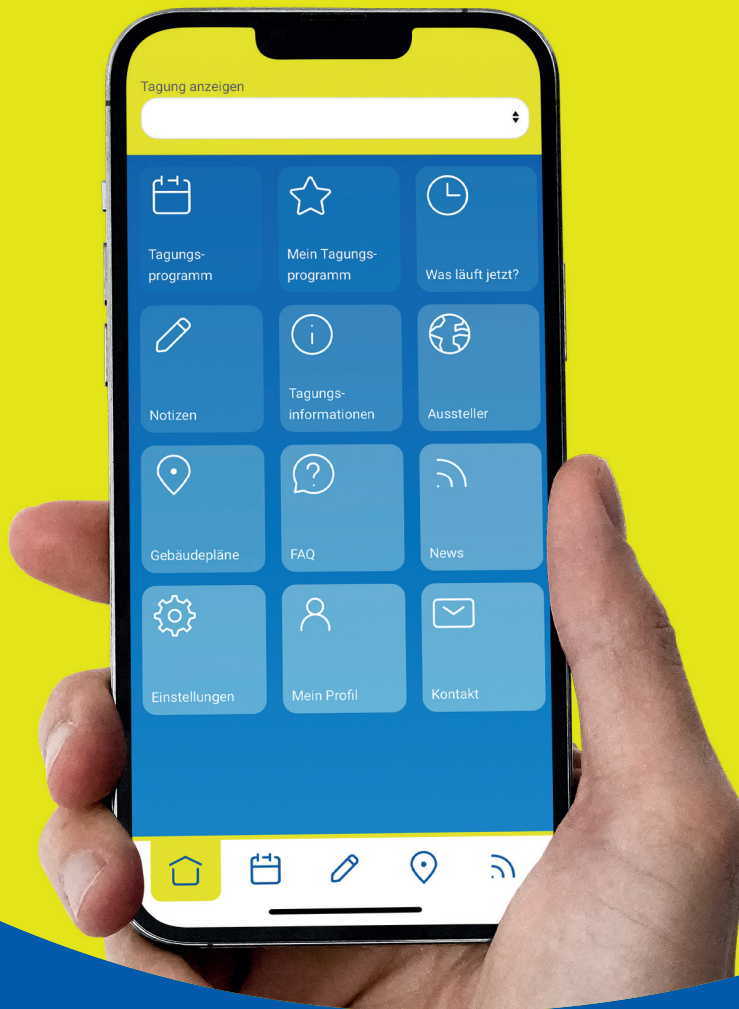
My special thanks go to the local organising committee at FAU, headed by Prof. Stefan Funk, Department of Physics. Finally, I would like to thank the DPG Head Office for its great support of all Spring Meetings.



Prof. Dr. Klaus Richter

President

Deutsche Physikalische Gesellschaft e. V.



# Navigate the Spring Meeting with the **DPG App**!

The DPG app informs you about the conference programme, the venues and the exhibitors. Features such as your personal conference calendar and detailed floor plans simplify finding your way around the conference!

for  
iOS



for  
Android



## Explore conference contributions on the new **DPG Map**.



**CURRENTLY  
IN BETA**

Dive into our network visualization and find related contributions.

Visit our platform at [map.dpg-verhandlungen.de](https://map.dpg-verhandlungen.de)





# Organisation

## Organiser

Deutsche Physikalische Gesellschaft e. V.  
Hauptstraße 5, 53604 Bad Honnef  
Phone +49 (0) 2224 9232-0  
Email [dpg@dpg-physik.de](mailto:dpg@dpg-physik.de)  
Website [www.dpg-physik.de](http://www.dpg-physik.de)

## Local Organiser

Prof. Dr. Stefan Funk  
Lehrstuhl für Physik  
Friedrich-Alexander-Universität Erlangen-Nürnberg  
Nikolaus-Fiebiger-Straße 2, 91058 Erlangen  
Email [erlangen26@dpg-tagungen.de](mailto:erlangen26@dpg-tagungen.de)

## Scientific Organisation

### Chair of the Matter and Cosmos Section (SMuK)

Prof. Dr. Anna Bakenecker  
TU Darmstadt, Fachbereich etit  
Merckstraße 25, 64283 Darmstadt  
Email [bakenecker@dpg-mail.de](mailto:bakenecker@dpg-mail.de)

### Chairs of the Participating Divisions

|      |                                                          |                                                                                                                    |
|------|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| (EP) | Extraterrestrial Physics                                 | – Dr. Alexander Warmuth ( <a href="mailto:awarmuth@aip.de">awarmuth@aip.de</a> )                                   |
| (GP) | History of Physics                                       | – Prof. Dr. Peter Heering ( <a href="mailto:peter.heering@uni-flensburg.de">peter.heering@uni-flensburg.de</a> )   |
| (GR) | Gravitation, Relativistic<br>Astrophysics, and Cosmology | – Prof. Dr. Luciano Rezzolla ( <a href="mailto:rezzolla@itp.uni-frankfurt.de">rezzolla@itp.uni-frankfurt.de</a> )  |
| (HK) | Hadronic and Nuclear Physics                             | – Prof. Dr. Peter Reiter ( <a href="mailto:peter.reiter@ikp.uni-koeln.de">peter.reiter@ikp.uni-koeln.de</a> )      |
| (MP) | Theoretical and Mathematical<br>Physics                  | – Prof. Dr. Martin Zirnbauer ( <a href="mailto:zirnbauer@uni-koeln.de">zirnbauer@uni-koeln.de</a> )                |
| (P)  | Plasma Physics                                           | – Dr. Kian Rahbarnia ( <a href="mailto:kian.rahbarnia@ipp.mpg.de">kian.rahbarnia@ipp.mpg.de</a> )                  |
| (ST) | Radiation and Medical Physics                            | – Dr. Anna Bakenecker ( <a href="mailto:bakenecker@dpg-mail.de">bakenecker@dpg-mail.de</a> )                       |
| (T)  | Particle Physics                                         | – Prof. Dr. Johannes Haller ( <a href="mailto:johannes.haller@uni-hamburg.de">johannes.haller@uni-hamburg.de</a> ) |

### Chair of the Participating Working Groups

|          |                                                   |                                                                                                                    |
|----------|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| (AGA)    | Physics and Disarmament                           | – Prof. Dr. Götz Neuneck ( <a href="mailto:neuneck@me.com">neuneck@me.com</a> )                                    |
| (AGI)    | Information                                       | – Dr. Uwe Kahlert ( <a href="mailto:kahlert@physik.rwth-aachen.de">kahlert@physik.rwth-aachen.de</a> )             |
| (AKE)    | Energy                                            | – Dr. Karl-Friedrich Ziegahn ( <a href="mailto:ziegahn@kit.edu">ziegahn@kit.edu</a> )                              |
| (AKC)    | Equal Opportunities                               | – OStR Agnes Sandner ( <a href="mailto:akc@dpg-physik.de">akc@dpg-physik.de</a> )                                  |
| (AKJDPG) | Young DPG                                         | – Simon Neuhaus ( <a href="mailto:neuhaus@jdpg.de">neuhaus@jdpg.de</a> )                                           |
| (AKPIK)  | Physics, Modern IT and<br>Artificial Intelligence | – Dr. Arash Rahimi-Iman ( <a href="mailto:arash.rahimi-iman@physik.jlug.de">arash.rahimi-iman@physik.jlug.de</a> ) |

## Symposia

SYMD – SMuK Dissertation Prize 2026

### Organisation of the Exhibition of Scientific Instruments and Literature

DPG-Ausstellungs-, Kongreß- und Verwaltungsgesellschaft mbH  
Hauptstraße 5, 53604 Bad Honnef  
Phone +49 (0)2224 9232-0  
Email [info@dpg-gmbh.de](mailto:info@dpg-gmbh.de)  
Website [www.dpg-gmbh.de](http://www.dpg-gmbh.de)

## Programme

The scientific programme consists of **1,580** contributions:

|       |                        |
|-------|------------------------|
| 8     | Plenary talks          |
| 3     | Evening talks          |
| 2     | Prize talks            |
| 1     | Ceremonial talk        |
| 96    | Invited talks          |
| 14    | Invited Overview talks |
| 16    | Invited Topical talks  |
| 1,194 | Talks                  |
| 48    | Group Reports          |
| 192   | Posters                |
| 4     | Tutorials              |
| 2     | Discussions            |

**The programme stated in this document corresponds to the status of the programme as of February 6, 2026 and will not be updated!**

## Information for Participants

The conference will be held March 15 – 20, 2026.

### Conference Information

#### Mutual Respect at Conferences

All participants are requested to contribute to a conference that values respect and a spirit of open communication. Please be mindful in your interactions with other participants – whether during individual sessions or elsewhere during the conference, and consider that individuals with diverse backgrounds may be sensitive to different forms and manifestations of social behavior, scientific criticism, and appreciation. Also note that any form of encroaching behaviour has no place at the DPG's meetings. Do not hesitate to contact the conference's awareness team, the conference office or the local conference organisers in the event of disturbances. The conference organiser will take appropriate action.

#### Conference Venues

Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)  
Audimax  
Bismarckstraße 1  
91054 Erlangen

Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)  
Kollegienhaus  
Universitätsstraße 15  
91054 Erlangen

The main conference venue (housing most lecture halls) are around the Schlossgarten (Kollegienhaus) and around the AudiMax building. A detailed map of the entire conference venue including all buildings with activities can be found at the end of this booklet. The position of the lecture rooms can be found at the DPG App.

#### Conference Office / Information Desk

The conference office and the information desk are located in the Orangerie building on the opposite side of the Schlossgarten from the Kollegienhaus. The opening hours are the following:

|           |          | <u>Registration</u> | <u>Information Desk</u> |
|-----------|----------|---------------------|-------------------------|
| Monday    | March 16 | 08:00 – 19:00       | 08:00 – 19:00           |
| Tuesday   | March 17 | 08:30 – 16:30       | 08:00 – 16:30           |
| Wednesday | March 18 | 08:30 – 16:30       | 08:00 – 16:30           |
| Thursday  | March 19 | 08:30 – 16:30       | 08:00 – 16:30           |
| Friday    | March 20 | 08:30 – 12:00       | 08:00 – 14:00           |

You will receive your name tag, a receipt for your conference fee and the printed short programme at the registration.

The name tag must be worn visibly during the entire conference.

The organisers, the staff of the conference desk, and the student assistants will be identifiable by name tags and  $\Phi$ -T-shirts in a uniform colour. Please contact them if you have any questions.

Do not hesitate to enquire about all necessary information concerning the conference, orientation in Erlangen, accommodation, restaurants, going out, and cultural events at the information desk.

### **Presentations**

Scientific presentations will be held either orally or by poster and will be given in English (conference language) or German.

All lecture halls will be equipped with a projector (16:9) or monitor (16:9) and a computer. Speakers are requested to upload their presentations on the conference website one day before the corresponding session. An email with the access data and the upload deadlines will be sent to the lecturers before the conference. If you require to change your uploaded contribution, you may again upload the document at the latest 4 hours before the session (not the talk) starts. In any case you should also bring a copy of your presentation on an USB drive as a backup.

The file formats accepted for all parallel sessions are pdf and Powerpoint. Own laptops cannot be used for the presentation. The presentations will be transferred to the provided PCs/laptops in the lecture hall before the session.

All lecture halls will be opened, at the latest, 30 minutes prior to the talks. Speakers are requested to be in the lecture hall at least 20 minutes prior to the start of the session, reporting to the chairperson of the session as well as the technical staff, to ensure that the presentation upload was successful, and to receive a brief introduction to the equipment in the lecture hall. If you need other presentation facilities, please ask for availability at the information desk as soon as you arrive at the conference.

Usually, presentations will have the following durations:

- Contributed talks: 15 minutes including discussion time and speaker change (12 min talk + 3 min discussion / speaker change).
- Invited talks: 30 minutes including discussion time and speaker change (25 min talk + 5 min discussion / speaker change).
- Plenary talks: 45 minutes without discussion time.

For further information please contact the division or working group at which you will be giving the presentation.

### **Poster Presentations**

The site for poster sessions is located in the Redoutensaal on the 1<sup>st</sup> floor next to Markgrafentheater. Posters must fit within a rectangle 85 cm wide and 120 cm high (DIN A0, portrait format).

The poster boards will be marked with the number according to the scientific programme. Authors are asked to mount their poster once the poster board with the corresponding poster number is prepared. Usually this will be arranged in the morning, or one hour before the session when there are several poster sessions per day. Each poster should display the number according to the scientific programme.

For the mounting of the poster please use the prepared pins/strips at the poster frame or contact the available student staff. The presenting authors should be at hand for discussion at their poster during at least half of the poster session and should note this time at the poster. The posters have to be removed after the session. **Any posters remaining on display will be removed and disposed without requesting your permission.** The conference management accepts no liability for the posters.

### **Broadcast of Plenary Talks**

All plenary talks will be presented in the AudiMax and broadcast in the lecture hall „Großer Hörsaal“ in the building „Alte Mathematik“.

### **Wilhelm and Else Heraeus Communication Programme**

Important notes for participants who apply for a grant in the WEH Communication Programme:

When registering at the conference office, you will receive your receipt of the conference fee along with a certificate for the WE-Heraeus Communication Programme. **Please keep this document safe.** Participation in the conference must be certified at the conference office with a stamp on the WEH receipt on the day of departure. You have the possibility to leave the stamped certificate with the staff members of the DPG (recommended!) or submit it to the DPG head office (weh@dpg-physik.de) by **April 3, 2026 at the latest**. For more detailed information refer to [weh.dpg-physik.de](http://weh.dpg-physik.de).

The Deutsche Physikalische Gesellschaft thanks the Wilhelm and Else Heraeus Foundation for the generous finan-

cial support of young academic talents. We hope that young physicists will continue to seize the offered opportunity for active scientific communication at scientific conferences. A total of about 44,800 young academics were supported by this programme so far.

### **Communication / Internet Access**

The FAU is a member of the eduroam union. If your university is also part of the eduroam union, you can use the university WiFi in all buildings via your own eduroam account. Alternatively, you can use the "FAU-Event" network.

### **Catering**

Coffee breaks: Coffee and tea are offered for free in the foyer of the following lecture hall buildings during the breaks.

|                  |                    |                                 |
|------------------|--------------------|---------------------------------|
| AudiMax:         | Monday             | 09:45 - 11:00 and 15:45 - 16:15 |
|                  | Tuesday to Friday  | 10:30 - 11:00 and 15:45 - 16:15 |
| Kollegienhaus:   | Monday to Friday   | 10:30 - 11:00 and 15:45 - 16:15 |
| Alte Mathematik: | Monday to Thursday | 10:30 - 11:00 and 15:45 - 16:15 |
| Hörsäle Medizin: | Friday             | 10:30 - 11:00                   |

Lunch: Erlangen offers a wide variety of options for lunch close to most lecture buildings, especially around the Schlossgarten.

### **Cloakroom**

Participants are asked to look after their wardrobe, valuables, laptops and other belongings. A cloakroom and luggage storage is available at the information desk at the Orangerie during the opening hours.

### **Notice Board**

All changes to the conference programme (i.e. cancellation of presentations, change of rooms, etc.) are also transferred directly to the online version of the programme which will be updated continuously and is available in different formats (sorted by publication date, filterable by conference parts and as an rss-feed). Please use the form [erlangen26.dpg-tagungen.de/programme/notice-board](http://erlangen26.dpg-tagungen.de/programme/notice-board) to notify changes or cancellations.

### **Lost Property**

You can hand in lost property at the information desk. During the conference, you can also collect your lost property there or afterwards at ECAP Laboratory, Nikolaus- Fiebinger- Straße 2, 91058 Erlangen.

### **Liability Exclusion**

Participants are asked to look carefully after their wardrobe, valuables, laptops and other belongings. There can be no liability assumed.

### **SAY CHEESE!**

The DPG Spring Meetings are basically public to the press. Please note: On behalf of DPG, photos and videos will be recorded during the Spring Meetings. In the context of public relations, these recordings (as the case may be) will be published on our website, in social media or within prints of the DPG for example.

### **CO<sub>2</sub> Compensation for the DPG Conferences**

By decision of its council, the DPG will compensate for fossil CO<sub>2</sub> emissions resulting from mobility for DPG conferences and committee meetings.

### **Acknowledgement**

The Deutsche Physikalische Gesellschaft (DPG) and the local organisers want to thank the following institutions for supporting the conference:

- the Wilhelm and Else Heraeus Foundation, Hanau
- the Friedrich-Alexander-Universität Erlangen-Nürnberg
- the sponsors of the conference
- and all staff who make the success of the conference possible.

### **Sponsors of the DPG Spring Meeting Erlangen 2026**





## **Social Events** (in chronological order)

### **Welcome Address**

At the occasion of the conference opening, the local organisers will give a welcome address on Monday, March 16, from 9:00 until 9:15 in the lecture hall AudiMax, Bismarckstraße 1, 91054 Erlangen.

### **Welcome Evening**

Monday, March 16, 19:00 – 21:30, at Heinrich-Lades-Halle, Rathausplatz 1, 91052 Erlangen

On Monday, the Welcome Evening will be held in the Heinrich-Lades-Halle. All registered participants are kindly invited. Snacks and drinks will be served. Register in time (08:00 to 19:00) and do not miss the opportunity to meet people in informal atmosphere. Please wear your name tag which you have received during registration.

### **Exhibition of Scientific Instruments and Literature**

From Tuesday, March 17, to Thursday, March 19, there will be an exhibition of scientific instruments and literature in the foyer of the AudiMax, Bismarckstraße 1, 91054 Erlangen. Companies (see list of exhibitors at the end of this booklet) will present their products. Opening hours are from 10:30 to 18:30. All conference participants are welcome to attend the exhibition. The entrance is free.

### **Ceremonial Session with Award Ceremony**

On Tuesday, March 17, at 13:45 the Ceremonial Session with Award Ceremony will take place in the AudiMax. The programme is as follows:

#### *Music*

#### **Welcome**

Prof. Dr. Stefan Funk, FAU Erlangen-Nürnberg  
Local Organiser

Prof. Dr. Joachim Hornegger  
President of the FAU Erlangen-Nürnberg

Dr. Florian Janik  
Mayor of the city of Erlangen

#### **Speech**

Prof. Dr. Klaus Richter, Universität Regensburg  
President of the Deutsche Physikalische Gesellschaft

#### *Music*

#### **Award Ceremony**

##### **Max-Planck-Medal 2026**

to Prof. Dr. Kurt Kremer, MPI für Polymerforschung, Mainz

##### **Stern-Gerlach-Medal 2026**

to Prof. Dr. Andrea Cavalleri, MPI für Struktur und Dynamik der Materie, Hamburg /  
University of Oxford, United Kingdom

##### **Dissertation Prize of the SMuK Section 2026**

*(The Laureate will be announced at the award ceremony on Tuesday)*

#### **Ceremonial Lecture**

Prof. Dr. Karl Jakobs, Universität Freiburg

*"The Higgs boson – Deciphering its nature at present and future colliders"*

#### *Music*

#### **Prize Lecture**

Prof. Dr. Mathias Bartelmann, Universität Heidelberg

*"Between fascination and abstraction. Is it possible to teach modern physics at high-schools?"*

---

## jDPG Pub Crawl

Tuesday, March 17, 21:00, Meeting Point: Eiweiher of the FAU (directly in front of the NatFak building).

If you need a breather during the conference or want to take the opportunity to network with others, join us on a lively pub crawl through Erlangen. We will wander through the pubs in groups, enjoying good drinks, great company and the chance to discover the local bar scene. Bring a good mood and energy – it's going to be a great evening!

## Evening Lectures

- **Public Evening Lecture** (in german language)

Tuesday, March 17, 19:00 – 20:00, AudiMax

Prof. Dr. Claudio Kopper and Dr. Christopher van Eldik, Friedrich-Alexander-Universität Erlangen-Nürnberg, will speak about *“Zu Wasser, zu Eis und in der Luft: Astroteilchenphysik mit Gammastrahlung und Neutrinos.”*

- **Lise-Meitner-Lecture**

Wednesday, March 18, 19:00 – 20:00, AudiMax

Prof. Dr. Michèle Heurs, Leibniz Universität Hannover, will speak about *“Gravitational wave astronomy – quo vadis?”*

- **Max-von-Laue-Lecture**

Thursday, March 18, 20:00 – 21:00, AudiMax

Prof. Dr. David Gross, will speak about *“My journey in Nuclear Physics—Quantum Chromodynamics and the threat of nuclear annihilation.”*

The Evening Lectures are open for the interested public and all conference participants. The entrance is free.

## Members' Assemblies of the Divisions

During the conference, the members' assemblies of the participating divisions will take place. Please refer to the scientific programme for the time and place of the meetings.



Österreichische  
Physikalische  
Gesellschaft



Deutsche Physikalische Gesellschaft

## Prof. Dr. Michèle Heurs

Leibniz Universität Hannover, Hannover, Germany

Deutsches Zentrum für Astrophysik (DZA), Görlitz, Germany

Deutsches Elektronen-Synchrotron DESY, Zeuthen, Germany

# Gravitational wave astronomy – quo vadis?

Meitner  
Lise Lectures 

© Silvia Steinbach

Öffentlicher Abendvortrag  
Friedrich-Alexander-Universität  
Erlangen-Nürnberg  
Bismarckstraße 1  
91054 Erlangen

Audimax

Eintritt frei

Mittwoch, den 18.03.2026 um 19:00 Uhr

[www.lise-meitner-lectures.de](http://www.lise-meitner-lectures.de)

## Synopsis of the Daily Programme

### Sunday, March 15, 2026

#### AKjDPG

|       |           |            |                                                                                                           |
|-------|-----------|------------|-----------------------------------------------------------------------------------------------------------|
|       |           |            | <b>Tutorials</b>                                                                                          |
| 14:00 | AM 00.014 | AKjDPG 1.1 | Quantising Gravity: The Path from General Relativity to Loop Quantum Gravity<br>•Kristina Giesel          |
| 15:00 | AM 00.014 | AKjDPG 1.2 | Jets 101: Reconstruction, Calibration, and Substructure at the LHC<br>•Chris Malena Delitzsch             |
| 16:00 | AM 00.014 | AKjDPG 1.3 | Probing hot and dense QCD matter with dileptons<br>•Anton Andronic                                        |
| 17:30 | AM 00.014 | AKjDPG 2.1 | Resource-Aware Deep Learning: Tracking Energy Consumption in Scientific AI Applications<br>•Kevin Schmitz |
|       |           |            | <b>Sessions</b>                                                                                           |
| 14:00 | AM 00.014 | AKjDPG 1   | jDPG Tutorials                                                                                            |
| 17:30 | AM 00.014 | AKjDPG 2   | jDPG/AKPIK Programmierworkshop                                                                            |

#### AKPIK

|       |           |         |                                |
|-------|-----------|---------|--------------------------------|
|       |           |         | <b>Session</b>                 |
| 17:30 | AM 00.014 | AKPIK 1 | jDPG/AKPIK Programmierworkshop |

### Monday, March 16, 2026

|       |         |        |                                                                                                                                                                                         |
|-------|---------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 09:00 | AudiMax |        | <b>Welcome Address</b>                                                                                                                                                                  |
|       |         |        | <b>Plenary Talks, Prize Talk</b>                                                                                                                                                        |
| 10:30 | AudiMax | PV I   | Exotic atoms: from fundamental tests of strong field quantum electrodynamics to nuclear and astrophysical applications<br>•Paul Indelicato (Laureate of the Gentner-Kastler-Prize 2026) |
| 11:00 | AudiMax | PV II  | Why the Invention of the World Wide Web was no Coincidence: Scientific Culture and Technological Innovation at CERN, 1972-1991<br>•Barbara Hof                                          |
| 11:45 | AudiMax | PV III | Copernicus Revisited: is the Earth special?<br>•Laura Kreidberg                                                                                                                         |

#### SYMD

|       |         |        |                                   |
|-------|---------|--------|-----------------------------------|
|       |         |        | <b>Session</b>                    |
| 13:45 | AudiMax | SYMD 1 | SMuK Dissertation Prize Symposium |

#### EP

|       |           |        |                                                                             |
|-------|-----------|--------|-----------------------------------------------------------------------------|
|       |           |        | <b>Invited Talk</b>                                                         |
| 14:45 | KH 01.019 | EP 1.1 | Nuclear Astrophysics and Gamma Rays: From Space to Earth<br>•Thomas Siegert |
|       |           |        | <b>Sessions</b>                                                             |
| 14:45 | KH 01.019 | EP 1   | Astrophysics I                                                              |
| 16:15 | KH 01.019 | EP 2   | Astrophysics I                                                              |



## Monday, March 16, 2026

**GR**

|       |           |        |                                                                                                         |
|-------|-----------|--------|---------------------------------------------------------------------------------------------------------|
| 14:45 | KH 01.016 | GR 1.1 | <b>Invited Talk</b><br>Recent Developments on Critical Collapse and Extremality<br>•Daniela Cors Agullo |
| 14:45 | KH 01.016 | GR 1   | <b>Sessions</b><br>Numerical Relativity I<br>Gravitational Waves I<br>Classical General Relativity I    |
| 16:15 | KH 01.016 | GR 2   |                                                                                                         |
| 16:15 | KH 02.012 | GR 3   |                                                                                                         |

**HK**

|       |            |        |                                                                                                                                                                                                                                                                                                            |
|-------|------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14:45 | MED 00.915 | HK 1.1 | <b>Invited Talks</b><br>ALICE Run 3 Physics Highlights<br>•Igor Altsybeev                                                                                                                                                                                                                                  |
| 15:15 | MED 00.915 | HK 1.2 | Ab initio studies on muon capture and rare decays<br>•Lotta Jokiniemi                                                                                                                                                                                                                                      |
| 14:45 | MED 00.915 | HK 1   | <b>Sessions</b><br>Invited Talks<br>Hadron Structure and Spectroscopy I<br>Hadron Structure and Spectroscopy II<br>Structure and Dynamics of Nuclei I<br>Structure and Dynamics of Nuclei II<br>Heavy-Ion Collisions and QCD Phases I<br>Nuclear Astrophysics I<br>Instrumentation I<br>Instrumentation II |
| 16:15 | PHIL C 301 | HK 2   |                                                                                                                                                                                                                                                                                                            |
| 16:15 | PHIL A 401 | HK 3   |                                                                                                                                                                                                                                                                                                            |
| 16:15 | AM 00.011  | HK 4   |                                                                                                                                                                                                                                                                                                            |
| 16:15 | AM 00.021  | HK 5   |                                                                                                                                                                                                                                                                                                            |
| 16:15 | PHIL C 601 | HK 6   |                                                                                                                                                                                                                                                                                                            |
| 16:15 | PHIL A 602 | HK 7   |                                                                                                                                                                                                                                                                                                            |
| 16:15 | PHIL A 301 | HK 8   |                                                                                                                                                                                                                                                                                                            |
| 16:15 | PHIL B 302 | HK 9   |                                                                                                                                                                                                                                                                                                            |

**MP**

|       |           |        |                                                                                                                                           |
|-------|-----------|--------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 14:45 | KH 02.013 | MP 1.1 | <b>Invited Talks</b><br>The Wehrl entropy problem: mathematical physics meets complex analysis and representation theory<br>•Rupert Frank |
| 15:15 | KH 02.013 | MP 1.2 | News on relative entropy<br>•Markus B. Fröb                                                                                               |
| 14:45 | KH 02.013 | MP 1   | <b>Session</b><br>Quantum Information: Entropy                                                                                            |

**P**

|       |           |       |                                                                                                                                                          |
|-------|-----------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16:15 | KH 02.016 | P 3.1 | <b>Invited Talks</b><br>EMC3-Eirene simulation of neutral source effects on density build-up in the W7-X island divertor<br>•Victoria Winters            |
| 16:45 | KH 02.016 | P 3.2 | Optimizing divertor heat loads on Wendelstein 7-X using multi-objective optimization<br>•Alexander Knieps                                                |
| 16:15 | KH 01.020 | P 4.1 | Data-integrated simulations and machine learning analysis of plasma processing of SiO <sub>x</sub> /Cu memristive devices<br>•Jan Trieschmann            |
| 16:45 | KH 01.020 | P 4.2 | A multi-ratio method for determination of the electric field from 2p states in transient argon discharges at atmospheric pressure<br>•Zdenek Bonaventura |



## Monday, March 16, 2026

**P**

|       |           |     |                         |
|-------|-----------|-----|-------------------------|
| 14:45 | KH 02.016 | P 1 | <b>Sessions</b>         |
| 14:45 | KH 01.020 | P 2 | Magnetic Confinement I  |
| 16:15 | KH 02.016 | P 3 | Astrophysical Plasmas   |
| 16:15 | KH 01.020 | P 4 | Magnetic Confinement II |
|       |           |     | Codes and Modeling I    |

**T**

|       |         |       |                                                                                                                   |
|-------|---------|-------|-------------------------------------------------------------------------------------------------------------------|
| 14:45 | AudiMax | T 1.1 | <b>Invited Overview Talks</b>                                                                                     |
|       |         |       | Top-quark physics in a new regime: precision, effective field theory, and the top-quark pair production threshold |
|       |         |       | •Knut Zoch                                                                                                        |
| 15:15 | AudiMax | T 1.2 | Monte Carlo event generators for the HL-LHC                                                                       |
|       |         |       | •Steffen Schumann                                                                                                 |

|       |           |      |                                     |
|-------|-----------|------|-------------------------------------|
| 14:45 | AudiMax   | T 1  | <b>Sessions</b>                     |
| 16:15 | AudiMax   | T 2  | Invited Overview Talks I            |
| 16:15 | KH 00.014 | T 3  | Neutrino Physics I                  |
| 16:15 | KH 00.016 | T 4  | Standard Model Physics I            |
| 16:15 | KH 00.020 | T 5  | Higgs Physics I                     |
| 16:15 | KH 00.023 | T 6  | Methods in Particle Physics I       |
| 16:15 | KH 00.024 | T 7  | Electronics, Trigger, DAQ I         |
| 16:15 | KH 01.011 | T 8  | Data, AI, Computing, Electronics I  |
| 16:15 | KH 01.012 | T 9  | Flavour Physics I                   |
| 16:15 | KH 01.013 | T 10 | Silicon Detectors I                 |
| 16:15 | KH 01.014 | T 11 | Axions/ALPS I                       |
| 16:15 | KH 01.022 | T 12 | Gaseous Detectors I                 |
| 16:15 | KH 02.013 | T 13 | Silicon Detectors II                |
| 16:15 | KH 02.014 | T 14 | Higgs Physics II                    |
| 16:15 | KH 02.018 | T 15 | Data, AI, Computing, Electronics II |
| 16:15 | AM 00.014 | T 16 | Searches/BSM I                      |
| 16:15 | KS H C    | T 17 | Search for Dark Matter I            |
| 16:15 | KS 00.004 | T 18 | Neutrino Astronomy I                |
| 16:15 | KS 00.005 | T 19 | Methods in Astroparticle Physics I  |
| 16:15 | KS 00.006 | T 20 | Gravitational Waves I               |
|       |           |      | Cosmic Rays I                       |

**GP**

|       |           |        |                                                                                      |
|-------|-----------|--------|--------------------------------------------------------------------------------------|
| 15:00 | KH 02.019 | GP 1.3 | <b>Invited Talk</b>                                                                  |
|       |           |        | Flucht oder Tod – das Schicksal verfolgter Mitglieder der DPG im Nationalsozialismus |
|       |           |        | •Stefan L. Wolff                                                                     |

|       |           |      |                                                    |
|-------|-----------|------|----------------------------------------------------|
| 13:45 | KH 02.019 | GP 1 | <b>Sessions</b>                                    |
| 16:15 | KH 02.019 | GP 2 | Opening Session: History of Physics within the DPG |
|       |           |      | History of Theoretical Physics                     |

**AKPIK**

|       |           |         |                |
|-------|-----------|---------|----------------|
| 16:00 | KS 00.003 | AKPIK 2 | <b>Session</b> |
|       |           |         | Parallel Talks |

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## Monday, March 16, 2026

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**AGI**

### **Invited Talks, Discussion**

|       |           |         |                                                                                                                            |
|-------|-----------|---------|----------------------------------------------------------------------------------------------------------------------------|
| 16:15 | KH 00.011 | AGI 1.1 | Diamond Open Access: Misconceptions, Systemic Constraints, Potentials<br>•Ulrich Herb                                      |
| 16:45 | KH 00.011 | AGI 1.2 | Green, Gold, Diamond, Platinum, Rhodium etc: SciPost's stance on modern publishing business models<br>•Jean-Sébastien Caux |
| 17:15 | KH 00.011 | AGI 1.3 | Expanding the Diamond Open Access Publishing Model: on the how's and why's<br>•Margo Bargheer                              |
| 17:45 | KH 00.011 | AGI 1.4 | Discussion<br>•Uwe Kahlert                                                                                                 |

### **Session**

|       |           |       |                                       |
|-------|-----------|-------|---------------------------------------|
| 16:15 | KH 00.011 | AGI 1 | Diamond Open Access – The final step? |
|-------|-----------|-------|---------------------------------------|

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|-------|----------------------|------------------------------------------------------|
| 19:00 | Heinrich-Lades-Halle | <b>Welcome Evening</b> (for registered participants) |
|-------|----------------------|------------------------------------------------------|

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## Tuesday, March 17, 2026

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|       |         |       |                                                                                                                                                  |
|-------|---------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| 09:00 | AudiMax | PV IV | <b>Plenary Talks, Prize Talk, Ceremonial Talk</b><br>Basics of plasma technologies: examples for applications and diagnostics<br>•Holger Kersten |
| 09:45 | AudiMax | PV V  | Invariants of Topological Order: An Operator-Algebraic Approach<br>•Yoshiko Ogata                                                                |

|       |         |        |                                                                                                                                                                       |
|-------|---------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14:00 | AudiMax | PV VI  | <b>Ceremonial Session with Award Ceremony</b><br>The Higgs boson – Deciphering its nature at present and future colliders<br>•Karl Jakobs                             |
|       |         | PV VII | Between fascination and abstraction. Is it possible to teach modern physics at high-schools?<br>•Matthias Bartelmann (Laureate of the Robert-Wichard-Pohl-Prize 2026) |

**EP**

|       |           |      |                                    |
|-------|-----------|------|------------------------------------|
| 11:00 | KH 01.019 | EP 3 | <b>Session</b><br>Astrophysics III |
|-------|-----------|------|------------------------------------|

**GR**

|       |           |        |                                                                                                                                       |
|-------|-----------|--------|---------------------------------------------------------------------------------------------------------------------------------------|
| 11:00 | KH 01.016 | GR 4.1 | <b>Invited Talk</b><br>From kinetic gases to an accelerated expanding universe – The Finsler Friedmann equation<br>•Christian Pfeifer |
| 11:00 | KH 01.016 | GR 4   | <b>Sessions</b><br>Cosmology I                                                                                                        |
| 16:15 | KH 01.016 | GR 5   | Relativistic Astrophysics I                                                                                                           |
| 16:15 | KH 02.012 | GR 6   | Black Holes I                                                                                                                         |

**HK**

|       |            |         |                                                                                       |
|-------|------------|---------|---------------------------------------------------------------------------------------|
| 11:00 | MED 00.915 | HK 10.1 | <b>Invited Talks</b><br>Baryon scattering amplitudes from lattice QCD<br>•John Bulava |
| 11:30 | MED 00.915 | HK 10.2 | Exploring Triaxial Deformation in Neutron-rich Nuclei<br>•Kathrin Wimmer              |
| 12:00 | MED 00.915 | HK 10.3 | Jet Targets for Nuclear and Hadron Physics Experiments<br>•Alfons Khoukaz             |
| 12:30 | MED 00.915 | HK 10.4 | Probing neutrinos with the KATRIN and LEGEND experiments<br>•Susanne Mertens          |
| 11:00 | MED 00.915 | HK 10   | <b>Sessions</b><br>Invited Talks                                                      |
| 16:15 | PHIL C 301 | HK 11   | Hadron Structure and Spectroscopy III                                                 |
| 16:15 | PHIL A 401 | HK 12   | Hadron Structure and Spectroscopy IV                                                  |
| 16:15 | AM 00.011  | HK 13   | Structure and Dynamics of Nuclei III                                                  |
| 16:15 | AM 00.021  | HK 14   | Structure and Dynamics of Nuclei IV                                                   |
| 16:15 | PHIL C 601 | HK 15   | Heavy-Ion Collisions and QCD Phases II                                                |
| 16:15 | PHIL A 602 | HK 16   | Nuclear Astrophysics II                                                               |
| 16:15 | PHIL A 301 | HK 17   | Instrumentation III                                                                   |
| 16:15 | PHIL B 302 | HK 18   | Instrumentation IV                                                                    |

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## Tuesday, March 17, 2026

**MP**

|       |           |        |                                                                                                                           |
|-------|-----------|--------|---------------------------------------------------------------------------------------------------------------------------|
|       |           |        | <b>Invited Talks</b>                                                                                                      |
| 11:00 | KH 02.013 | MP 2.1 | Frustration free Hamiltonians for Finitely Correlated States – ground space structure and spectral gap<br>•Norbert Schuch |
| 16:15 | KH 02.013 | MP 3.1 | Osterwalder-Schrader axioms for a class of unitary 2D Conformal Field Theories<br>•Maria Stella Adamo                     |
| 16:45 | KH 02.013 | MP 3.2 | Schwarzian Field Theory for Probabilists<br>•Peter Wildemann                                                              |
| 17:15 | KH 02.013 | MP 3.3 | Local topological order and boundary algebras<br>•Pieter Naaijken                                                         |
|       |           |        | <b>Sessions</b>                                                                                                           |
| 11:00 | KH 02.013 | MP 2   | Correlated States                                                                                                         |
| 16:15 | KH 02.013 | MP 3   | Quantum Field Theory I: Axiomatic, Probabilistic, Algebraic, Conformal                                                    |

**P**

|       |           |       |                                                                                                    |
|-------|-----------|-------|----------------------------------------------------------------------------------------------------|
|       |           |       | <b>Invited Talks</b>                                                                               |
| 11:00 | KH 02.016 | P 5.1 | Nanoparticles prepared by sputter-driven gas aggregation<br>•Andrey Shukurov                       |
| 11:00 | KH 01.020 | P 6.1 | Controlled Exposure of High-Temperature Ceramics in the Scrape-Off Layer of WEST<br>•B. De Martino |
| 16:15 | KH 02.016 | P 7.1 | Post-puff SOL broadening on MAST-U: evidence for cross-field transport changes<br>•Yacopo Damizia  |
| 16:15 | KH 01.020 | P 8.1 | Near-plasma Chemical Surface Engineering<br>•Paula Navascués                                       |
|       |           |       | <b>Sessions</b>                                                                                    |
| 11:00 | KH 02.016 | P 5   | Low Pressure Plasmas I                                                                             |
| 11:00 | KH 01.020 | P 6   | Plasma Wall Interaction I                                                                          |
| 16:15 | KH 02.016 | P 7   | Magnetic Confinement III                                                                           |
| 16:15 | KH 01.020 | P 8   | Low Pressure Plasmas II                                                                            |

**ST**

|       |           |      |                                    |
|-------|-----------|------|------------------------------------|
|       |           |      | <b>Sessions</b>                    |
| 11:00 | KH 01.013 | ST 1 | Medical Imaging                    |
| 16:15 | KH 01.013 | ST 2 | Detectors for Treatment Monitoring |

**T**

|       |           |        |                                                                                                               |
|-------|-----------|--------|---------------------------------------------------------------------------------------------------------------|
|       |           |        | <b>Invited Overview Talks</b>                                                                                 |
| 11:00 | AudiMax   | T 21.1 | Three Decades of Dark Matter Annual Modulation Searches: Overview and Current Status<br>•Karoline Schaeffner  |
| 11:30 | AudiMax   | T 21.2 | Status and meaning of current tensions in cosmology<br>•Julien Lesgourgues                                    |
| 12:00 | AudiMax   | T 21.3 | In search of the unknown: Pushing the boundaries in searches for new physics at the LHC<br>•Danyer Perez Adan |
|       |           |        | <b>Sessions</b>                                                                                               |
| 11:00 | AudiMax   | T 21   | Invited Overview Talks II                                                                                     |
| 16:15 | AudiMax   | T 22   | Neutrino Physics II                                                                                           |
| 16:15 | KH 00.011 | T 23   | Top Physics I                                                                                                 |

## Tuesday, March 17, 2026

**T**

|       |           |      |                                      |
|-------|-----------|------|--------------------------------------|
| 16:15 | KH 00.014 | T 24 | Standard Model Physics II            |
| 16:15 | KH 00.016 | T 25 | Higgs Physics III                    |
| 16:15 | KH 00.020 | T 26 | Methods in Particle Physics II       |
| 16:15 | KH 00.023 | T 27 | Muon Detectors                       |
| 16:15 | KH 00.024 | T 28 | Data, AI, Computing, Electronics III |
| 16:15 | KH 01.011 | T 29 | Flavour Physics II                   |
| 16:15 | KH 01.012 | T 30 | Silicon Detectors III                |
| 16:15 | KH 01.014 | T 31 | Scintillator Detectors I             |
| 16:15 | KH 01.019 | T 32 | Higgs Physics IV                     |
| 16:15 | KH 01.022 | T 33 | Silicon Detectors IV                 |
| 16:15 | KH 02.014 | T 34 | Data, AI, Computing, Electronics IV  |
| 16:15 | KH 02.018 | T 35 | Searches/BSM II                      |
| 16:15 | AM 00.014 | T 36 | Search for Dark Matter II            |
| 16:15 | KS H C    | T 37 | Neutrino Astronomy II                |
| 16:15 | KS 00.004 | T 38 | Methods in Astroparticle Physics II  |
| 16:15 | KS 00.005 | T 39 | Gravitational Waves II               |
| 16:15 | KS 00.006 | T 40 | Cosmic Rays II                       |

**GP**

|       |           |        |                                                                                                                      |
|-------|-----------|--------|----------------------------------------------------------------------------------------------------------------------|
|       |           |        | <b>Invited Talk</b>                                                                                                  |
| 16:15 | KH 02.019 | GP 4.1 | Scientific Instruments and the Evolution of Experimental Volcanology: Insights from Mount Etna<br>•Valentina Roberti |
|       |           |        | <b>Sessions</b>                                                                                                      |
| 11:00 | KH 02.019 | GP 3   | Particles in Practice                                                                                                |
| 16:15 | KH 02.019 | GP 4   | Instruments and Measurement                                                                                          |
| 18:30 | KH 02.019 | GP 5   | Members' Assembly                                                                                                    |

**AKE**

|       |           |         |                                                                                                                                                                                      |
|-------|-----------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |           |         | <b>Invited Talk</b>                                                                                                                                                                  |
| 11:00 | KH 01.022 | AKE 1.1 | Unterwasserpumpspeicher in den Braunkohletagebauen des Rheinischen Reviers – die Lösung zur bezahlbaren Grundlastenergieversorgung der deutschen Industrie<br>•Horst Schmidt-Böcking |
|       |           |         | <b>Session</b>                                                                                                                                                                       |
| 11:00 | KH 01.022 | AKE 1   | Innovative Contributions for the Energy System Transformation                                                                                                                        |

**AKjDPG**

|       |           |            |                                                                                         |
|-------|-----------|------------|-----------------------------------------------------------------------------------------|
|       |           |            | <b>Invited Talks</b>                                                                    |
| 13:00 | AM 00.014 | AKjDPG 3.1 | From a career in academia to cutting-edge research in industry<br>•Achim Schöll         |
| 19:00 | AM 00.014 | AKjDPG 4.1 | from a nuclear physicist to a nuclear instrumentation architect<br>•Banu Oezel Tashenov |
| 19:25 | AM 00.014 | AKjDPG 4.2 | From ATLAS to Banking<br>•Elias Rüttinger                                               |
| 19:50 | AM 00.014 | AKjDPG 4.3 | Podium discussion with the three speakers<br>•Michael Lupberger                         |
|       |           |            | <b>Sessions</b>                                                                         |
| 13:00 | AM 00.014 | AKjDPG 3   | yHEP/jDPG Physicists Beyond Academia I                                                  |
| 19:00 | AM 00.014 | AKjDPG 4   | yHEP/jDPG Physicists Beyond Academia II                                                 |



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## Tuesday, March 17, 2026

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### AKPIK

|       |        |           |                                                                             |
|-------|--------|-----------|-----------------------------------------------------------------------------|
|       |        |           | <b>Invited Talks</b>                                                        |
| 11:00 | KS H C | AKPIK 3.1 | Large Language Models for Research Data Access<br>•Jutta Schnabel           |
| 11:30 | KS H C | AKPIK 3.2 | Deep Learning-Based Imaging of MeerKAT Observations<br>•Kevin Schmitz       |
| 12:00 | KS H C | AKPIK 3.3 | Towards FAIR fundamental physics: PUNCH4NFDI approach<br>•Victoria Tokareva |
|       |        |           | <b>Session</b>                                                              |
| 11:00 | KS H C | AKPIK 3   | Invited Talks                                                               |

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### AGI

|       |           |       |                                 |
|-------|-----------|-------|---------------------------------|
|       |           |       | <b>Session</b>                  |
| 11:00 | KH 00.024 | AGI 2 | Information Service for Physics |

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|       |               |                                                                            |
|-------|---------------|----------------------------------------------------------------------------|
| 10:30 | Foyer AudiMax | <b>Exhibition of Scientific Instruments and Literature</b> (free entrance) |
|-------|---------------|----------------------------------------------------------------------------|

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|-------|--------------|-----------------------|
| 21:00 | Eiweiher FAU | <b>jDPG Pub Crawl</b> |
|-------|--------------|-----------------------|

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|-------|---------|---------|------------------------------------------------------------------------------------------------------------------------------------|
|       |         |         | <b>Evening Lecture</b> (free entrance)                                                                                             |
| 19:00 | AudiMax | PV VIII | Zu Wasser, zu Eis und in der Luft: Astroteilchenphysik mit Gammastrahlung und Neutrinos<br>•Claudio Kopper, •Christopher van Eldik |

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## Wednesday, March 18, 2026

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|       |         |       |                                                                                                                                   |
|-------|---------|-------|-----------------------------------------------------------------------------------------------------------------------------------|
| 09:00 | AudiMax | PV IX | <b>Plenary Talks</b><br>Status and perspectives for science at FAIR (Facility for Antiproton and Ion Research)<br>•Thomas Nilsson |
| 09:45 | AudiMax | PV X  | Precision at the Energy Frontier: What the LHC is revealing about Fundamental Particle Physics<br>•Ludovica Aperio Bella          |

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**EP**

|       |              |        |                                                                                                                                                                                                                                  |
|-------|--------------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11:00 | KH 01.019    | EP 4.1 | <b>Invited Talks</b><br>Assessing the immediate dynamical and long-term radiative effects of the Hunga Tonga Hunga Ha'apai volcanic eruption using state-of-art active and passive ground-based remote sensing<br>•Gunter Stober |
| 13:45 | KH 01.019    | EP 6.1 | Simulation of the photosphere and chromospheres of sunspots<br>•Aswathi Krishnan Kutty                                                                                                                                           |
| 14:15 | KH 01.019    | EP 6.2 | Dynamics of a solar prominence simulated with MURaM<br>•Lisa-Marie Zessner                                                                                                                                                       |
| 11:00 | KH 01.019    | EP 4   | <b>Sessions</b><br>Near-Earth Space                                                                                                                                                                                              |
| 12:30 | KH 01.019    | EP 5   | Members' Assembly                                                                                                                                                                                                                |
| 13:45 | KH 01.019    | EP 6   | Sun and Heliosphere I                                                                                                                                                                                                            |
| 16:15 | Redoutensaal |        | EP 7      Poster Session                                                                                                                                                                                                         |

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**GR**

|       |              |        |                                                                                                                            |
|-------|--------------|--------|----------------------------------------------------------------------------------------------------------------------------|
| 11:00 | KH 01.016    | GR 7.1 | <b>Invited Talk</b><br>Electromagnetic jets as strong-gravity probe for rapidly spinning black holes<br>•Filippo Camilloni |
| 11:00 | KH 01.016    | GR 7   | <b>Sessions</b><br>Relativistic Astrophysics II                                                                            |
| 13:45 | KH 01.016    | GR 8   | Gravitational Waves II                                                                                                     |
| 13:45 | KH 02.012    | GR 9   | Black Holes II                                                                                                             |
| 16:15 | Redoutensaal |        | GR 10      Poster                                                                                                          |

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**HK**

|       |            |         |                                                                                                                       |
|-------|------------|---------|-----------------------------------------------------------------------------------------------------------------------|
| 11:00 | MED 00.915 | HK 19.1 | <b>Invited Talks</b><br>Nucleosynthesis of heavy elements in explosive astrophysical environments<br>•Daniel Siegel   |
| 11:30 | MED 00.915 | HK 19.2 | Recent results from laser spectroscopy with CRIS at ISOLDE: nuclear structure studies and beyond<br>•Jessica Warbinek |
| 12:00 | MED 00.915 | HK 19.3 | QCD at FAIR: Strong QCD Across Communities<br>•Johan Messchendorp                                                     |
| 12:30 | MED 00.915 | HK 19.4 | New Directions in Micropattern Gaseous Detector Technologies<br>•Philip Hauer                                         |
| 11:00 | MED 00.915 | HK 19   | <b>Sessions</b><br>Invited Talks                                                                                      |
| 13:45 | AM 00.014  | HK 20   | Focus Session: QCD@FAIR                                                                                               |
| 13:45 | AM 00.011  | HK 21   | Structure and Dynamics of Nuclei V                                                                                    |
| 13:45 | AM 00.021  | HK 22   | Structure and Dynamics of Nuclei VI                                                                                   |
| 13:45 | PHIL C 301 | HK 23   | Heavy-Ion Collisions and QCD Phases III                                                                               |

## Wednesday, March 18, 2026

**HK**

|       |              |       |                                        |
|-------|--------------|-------|----------------------------------------|
| 13:45 | PHIL A 401   | HK 24 | Heavy-Ion Collisions and QCD Phases IV |
| 13:45 | PHIL A 602   | HK 25 | Nuclear Astrophysics III               |
| 13:45 | PHIL A 301   | HK 26 | Instrumentation V                      |
| 16:15 | Redoutensaal | HK 27 | Poster Session                         |

**MP**

|                      |           |        |                                                                                                   |
|----------------------|-----------|--------|---------------------------------------------------------------------------------------------------|
| <b>Invited Talks</b> |           |        |                                                                                                   |
| 11:00                | KH 02.013 | MP 4.1 | Exact Schwinger functions for a class of bounded interactions in $d \geq 2$<br>•Wojciech Dybalski |
| 11:30                | KH 02.013 | MP 4.2 | L4 bound for the energy density in thermal field theory<br>•Daniela Cadamuro                      |
| 13:45                | KH 02.013 | MP 5.1 | Nontrivial Riemann Zeros as Spectrum<br>•Enderalp Yakaboylu                                       |

|                 |              |      |                                                          |
|-----------------|--------------|------|----------------------------------------------------------|
| <b>Sessions</b> |              |      |                                                          |
| 11:00           | KH 02.013    | MP 4 | Quantum Field Theory II                                  |
| 13:45           | KH 02.013    | MP 5 | Quantum Mechanics: Spectral Theory and Many-Body Systems |
| 16:15           | KH 02.013    | MP 6 | Holography: AdS/CFT                                      |
| 17:30           | KH 02.013    | MP 7 | Members' Assembly                                        |
| 18:00           | Redoutensaal | MP 8 | Poster Session                                           |

**P**

|                      |           |        |                                                                                                                                                          |
|----------------------|-----------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Invited Talks</b> |           |        |                                                                                                                                                          |
| 11:00                | KH 01.020 | P 9.1  | Controlling spokes in magnetron sputtering discharges<br>•Martin Rudolph                                                                                 |
| 11:00                | KH 02.016 | P 10.1 | Laser fusion activities in Germany – applications in planetary and stellar astrophysics and experiments at high-power laser facilities<br>•Dominik Kraus |
| 13:45                | KH 02.016 | P 11.1 | Proxima Fusion – Building stellarators to power the future<br>•Jonathan Schilling                                                                        |
| 14:15                | KH 02.016 | P 11.2 | Equilibrium and stability in Wendelstein 7-X high beta plasmas<br>•Henning Thomsen                                                                       |
| 13:45                | KH 01.020 | P 12.1 | Modelling and analysis of DBDs for thin-film deposition at atmospheric pressure<br>•Marjan Stankov                                                       |
| 16:15                | KH 01.020 | P 13.1 | Thin film deposition with dielectric-barrier discharges at atmospheric pressure: open questions and some answers<br>•Lars Broecker                       |

|                 |           |      |                                 |
|-----------------|-----------|------|---------------------------------|
| <b>Sessions</b> |           |      |                                 |
| 11:00           | KH 01.020 | P 9  | Low Pressure Plasmas III        |
| 11:00           | KH 02.016 | P 10 | High Energy Density Physics I   |
| 13:45           | KH 02.016 | P 11 | Magnetic Confinement IV         |
| 13:45           | KH 01.020 | P 12 | Atmospheric Pressure Plasmas I  |
| 16:15           | KH 01.020 | P 13 | Atmospheric Pressure Plasmas II |

**ST**

|                      |           |        |                                                                                                                  |
|----------------------|-----------|--------|------------------------------------------------------------------------------------------------------------------|
| <b>Invited Talks</b> |           |        |                                                                                                                  |
| 16:15                | KH 01.013 | ST 4.1 | Introduction to modern nuclear medicine: almost one century of interdisciplinary innovations<br>•Stephan Nekolla |
| 16:45                | KH 01.013 | ST 4.2 | Personendosimetrie in der Nuklearmedizin<br>•Felix Bärenfänger                                                   |
| 17:15                | KH 01.013 | ST 4.3 | Dosimetry in Targeted Radionuclide Therapy: Challenges, Concepts, and Perspectives<br>•Johannes Tran-Gia         |

## Wednesday, March 18, 2026

**ST**

### Sessions

|       |           |      |                                               |
|-------|-----------|------|-----------------------------------------------|
| 13:45 | KH 01.013 | ST 3 | Detectors for Medical Applications            |
| 16:15 | KH 01.013 | ST 4 | DPG meets DGMP: Dosimetry in Nuclear Medicine |

**T**

### Invited Overview Talks

|       |         |        |                                                                                                       |
|-------|---------|--------|-------------------------------------------------------------------------------------------------------|
| 11:00 | AudiMax | T 41.1 | One of a kind: the Higgs boson<br>•Matteo Bonanomi                                                    |
| 11:30 | AudiMax | T 41.2 | Higgs Physics at the LHC and Beyond: Connecting Colliders and the Early Universe<br>•Thomas Biekötter |
| 12:00 | AudiMax | T 41.3 | Gravitational waves from cosmological phase transitions.<br>•Thomas Konstandin                        |

### Invited Topical Talks

|       |            |        |                                                                                                                                 |
|-------|------------|--------|---------------------------------------------------------------------------------------------------------------------------------|
| 13:45 | AudiMax    | T 43.1 | Upgrade of the ATLAS tracker for HL-LHC: production status and challenges<br>•Roland Koppenhoefer                               |
| 14:15 | AudiMax    | T 43.2 | Entering the high-granularity calorimetry era: the CMS HGCal upgrade<br>•Antoine Laudrain                                       |
| 14:45 | AudiMax    | T 43.3 | Searching for New Physics in Otherwise Lost LHC Data<br>•Falk Bartels                                                           |
| 15:15 | AudiMax    | T 43.4 | Federated Computing Infrastructures<br>•Inga Lakomic                                                                            |
| 13:45 | MED 00.915 | T 44.1 | Probing Heavy New Physics at the Precision Frontier with Effective Field Theory<br>•Peter Stangl                                |
| 14:15 | MED 00.915 | T 44.2 | Hadron Spectroscopy at Belle (II)<br>•Stefan Wallner                                                                            |
| 14:45 | MED 00.915 | T 44.3 | Rare B meson decays at Belle II: indirect searches for new physics at the luminosity frontier<br>•Ana Luisa Moreira de Carvalho |
| 15:15 | MED 00.915 | T 44.4 | Search for CP violation in $D^0 \rightarrow K_S^0 K_S^0$ decays at the LHCb experiment<br>•Giulia Tuci                          |

### Sessions

|       |            |      |                                                                  |
|-------|------------|------|------------------------------------------------------------------|
| 11:00 | AudiMax    | T 41 | Invited Overview Talks III                                       |
| 12:40 | KS H C     | T 42 | Annual Meeting of Young Scientists in High Energy Physics (yHEP) |
| 13:45 | AudiMax    | T 43 | Invited Topical Talks I                                          |
| 13:45 | MED 00.915 | T 44 | Invited Topical Talks II                                         |
| 16:15 | AudiMax    | T 45 | Neutrino Physics III                                             |
| 16:15 | KH 00.011  | T 46 | Top Physics II                                                   |
| 16:15 | KH 00.014  | T 47 | Higgs Physics V                                                  |
| 16:15 | KH 00.020  | T 48 | Methods in Particle Physics III                                  |
| 16:15 | KH 00.023  | T 49 | Electronics, Trigger, DAQ II                                     |
| 16:15 | KH 00.024  | T 50 | Data, AI, Computing, Electronics V                               |
| 16:15 | KH 01.011  | T 51 | Flavour Physics III                                              |
| 16:15 | KH 01.012  | T 52 | Silicon Detectors V                                              |
| 16:15 | KH 01.014  | T 53 | Scintillator Detectors II                                        |
| 16:15 | KH 01.019  | T 54 | Higgs Physics VI                                                 |
| 16:15 | KH 01.022  | T 55 | Silicon Detectors VI                                             |
| 16:15 | KH 02.014  | T 56 | Data, AI, Computing, Electronics VI                              |
| 16:15 | KH 02.016  | T 57 | Outreach I                                                       |
| 16:15 | KH 02.018  | T 58 | Searches/BSM III                                                 |
| 16:15 | KS H C     | T 59 | Neutrino Astronomy III                                           |
| 16:15 | KS 00.004  | T 60 | Methods in Astroparticle Physics III                             |
| 16:15 | KS 00.005  | T 61 | Gamma Astronomy I                                                |
| 16:15 | KS 00.006  | T 62 | Cosmic Rays III                                                  |

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## Wednesday, March 18, 2026

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**GP**

### Sessions

11:00 KH 02.019 GP 6 Physics and People  
13:45 KH 02.019 GP 7 Practices and Experiments

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**AKjDPG**

### Session

13:45 KH 00.011 AKjDPG 5 Artificial Intelligence in Scientific Publishing

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**AKPIK**

### Session

13:45 KH 00.011 AKPIK 4 Artificial Intelligence in Scientific Publishing

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**AGA**

### Invited Talks

14:00 KH 00.016 AGA 1.1 How Missile Defence Works. A Look into Technical Details  
•Markus Schiller  
15:00 KH 00.016 AGA 1.2 Technical and Security Aspects of Hypersonic Weapons  
•David Wright

### Sessions

14:00 KH 00.016 AGA 1 Missile Defense and Outer Space  
17:00 KH 00.016 AGA 2 Nuclear Fuel Cycle  
18:30 KH 00.016 AGA 3 Members' Assembly

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**AGI**

### Invited Talks, Discussion

13:45 KH 00.011 AGI 3.1 Scientific publishing in the era of AI  
•Dominik Elsässer  
14:15 KH 00.011 AGI 3.2 Intelligence and the Art of Scientific Publishing – an Editor's Perspective  
•Andreas Buchleitner  
14:35 KH 00.011 AGI 3.3 Prompt or perish – the research life cycle in times of genAI  
•Sandra Geisler  
15:05 KH 00.011 AGI 3.4 Discussion  
•Uwe Kahlert, •Tim Ruhe

### Session

13:45 KH 00.011 AGI 3 Artificial Intelligence in Scientific Publishing

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**JOB**

### Invited Talk

12:30 AM 00.014 JOB 1.1 Data-Analytics in der HUK-COBURG – Wie Physiker den Weg in ein datengetriebenes Versicherungsunternehmen mitgestalten  
•Jannik Hofestädt, •Andreas Gleixner, •Goran Nakerst

### Session

12:30 AM 00.014 JOB 1 Job Market

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10:30 Foyer AudiMax **Exhibition of Scientific Instruments and Literature** (free entrance)

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## Wednesday, March 18, 2026

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|       |         |       |                                                                                                            |
|-------|---------|-------|------------------------------------------------------------------------------------------------------------|
| 19:00 | AudiMax | PV XI | <b>Lise-Meitner-Lecture</b> (free entrance)<br>Gravitational wave astronomy – quo vadis?<br>•Michèle Heurs |
|-------|---------|-------|------------------------------------------------------------------------------------------------------------|

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## Thursday, March 19, 2026

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|       |         |         |                                                                                             |
|-------|---------|---------|---------------------------------------------------------------------------------------------|
| 09:00 | AudiMax | PV XII  | <b>Plenary Talks, Evening Talk</b><br>AI in the context of medical images<br>•Stefan Wesarg |
| 09:45 | AudiMax | PV XIII | LISA: The first space-based gravitational-wave observatory<br>•Guido Mueller                |

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**EP**

|       |           |        |                                                                                                          |
|-------|-----------|--------|----------------------------------------------------------------------------------------------------------|
| 11:00 | KH 01.019 | EP 8.1 | <b>Invited Talk</b><br>Solar and heliospheric studies with the LOFAR radio telescope<br>•Christian Vocks |
| 11:00 | KH 01.019 | EP 8   | <b>Sessions</b><br>Sun and Heliosphere II                                                                |
| 13:45 | KH 01.019 | EP 9   | Sun and Heliosphere III                                                                                  |

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**GR**

|       |           |         |                                                                                             |
|-------|-----------|---------|---------------------------------------------------------------------------------------------|
| 11:00 | KH 01.016 | GR 11.1 | <b>Invited Talk</b><br>Numerical Relativity for LISA and the Einstein Telescope<br>•Nils Vu |
| 11:00 | KH 01.016 | GR 11   | <b>Sessions</b><br>Numerical Relativity II                                                  |
| 13:45 | KH 01.016 | GR 12   | Relativistic Astrophysics III / Gravitational waves III                                     |
| 13:45 | KH 02.012 | GR 13   | Quantum Gravity and Quantum Cosmology I                                                     |
| 16:15 | KH 01.016 | GR 14   | Relativistic Astrophysics IV                                                                |
| 16:15 | KH 02.012 | GR 15   | Quantum Gravity and Quantum Cosmology II                                                    |
| 17:15 | KH 01.016 | GR 16   | Members' Assembly                                                                           |

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## Thursday, March 19, 2026

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**HK**

### Invited Talks

|       |                    |                                                                                                    |
|-------|--------------------|----------------------------------------------------------------------------------------------------|
| 11:00 | MED 00.915 HK 28.1 | Toward the Island of Stability<br>•Khuyagbaatar Jadambaa                                           |
| 11:30 | MED 00.915 HK 28.2 | From stars to underground labs: Nuclear astrophysics measurements at Felsenkeller<br>•Eliana Masha |
| 12:00 | MED 00.915 HK 28.3 | Hunting exotic mesons in the light-quark sector at GlueX<br>•Farah Afzal                           |
| 12:30 | MED 00.915 HK 28.4 | Dispersive analyses of Primakoff reactions with kaons<br>•Bastian Kubis                            |

### Sessions

|       |                  |                                         |
|-------|------------------|-----------------------------------------|
| 11:00 | MED 00.915 HK 28 | Invited Talks                           |
| 13:45 | PHIL C 301 HK 29 | Hadron Structure and Spectroscopy V     |
| 13:45 | PHIL A 401 HK 30 | Hadron Structure and Spectroscopy VI    |
| 13:45 | AM 00.011 HK 31  | Structure and Dynamics of Nuclei VII    |
| 13:45 | PHIL C 601 HK 32 | Heavy-Ion Collisions and QCD Phases V   |
| 13:45 | PHIL A 602 HK 33 | Nuclear Astrophysics IV                 |
| 13:45 | AM 00.021 HK 34  | Fundamental Symmetries I                |
| 13:45 | PHIL A 301 HK 35 | Instrumentation VI                      |
| 13:45 | PHIL B 302 HK 36 | Instrumentation VII                     |
| 16:15 | PHIL C 301 HK 37 | Hadron Structure and Spectroscopy VII   |
| 16:15 | PHIL A 401 HK 38 | Hadron Structure and Spectroscopy VIII  |
| 16:15 | AM 00.011 HK 39  | Structure and Dynamics of Nuclei VIII   |
| 16:15 | PHIL C 601 HK 40 | Heavy-Ion Collisions and QCD Phases VI  |
| 16:15 | PHIL A 602 HK 41 | Heavy-Ion Collisions and QCD Phases VII |
| 16:15 | AM 00.021 HK 42  | Fundamental Symmetries II               |
| 16:15 | PHIL B 604 HK 43 | Computing and Outreach                  |
| 16:15 | PHIL A 301 HK 44 | Instrumentation VIII                    |
| 16:15 | PHIL B 302 HK 45 | Instrumentation IX                      |
| 18:00 | AM 00.017 HK 46  | Members' Assembly                       |

**MP**

### Invited Talk

|       |                  |                                                                         |
|-------|------------------|-------------------------------------------------------------------------|
| 11:00 | KH 02.013 MP 9.1 | Light Cone Structure of Quantum Spacetime Geometry<br>•Wolfgang Wieland |
|-------|------------------|-------------------------------------------------------------------------|

### Sessions

|       |                 |                                     |
|-------|-----------------|-------------------------------------|
| 11:00 | KH 02.013 MP 9  | Geometry, Black Holes, Universality |
| 13:45 | KH 02.013 MP 10 | Strong Fields                       |
| 16:15 | KH 00.015 MP 11 | Various Topics in Relativity        |

**P**

### Invited Talks

|       |                  |                                                                                                                     |
|-------|------------------|---------------------------------------------------------------------------------------------------------------------|
| 11:00 | KH 01.020 P 15.1 | Demonstration of X-ray Diagnostics for Heavy-Ion-Heated Matter<br>•Julian Lütgert                                   |
| 16:15 | KH 02.016 P 17.1 | Energetic proton damage for simulating fusion relevant neutron damage on reactor materials<br>•Rahul Rayaprolu      |
| 16:15 | KH 01.020 P 18.1 | High-energy-density and high-pressure states investigated with x-ray imaging at HED-HiBEF<br>•Alejandro Laso Garcia |

## Thursday, March 19, 2026

HK

### Sessions

|       |              |      |                                  |
|-------|--------------|------|----------------------------------|
| 11:00 | KH 02.016    | P 14 | Magnetic Confinement V           |
| 11:00 | KH 01.020    | P 15 | High Energy Density Physics II   |
| 13:45 | Redoutensaal | P 16 | Poster Session Plasma Physics    |
| 16:15 | KH 02.016    | P 17 | Plasma Wall Interaction II       |
| 16:15 | KH 01.020    | P 18 | High Energy Density Physics III  |
| 17:30 | KH 01.020    | P 19 | Atmospheric Pressure Plasmas III |
| 18:30 | KS H C       | P 20 | Members' Assembly                |

ST

### Invited Talks

|       |           |        |                                                                                                                                      |
|-------|-----------|--------|--------------------------------------------------------------------------------------------------------------------------------------|
| 11:00 | KH 01.013 | ST 5.1 | Prompt-Gamma-Based Range Verification<br>•Beatrice Foglia                                                                            |
| 11:30 | KH 01.013 | ST 5.2 | Carbon-ion radiotherapy monitoring with charged nuclear fragments<br>•Maria Martisikova                                              |
| 12:00 | KH 01.013 | ST 5.3 | Radioactive ion beams for real-time PET-guided adaptive particle therapy<br>•Daria Boscolo for the BARB Collaboration                |
| 12:30 | KH 01.013 | ST 5.4 | Helium as a Range Probe in Carbon-Ion Therapy: From Concept to Mixed-Beam Experiments<br>•Lennart Volz for the PROMISE collaboration |
| 16:45 | KH 01.013 | ST 8.1 | Healing Patients, Heating the Planet: Why Circularity Matters in Healthcare<br>•Katharina Hesels                                     |

### Sessions

|       |              |       |                                                       |
|-------|--------------|-------|-------------------------------------------------------|
| 11:00 | KH 01.013    | ST 5  | Focus Session: Range Verification in Particle Therapy |
| 14:15 | Redoutensaal | ST 6  | Poster Session                                        |
| 16:15 | KH 01.013    | ST 7  | Radiation Therapy                                     |
| 16:45 | KH 01.013    | ST 8  | Keynote Session                                       |
| 17:15 | KH 01.013    | ST 9  | Prize Ceremony and Closing Session                    |
| 17:45 | KH 01.013    | ST 10 | Members' Assembly                                     |

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### Invited Overview Talks,

|       |         |        |                                                                                                                           |
|-------|---------|--------|---------------------------------------------------------------------------------------------------------------------------|
| 11:00 | AudiMax | T 63.1 | Binary Black Hole Populations: Scientific Perspectives for the Einstein Telescope<br>•Michela Mapelli                     |
| 11:30 | AudiMax | T 63.2 | JUNO's First Light: High-Precision Reactor Neutrino Oscillations<br>•Michael Wurm                                         |
| 12:00 | AudiMax | T 63.3 | Flavour physics at the precision frontier: recent highlights from the LHCb and Belle II experiments<br>•Evelina Gersabeck |

### Invited Topical Talks

|       |            |        |                                                                                                                                                          |
|-------|------------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:45 | AudiMax    | T 64.1 | Charting the Higgs Sector with Effective Field Theories<br>•Ilaria Brivio                                                                                |
| 14:15 | AudiMax    | T 64.2 | Probing CP invariance of Higgs boson production and decay and its interpretation in effective field theories with the ATLAS detector<br>•Lorenzo Rossini |
| 14:45 | AudiMax    | T 64.3 | b-tagging unlocks the Higgs potential<br>•Nicole Hartman                                                                                                 |
| 15:15 | AudiMax    | T 64.4 | Modern Machine Learning for LHC Event Generation<br>•Ramon Winterhalder                                                                                  |
| 13:45 | MED 00.915 | T 65.1 | Atmospheric neutrino oscillations with IceCube and the IceCube Upgrade<br>•Jan Weldert                                                                   |
| 14:15 | MED 00.915 | T 65.2 | Exploring the Gravitational Wave Universe with Pulsar Timing Arrays<br>•Andrea Mitridate                                                                 |

## Thursday, March 19, 2026

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|                 |                   |                                                                                                           |
|-----------------|-------------------|-----------------------------------------------------------------------------------------------------------|
| 14:45           | MED 00.915 T 65.3 | Supernova Remnants as Accelerators of Galactic Cosmic Rays<br>•Robert Brose                               |
| 15:15           | MED 00.915 T 65.4 | Supermassive black holes and their relativistic jets: a beacon into the early universe<br>•Lea Marcotulli |
| <b>Sessions</b> |                   |                                                                                                           |
| 11:00           | AudiMax T 63      | Invited Overview Talks IV                                                                                 |
| 13:45           | AudiMax T 64      | Invited Topical Talks III                                                                                 |
| 13:45           | MED 00.915 T 65   | Invited Topical Talks IV                                                                                  |
| 16:15           | AudiMax T 66      | Neutrino Physics IV                                                                                       |
| 16:15           | KH 00.011 T 67    | Top Physics III                                                                                           |
| 16:15           | KH 00.014 T 68    | Standard Model Physics III                                                                                |
| 16:15           | KH 00.020 T 69    | Methods in Particle Physics IV                                                                            |
| 16:15           | KH 00.023 T 70    | Electronics, Trigger, DAQ III                                                                             |
| 16:15           | KH 00.024 T 71    | Data, AI, Computing, Electronics VII                                                                      |
| 16:15           | KH 01.011 T 72    | Flavour Physics IV                                                                                        |
| 16:15           | KH 01.012 T 73    | Calorimeters I                                                                                            |
| 16:15           | KH 01.014 T 74    | Gaseous Detectors II                                                                                      |
| 16:15           | KH 01.019 T 75    | Higgs Physics VII                                                                                         |
| 16:15           | KH 01.022 T 76    | Silicon Detectors VII                                                                                     |
| 16:15           | KH 02.013 T 77    | Higgs Physics VIII                                                                                        |
| 16:15           | KH 02.014 T 78    | Flavour Physics V                                                                                         |
| 16:15           | KH 02.018 T 79    | Searches/BSM IV                                                                                           |
| 16:15           | KH 02.019 T 80    | Axions/ALPs II                                                                                            |
| 16:15           | AM 00.014 T 81    | Search for Dark Matter III                                                                                |
| 16:15           | KS H C T 82       | Neutrino Astronomy IV                                                                                     |
| 16:15           | KS 00.004 T 83    | Methods in Astroparticle Physics IV                                                                       |
| 16:15           | KS 00.005 T 84    | Gamma Astronomy II                                                                                        |
| 16:15           | KS 00.006 T 85    | Cosmic Rays IV                                                                                            |
| 18:30           | AM 00.014 T 86    | Members' Assembly                                                                                         |

AKC

|                      |                   |                                                                                                   |
|----------------------|-------------------|---------------------------------------------------------------------------------------------------|
| <b>Invited Talks</b> |                   |                                                                                                   |
| 11:15                | KH 01.011 AKC 1.1 | Visibility, invisibility and hypervisibility of women in quantum technologies<br>•Tamar Grosz     |
| 11:45                | KH 01.011 AKC 1.2 | Leadership, Cooperation and Conflicts in Physics: Research Leaders' Perspectives<br>•Maike Reimer |
| 12:15                | KH 01.011 AKC 1.3 | From Taboo to Transformation: Addressing Gender-Based Violence in Academia<br>•Anja Wiede         |
| <b>Sessions</b>      |                   |                                                                                                   |
| 11:00                | KH 01.011 AKC 1   | AKC                                                                                               |
| 13:00                | KH 01.011 AKC 2   | Women in Physics Lunch                                                                            |

AGA

|                      |                   |                                                                                                    |
|----------------------|-------------------|----------------------------------------------------------------------------------------------------|
| <b>Invited Talks</b> |                   |                                                                                                    |
| 11:00                | KH 00.016 AGA 4.1 | Quantum Technology Military Applications and Strategic Implications for Defence<br>•Michal Krelina |
| 12:00                | KH 00.016 AGA 4.2 | Risiko Dual-use-Forschung<br>•Wolfgang Liebert                                                     |
| 15:15                | KH 00.016 AGA 6.1 | Modeling Nuclear Weapon Effects from Trinity to Nuclear War<br>•Sébastien Philippe                 |

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## Thursday, March 19, 2026

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**AGA**

|       |           |         |                                                                                                   |
|-------|-----------|---------|---------------------------------------------------------------------------------------------------|
| 16:15 | KH 00.016 | AGA 6.2 | From Local Impacts to Global Risks: New Science on Nuclear War Consequences<br>•Friederike Friess |
| 11:00 | KH 00.016 | AGA 4   | <b>Sessions</b><br>Dual-Use Technologies                                                          |
| 14:00 | KH 00.016 | AGA 5   | Safeguards                                                                                        |
| 15:15 | KH 00.016 | AGA 6   | Nuclear Weapon Effects                                                                            |
| 17:30 | KH 00.016 | AGA 7   | An Overview of Physics and Disarmament Research in Germany – Social Event & Poster Session        |

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|-------|---------------|----------------------------------------------------------------------------|
| 10:30 | Foyer AudiMax | <b>Exhibition of Scientific Instruments and Literature</b> (free entrance) |
|-------|---------------|----------------------------------------------------------------------------|

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|       |         |        |                                                                                                                                                              |
|-------|---------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 20:00 | AudiMax | PV XIV | <b>Max-von-Laue-Lecture</b> (free entrance)<br>My journey in Nuclear Physics – Quantum Chromodynamics and the threat of nuclear annihilation<br>•David Gross |
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## Friday, March 20, 2026

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**EP**

|       |           |         |                                                                               |
|-------|-----------|---------|-------------------------------------------------------------------------------|
| 09:00 | KH 01.019 | EP 10.1 | <b>Invited Talks</b><br>The diversity of low mass exoplanets<br>•Kristine Lam |
| 11:00 | KH 01.019 | EP 11.1 | Iron and the search for life on Mars<br>•Christian Schröder                   |
| 09:00 | KH 01.019 | EP 10   | <b>Sessions</b><br>Exoplanets and Astrobiology                                |
| 11:00 | KH 01.019 | EP 11   | Planets and Small Bodies                                                      |

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**GR**

|       |           |         |                                                                                   |
|-------|-----------|---------|-----------------------------------------------------------------------------------|
| 09:00 | KH 01.016 | GR 17.1 | <b>Invited Talk</b><br>Radio Cosmology and the Cosmic Dawn<br>•Jonathan Pritchard |
| 09:00 | KH 01.016 | GR 17   | <b>Sessions</b><br>Cosmology II                                                   |
| 11:00 | KH 01.016 | GR 18   | Cosmology III                                                                     |
| 11:00 | KH 02.012 | GR 19   | Numerical Relativity III                                                          |

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**HK**

|       |            |         |                                                                                  |
|-------|------------|---------|----------------------------------------------------------------------------------|
| 09:00 | MED 00.915 | HK 47.1 | <b>Invited Talks</b><br>Supernova signatures on Earth and beyond<br>•Jenny Feige |
|-------|------------|---------|----------------------------------------------------------------------------------|

## Friday, March 20, 2026

**HK**

|                 |                    |                                                                                                   |
|-----------------|--------------------|---------------------------------------------------------------------------------------------------|
| 09:30           | MED 00.915 HK 47.2 | ALICE 3 – The next-generation heavy-ion experiment at the LHC<br>•Lars Döpper                     |
| 10:00           | MED 00.915 HK 47.3 | Towards Physics Operation of the CBM Experiment at FAIR<br>•Adrian Rodríguez Rodríguez            |
| 11:00           | MED 00.915 HK 48.1 | Probing confinement and string-breaking with quantum simulations<br>•Torsten Zache                |
| 11:30           | MED 00.915 HK 48.2 | Exploring stochastic aspects of nuclear gamma decays with photonuclear reactions<br>•Johann Isaak |
| 12:00           | MED 00.915 HK 48.3 | Precision QCD with ePIC at the Electron-Ion Collider<br>•Tyler Kutz                               |
| <b>Sessions</b> |                    |                                                                                                   |
| 09:00           | MED 00.915 HK 47   | Invited Talks                                                                                     |
| 11:00           | MED 00.915 HK 48   | Invited Talks                                                                                     |

**P**

|                      |                  |                                                                                                                                  |
|----------------------|------------------|----------------------------------------------------------------------------------------------------------------------------------|
| <b>Invited Talks</b> |                  |                                                                                                                                  |
| 09:00                | KH 01.013 P 21.1 | Performance Pitfalls and Design Principles of Retarding Potential Analyzers<br>•Thomas Trottenberg                               |
| 09:30                | KH 01.013 P 21.2 | Microwave cavity resonance spectroscopy: a novel approach for spatially resolved electron density measurements<br>•Jens Oberrath |
| 09:00                | KH 01.012 P 22.1 | ERO/ERO2.0 modelling for tokamaks, stellarators and linear plasma devices<br>•Juri Romazanov                                     |
| <b>Sessions</b>      |                  |                                                                                                                                  |
| 09:00                | KH 01.013 P 21   | Codes and Modeling II                                                                                                            |
| 09:00                | KH 01.012 P 22   | Plasma Wall Interaction III                                                                                                      |
| 11:00                | KH 01.012 P 23   | Low Pressure Plasmas IV                                                                                                          |
| 11:00                | KH 01.013 P 24   | Laser Plasmas                                                                                                                    |
| 11:30                | KH 01.012 P 25   | Plasma Wall Interaction IV                                                                                                       |

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|                               |                 |                                                                                                                         |
|-------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>Invited Overview Talks</b> |                 |                                                                                                                         |
| 11:00                         | AudiMax T 107.1 | Beyond the Main Detectors: An Overview of Smaller Experiments at the LHC<br>•Felix Kling                                |
| 11:30                         | AudiMax T 107.2 | Pimp my ride: Overhauling the ATLAS and CMS experiments to ride the High Luminosity Highway at the LHC<br>•Stefan Maier |
| 12:00                         | AudiMax T 107.3 | Overview of the solar model and LUNANOVA<br>•Daniel Bemmerer                                                            |
| <b>Sessions</b>               |                 |                                                                                                                         |
| 09:00                         | AudiMax T 87    | Neutrino Physics V                                                                                                      |
| 09:00                         | KH 00.011 T 88  | Top Physics IV                                                                                                          |
| 09:00                         | KH 00.014 T 89  | Higgs Physics IX                                                                                                        |
| 09:00                         | KH 00.015 T 90  | Calorimeters II                                                                                                         |
| 09:00                         | KH 00.020 T 91  | Methods in Particle Physics V                                                                                           |
| 09:00                         | KH 00.023 T 92  | Electronics, Trigger, DAQ IV                                                                                            |
| 09:00                         | KH 00.024 T 93  | Data, AI, Computing, Electronics VIII                                                                                   |
| 09:00                         | KH 01.011 T 94  | Flavour Physics VI                                                                                                      |
| 09:00                         | KH 01.014 T 95  | Gaseous Detectors III                                                                                                   |
| 09:00                         | KH 01.020 T 96  | Outreach II                                                                                                             |
| 09:00                         | KH 01.022 T 97  | Silicon Detectors VIII                                                                                                  |
| 09:00                         | KH 02.013 T 98  | Higgs Physics X                                                                                                         |

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## Friday, March 20, 2026

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**EP**

|       |           |       |                                    |
|-------|-----------|-------|------------------------------------|
| 09:00 | KH 02.014 | T 99  | Searches/BSM V                     |
| 09:00 | KH 02.016 | T 100 | Miscellaneous                      |
| 09:00 | KH 02.018 | T 101 | Searches/BSM VI                    |
| 09:00 | KH 02.019 | T 102 | Axions/ALPs III                    |
| 09:00 | AM 00.014 | T 103 | Search for Dark Matter IV          |
| 09:00 | KS H C    | T 104 | Neutrino Astronomy V               |
| 09:00 | KS 00.004 | T 105 | Methods in Astroparticle Physics V |
| 09:00 | KS 00.005 | T 106 | Gamma Astronomy III                |
| 11:00 | AudiMax   | T 107 | Invited Overview Talks V           |

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**AGA**

|       |           |       | <b>Session</b> |
|-------|-----------|-------|----------------|
| 09:30 | KH 00.016 | AGA 8 | Verification   |

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## Plenary, Prize, Ceremonial, and Evening Talks

### Prize Talk

PV I Mon 10:30 AudiMax

**Exotic atoms: from fundamental tests of strong field quantum electrodynamics to nuclear and astrophysical applications** — •PAUL INDELICATO — Laboratoire Kastler Brossel, Sorbonne Université, Campus P. et M. Curie, 4 Place Jussieu, Paris, France — Laureate of the Gentner-Kastler-Prize 2026

Atoms where an electron is replaced by a heavier particle like the muon or an antinucleus like antiprotons are called exotic atoms. Because of the large mass of the particle, they allow to test bound state quantum electrodynamics (BSQED) in very strong fields. One can then study transitions between circular Rydberg states of such atoms to test BSQED without influence from the nucleus. Lower levels allow to do nuclear physics or strong interaction physics. A new kind of detectors, microcalorimeters have resolutions  $\approx 200$  times better than the Ge detectors used in the past, which allows for high precision x-ray energy measurements. They have been used on muonic atoms to test BSQED and to measure light nuclei charge radius. Test of BSQED in antiprotonic atoms are performed at the ELENA ring at CERN. It may be possible in the future that antideuterium atoms may also be observed at ELENA. Atoms with heavier antinuclei could be present in cosmic rays, following decay of dark matter. Their x-rays could be detected using detectors flying on balloons in the atmosphere like GAPS (General AntiParticle Spectrometer).

In my talk I will present results of advanced calculation, using all-order vacuum polarization for several kind of exotic atoms and exact finite size corrected self-energy for muonic atoms. I will then compare to recent measurements and possible future observations.

### Plenary Talk

PV II Mon 11:00 AudiMax

**Why the Invention of the World Wide Web was no Coincidence: Scientific Culture and Technological Innovation at CERN, 1972-1991** — •BARBARA HOF — Université de Lausanne, Switzerland

How does the development of the Web look when examined through the lens of the history of physics? What factors contributed to this computing invention, which became a public success only in the 1990s, and to what extent can its development be attributed to international collaboration and existing technical infrastructures? My talk explores why CERN's unique blend of international data exchange, a culture of open science, and cutting-edge accelerator research made it the ideal breeding ground for a universal information system. I argue that, long before the creation of the Web application, CERN had already established a robust infrastructure of networked computers and the corresponding expertise. These conditions, born out of the necessity of exchanging experimental physics data both within CERN and across institutional and national borders, were crucial to the Web's development. Drawing on original archival materials, I will trace the evolution of networking at CERN from the early 1970s to the creation of the Web two decades later. The history of the Web also prompts reflection on the broader role of developing applications in and for physical research, as well as the pursuit of practical solutions. These factors are relevant to physics and its history far beyond the invention of the Web.

### Plenary Talk

PV III Mon 11:45 AudiMax

**Copernicus Revisited: is the Earth special?** — •LAURA KREIDBERG — Max Planck Institute for Astronomy, Heidelberg, Germany

Nearly 500 years ago, Nicolas Copernicus published his disruptive theory that Earth is not the center of the universe. This "Copernican demotion" has held

fast over the centuries, as astronomers have learned that there is nothing particularly remarkable about Earth or even the Milky Way. In the last two decades, however, a new test of the Copernican Principle has emerged – the discovery of an abundance of planets orbiting other stars. These discoveries allow us to put Earth in context and evaluate whether the formation, architecture, and present-day characteristics of our Solar System are in fact typical. Thanks to the revolutionary capabilities of the James Webb Space Telescope (JWST), we are finally able to study other Earth-size planets in detail, and in particular search for and characterize their atmospheres. In this talk, I will give a status report on JWST observations of rocky planets. I will cover the latest results for the iconic TRAPPIST-1 system, the study of the surface of the airless planet LHS 3844b, the search for atmospheres on lava worlds, and observations of planets in the radius valley at the boundary of rocky and gaseous worlds. Taken together, these results provide a first picture of the building blocks available for the origin of life on terrestrial planets beyond the Solar System, providing essential context for how special Earth really is.

### Plenary Talk

PV IV Tue 9:00 AudiMax

**Basics of plasma technologies: examples for applications and diagnostics** — •HOLGER KERSTEN — Kiel University, IEAP, 24098 Kiel

Gas discharges involving surface phenomena have been studied for more than 250 years (1). Classification of discharge modes was initially based on their visual appearance and later by their current-voltage characteristics. Oscillating or pulsing of power supplied, involvement of magnetic fields, effects of electrode material and geometry etc. make the situation more complicated (2). Effects like secondary electron emission, thermionic emission, drifts in magnetic fields, gas heating, flow pattern and collision processes affect the discharge mechanisms which are important for various plasma-based applications in thin film deposition or plasma etching as well as in plasma fusion or electric space propulsion.

In order to optimize the related processes suitable diagnostics for the plasma bulk as well as for the sheath in front of solid surfaces are necessary. Among them, methods for flux measurement of charged and neutral species toward plasma-facing surfaces by probes are of special interest. In addition to well-established conventional probe diagnostics also the principles of non-conventional diagnostics as calorimetric probes (CPs) and force probes (FPs) will be discussed (3).

(1) J. Cipo, H. Kersten, ViP 30(2018), 34-42.

(2) A. Anders, Appl. Phys. Rev. 11(2024), 031310.

(3) J. Benedikt, H. Kersten, A. Piel, PSST 30(2021), 033001.

### Plenary Talk

PV V Tue 9:45 AudiMax

**Invariants of Topological Order: An Operator-Algebraic Approach** — •YOSHIKO OGATA — Research Institute for Mathematical Sciences, Kyoto University, Kyoto 606-8502 JAPAN

Recently, topological phases of matter have attracted significant attention in physics and mathematics. In this talk, I will explain the operator-algebraic approach to this subject. This approach allows us to treat infinite systems directly. A key benefit of considering infinite systems is that it provides a stable theory. In particular, this framework enables us to describe quasi-particle excitations, known as anyons, as invariants in the classification of topological order, in a mathematically rigorous way. I will also present recent developments within this framework.

## PV VI+VII: Ceremonial Session with Award Ceremony

Time: Tuesday 14:00–16:00

Location: AudiMax

### Ceremonial Talk

PV VI AudiMax

**The Higgs boson - Deciphering its nature at present and future colliders** — •KARL JAKOBS — Physikalisches Institut, University of Freiburg

After the discovery of the Higgs boson at the Large Hadron Collider (LHC) at CERN, particle physics has entered a new era. With the successful data taking at the LHC over the past decade, many properties of this particle have been measured and found to be in agreement with expectations from the Standard Model. Despite this, important questions of particle physics, such as the nature of dark matter and the origin of the matter-antimatter asymmetry in the universe, remain open and call for experimental exploration. The Higgs field itself is linked to deep structural questions of the Standard Model such as flavour,

naturalness and the stability of the vacuum. Probed with highest precision at the quantum level, the Higgs boson may hold the key to shed light on some of these questions and to build a bridge between particle physics and cosmology.

In this talk, the role of the Higgs boson in the Standard Model and our present understanding of its properties are discussed. The largely increased accuracy expected to be reached at the High-Luminosity LHC and at the proposed next-generation Future Circular Collider at CERN will turn the Higgs boson into a precision tool. Measuring its self-interaction, rare decays, and couplings with unprecedented accuracy provides high sensitivity to physics beyond the Standard Model and may provide a giant leap forward in the understanding of nature.

## Prize Talk

PV VII AudiMax

**Between fascination and abstraction. Is it possible to teach modern physics at high-schools?** — •MATTHIAS BARTELMANN — Institute for Theoretical Physics, Heidelberg University — Laureate of the Robert-Wichard-Pohl-Prize 2026

Since this talk is related to the Robert Wichard Pohl Prize, which is awarded also for the conveyance of physics, let me take the opportunity to speak about some sore points in physics education and a possible approach to a solution. Undeniably, high-school teachers are decisive for instilling fascination for, or raising disgust against physics in formative years. If we want to pass our fascination for physics on to further generations, teaching teachers must be among our most important objectives. But modern physics is necessarily develop-

ing towards higher degrees of abstraction whose mathematical expression is more and more remote from the mathematics available at high-schools. Consequently, the fascination for modern physics is often lost at high-schools, physics is mistaken for an application of formulae appearing out of the blue, and essential ideas characteristic for physics do not appear. But is it possible to teach the most fascinating aspects of modern physics without having its mathematical foundation available? In this talk, I intend to argue that this is indeed possible. For this purpose, I will describe and discuss a lecture series recently introduced and tested at Heidelberg University. The lecture consists of three parts, one experimental, one theoretical, and one on timely applications. I will focus on the theoretical part, which is arguably the most difficult, and describe its motivation, ideas, structure, and summarize part of its contents.

## Evening Talk

PV VIII Tue 19:00 AudiMax

**Zu Wasser, zu Eis und in der Luft: Astroteilchenphysik mit Gammastrahlung und Neutrinos** — •CLAUDIO KOPPER und •CHRISTOPHER VAN ELDIK — Naturwissenschaftliche Fakultät, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

1.000.000.000.000.000 Elektronenvolt: Diese unvorstellbar hohe Energie erreichen geladene Teilchen in den „kosmischen Beschleunigern“ unserer Milchstraße – eine weit höhere Energie, als der zur Zeit größte durch Menschen gebaute Teilchenbeschleuniger LHC ermöglicht. Welche Himmelsobjekte sind für dieses Phänomen verantwortlich? Wie funktionieren diese Beschleuniger?

Mit speziellen Gammastrahlung-Teleskopen in Namibia und Chile und Neutrino-Observatorien im Mittelmeer und dem antarktischen Eis gehen Erlanger Forscher diesen Fragen auf den Grund. Sie finden dabei ein Universum vor, das völlig anders aussieht, als die Betrachtung des Sternenhimmels mit dem bloßen Auge vermuten lässt.

## Plenary Talk

PV IX Wed 9:00 AudiMax

**Status and perspectives for science at FAIR (Facility for Antiproton and Ion Research)** — •THOMAS NILSSON — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The international FAIR project is currently rapidly developing from the construction phase towards the delivery of cutting-edge science. The installations within the scope of the FAIR2028 stage will soon serve a large international community in nuclear, hadron, atomic and plasma physics, as well as material science and biophysics, offering new, world-unique opportunities. With our accelerators and lasers, we will recreate and study some of the most extreme conditions found in Nature – the Universe in the lab.

The scientific groundwork has been laid through the intermediate FAIR Phase-0 programme at the existing GSI infrastructure, where new and upgraded instrumentation and beams for FAIR have been utilized for science. Thus, the international collaborations are poised for the imminent exploitation of the new facility.

The status of the FAIR project will be reported, focusing on the path towards and beyond the first scientific experiments, underpinned by selected results from the FAIR Phase-0 programme. Furthermore, an outlook on the next phases of science at FAIR will be presented.

## Plenary Talk

PV X Wed 9:45 AudiMax

**Precision at the Energy Frontier: What the LHC is revealing about Fundamental Particle Physics** — •LUDOVICA APERIO BELLA — DESY, Hamburg, Germany

The Large Hadron Collider (LHC), the most powerful particle accelerator ever built, has opened an unprecedented window onto the fundamental laws of nature. Across the vast set of results published by its major experiments (ATLAS, CMS, LHCb and ALICE), the Standard Model (SM) remains the most successful framework for describing the elementary constituents of matter and their interactions. Historically, precise relations among SM parameters enabled the prediction of the top-quark mass and placed stringent constraints on the Higgs boson long before their discoveries.

Today, thanks to the extraordinary volume and quality of LHC data, precision measurements of key SM parameters have become central to the LHC physics program. These measurements provide some of the most sensitive tests of the internal consistency of the SM and offer unique opportunities to uncover deviations that could signal new physics.

This talk will present recent high-impact results from the LHC collaborations, highlighting landmark measurements that have achieved unprecedented precision and discussing their implications for the structure of the SM and the broader physics landscape. Prospects for the High-Luminosity LHC era will also be outlined, where an order-of-magnitude increase in data will enable even more stringent tests.

## Evening Talk

PV XI Wed 19:00 AudiMax

**Lise-Meitner-Lecture: Gravitational wave astronomy – quo vadis?** — •MICHÈLE HEURS — Leibniz Universität Hannover, Hannover, Germany — Deutsches Zentrum für Astrophysik (DZA), Görlitz, Germany — Deutsches Elektronen-Synchrotron DESY, Zeuthen, Germany

Since the first direct detection of gravitational waves (GWs) in 2015, we have opened an entirely new observation window into the Universe (complementary to the electromagnetic spectrum, neutrinos, and cosmic rays), heralding the era of multi-messenger astronomy with GWs. A wealth of scientific insights has already been gained – but so much more is yet to be discovered!

The sensitivity of current GW detectors is so incredible that the quantum noise of the employed ultra-stable laser light would be limiting. This necessitates the use of non-classical (“squeezed”) light, which is already routinely employed in the current (second) generation of detectors, e.g., aLIGO and AdVirgo. Many additional noise sources, such as seismic and thermal noise, pose further challenges for future (third-generation) detectors, e.g., the Einstein Telescope, a planned underground GW observatory in Europe.

To learn more about our Universe, we must achieve ever-higher detection rates for meaningful GW astronomy, which requires ever-greater detection sensitivity and larger detection bandwidth. In my talk, I will introduce the principle of interferometric GW detection, highlight some of the advanced technologies (employed and under development), and shed light on the plans for future interferometric GW observatories.

## Plenary Talk

PV XII Thu 9:00 AudiMax

**AI in the context of medical images** — •STEFAN WESARG — Fraunhofer Institute for Computer Graphics Research IGD, Darmstadt, Germany

AI is transforming how medical image data is used for diagnosis and therapy of diseases. Most prominently, it can help in uncovering complex patterns in radiology that exceed human perception or speed up the analysis of such data. Current machine learning approaches will be covered by focussing on their applications to medical image data. This includes diagnosis, disease monitoring, and early detection. Key themes include methods for organ and lesion segmentation, analysis of multimodal imaging data, and integrating image-based features with clinical information to create robust decision-support systems. The abstract also addresses AI-driven prosthetics development based on image data. Finally, we will outline challenges such as generalization and implementation in real-world workflows.

## Plenary Talk

PV XIII Thu 9:45 AudiMax

**LISA: The first space-based gravitational-wave observatory** — •GUIDO MUELLER — Max Planck Institute for Gravitational Physics (Albert Einstein Institut), Hannover, Germany — Leibniz Universität Hannover, Germany — University of Florida, Gainesville, FL USA

Since their first detection, gravitational waves (GWs) have become a central pillar of current and future efforts to study the Universe. Ground-based observatories have opened a new observational window, allowing us to detect GWs from mergers of neutron stars and black holes with masses up to a few hundred solar masses.

The first space-based gravitational-wave observatory, the Laser Interferometer Space Antenna (LISA), will extend these observations to the millihertz band, the natural frequency range of sources involving massive black holes with masses of millions of solar masses. In 2024, LISA was adopted by ESA as its next L-class mission, with a launch anticipated in the mid-2030s. The mission is currently progressing through its preliminary design reviews, consolidating the overall design and paving the way toward full implementation.

In this plenary talk, I will discuss the science case for LISA, introduce the mission concept, highlight the key technological challenges, and outline the roadmap from engineering models to flight hardware.

## Evening Talk

PV XIV Thu 20:00 AudiMax

**Max-von-Laue-Lecture: My journey in Nuclear Physics – Quantum Chromodynamics and the threat of nuclear annihilation** — •DAVID GROSS — University of California, Santa Barbara

## Symposium SMuK Dissertation Prize 2026 (SYMD)

jointly organised by  
the divisions of the Matter and Cosmos Section (SMuK)

Claus Lämmerzahl  
ZARM, Universität Bremen  
Am Fallturm  
28359 Bremen  
claus.laemmerzahl@zarm.uni-bremen.de

The Matter and Cosmos Section, with its divisions Extraterrestrial Physics (EP), Gravitation and Relativity (GR), Hadronic and Nuclear Physics (HK), Theoretical and Mathematical Physics (MP), Plasma Physics (P), Radiation and Medical Physics (ST), and Particle Physics (T), awards a dissertation prize in recognition of outstanding research in the context of a doctoral thesis and its excellent communication. The award committee selects up to four candidates from the nominations who will present their doctoral theses at this symposium.

## Overview of Invited Talks and Sessions

(Lecture hall AudiMax)

### Sessions

|        |     |             |         |                                          |
|--------|-----|-------------|---------|------------------------------------------|
| SYMD 1 | Mon | 13:45–14:45 | AudiMax | <b>SMuK Dissertation Prize Symposium</b> |
|--------|-----|-------------|---------|------------------------------------------|

The abstracts of the talks of the candidates will be published at <https://www.dpg-verhandlungen.de> prior to the conference.

## Extraterrestrial Physics Division Fachverband Extraterrestrische Physik (EP)

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### Overview of Invited Talks and Sessions

(Lecture hall KH 01.019; Poster Redoutensaal)

#### Plenary Talk of the Extraterrestrial Physics Division

PV III   Mon   11:45–12:30   AudiMax   **Copernicus Revisited: is the Earth special?** — •LAURA KREIDBERG

#### Invited Talks

|         |     |             |           |                                                                                                                                                                                                                |
|---------|-----|-------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| EP 1.1  | Mon | 14:45–15:15 | KH 01.019 | <b>Nuclear Astrophysics and Gamma Rays: From Space to Earth</b> — •THOMAS SIEGERT                                                                                                                              |
| EP 4.1  | Wed | 11:00–11:30 | KH 01.019 | <b>Assessing the immediate dynamical and long-term radiative effects of the Hunga Tonga Hunga Ha’apai volcanic eruption using state-of-art active and passive ground-based remote sensing</b> — •GUNTER STÖBER |
| EP 6.1  | Wed | 13:45–14:15 | KH 01.019 | <b>Simulation of the photosphere and chromospheres of sunspots</b> — •ASWATHI KRISHNAN KUTTY, ROBERT H. CAMERON, DAMIEN PRZYBYLSKI, TANAYVEER BHATIA, SAMI K. SOLANKI                                          |
| EP 6.2  | Wed | 14:15–14:45 | KH 01.019 | <b>Dynamics of a solar prominence simulated with MURaM</b> — •LISA-MARIE ZESSNER, ROBERT CAMERON, SAMI SOLANKI, DAMIEN PRZYBYLSKI                                                                              |
| EP 8.1  | Thu | 11:00–11:30 | KH 01.019 | <b>Solar and heliospheric studies with the LOFAR radio telescope</b> — •CHRISTIAN VOCKS                                                                                                                        |
| EP 10.1 | Fri | 9:00– 9:30  | KH 01.019 | <b>The diversity of low mass exoplanets</b> — •KRISTINE LAM                                                                                                                                                    |
| EP 11.1 | Fri | 11:00–11:30 | KH 01.019 | <b>Iron and the search for life on Mars</b> — •CHRISTIAN SCHRÖDER                                                                                                                                              |

#### Sessions

|              |     |             |              |                                    |
|--------------|-----|-------------|--------------|------------------------------------|
| EP 1.1–1.3   | Mon | 14:45–15:45 | KH 01.019    | <b>Astrophysics I</b>              |
| EP 2.1–2.7   | Mon | 16:15–18:00 | KH 01.019    | <b>Astrophysics II</b>             |
| EP 3.1–3.5   | Tue | 11:00–12:15 | KH 01.019    | <b>Astrophysics III</b>            |
| EP 4.1–4.3   | Wed | 11:00–12:00 | KH 01.019    | <b>Near-Earth Space</b>            |
| EP 5         | Wed | 12:30–13:45 | KH 01.019    | <b>Members’ Assembly</b>           |
| EP 6.1–6.6   | Wed | 13:45–15:45 | KH 01.019    | <b>Sun and Heliosphere I</b>       |
| EP 7.1–7.2   | Wed | 16:15–18:45 | Redoutensaal | <b>Poster Session</b>              |
| EP 8.1–8.5   | Thu | 11:00–12:30 | KH 01.019    | <b>Sun and Heliosphere II</b>      |
| EP 9.1–9.6   | Thu | 13:45–15:15 | KH 01.019    | <b>Sun and Heliosphere III</b>     |
| EP 10.1–10.5 | Fri | 9:00–10:30  | KH 01.019    | <b>Exoplanets and Astrobiology</b> |
| EP 11.1–11.4 | Fri | 11:00–12:25 | KH 01.019    | <b>Planets and Small Bodies</b>    |

#### Members’ Assembly of the Extraterrestrial Physics Division

Wed   12:30–13:45   KH 01.019

## Sessions

– Invited Talks, Contributed Talks, and Posters –

### EP 1: Astrophysics I

Time: Monday 14:45–15:45

Location: KH 01.019

#### Invited Talk

EP 1.1 Mon 14:45 KH 01.019

**Nuclear Astrophysics and Gamma Rays: From Space to Earth** — •THOMAS SIEGERT — JMU Würzburg

Gamma rays provide a unique window on nuclear processes occurring throughout the Universe, directly tracing radioactive isotopes and matter antimatter annihilation. In this talk, I will review key results from gamma-ray line spectroscopy in space, focusing on observations from 22 years of the now completed ESA satellite mission INTEGRAL. Measurements of radioactive isotopes, such as  $^{26}\text{Al}$  and  $^{60}\text{Fe}$ , reveal ongoing nucleosynthesis in the Galaxy and connect stellar explosions to traces found on Earth, including signatures preserved in ocean crust sediments. In this context, the long-standing puzzle of the Galactic 511 keV positron annihilation emission is also discussed. NASA's Compton Spectrometer and Imager (COSI) mission, scheduled for launch in 2027, is expected to significantly advance MeV measurements thanks to its increased sensitivity and imaging capabilities. I will introduce the Compton telescope concept and highlight open questions addressed by COSI, such as the role of massive stars and supernovae in Galactic feedback. Finally, I will show how analysis and imaging techniques developed for space-based gamma-ray astronomy are now being applied on Earth, enabling isotopic imaging of radioactive residues in nuclear facilities and related environments.

EP 1.2 Mon 15:15 KH 01.019

**Contribution of Stellar flares to the 511keV galactic positron budget** — •SAURABH MITTAL and THOMAS SIEGERT — Julius-Maximilian-Universität, Würzburg

The origin of the Galactic 511 keV positron annihilation line has been a mystery for five decades. One proposed explanation is positron production in stellar flares, motivated by the detection of the 511 keV line in solar flares and by the association of this emission with old stellar populations. In this work, we explore this scenario using two complementary approaches. First, we build a theoretical model to estimate the quasi-persistent 511 keV emission from flaring stars. Starting from solar flare observations, we construct empirical scaling relations between flare energy and 511 keV luminosity and extend them to Galactic stel-

lar populations using flare-frequency-energy distributions for different spectral types. In parallel, we analyze INTEGRAL/SPI data in the 511 keV band using combinations of known point sources and simple spatial templates, such as disk and bulge components modeled as two-dimensional Gaussians. We also test alternative descriptions in which no bulge template is assumed and the emission is instead described by a disk component together with a population of globular clusters, scaled by their masses and distances. This ongoing work aims to assess whether stellar flares can plausibly account for the observed Galactic 511 keV emission.

EP 1.3 Mon 15:30 KH 01.019

**On the cosmic-ray diffusion tensor in dynamical galactic halos** — JENS KLEIMANN<sup>1</sup>, •HORST FICHTNER<sup>1</sup>, MICHAEL STEIN<sup>2</sup>, RALF-JUERGEN DETTMAR<sup>2</sup>, DOMINIK BOMANS<sup>2</sup>, and SEAN OUGHTON<sup>3</sup> — <sup>1</sup>Theoretische Physik IV, Ruhr-Universität Bochum, Germany — <sup>2</sup>Astronomisches Institut, Ruhr-Universität Bochum, Germany — <sup>3</sup>Department of Mathematics, University of Waikato, New Zealand

Galactic halos separate the interstellar from the intergalactic medium. One question related to their physics is: How are cosmic rays transported within these dynamic regions of low density plasma permeated by a turbulent magnetic field? An understanding of cosmic-ray transport in galactic halos is of significance for explaining, e.g., the radio continuum measurements of synchrotron radiation from energetic electrons. Of central importance for the transport is the spatial diffusion tensor of cosmic rays, which can be computed in an ab-initio manner if the turbulence in the background medium is known. After a 'hydrodynamic validation', which revealed a persistent instability of the near-axis flow and could be traced to the galaxy mass, we present numerical solutions of the Reynolds-averaged single-fluid MHD equations. This way we obtained the physical properties of both large-scale MHD and small-scale turbulent quantities and, by employing a state-of-the-art nonlinear theory, the coefficients of parallel and perpendicular diffusion. The simulation results reveal variations in turbulence quantities in a dynamical halo that translate in a significant variation of the corresponding diffusion tensor of cosmic rays.

### EP 2: Astrophysics II

Time: Monday 16:15–18:00

Location: KH 01.019

EP 2.1 Mon 16:15 KH 01.019

**Modeling the low-ionization broad-line region in a sample of OI/CaII emitters detected by VLT/MUSE and DESI** — •TIANYU ZHAO — Institut für Astrophysik Georg-August-Universität Göttingen Friedrich-Hund-Platz 1 D-37077 Göttingen Germany

Broad emission-line (BEL) profiles in active galactic nuclei (AGN) contain information about the structure and kinematics of the broad-line region (BLR), where these lines are emitted, as the BEL shape is governed by the BEL-emitting gas moving in the potential of the supermassive black hole (SMBH). The study of BEL profiles is thus a powerful tool to study accretion processes onto SMBHs. However, for the largest part of the AGN population, it is impossible to directly \*read-of\* information from the line profiles as additional effects such as turbulence or optical-depths effects distort the clear kinematic signature of the moving BLR gas. Only recently, the profiles of O I 8446 and the near-infrared Ca II triplet have been recognized as a powerful diagnostic tool for BLR kinematics, because these line presumably arise in the dense atmosphere/corona of the accretion disk. Novel studies suggest, that these line are not significantly influenced by internal turbulence, thus clearly revealing the kinematic signature\*namely double-peaked profiles\*of a line-emitting BLR disk. In this master's thesis, I aim to extend the sample of known OI and Ca II emitters with complex, i.e., not single-peaked, profiles, and constrain the kinematics of the OI/CaII-emitting regions.

EP 2.2 Mon 16:30 KH 01.019

**A Three-Dimensional Tomographic Map of Galactic Cosmic-Ray Proton Density** — •HANIEH ZANDINEJAD and TORSTEN ENSSLIN — Max Planck Institute for Astrophysics, Karl-Schwarzschild-Str. 1, 85741 Garching

Cosmic rays (CRs) are a ubiquitous non-thermal component of the interstellar medium in the Galaxy. While their number density can be inferred from local

measurements on Earth, their three-dimensional distribution has largely been explored through simulations. A data-driven three-dimensional map of CRs is therefore essential to better understand their spatial distribution and the locations of their sources.

We infer the spatial distribution of cosmic-ray protons (CRp) by exploiting diffuse gamma-ray emission produced in inelastic hadronic collisions of CRs with interstellar gas. Using gamma-ray data from the Fermi Large Area Telescope together with a three-dimensional gas map, we reconstruct the CRp density in a morphological matching approach based on numerical methods from information field theory. The resulting three-dimensional CRp density is obtained as an ensemble of posterior samples, whose variance quantifies statistical uncertainties and whose mean is consistent with local cosmic-ray proton measurements.

In this talk, I will outline the construction of the prior model, present the morphological matching approach, and discuss the resulting three-dimensional CRp density map, highlighting current challenges in cosmic-ray tomography and the status of the project.

EP 2.3 Mon 16:45 KH 01.019

**Accretion Regimes of Neutrino-Cooled Flows onto Black Holes** — •JAVIERA HERNÁNDEZ MORALES<sup>1</sup> and DANIEL SIEGEL<sup>1,2</sup> — <sup>1</sup>University of Greifswald — <sup>2</sup>University of Guelph

Neutrino-cooled accretion disks can form in the aftermath of neutron-star mergers as well as during the collapse of rapidly rotating massive stars and the accretion-induced collapse of rapidly rotating white dwarfs. At sufficiently high accretion rates, electrons present in the disk become degenerate, which leads to the neutronization of the accreting plasma and makes these astrophysical systems promising sources of rapid neutron-capture nucleosynthesis (the *r*-process). We present a one-dimensional, general-relativistic, viscous-hydrodynamic model of neutrino-cooled accretion disks around black holes. We

chart the composition of the accretion flow and systematically explore a vast parameter space of accretion rates of  $\dot{M} \sim 10^{-6} - 10^6 M_{\odot} \text{ s}^{-1}$ , black hole masses of  $M_{\bullet} \sim 1 - 10^6 M_{\odot}$ , dimensionless spins of  $\chi_{\bullet} \in [0, 1)$ , and  $\alpha$ -viscosity values of  $\alpha \sim 10^{-3} - 1$ . We find that outflows from such disks are promising sites for  $r$ -process nucleosynthesis up to  $M_{\bullet} \leq 3000 M_{\odot}$ . These give rise to lanthanide-bearing ‘red’ super-kilonovae transients mostly for  $M_{\bullet} \leq 200 - 500 M_{\odot}$  and lanthanide-suppressed ‘blue’ super-kilonovae for larger  $M_{\bullet}$ . Proton-rich outflows can develop specifically for large black hole masses ( $M_{\bullet} \geq 100 M_{\odot}$ ) in certain accretion regimes, which may give rise to proton-rich isotopes via neutrino-induced proton-capture nucleosynthesis (the  $\nu p$ -process). We test some of these scenarios by following the trajectories of potential disk winds with the nuclear reaction network WinNet.

EP 2.4 Mon 17:00 KH 01.019

**R-process nucleosynthesis in collapsar accretion disk outflows and cosmic chemical evolution** — •AMAN AGARWAL<sup>1</sup> and DANIEL SIEGEL<sup>1,2</sup> —  
<sup>1</sup>Institute of Physics, University of Greifswald, D-17489 Greifswald, Germany —  
<sup>2</sup>Department of Physics, University of Guelph, Guelph, Ontario, Canada, N1G 2W1

The collapse of rapidly rotating massive stars (“collapsars”;  $M_{\text{ZAMS}} \leq 40 M_{\odot}$  at birth) are leading models for long gamma-ray burst (GRBs) central engines and promising sources of neutron-rich environments for  $r$ -process nucleosynthesis. Here, we extend the range of collapsars and explore collapsar accretion disk flows around black holes of mass  $M_{\bullet} = 3 - 3000 M_{\odot}$  using long-term, three-dimensional general-relativistic magnetohydrodynamics simulations with weak interactions and find that the accretion flows neutronize above an “ignition” accretion rate  $\dot{M}_{\text{ign}}$ . We present remarkable agreement between our simulations and the analytic result  $\dot{M}_{\text{ign}} \propto \alpha^{5/3} M_{\bullet}^{4/3}$  with  $\alpha_{\text{eff}}$  being the effective Shakura-Sunyaev viscosity. We demonstrate by semi-analytical modeling that stellar models of  $\sim 250 - 10^5 M_{\odot}$  mass can give rise to BHs of  $M_{\bullet} \sim 30 - 1000 M_{\odot}$  accreting at  $\dot{M} \geq \dot{M}_{\text{ign}}$ , yielding  $\sim 10 - 100 M_{\odot}$  of  $r$ -process elements per event. We highlight their potential as multi-messenger sources of optical/IR transients (“super-kilonovae”) and gravitational waves (GWs) for third-generation (3G) GW detectors. Using a one-zone chemical evolution model and a projection of future 3G GW and abundance observations, we demonstrate a correlation technique to infer the percentage contribution of multiple sources to galactic and cosmic  $r$ -process enrichment.

EP 2.5 Mon 17:15 KH 01.019

**Differential Rendering of the Night Sky in Imaging Atmospheric Cherenkov Telescopes** — •GERRIT ROELLINGHOFF and STEFAN FUNK — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

Imaging Atmospheric Cherenkov Telescopes detect Cherenkov light against an irreducible optical background stemming from the night sky, e.g. from stars, airglow, zodiacal light and moonlight. We present a differentiable forward model for predicting this pixel-wise night sky background. The model includes single-scattering atmospheric radiative transfer and ray-traced instrument responses

and spectrally models major contributors. Automatic differentiation enables gradient computation with respect to physical parameters such as aerosol optical depth and pointing offsets. This allows for efficient recovery of atmospheric and instrumental parameters from measured data, providing a new approach to instrument calibration for current and future IACT arrays.

EP 2.6 Mon 17:30 KH 01.019

**Bayesian imaging of cosmic-ray air showers** — •MRINAL JETTI — Max Planck Institute for Astrophysics, Karl-Schwarzschild-Str. 1, 85748 Garching, Germany  
 High-energy cosmic rays interacting with Earth’s atmosphere generate cascades of secondary particles known as extensive air showers. The electromagnetic component of these showers, consisting primarily of electrons, positrons, and photons, emits coherent, pulsed radio signals. Imaging air showers via their radio emission to infer the shower’s structure and its development and, ultimately, the properties of the primary cosmic-ray particle remains a long-standing problem, with several classical reconstruction methods having been developed.

This project aims to image extensive air showers using their radio emission, measured as time-dependent electric field traces recorded by ground-based antenna arrays. The air shower is modeled as a system of relativistically moving current distributions that give rise to the observed radio signal. Using Bayesian inference within the framework of Information Field Theory, implemented within the Python package NIFTy (Numerical Information Field Theory), the inverse problem of reconstructing the underlying current distributions from the measured electric field traces is addressed.

EP 2.7 Mon 17:45 KH 01.019

**Observations of the dark matter halo of the Andromeda Galaxy with INTEGRAL/SPI** — •LAURA EISENBERGER, THOMAS SIEGERT, SAURABH MITTAL, RUDI REINHARDT, DIMITRIS TSATSIS, NIKLAS C. BAUER, PATRIK EHRMANN, and MANJA ZIMMERER — Julius-Maximilians-Universität Würzburg, Fakultät für Physik und Astronomie, Institut für Theoretische Physik und Astrophysik, Lehrstuhl für Astronomie, Emil-Fischer-Str. 31, 97074 Würzburg

The Andromeda galaxy (M31) is a promising target for the indirect search of dark matter (DM) due to its proximity and expected massive DM halo. It functions as test case for a Milky Way (MW) like galaxy as the isotropic emission from the MW halo itself cannot be measured without large efforts with coded mask telescopes. Since weakly interacting massive particles also produce a significant flux of secondary MeV photons from inverse Compton scattering and positron annihilation,  $\gamma$ -ray observations in the MeV range are a powerful probe of DM with a wide mass range from MeV up to TeV.

We use the spectrum obtained from SPI observations of the M31 region including M33 in order to constrain different DM models. We model the halos of M31 and M33 as extended emission and take the uncertainty of the DM distribution into account by considering different density profiles and substructure boosting. From the 511 keV line from positron annihilation, we estimate the pair production rate in M31 to put a lower mass limit on thermal DM. With forthcoming missions like COSI-SMEX, a coherent multi-galaxy analysis promises to significantly improve upon existing DM constraints.

## EP 3: Astrophysics III

Time: Tuesday 11:00–12:15

Location: KH 01.019

EP 3.1 Tue 11:00 KH 01.019

**mw-atlas: Towards the three-dimensional shape of the Milky Way Galaxy in Gas and Dust** — •FABIAN POLNITZKY, LAURIN SÖDING, and PHILIPP MERTSCH — RWTH Aachen University

From our position inside the Milky Way, we have a unique vantage point which obscures the galaxy’s overall shape. Despite decades of research, no definite answer has been found regarding its exact structure. In recent years, the focus has shifted towards three-dimensional spatial mapping of the galaxy, in comparison to two-dimensional observations of the sky, leading to the discovery of previously unknown features such as the Radcliffe Wave.

To construct these maps, we require new observational data, but more importantly, new statistical techniques that bridge the transition from two to three dimensions. A promising avenue for this is information field theory, which was successfully used to map the spatial distribution of parts of the Milky Way.

Components, that are mapped in three dimensions now, include neutral hydrogen gas across the entire galaxy and interstellar dust in the local neighbourhood of the sun. In my talk, I will provide an overview of the techniques used to create these maps, summarize our current understanding, and highlight what we know about them. I will also discuss how combining neutral hydrogen gas and interstellar dust can further improve our three-dimensional view of the Milky Way, by leveraging correlations between them.

EP 3.2 Tue 11:15 KH 01.019

**mw-atlas: Inferring the Milky Ways gravitational potential from stellar streams** — •MATTHIAS HÜBL and PHILIPP MERTSCH — RWTH Aachen University

The Milky Ways gravitational potential governs the large scale dynamics and imprints itself on the movement of gas, dust and stars around the Galactic center. Stellar streams, groups of stars that were stripped from a common progenitor cluster, can be seen as tracer particles within this potential that have very similar kinematic properties. Seen as elongated features along the sky, they almost perfectly map out orbits, and with the abundance of high quality astronomical data taken in recent years, it is now feasible to use them to constrain the Milky Ways gravitational potential in unprecedented ways. Using powerful and flexible methods like geometric variational inference, it is possible to infer the potential without fixing its exact shape to a rigid analytical form. This way we are able to constrain the deviation of the gravitational potential from a perfectly spherical one, namely its triaxiality, and thus the shape of the Galaxies dark matter halo within our Bayesian framework.



EP 3.3 Tue 11:30 KH 01.019

**An in-depth characterization of fiber-to-chip coupling interfaces in arrayed waveguide spectrographs for astronomy** — •TIM SCHLEIFER<sup>1,2</sup>, AASHIA RAHMAN<sup>2</sup>, KALAGA MADHAV<sup>2</sup>, MICHAEL GENSCH<sup>1,3</sup>, and ANDREAS STOLL<sup>2</sup> — <sup>1</sup>Technische Universität Berlin, Berlin, Germany — <sup>2</sup>Leibniz-Institut für Astrophysik Potsdam, Potsdam, Germany — <sup>3</sup>DLR Institute of Space Research, Berlin, Germany

Astrophotonics offers a pathway toward miniaturized and highly stable astronomical instruments for next-generation telescopes. A chip-based arrayed waveguide grating (AWG) acts as the main dispersive element in an astrophotonic spectrograph, with a key limitation arising at the fiber-to-chip interface, where coupling losses can critically impact overall throughput. Characterizing and optimizing this interface is essential to ensuring efficient light transfer. This work focuses on the development of a warm astrophotonic spectrograph based on an AWG with a 16-fiber input array coupled to the AWG chip. A silica-on-silicon AWG chip with 15 input waveguides and a diced output facet was used. The resulting echellogram was recorded using a C-RED 2, an infrared camera used in astronomy. A detailed characterization of fiber-to-chip coupling that includes theoretical models, simulations, and experimental measurements was done for a single fiber coupled to an input waveguide of the AWG. Subsequently, all 16 input waveguides were individually assessed to evaluate performance variations across the array. Future work includes a characterization of throughput and spectral resolution followed by an on-sky test to demonstrate the feasibility of a multi-fiber astrophotonic spectrograph.

EP 3.4 Tue 11:45 KH 01.019

**Langmuir waves in astrophysical Druyvesteyn plasmas** — SIMON TISCHMANN<sup>1</sup>, RUDI GAELZER<sup>2</sup>, DUSTIN LEE SCHROEDER<sup>1</sup>, MARIAN LAZAR<sup>3</sup>, and •HORST FICHTNER<sup>1</sup> — <sup>1</sup>Theoretische Physik IV, Ruhr-Universität Bochum, Germany — <sup>2</sup>Instituto de Física, Universidade Federal do Rio Grande do Sul, Brazil — <sup>3</sup>Centre for Mathematical Plasma Astrophysics, Department of Mathematics, KU Leuven, Belgium

We present a new model for linear dispersion studies in astrophysical plasmas, by introducing astrophysical Druyvesteyn plasmas. This model can reproduce not

only high-energy tails, as observed in situ in the solar wind, but also low-energy flat-tops of the velocity distributions, like those of electrons in interplanetary shocks. The dispersion relation of longitudinal waves is derived in terms of the newly introduced Druyvesteyn dispersion function. The dispersion curves as well as damping rates of high-frequency Langmuir waves are numerically computed for the isotropic case using the ALPS code, and their analytical approximations are provided in the limit of weak damping. This way we offer a new tool for modeling longitudinal waves, and in particular Langmuir waves, that may be useful for other astrophysical systems which are in non-equilibrium states as evidenced by direct in-situ measurements, like the solar corona and planetary environments, as well as by indirect observations of nonthermal sources of waves and emissions.

EP 3.5 Tue 12:00 KH 01.019

**Adequate Coordinate System for Space Navigation** — •HANS-OTTO CARMESIN — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

The International Astronomical Union (IAU) realized, that the coordinate systems of relativity theory are insufficient for space navigation. Therefore, the IAU proclaimed the problem of finding an adequate coordinate system (ACS).

Here, that problem is solved:

- (1) A measurement procedure is presented.
- (2) For each Point  $P$ , an ACS and its velocity  $\vec{v}_{ACS,CS}$  relative to an arbitrary coordinate system (CS) are deduced.
- (3) The ACS is confirmed by an observation at Earth and at space.
- (4) The universal zero of the fractional kinematic time difference  $\delta t_{kin, fractional}$  is derived.
- (5) For each Point  $P$ , the fractional kinematic time difference  $\delta t_{kin, fractional}$  is derived and predicted.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster.

Carmesin, H.-O. (2025): Construction of a Physically Adequate Coordinate System with Help of an Observation on Earth's Ground. J Geosci Earth Planet Syst, 1(1), pp. 01-12.

## EP 4: Near-Earth Space

Time: Wednesday 11:00–12:00

Location: KH 01.019

### Invited Talk

EP 4.1 Wed 11:00 KH 01.019

**Assessing the immediate dynamical and long-term radiative effects of the Hunga Tonga Hunga Ha'apai volcanic eruption using state-of-art active and passive ground-based remote sensing** — •GUNTER STÖBER — University of Bern, Institute of Applied Physics, Bern, Switzerland — Oeschger Center for Climate Change Research, Bern, Switzerland

The Hunga Tonga Hunga Ha'apai (HTHH) volcanic eruption on 15th January 2022 launched atmospheric gravity waves (GW) traveling around the entire globe, reaching altitudes up to the mesosphere/ lower thermosphere (MLT) and even beyond that height. These GW had unprecedentedly high phase speeds of 170-240 m/s and reached amplitudes of 40- 50 m/s in the zonal and meridional wind components. Global available meteor radar observations of MLT winds together with multistatic meteor radar networks and high-resolution gravity wave modeling with the High Altitude Mechanistic Circulation Model (HIAMCM) reveal the global propagation of the volcanic GW and their global propagation for more than 24 hours.

However, the larger impact of the HTHH eruption is caused by the released water vapor. The volcanic plume injected about 13 Tg of water vapor into the stratosphere and mesosphere. Due to residual circulation, this water vapor is now distributed around the globe and observed by both ground-based and spaceborne sensors. Here, we present observations of ground-based and balloon-borne sensors to measure the excess water vapor due to HTHH in the middle atmosphere.

EP 4.2 Wed 11:30 KH 01.019

**Midlatitude impact of the extreme geomagnetic storm of May 10/11, 2024** — •MIRIAM SINNHUBER<sup>1</sup>, CHAO YUE<sup>2</sup>, and YUXUAN LI<sup>2</sup> — <sup>1</sup>Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>2</sup>Peking University, Beijing, China

On May 10-11, two CMEs arriving within few hours initiated the first extreme

geomagnetic storm since the Halloween storm of October/November 2003. Polar lights were clearly visible well into midlatitudes, down to the Alps in Germany. Here, we use fluxes of precipitating electrons from the Chinese FengYun 3E satellite to derive rates of midlatitude ionization. These ionization rates are discussed and compared to observations of NO and N<sub>2</sub>O in the mesosphere obtained from the ACE-FTS/SCISAT.

EP 4.3 Wed 11:45 KH 01.019

**EPP-NOy Upper-Boundary Condition, validation and long-term trends** — •STEFAN BENDER<sup>1</sup>, BERND FUNKE<sup>1</sup>, MANUEL LÓPEZ PUERTAS<sup>1</sup>, GABRIELE STILLER<sup>2</sup>, PETER BERNATH<sup>3</sup>, and CHRISTOPHER BOONE<sup>3</sup> — <sup>1</sup>IAA-CSIC, Granada, Spain — <sup>2</sup>KIT, Karlsruhe, Germany — <sup>3</sup>University of Waterloo, Waterloo, Canada

Polar winter descent of NOy produced by energetic particle precipitation (EPP) in the mesosphere and lower thermosphere affects polar stratospheric ozone by catalytic reactions. This, in turn, may affect regional climate via radiative and dynamical feedbacks. NOy observations by MIPAS/Envisat during 2002–2012 have provided observational constraints on the solar-activity modulated variability of stratospheric EPP-NOy. These constraints have been used to formulate a chemical upper boundary condition (UBC) for climate models in the context of solar forcing recommendations. We have updated the UBC with the recently released, reprocessed MIPAS version 8 data. We compare this updated NOy UBC model to data from the ACE-FTS solar occultation instrument which has been providing measurements since 2004 and is still actively providing data today. This 20+-year, long-term dataset will enable us to assess the validity of the assumptions underlying the UBC model, such as its climatological approach. Any deviation will enable us to assess the projected, climate-change induced changes in middle atmospheric transport, e.g. via the Brewer-Dobson circulation.

## EP 5: Members' Assembly

Time: Wednesday 12:30–13:45

Location: KH 01.019

All members of the Extraterrestrial Physics Division are invited to participate.

## EP 6: Sun and Heliosphere I

Time: Wednesday 13:45–15:45

Location: KH 01.019

## Invited Talk

EP 6.1 Wed 13:45 KH 01.019

**Simulation of the photosphere and chromospheres of sunspots** — •ASWATHI KRISHNAN KUTTY, ROBERT H. CAMERON, DAMIEN PRZYBYLSKI, TANAYVEER BHATIA, and SAMI K. SOLANKI — Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Goettingen

Sunspots are one of the most prominent features of the solar surface and are characterized by a dark central core called the umbra, which is surrounded by a collection of filamentary structures called the penumbra. The penumbra is on average considerably brighter than the umbra but darker than the surrounding quiet Sun. At the photospheric level, the nearly horizontal Evershed flow is directed outward from the outer edge of the umbra along penumbral filaments. On the other hand, in the chromosphere, the flow is reversed and the plasma flows inwards towards the umbra. Radiative magneto-hydrodynamic (rMHD) codes have simulated sunspots in the upper convection zone and photosphere (Heinemann et al., 2007; Rempel et al., 2009). However, simulations of sunspots that include a realistic treatment of the chromosphere and corona have not yet been performed. The structure and evolution of the chromospheric field will be important in understanding magnetic reconnection and processes that are important for flare initiation. In this talk, I will present the first simulations of sunspots that reach layers above the solar photosphere.

## Invited Talk

EP 6.2 Wed 14:15 KH 01.019

**Dynamics of a solar prominence simulated with MURaM** — •LISA-MARIE ZESSNER, ROBERT CAMERON, SAMI SOLANKI, and DAMIEN PRZYBYLSKI — Max Planck Institute for Solar System Research, Göttingen, Germany

Solar prominences are cool and dense plasma clouds suspended in the hot solar corona, supported by the solar magnetic field. These complex and dynamic structures exhibit various types of mass motion and exchange mass with the solar surface and the surrounding atmosphere. Understanding the nature and origin of these dynamics is an important part of solar prominence research.

We use the 3D radiative magnetohydrodynamic code MURaM to simulate the formation and properties of solar prominences in a dipped magnetic arcade configuration. The prominence formation process starts by injection of cool and dense plasma seeds from the chromosphere into the corona. These injections are accompanied by photospheric flux cancellation and reconfigurations of the magnetic field above the surface. The subsequent mass build-up of the prominence is a combination of these continued cool injections and condensation of hot plasma. The resulting prominence structure is dynamic, featuring differently oriented structures and drainage to the surface. In this talk, we present the evolution of individual injection events that feed the prominence, as well as the motion and dynamics of the prominence plasma.

EP 6.3 Wed 14:45 KH 01.019

**The Current Layer Missing in the Standard Model of Photospheric Flux Cancellation and CME Initiation** — •BERNHARD KLIEM — Institute of Physics and Astronomy, University of Potsdam

Flux cancellation, driven by flows that converge at the polarity inversion line (PIL), is a common process in the evolution of photospheric magnetic flux. The standard model of photospheric flux cancellation predicts the formation and growth of a magnetic flux rope above the PIL, low in the corona (van Ballegoijen & Martens 1989). Consequently, the cancellation process is considered a pathway to CME initiation by magnetohydrodynamic (MHD) instability, which requires a flux rope to exist at the onset point. Recent MHD simulations of flux cancellation additionally reveal the formation of a vertical current layer or sheet between the PIL and the forming flux rope. This allows for CME initiation by tearing of the vertical current layer, which forms a plasmoid (seed flux rope) during the initiation of a subsequent eruption and is known as the reconnection model for CME initiation. MHD simulations of flux cancellation will be presented, which address the initiation of eruption by MHD instability vs. reconnection and its parametric dependence. Some runs reveal the formation of plasmoids in the slow-rise phase, merging with the main forming flux rope. This could be a model of confined precursor flares and can lead to a non-equilibrium state of the main rope prior to its eruption.

EP 6.4 Wed 15:00 KH 01.019

**Strongly localized heating in polytropic expanding stellar wind models** — •LUKAS WESTRICH<sup>1,2</sup>, BIDZINA SHERGELASHVILI<sup>1,2,3,4</sup>, and HORST FICHTNER<sup>1</sup>

— <sup>1</sup>Theoretical Physics IV, Ruhr-Universität Bochum, Universitätsstrasse 150, 44780 Bochum, Germany — <sup>2</sup>Centre for Computational Helio Studies, Faculty of Natural Sciences and Medicine, Ilia State University, Cholokashvili Ave. 3/5, 0162 Tbilisi, Georgia — <sup>3</sup>Evgeni Kharadze Georgian National Astrophysical Observatory, M. Kostava street 47/57, 0179 Tbilisi, Georgia — <sup>4</sup>Institut für Weltraumforschung, Österreichische Akademie der Wissenschaften, Schmiedlstrasse 6, 8042 Graz, Austria

In this talk, we present novel polytropic, expanding solar wind models that include a strongly localized heating source. After introducing the (quasi-)discontinuous solar wind models, we discuss the polytropic index and its use as a simplified description of the energy balance in the expanding plasma. In addition to the \*background\* energy-balance process captured by the polytropic index and for a few solutions a Hollweg type like heat conduction, we introduce a strongly localized heating mechanism - possibly due to acoustic waves - and construct new polytropic stellar wind models, both analytical and numerical. These new stellar wind models may be of particular interest in light of recent Parker Solar Probe observations, which reveal strongly varying wind streams and the presence of acoustic waves close to the Sun.

EP 6.5 Wed 15:15 KH 01.019

**Solar wind heat flux with kappa distributions** — •KLAUS SCHERER<sup>1</sup>, MARIAN LAZAR<sup>2</sup>, HORST FICHTNER<sup>1</sup>, and LUKAS WESTRICH<sup>1</sup> — <sup>1</sup>Institut für Theoretische Physik, Lehrstuhl IV: Plasma-Astroteilchenphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — <sup>2</sup>Centre for mathematical Plasma Astrophysics, Department of Mathematics, KU Leuven, Celestijnenlaan 200B, 3001 Leuven, Belgium

In the collisionless solar wind between 0.3 and 5 au, the proton usually have Maxwellian velocity distributions, while the electron distributions exhibit extended tails in the anti-sunward direction and a (spherical) cut-off towards the Sun. In case such electron distributions are assumed to be Maxwellians the resulting heat flux was modelled and discussed in Hollweg (1974). We apply this approach replacing the Maxwellian by a Kappa distribution, using both the classical standard Kappa distribution (SKD) and the newer regularized Kappa distribution (RKD). In contrast to SKDs, RKDs allow the calculation of the heat flux for any positive value of the kappa parameter. We present (semi-)analytical results and employ them in a one-dimensional hydrodynamic model of the solar wind expansion to show the impact of the distribution function on the magnitude of the heat flux.

EP 6.6 Wed 15:30 KH 01.019

**On the complexity of plasma instabilities in the solar wind: Three electron-component formalism of heat-flux instabilities** — •DUSTIN LEE SCHRÖDER<sup>1</sup>, MARIAN LAZAR<sup>1,2</sup>, and HORST FICHTNER<sup>1</sup> — <sup>1</sup>Ruhr-Universität Bochum — <sup>2</sup>Katholieke Universiteit Leuven

Despite the fact that electrons observed in-situ in space plasmas have three major components, the quasithermal core, and the suprathermal halo and strahl, the analysis of instabilities triggered by kinetic anisotropies (such as a relative drift of the strahl) generally considers only two of these components. We aim to demonstrate that a realistic modeling, with all three components, is achievable, in the present analysis focusing on heat-flux instabilities. In the absence of particle-particle collisions, these instabilities are responsible for the regularization of the heat flux carried mainly by suprathermal electrons. The velocity distributions of the electron populations are modeled according to in-situ observations, with a Maxwellian core and  $\kappa$ -distributed halo and strahl components. We exploit new advanced numerical codes (DIS-K and ALPS), capable of solving the linear dispersion and stability properties of such plasma systems. The unstable solutions differ significantly from those obtained with simplified models with only two components. The growth rates now predict the excitation and interplay of two unstable modes, whistler heat-flux and/or firehose heat-flux instabilities. The two instabilities are triggered by the two relative drifts, core-strahl and halo-strahl, and may have new consequences in the regularization of the heat-flux.

## EP 7: Poster Session

Time: Wednesday 16:15–18:45

Location: Redoutensaal

EP 7.1 Wed 16:15 Redoutensaal

**Towards Ultra-Broadband Terahertz Time-Domain Spectroscopy for Space Research** — •BRUNO BROER<sup>1,2</sup>, DOMINIC AZIH<sup>1,2</sup>, YOOKYUNG HA<sup>2,1</sup>, JONAS WOESTE<sup>1,2</sup>, EMMA KINNE<sup>1,2</sup>, SERGEY PAVLOV<sup>2</sup>, OLIVER GUECKSTOCK<sup>3</sup>, TOM SEIFERT<sup>3,4</sup>, NIKOLA STOJANOVIC<sup>2</sup>, TOBIAS KAMPFRATH<sup>3,4</sup>, and MICHAEL GENSCHE<sup>1,2</sup> — <sup>1</sup>Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany — <sup>2</sup>German Aerospace Center (DLR), Institute of Space Research, Rutherfordstr. 2, 12489 Berlin, Germany — <sup>3</sup>Free University Berlin, Arnimallee 14, 14195 Berlin, Germany — <sup>4</sup>TeraSpinTec GmbH, Lüneburger Str. 26, 10557 Berlin, Germany

Femtosecond lasers have in recent years been shown to be compact, robust and space qualified, in particular regarding their radiation hardness [1]. This opens up opportunities for compact Terahertz Time-Domain Spectroscopy (THz TDS) systems to detect gases (e.g. CO<sub>2</sub>) and solids on planetary missions. By avoiding cryogenically cooled direct detectors and bulky opto-mechanics of conventional instruments e.g. in Fourier Transform Infrared systems, THz TDS becomes of high interest for in-situ sensing applications requiring robustness, compactness and high energy/mass efficiency. Here we show our progress en route to a THz TDS setup for space applications with a bandwidth of over 30 THz and a frequency resolution of below 100 GHz.

[1] J. Lee, K. Lee, Y. Jang et al. "Testing of a femtosecond pulse laser in outer space" Scientific Reports 4, 5134 (2014)

EP 7.2 Wed 16:15 Redoutensaal

**Time-Domain Spectroscopy Techniques for the Identification of Minerals and Gases in Space Research** — •EMMA KINNE<sup>1,2</sup>, YOOKYUNG HA<sup>1,2</sup>, SERGEY G. PAVLOV<sup>2</sup>, JONAS WOESTE<sup>1,2</sup>, DOMINIC AZIH<sup>1,2</sup>, BRUNO BROER<sup>1,2</sup>, NIKOLA STOJANOVIC<sup>2</sup>, and MICHAEL GENSCHE<sup>1,2</sup> — <sup>1</sup>Technische Universität Berlin, Berlin, Germany — <sup>2</sup>DLR Institute of Space Research, Berlin, Germany

On planetary missions, the identification of gases and the characterization of solids by their spectroscopic fingerprint are typically performed by infrared and/or Raman spectrometers. The advent of space-qualified femtosecond lasers enables to perform the same task by a new class of time-domain techniques which have the potential to be much more robust, compact and sensitive. Methods such as Time-Domain Raman Spectroscopy (TDRS) and Rotational Coherent Raman Scattering (RCRS) retrieve Raman-active fingerprints of solids and molecules, respectively. Recently, we reported TDRS to be a viable alternative to continuous wave Raman spectroscopy in identifying minerals [1]. Here, we demonstrate that the same experimental setup, that is used for TDRS, can detect molecular species via RCRS. We report measured rotational revival signatures from N<sub>2</sub> and O<sub>2</sub> at room temperature and atmospheric pressure. Simulations using the LIMA software further show that this setup could detect a wide range of molecular species under extraterrestrial conditions.

[1] Y. Ha, et. al., Time-Domain Raman Spectroscopy: An Emerging Technique in Space Exploration? J. Raman Spectrosc. 56 (2025)

## EP 8: Sun and Heliosphere II

Time: Thursday 11:00–12:30

Location: KH 01.019

## Invited Talk

EP 8.1 Thu 11:00 KH 01.019

**Solar and heliospheric studies with the LOFAR radio telescope** — •CHRISTIAN VOCKS — Leibniz-Institut für Astrophysik Potsdam (AIP), Potsdam, Germany  
LOFAR is a radio interferometer observing in two frequency bands, 10 - 90 MHz and 110 - 250 MHz. As a software telescope, it offers great flexibility and various simultaneous observing modes. Solar radio radiation in the low and high band originates from the upper and middle corona, respectively. Thermal bremsstrahlung of the quiet solar corona provides information on coronal structure and temperatures. Non-thermal plasma emission of energetic electrons from solar flares or coronal mass ejection (CME) shock fronts makes LOFAR well suited for solar activity studies. Observations of type III radio bursts, caused by energetic electron beams, provide information on source locations relative to EUV and X-ray sources, as well as on electron and radio wave propagation in the corona. "beam-formed" images of type II bursts reveal electron acceleration at CME shock fronts.

Since the lowest LOFAR frequencies correspond to the upper corona and transition into the solar wind, LOFAR is an ideal instrument for Space Weather studies. Joint observing campaigns with Solar Orbiter and Parker Solar Probe allow for tracing space weather events from their coronal source through the inner heliosphere on their way towards Earth. LOFAR is currently undergoing the upgrade to LOFAR2.0 with simultaneous low- and high-band observations and improved imaging capabilities. Space Weather studies with LOFAR2.0 will be complementary to the upcoming SKA that covers frequencies above 50 MHz.

EP 8.2 Thu 11:30 KH 01.019

**Transition of energetic electrons from the solar corona into interplanetary space** — •LILLY ZEBERER — Universität Potsdam, Institut für Physik und Astronomie, Potsdam, Germany

Solar radio bursts are a phenomenon on the Sun that is closely related to solar flares. They are caused by accelerated energetic particles traveling away from the Sun and are divided into different types. Focusing on type III bursts, their most important feature is the rapid frequency drift from high to low frequencies, corresponding to height in the corona. Using LOFAR data as well as data from the Parker Solar Probe (PSP) FIELDS instrument suite, this work aims to improve a chosen heliospheric density model, especially in the transition region from the solar corona into interplanetary space. Heliospheric density models are an important tool in interpreting radio data, even though the heliosphere is highly structured and they cannot be global. This work uses fitting of the frequency drift of type III radio bursts in combined dynamic spectra of LOFAR and PSP data to then calculate source velocities and observe how they behave as the particles move away from the Sun.

EP 8.3 Thu 11:45 KH 01.019

**Advances in ground-based space weather monitoring with compact CALLISTO** — •DANIELA BANYŚ<sup>1</sup>, DAVID WENZEL<sup>1</sup>, LUTZ HEINRICH<sup>1</sup>, FRANK TANDLER<sup>1</sup>, and CHRISTIAN MONSTEIN<sup>2</sup> — <sup>1</sup>Institute for Solar-Terrestrial Physics, German Aerospace Center (DLR e.V.), Germany — <sup>2</sup>Ricerche Solari Locarno IRSOL, Switzerland

DLR has installed various compact CALLISTO receivers as part of the Solar Ionosphere Global Network (SIGN), equipped with spectrometers covering 10-80 MHz, 45-860 MHz, and 1000-1600 MHz in Wairakei, New Zealand. Together with the existing SIGN station in Neustrelitz, Germany, this network provides almost 24/7 continuous observations of solar radio bursts, enabling detailed studies of flare-accelerated electrons and coronal mass ejections. The CALLISTO receivers have been optimized in hardware and software to increase signal-to-noise ratio, simplify maintenance, and improve comparability. Furthermore, a filtering technique has been developed that harmonizes frequency spectra, removes noise, and reduces radio frequency interferences (RFIs), producing cleaner data for automated burst identification and classification.

This setup demonstrates the potential of compact, ground-based CALLISTO stations for continuous solar monitoring and reliable space weather event analysis.

EP 8.4 Thu 12:00 KH 01.019

**Probing Flare Energy Release with STIX Hard X-ray Lightcurves** — •OLIVER FLOR — Leibniz Institute for Astrophysics Potsdam, Potsdam, Germany — University of Potsdam, Potsdam, Germany

Investigating hard X-ray (HXR) emission provides valuable insights into the energy release and particle acceleration mechanisms inherent to the flaring process. We present a statistical study of the HXR lightcurves of all flares with GOES classification M5 or larger of the current solar cycle that were observed by Solar Orbiter STIX with sufficient counts above 25keV.

Using a suite of timeseries analysis tools such as Gaussian Decomposition and Wavelet analysis, we investigate how the number of HXR peaks, as well as their periods and amplitudes and the presence of potential quasi periodic pulsations (QPPs) vary across a decade of flare magnitudes.

The results of this data analysis allow us to explore the physical implications of detecting multiple HXR bursts within individual flares. Specifically, we investigate how characteristic timescales and potential QPPs may reflect underlying processes, such as repetitive magnetic reconnection or oscillation of MHD waves, thereby expanding our understanding of energy release during solar flares.

EP 8.5 Thu 12:15 KH 01.019

**Constraining ion acceleration in behind-the-limb gamma-ray flares with Fermi-LAT, SoHO/STIX, and ground-based radio observations** — •ALEXANDER WARMUTH — Leibniz-Institut für Astrophysik Potsdam (AIP), Potsdam, Germany

Compared to energetic electrons in solar flares, which can be readily observed in hard X-rays and radio, our understanding of energetic ions is severely deficient. Our main diagnostics for ions are gamma-ray observations, which remain challenging. A particularly intriguing case are behind-the-limb (BTL) gamma-ray flares, where the flare is occulted as seen from Earth, but nevertheless gamma-ray emission is detected by near-Earth spacecraft. Here, we investigate the relationship between the gamma-ray emission measured with Fermi-LAT, hard X-ray observations from STIX on Solar Orbiter, and ground-based radio observations,

for small sample of BTL gamma-ray flares. In all events, type II radio bursts were present that were synchronized in time with the gamma-ray emission. Conversely, we find a significant delay between the impulsive phase of the flare as recorded by STIX and the gamma-ray emission. These findings support the notion that the highly relativistic ions that produce the gamma-rays in BTL flares are accelerated at CME-driven propagating coronal shock waves rather than in large-scale coronal loops.

## EP 9: Sun and Heliosphere III

Time: Thursday 13:45–15:15

Location: KH 01.019

EP 9.1 Thu 13:45 KH 01.019

**Langmuir waves in astrophysical Druyvesteyn plasmas** — SIMON TISCHMANN<sup>1</sup>, RUDI GAELZER<sup>2</sup>, DUSTIN LEE SCHROEDER<sup>1</sup>, MARIAN LAZAR<sup>3</sup>, and HORST FICHTNER<sup>1</sup> — <sup>1</sup>Theoretische Physik IV, Ruhr-Universität Bochum, Germany — <sup>2</sup>Instituto de Física, Universidade Federal do Rio Grande do Sul, Brazil — <sup>3</sup>Centre for Mathematical Plasma Astrophysics, Department of Mathematics, KU Leuven, Belgium

We present a new model for linear dispersion studies in astrophysical plasmas, by introducing astrophysical Druyvesteyn plasmas. This model can reproduce not only high-energy tails, as observed in situ in the solar wind, but also low-energy flat-tops of the velocity distributions, like those of electrons in interplanetary shocks. The dispersion relation of longitudinal waves is derived in terms of the newly introduced Druyvesteyn dispersion function. The dispersion curves as well as damping rates of high-frequency Langmuir waves are numerically computed for the isotropic case using the ALPS code, and their analytical approximations are provided in the limit of weak damping. This way we offer a new tool for modeling longitudinal waves, and in particular Langmuir waves, that may be useful for other astrophysical systems which are in non-equilibrium states as evidenced by direct in-situ measurements, like the solar corona and planetary environments, as well as by indirect observations of nonthermal sources of waves and emissions.

EP 9.2 Thu 14:00 KH 01.019

**The accuracy of REleASE forecasts for different heliographic longitude distances** — H. DRÖGE<sup>1</sup>, A. POSNER<sup>2</sup>, B. HEBER<sup>1</sup>, M. MALANDRAKI<sup>3</sup>, M. KARAVOLOS<sup>3</sup>, and L. TSIPIS<sup>3</sup> — <sup>1</sup>Christian-Albrechts-Universität zu Kiel (CAU), Kiel, Germany — <sup>2</sup>NASA — <sup>3</sup>National Observatory of Athens, Greece

Forecast systems and predictions of hazardous Solar Energetic Particle (SEP) events are needed to support space missions. Especially in view of future plans for human exploration of Mars, a radiation protection strategy needs to be implemented with the goal of reliably providing advance warning of sudden radiation hazards. REleASE utilises the close correlation between near-relativistic electrons and the slower protons to provide, on average, one hour of advance warning of particle events observed close to earth. Originally, REleASE used real-time data from SOHO/EPHIN and later ACE/EPAM (HESPERIA/REleASE) to issue short-term warnings before a significant flux increase of 20 – 50 MeV protons. The method was adapted to work with the HET and SEPT instruments onboard STEREO-A, and an operational STEREO/REleASE system was created. With two REleASE systems now operational, we have the possibility to directly compare forecasts from different points in the heliosphere. Human explorers following Hohmann trajectories to and from Mars will be up to 22° away in longitudinal magnetic connection distance from the alert system. We used the 2022 to 2025 passage of STEREO-A by Earth to test whether remote REleASE forecasts can provide timely and sufficiently accurate information for the location of another spacecraft.

EP 9.3 Thu 14:15 KH 01.019

**Unusual Sun-Earth magnetic connections during relativistic solar particle events** — K.-L. KLEIN<sup>2</sup>, B. HEBER<sup>1</sup>, M. HÖRLÖCK<sup>1</sup>, S. JENSEN<sup>1</sup>, P. KÜHL<sup>1</sup>, and H. SIERKS<sup>3</sup> — <sup>1</sup>Christian-Albrechts-Universität zu Kiel (CAU), Kiel, Germany — <sup>2</sup>LIRA, Observatoire de Paris, France — <sup>3</sup>MPI für Sonnensystemforschung, Göttingen, Germany

The Sun accelerates charged particles sometimes to relativistic energies during eruptive events, leading to so called 'Ground-Level Enhancement' (GLE). Observations of the solar atmosphere at EUV, X-ray, and radio wavelengths provide insight into the dynamics of the coronal magnetic structures during eruptive flares. The timing of the onset of a GLE with respect to the solar eruption is therefore a primary diagnostic tool for identifying the time and place where the relativistic protons are released. Recent numerical simulations suggest that gradient and curvature drifts near and in the heliospheric current sheet may be essential for relativistic protons to reach the Earth when the eruption occurs far from the footpoint of the magnetic field line connecting the Earth with the Sun. If drifts favor protons at Earth, they should hinder electrons. In contrast to this prediction, relativistic electron observations during GLEs between 1991 and 2025 show

that the first electrons arrive at Earth within a few minutes of the GLE onset. We present an alternative scenario where radio observations suggest a transient magnetic connection established between the Earth and an eruptive region behind the solar limb.

EP 9.4 Thu 14:30 KH 01.019

**First look at the solar cosmic ray event on 11 November 2025 as measured by neutron monitors** — CHRISTIAN STEIGIES<sup>1</sup>, LUKAS BÄNI<sup>2</sup>, and ROLF BÜTIKOFER<sup>2</sup> — <sup>1</sup>Christian-Albrechts-Universität zu Kiel, Germany — <sup>2</sup>Universität Bern, Switzerland

On 11 November 2025, the global network of neutron monitors measured an increase in the count rate caused by solar cosmic rays. This event was number 77 of solar cosmic rays observed at ground since 1942: GLE77. It was caused by an X5 class flare at 10:10 UTC and is comparable in size to the last major GLE on 6 December 2006 (GLE70). Since some neutron monitor stations at low latitudes, such as Mexico, also observed a significant increase in the count rate during GLE77, the energy spectrum was harder than during GLE70 and during the very large GLE69 on 20 January 2005. Based on the neutron monitor measurements, we estimated the characteristics of solar cosmic rays during the maximum phase of GLE77. This allows to assess the maximum additional radiation exposure at flight altitude caused by solar cosmic rays during GLE77.

EP 9.5 Thu 14:45 KH 01.019

**Single Detector Counter Cross-Calibration – SOHO, Chandra/EPHIN, and AMS-02 Results** — L. ROMANEHESEN<sup>1</sup>, B. HEBER<sup>1</sup>, M. DUMBOVIC<sup>2</sup>, M. HÖRLÖCK<sup>1</sup>, M. KÖBERLE<sup>1</sup>, P. KÜHL<sup>1</sup>, and A. PAPAIOANNOU<sup>3</sup> — <sup>1</sup>Christian-Albrechts-Universität zu Kiel (CAU), Kiel, Germany — <sup>2</sup>University of Zagreb, Faculty of Science, Zagreb, Croatia — <sup>3</sup>National Observatory of Athens, Greece

Here we demonstrate that single-detector counter rates from the Electron, Proton, and Helium Instrument (EPHIN) onboard SOHO and Chandra provide a reliable and stable proxy for monitoring Galactic Cosmic Rays (GCRs). Using detailed GEANT4 simulations, the response of the EPHIN SSD-F detector is shown to be dominated by protons and helium nuclei with energies above approximately 50 MeV, corresponding to an effective rigidity of about 2.15 GV.

A direct cross-calibration between SOHO/EPHIN and AMS-02 proton and helium fluxes is performed for the period 2011–2019 and reveals an excellent agreement. Small systematic differences between SOHO and Chandra EPHIN measurements are attributed to different spacecraft geometries and shielding environments. Nevertheless, both instruments show consistent long-term trends and accurately reproduce the solar-cycle modulation of GCRs observed by AMS-02.

This study has received funding from the EU's Horizon 2020 research and innovation program under grant agreement No. 101004159 (SPEARHeAD). The SOHO/EPHIN is supported under Grant 50 OC 2102 by the German BMFW through DLR.

EP 9.6 Thu 15:00 KH 01.019

**Cross calibration of SOHO ~ 1 GV proton and helium fluxes with PAMELA and AMS-02** — MALTE HÖRLÖCK<sup>1</sup>, BERND HEBER<sup>1</sup>, MARLON KÖBERLE<sup>1</sup>, PATRICK KÜHL<sup>1</sup>, LISA ROMANESEN<sup>1</sup>, and ATHANASIOS PAPAIOANNOU<sup>2</sup> — <sup>1</sup>Christian-Albrechts-Universität zu Kiel (CAU), Kiel, Germany — <sup>2</sup>National Observatory of Athens, Greece

Reliable measurements of Galactic Cosmic Rays (GCRs) and Solar Energetic Particles (SEPs) require well-calibrated spaceborne particle instruments. This study presents a cross-calibration of the Electron, Proton and Helium Instrument (EPHIN) aboard SOHO with high-precision proton and helium measurements from PAMELA and AMS-02. The analysis extends the established  $\Delta E - \Delta E$  technique to later mission phases, accounting for detector aging and changes in instrument response after 2017.

A GEANT4-based model of EPHIN, including a simplified representation of the SOHO spacecraft, is used to derive energy response functions for penetrating protons and helium nuclei. Simulated detector responses based on force-field-modulated GCR spectra reproduce the observed EPHIN energy-loss distributions within about 30%. Effective energies and fluxes are obtained using a

bow-tie inversion method and compared with AMS-02 and PAMELA observations during quiet solar conditions. The results show agreement within the combined systematic uncertainties, demonstrating that SOHO/EPHIN continues to

provide valuable and reliable energetic particle measurements for long-term heliospheric studies.

## EP 10: Exoplanets and Astrobiology

Time: Friday 9:00–10:30

Location: KH 01.019

### Invited Talk

EP 10.1 Fri 9:00 KH 01.019

**The diversity of low mass exoplanets** — •KRISTINE LAM — Institut für Weltraumforschung, Deutsche Zentrum für Luft- und Raumfahrt (DLR)

Exoplanet discoveries and characterisation have revealed astonishing diversity. With the improved capability of observing facilities, an increasing number of low mass exoplanets are being characterised to unprecedented precision. In this talk, I will review the current exoplanet demographics with a focus on low mass exoplanets detected by transit and radial velocity surveys. We will dive into different exoplanet populations (super-Earths, sub-Neptunes, ultra-short-period planets, water worlds) and the various physical processes that could have sculpted each class of exoplanets. I will also give an overview of upcoming space- and ground-based telescopes and their expected impact on demographic studies and our understanding of exoplanetary systems and their evolution pathways.

EP 10.2 Fri 9:30 KH 01.019

**Investigating the exoplanet HD88986 b by using TESS & CHEOPS space telescope data.** — •DANIAL ALMASIAN — Shahid Beheshti University, Tehran, Iran

The discovery of transiting planets with orbital periods exceeding 40 days has been exceptionally rare among the 5000+ planets identified to date. This dearth of findings poses a significant challenge to studying planetary demographics, formation, and evolution. In this study, we report detecting and characterizing HD88986 b, a potentially transiting sub-Neptune with the longest orbital period of any known transiting small planet. Our analysis drew on a combination of two sectors of TESS data and a 7-day observation from CHEOPS. Additionally, TLS was utilized for the analysis of HD88986 data. Our findings indicate that HD88986 b, exhibiting two likely single transits on sector 21 and sector 48, both consistent with the predicted transit time from the RV model, is a likely transit candidate. The wide orbit of HD88986 b suggests that the planet did not experience significant mass loss due to XUV radiation from its host star, likely retaining its original composition and offering insights into its formation. Furthermore, the cold nature of HD88986 b, owing to its extended orbital period, presents exciting prospects for future studies on the characterization of its cold atmosphere composition.

EP 10.3 Fri 9:45 KH 01.019

**Does atmospheric composition actually trace planet formation? Results from observing aligned vs misaligned hot Jupiters as a testbed** — •EVA-MARIA AHRER<sup>1</sup>, JAMES KIRK<sup>2</sup>, and BOWIE-ALIGN COLLABORATION<sup>3</sup> — <sup>1</sup>Max Planck Institute for Astronomy, Heidelberg, Germany — <sup>2</sup>Imperial College London, London, UK — <sup>3</sup>Bristol, Oxford, Warwick, Imperial, Exeter +

I will present the JWST program 'BOWIE-ALIGN', dedicated to test our understanding of planet formation with measurements of the composition of exoplanetary atmospheres, specifically hot Jupiters. It is unclear what variations in atmospheric chemistry can be attributed to different planet formation histories, made even more difficult by uncertainties in planetary evolution.

In our study, we compare the composition of a sample of seven hot Jupiters, where half their orbits are aligned and the other half misaligned relative to their host stars' spin axes. It is believed that aligned hot Jupiters around F stars are the outcome of disc migration, while misaligned ones arise from high-eccentricity migration. With this program we investigate whether these two subsets of exoplanets that are expected to have had very different formation pathways show any significant differences in their atmospheric composition.

I will summarise the observations of these seven hot Jupiters with JWST NIR-Spec/G395H, and the outcome of this program. Specifically I will address if atmospheric composition using JWST can be used to make inferences about formation.

EP 10.4 Fri 10:00 KH 01.019

**High-Resolution 3D Corona-Wind Models for Exoplanet Space Weather Around Solar-Type Stars** — •YUEHONG CHEN and JULIÁN ALVARADO-GÓMEZ — Leibniz Institute for Astrophysics Potsdam, Potsdam, Germany

Space-weather conditions experienced by exoplanets are strongly influenced by the state of the host-star corona and its magnetized wind. Existing studies typically constrain either coronal X-ray emission (spatially unresolved) or stellar winds (difficult to observe), and rarely connect both within a fully three-dimensional (3D) framework. Here we use the Space Weather Modeling Framework with the Alfvén Wave Solar Model (SWMF-AWSoM), driven by global convective dynamo-generated surface magnetic maps, to model fully 3D solar-type stellar coronae and winds spanning rotation rates  $1.0\text{--}23.3\Omega_{\odot}$ . Our models reproduce dense (1–2 orders of magnitude above solar) and ultra-hot ( $\sim 10\text{ MK}$ ) coronae at high spatial resolution. We further show that enhanced coronal activity is accompanied by stronger winds, leading to elevated wind pressures that shape exoplanetary space environments. As illustrative cases, we evaluate wind pressures for super-Earth candidates Kepler-1638 b and Kepler-452 b, and find that an Earth-like dynamo can plausibly sustain magnetopauses of  $r_M \approx 5\text{--}10 R_p$  under quiescent wind conditions. Overall, given the limited ability of current instrumentation to characterize exoplanet high-energy irradiation and particle environments in detail, our framework provides observation-informed inputs for exoplanet space-weather and habitability studies around solar-type stars.

EP 10.5 Fri 10:15 KH 01.019

**Detectability of Atmospheric Climate and Biosignatures with the Large Interferometer for Exoplanets (LIFE) for terrestrial-type Exoplanets** — •JOHN LEE GRENFELL<sup>1,2</sup>, BENJAMIN TAYSUM<sup>1</sup>, IRIS VAN ZELST<sup>1,3</sup>, FRANZ SCHREIER<sup>1,4</sup>,

HAMISH INNES<sup>1,2</sup>, ALEXIS SMITH<sup>1</sup>, SZILARD CSIZMADIA<sup>1</sup>, NICOLAS IRO<sup>1</sup>, SARAH RUGHEIMER<sup>5,6</sup>, THEA KOZAKIS<sup>7</sup>, ELEONORA ALE<sup>8</sup>, LENA NOACK<sup>2</sup>, TIM LICHTENBERG<sup>9</sup>, SASCHA QUANZ<sup>8,10</sup>, KONSTANTIN HERBST<sup>1,11</sup>, MIRIAM SINNHUBER<sup>12</sup>, ANDREAS BARTENSLAGER<sup>12</sup>, JUAN CABRERA<sup>1</sup>, and HEIKE RAUER<sup>2,13</sup> — <sup>1</sup>Inst. Space Science, DLR, Berlin, Germany — <sup>2</sup>Inst. Geologische Wissenschaften, Freie Uni. Berlin, Germany — <sup>3</sup>Centre for Astronomy and Astrophysics, TU Berlin, Germany — <sup>4</sup>DLR-IMF, Oberpfaffenhofen, Germany — <sup>5</sup>Dept Physics and Astronomy, York Uni., Canada — <sup>6</sup>Inst. Astronomy, Uni. Edinburgh, Scotland, UK — <sup>7</sup>IAA-CSIC, Granada, Spain — <sup>8</sup>ETH-IPA, Zürich, Switzerland — <sup>9</sup>Kapteyn Astron. Inst., Uni. Groningen, The Netherlands — <sup>10</sup>ETH, Dept. Earth Plan. Sci., Zürich, Switzerland — <sup>11</sup>PHAB, Uni. Oslo, Norway — <sup>12</sup>KIT, Karlsruhe, Germany — <sup>13</sup>DLR Markgrafenstr. 37, Berlin, Germany

We investigate the detectability of atmospheric biosignatures with the LIFE mission. Starting with the modern Earth we model the climate, photochemistry and spectra of Earth-like planets over a range of insolation, gravity, humidity, albedo, atmospheric mass and carbon dioxide abundances and investigate detectability of key atmospheric species by LIFE for Earth-like planets assumed to lie at 10pc for the LIFE (20-day viewing) baseline case.

## EP 11: Planets and Small Bodies

Time: Friday 11:00–12:25

Location: KH 01.019

### Invited Talk

EP 11.1 Fri 11:00 KH 01.019

**Iron and the search for life on Mars** — •CHRISTIAN SCHRÖDER — Max Planck Institute for Solar System Research, Göttingen, Germany

Iron is a major rock-forming element. Because it is redox-active, it connects the geosphere with (bio)geochemical cycles of the CHNOPS elements essential to life. Compared to Earth, Mars has accreted from a more oxidized reservoir and therefore retained more iron in its mantle. This iron remains mobile in aqueous systems because Mars' atmosphere and water have never been fully oxygenated. Iron thus plays a dominant role in the search for life on the Red Planet when

assessing its habitability as well as the preservation and detection of potential biosignatures. For example: Serpentinization of iron-bearing olivine can generate organic molecules through Fisher-Tropsch type synthesis; minerals indicating iron redox cycling provide strong potential biosignatures; reactive iron mineral phases sequester and preserve organic carbon compounds as potential biosignatures over geological timescales; but iron may also hamper the detection of organic compounds with GCMS or Raman spectroscopy. This presentation will put recent results into the context of the current state of international Mars exploration.

EP 11.2 Fri 11:30 KH 01.019

**Sonar Simulations of the TRIPLE Forefield Reconnaissance System with COMSOL** — •JULIEN LEROUX, ALEXANDROS DESLIS, ÖMER ALTUG, JAN AUDEHM, MIA GIANG DO, LARS HEUERMANN, DIRK HEINEN, LUKAS MICHELS, ANDREAS NÖLL, CHRISTOPHER WIEBUSCH, and SIMON ZIERKE — Physics Institute IIIb, RWTH Aachen, Germany

The TRIPLE (Technologies for Rapid Ice Penetration and Subglacial Lake Exploration) project line was initiated by the German Space Agency at DLR in order to pioneer the exploration of subglacial oceans on icy moons such as Europa and Enceladus, in the search for extraterrestrial life. In TRIPLE, we explore numerous technologies to safely navigate a melting probe through the ice cover. The melting probe must be able to detect hazards such as debris or crevasses, as well as locating an anchoring point at the water-ice boundary below the glacier. For this, the TRIPLE Forefield Reconnaissance System (TRIPLE-FRS) employs a combination of radar and sonar integrated into the melting head of the probe. This system must preserve the melting head's narrow profile, high melting speed, and maximize the reconnaissance performance. For the optimization of the sonar system, we perform finite element simulations using COMSOL. We present the latest results from these studies.

EP 11.3 Fri 11:45 KH 01.019

**Characterising and Evaluating Acoustic Transducers in Water for TRIPLE-FRS** — •ALEXANDROS DESLIS, ÖMER ALTUG, JAN AUDEHM, MIA GIANG DO, DIRK HEINEN, LARS HEUERMANN, JULIEN LEROUX, LUKAS MICHELS, ANDREAS NÖLL, CHRISTOPHER WIEBUSCH, and SIMON ZIERKE — III. Physikalisches Institut B - RWTH Aachen University

The TRIPLE project line, initiated by the German Space Agency at DLR, aims to develop technologies for the exploration of subglacial ocean worlds on moons of the outer solar system, in the search for extraterrestrial life. TRIPLE consists of three core components: a melting probe for penetrating the ice, an autonomous underwater exploration vehicle, and an astrobiological laboratory for sample analysis. One key subsystem of the melting probe is the Forefield Reconnaissance System (FRS), which enables the detection of obstacles within the

ice as well as the identification of the ice-water boundary. It includes a sonar which employs a piezoelectric tonpilz transducer to both emit and receive acoustic signals. Several transducer designs were evaluated in water in the laboratory. Here, we compare key acoustic parameters, such as sending and receiving performances, across these designs in search for the most promising setup for the mission's needs. This presentation introduces the methods and presents results of these studies.

EP 11.4 Fri 12:00 KH 01.019

**Time-Variability of the Galactic Positron Annihilation Signal** — •RUDI REINHARDT and THOMAS SIEGERT — Julius-Maximilians-Universität Würzburg, Würzburg, Germany

The interactions of low-energy cosmic-rays with asteroids might lead to a measurable variable gamma-ray foreground emission within our Solar system. Siegert (2024) modeled the spatial distribution of all relevant asteroid populations (Main Belt Asteroids, Jovian and Neptunian Trojans and the Kuiper Belt) to calculate their appearances by line-of-sight integrations. The signal is expected to vary in time due to the relative motion of Earth and the asteroids. In this work we used 20 yr of INTEGRAL/SPI data to search for this time-variable foreground albedo in both, the 511 keV line and the ortho-Positronium (oPs) continuum. Since the Galaxy is bright in the bulge at 511 keV, we can determine its variability on a two year timescale, which allows us to constrain the possible contributions from all asteroid families. Our analysis shows no significant emission signal for all considered populations. However, we find a significant 511 keV signal in the vicinity of the Galactic center, which may mimic variable diffuse emission unless its time variability is taken into account. In a 20x20 deg<sup>2</sup> region around the Galactic center, we find several point-like hotspots which coincide spatially with the distribution of globular clusters. Preliminary results of GEANT4 simulations of electromagnetic and hadronic interactions of cosmic-rays with asteroids agree with contemporaneous simulations by DeGaetano et al. (2023) using FLUKA, with fluxes being several orders of magnitude smaller than previously estimated.

**Poster Pitch: EP 25 (Broer), EP 26 (Kinne)**

# Gravitation, Relativistic Astrophysics, and Cosmology Division

## Fachverband Gravitation, Relativistische Astrophysik und Kosmologie (GR)

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### Overview of Invited Talks and Sessions

(Lecture halls KH 01.016 and KH 02.012; Poster Redoutensaal)

#### Invited Talks

|         |     |             |           |                                                                                                                                                                                      |
|---------|-----|-------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| GR 1.1  | Mon | 14:45–15:15 | KH 01.016 | <b>Recent Developments on Critical Collapse and Extremality</b> — •DANIELA CORS AG-ULLO                                                                                              |
| GR 4.1  | Tue | 11:00–11:30 | KH 01.016 | <b>From kinetic gases to an accelerated expanding universe - The Finsler Friedmann equation</b> — •CHRISTIAN PFEIFER, NICOLETA VOICU, ANNAMARIA FRIEDL-SZASZ, ELENA POPOVICI-POPESCU |
| GR 7.1  | Wed | 11:00–11:30 | KH 01.016 | <b>Electromagnetic jets as strong-gravity probe for rapidly spinning black holes</b> — •FILIPPO CAMILLONI, LUCIANO REZZOLLA                                                          |
| GR 11.1 | Thu | 11:00–11:30 | KH 01.016 | <b>Numerical Relativity for LISA and the Einstein Telescope</b> — •NILS VU                                                                                                           |
| GR 17.1 | Fri | 9:00– 9:30  | KH 01.016 | <b>Radio Cosmology and the Cosmic Dawn</b> — •JONATHAN PRITCHARD                                                                                                                     |

#### Sessions

|               |     |             |              |                                                                |
|---------------|-----|-------------|--------------|----------------------------------------------------------------|
| GR 1.1–1.1    | Mon | 14:45–15:15 | KH 01.016    | <b>Numerical Relativity I</b>                                  |
| GR 2.1–2.5    | Mon | 16:15–17:30 | KH 01.016    | <b>Gravitational Waves I</b>                                   |
| GR 3.1–3.5    | Mon | 16:15–17:30 | KH 02.012    | <b>Classical General Relativity I</b>                          |
| GR 4.1–4.3    | Tue | 11:00–12:00 | KH 01.016    | <b>Cosmology I</b>                                             |
| GR 5.1–5.5    | Tue | 16:15–17:30 | KH 01.016    | <b>Relativistic Astrophysics I</b>                             |
| GR 6.1–6.5    | Tue | 16:15–17:30 | KH 02.012    | <b>Black Holes I</b>                                           |
| GR 7.1–7.3    | Wed | 11:00–12:00 | KH 01.016    | <b>Relativistic Astrophysics II</b>                            |
| GR 8.1–8.6    | Wed | 13:45–15:15 | KH 01.016    | <b>Gravitational Waves II</b>                                  |
| GR 9.1–9.6    | Wed | 13:45–15:15 | KH 02.012    | <b>Black Holes II</b>                                          |
| GR 10.1–10.18 | Wed | 16:15–18:45 | Redoutensaal | <b>Poster</b>                                                  |
| GR 11.1–11.3  | Thu | 11:00–12:00 | KH 01.016    | <b>Numerical Relativity II</b>                                 |
| GR 12.1–12.6  | Thu | 13:45–15:15 | KH 01.016    | <b>Relativistic Astrophysics III / Gravitational waves III</b> |
| GR 13.1–13.6  | Thu | 13:45–15:15 | KH 02.012    | <b>Quantum Gravity and Quantum Cosmology I</b>                 |
| GR 14.1–14.3  | Thu | 16:15–17:00 | KH 01.016    | <b>Relativistic Astrophysics IV</b>                            |
| GR 15.1–15.3  | Thu | 16:15–17:00 | KH 02.012    | <b>Quantum Gravity and Quantum Cosmology II</b>                |
| GR 16         | Thu | 17:15–19:00 | KH 01.016    | <b>Members' Assembly</b>                                       |
| GR 17.1–17.3  | Fri | 9:00–10:00  | KH 01.016    | <b>Cosmology II</b>                                            |
| GR 18.1–18.3  | Fri | 11:00–11:45 | KH 01.016    | <b>Cosmology III</b>                                           |
| GR 19.1–19.4  | Fri | 11:00–12:00 | KH 02.012    | <b>Numerical Relativity III</b>                                |

#### Members' Assembly of the Gravitation, Relativistic Astrophysics, and Cosmology Division

Thursday 17:15–19:00 KH 01.016



## Sessions

– Invited Talks, Contributed Talks, and Posters –

### GR 1: Numerical Relativity I

Time: Monday 14:45–15:15

Location: KH 01.016

#### Invited Talk

GR 1.1 Mon 14:45 KH 01.016

**Recent Developments on Critical Collapse and Extremality** — •DANIELA CORS AGULLO — DAMTP, Cambridge University

The threshold of black hole formation explored by Choptuik in 1993 contains a critical point, a codimension-1 attractor that induces nearby spacetimes to display critical phenomena. In spherical symmetry, this picture is consistent across different configurations, indicating a simple structure of extremely nonlinear spacetimes. However, taking away symmetry restrictions seems to also take away

this simplicity. In this talk, I will review current efforts in the numerical relativity community to understand the complicated structure of the threshold beyond spherical symmetry. It is worth noting that, even within spherical symmetry, the critical point is not unique: it can be a naked singularity, as found by Choptuik, a metastable star or, as recent work shows, an extremal black hole. In the talk, I will also discuss the mathematical and numerical efforts undertaken to construct extremal black holes.

### GR 2: Gravitational Waves I

Time: Monday 16:15–17:30

Location: KH 01.016

GR 2.1 Mon 16:15 KH 01.016

**Insights from the test-mass limit for effective-one-body models: elliptic and hyperbolic motion** — •SIMONE ALBANESI for the Einstein Telescope-Collaboration — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany — INFN sezione di Torino, Torino, Italy

The effective-one-body (EOB) approach provides an accurate description of the dynamics of comparable mass binaries, including non-circularized configurations. By construction, the EOB formalism incorporates the test-mass limit and can therefore strongly benefit from results obtained in black-hole perturbation theory. In this talk, we discuss recent test-mass results for elliptic and hyperbolic motion and show how these results can be used to better understand and inform the analytical prescriptions employed in EOB models. We further analyze the merger properties of eccentric binaries and dynamical captures in the test-mass limit. These results provide guidance for the construction of a generic mass-ratio ringdown model, enabling a more complete description of non-circularized plunge-mergers. Finally, we discuss new numerical relativity simulations and highlight their analogies with the test-mass case.

GR 2.2 Mon 16:30 KH 01.016

**Identifying Sub-Solar Primordial Black Holes for Einstein Telescope Using Deep Learning Methods** — •CANER BAHCECI, WALEED ESMAIL, and ALEXANDER KAPPES — Institut für Kernphysik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149, Münster

The development of the third-generation gravitational-wave detectors marks a significant advance in the search for primordial black holes (PBHs). In particular, the Einstein Telescope (ET), with its excellent low-frequency sensitivity, will allow an early detection of gravitational-wave signals from compact binaries, including sub-solar-mass systems. In this talk, I will present the methodology used to simulate large-scale datasets of sub-solar-mass PBH binary coalescences developed for ET. Additionally, the talk will discuss how these datasets are employed to train deep learning models to distinguish signals originating either from astrophysical black holes or potentially primordial black holes.

GR 2.3 Mon 16:45 KH 01.016

**Astrophysical insights from hierarchical black hole mergers in the era of next-generation detectors** — •ANGELA BORCHERS<sup>1,2</sup> and FRANK OHME<sup>1,2</sup> — <sup>1</sup>Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover, Germany — <sup>2</sup>Leibniz Universität Hannover, Hannover, Germany

Black-hole binaries can form through a variety of astrophysical pathways, each leaving distinct imprints on their observable properties. One such pathway is the hierarchical formation of black holes through repeated mergers, which produces black holes with characteristic spin signatures. These spins carry information about both the escape velocity of the host environment and the spins of first-generation black holes. Currently, however, observations of binary black hole mergers by the LIGO-Virgo-KAGRA Collaborations typically have spin measurements with substantial uncertainties, limiting our ability to extract this

information. The improved sensitivities of next-generation gravitational-wave detectors, such as the Einstein Telescope and Cosmic Explorer, will enable the observation of many more mergers and provide significantly more precise measurements of binary parameters, including spins. In this talk, I will present simulations of mock observations for Einstein Telescope based on the population properties inferred from the latest gravitational-wave catalog, GWTC-4, and discuss whether spin measurements from next-generation detectors can be used to gain insight into the astrophysical environments and merger histories of binary black holes.

GR 2.4 Mon 17:00 KH 01.016

**Effective Gravitoelectric Lagrangian for Neutron Star Dynamical Tides** — •FELIX LICHTNER — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

The tidal deformations of neutron stars in binary systems can have a significant impact on the emitted waveforms of gravitational waves. Studying these effects provides a direct window into the internal dynamics of neutron stars, in particular their still unknown equation of state. We characterize the tidal dynamics of a rotating neutron star in an external gravitational field by a systematic construction of a Lagrangian in the framework of effective field theory. This Lagrangian is constructed from the degrees of freedom describing the leading order gravitoelectric effects for neutron stars modeled as a perfect fluid, as is done e.g. in [Gupta, Steinhoff, Hinderer (2021)]. Integrating out the gravitational interactions to third post Newtonian order, we produce an effective description of the gravitoelectric binary dynamics. Further, we characterize the tidal spin via an analysis of the symmetries in the Lagrangian. Finally, we show that the equations of motion as well as the stress-energy tensor attained from the Lagrangian reproduce the Mathisson-Papapetrou-Dixon (MPD) equations of motion describing general extended objects in General Relativity.

GR 2.5 Mon 17:15 KH 01.016

**Accounting for the Known Unknowns: Systematic Waveform Errors in Gravitational-Wave Analyses** — •FRANK OHME<sup>1,2</sup>, SUMIT KUMAR<sup>1,3</sup>, and MAX MELCHING<sup>1,4</sup> — <sup>1</sup>Max Planck Institute for Gravitational Physics, Hannover, Germany — <sup>2</sup>Leibniz Universität, Hannover, Germany — <sup>3</sup>Utrecht University, Utrecht, The Netherlands — <sup>4</sup>California Institute of Technology, Pasadena, USA

The analysis of gravitational-wave observations relies heavily on models of the instrument noise and the expected signal shape. While models of the instrument's calibration and its noise naturally incorporate some uncertainty, the signal templates are typically treated as perfect. However, we know that this is an idealisation. In this talk, I present a versatile and robust method to incorporate systematic waveform-model uncertainties in the analysis of compact binary mergers. I show that treating signal models as uncertain may decrease the accuracy of the inferred source parameters, but otherwise ignored systematic biases are also reduced. Applying our method to real events, I illustrate that instead of losing accuracy, the main effect is to gain confidence in any results that remain robust with respect to the introduction of systematic errors.

## GR 3: Classical General Relativity I

Time: Monday 16:15–17:30

Location: KH 02.012

GR 3.1 Mon 16:15 KH 02.012

**What can Holography teach us about scale without conformal invariance?** — •LAVISH CHAWLA and MARIO FLORY — Jagiellonian University in Krakow, Poland

Whether Poincaré invariance together with scale invariance necessarily enhances to full conformal symmetry in quantum field theories remains a longstanding and subtle question. In this talk, we will present our results on this problem from the perspective of the holographic correspondence. In holography, the isometry group of the bulk spacetime corresponds to the global symmetries of a dual quantum field theory. Motivated by this relation, we study spacetimes with one warped extra dimension whose isometry group corresponds to scale without conformal invariance. We show that the Weyl tensor provides an important diagnostic: it vanishes for metrics corresponding to conformal invariance and is nonzero for those corresponding only to scale invariance. With this local geometric condition, we prove the following theorem: For putative boundary theories in two and higher dimensions, the bulk metric cannot exhibit scale without conformal invariance if its warped extra dimension is compact and the null energy condition is required to hold.

GR 3.2 Mon 16:30 KH 02.012

**Formulating the complete initial boundary value problem in numerical relativity to model black hole echoes** — •CONNER DAILEY — Institute for Theoretical Physics, Jena, Germany, Fröbelstieg 1 07743 Jena

In an attempt to simulate black hole echoes (generated by potential quantum-gravitational structure) in numerical relativity, we recently described how to implement a reflecting boundary outside of the horizon of a black hole in spherical symmetry. Here, we generalize this approach to spacetimes with no symmetries and implement it numerically using the generalized harmonic formulation. We cast the evolution equations and the numerical implementation into a Summation By Parts (SBP) scheme, which seats our method closer to a class of provably numerically stable systems. We implement an embedded boundary numerical framework that allows for arbitrarily shaped domains on a rectangular grid and even boundaries that evolve and move across the grid. As a demonstration of this framework, we study the evolution of gravitational wave scattering off a boundary either inside, or just outside, the horizon of a black hole. This marks a big leap toward the goal of a generic framework to obtain gravitational waveforms for behaviors motivated by quantum gravity near the horizons of merging black holes.

GR 3.3 Mon 16:45 KH 02.012

**Revisiting Synchronisation Systems and Applications in Geodesy** — •BENNET GRÜTZNER, EVA HACKMANN, and CLAUS LÄMMERZAHN — ZARM, Universität Bremen

Establishment of International Atomic Time (TAI) requires a global clock network and definitions of synchronisation and simultaneity. On the rotating Earth, this is a non-trivial task due to the Sagnac effect. In geodesy and positioning, this is usually addressed within a post-Newtonian framework. In our work, we extend the synchronisation framework beyond such approximative approaches. We introduce synchronisation systems and provide them with a mathematically rigorous characterisation. We then classify them according to their properties and describe an operational realisation. Finally, we illustrate the framework by discussing synchronisation via the electronically stabilised (ELSTAB) fibre link between Braunschweig and Potsdam.

GR 3.4 Mon 17:00 KH 02.012

**Discrete Spacetime Blocks for Visualizing GR: Interactive Geodesics in a (2+1D) Schwarzschild Sector Model** — •VASSILIOS MARAKIS, RAHEL GABRIEL, CORVIN ZAHN, and UTE KRAUS — Universität Hildesheim

We present an interactive web application that constructs sector models of curved spacetime. The spacetime is discretized into a mesh of locally flat Minkowski "blocks" in two spatial dimensions and time. Within each block, massive particles and light trajectories are represented as straight worldline segments, while block to block transition implemented as rotations and local Lorentz boosts encode the gravitational curvature. This piecewise flat approach enables an intuitive, visual treatment of general relativity. Geodesics emerge from local inertial motion plus the accumulated effect of successive boundary transformations. The result is a browser based sandbox for geodesics, that combines the concept of local flatness and global curvature understandable without requiring a full differential geometry toolkit during exploration.

GR 3.5 Mon 17:15 KH 02.012

**Relativistic orbital perturbation theory** — OLEKSII YANCHYSHEN, EVA HACKMANN, and •CLAUS LÄMMERZAHN — ZARM and ITP, University of Bremen

Within a Newtonian framework orbital perturbation theory is based on the Keplerian orbits as exact solution of the Kepler problem. Perturbation forces lead to time dependent orbital parameters like the semimajor axis, eccentricity, inclination, perigee, and ascending node. Within a relativistic framework we start with the exact solution of the geodesic equation in Schwarzschild space-time. Perturbation forces then lead to a time-dependence of orbital parameters, some of which we newly defined. Their time dependence is described by a relativistic generalization of the Gauß equations. In the presentation this formalism is explained and some applications to perturbations like radiation reaction will be outlined. This new approach is mathematically more challenging but leads to a faster convergence of results than post-Newtonian approaches in the strong field regime.

## GR 4: Cosmology I

Time: Tuesday 11:00–12:00

Location: KH 01.016

## Invited Talk

GR 4.1 Tue 11:00 KH 01.016

**From kinetic gases to an accelerated expanding universe - The Finsler Friedmann equation** — •CHRISTIAN PFEIFER<sup>1</sup>, NICOLETA VOICU<sup>2</sup>, ANNAMARIA FRIEDL-SZASZ<sup>2</sup>, and ELENA POPOVICI-POPESCU<sup>2</sup> — <sup>1</sup>ZARM, University of Bremen, Germany — <sup>2</sup>Faculty of Mathematics and Computer Science, Transilvania University, Brasov, Romania

The dynamics and the gravitational field of kinetic gases are usually described by the Einstein-Vlasov/Boltzmann equations. The evolution of the gas on phase space is encoded in the 1-particle distribution function (1PDF), while the Einstein equations determine the gravitational field of the kinetic gas from an energy momentum tensor that is obtained by averaging the 1PDF over all physical gas particle velocities (or momenta). Thus, the dynamics of the kinetic gas are described on phase space, but its gravitational field is derived on spacetime through an averaging procedure, which does not take all available information of the gas into account. The immediate question is, how does the full 1PDF of a kinetic gas gravitate?

In this talk, I will discuss that Finsler gravity naturally elevates the geometry of spacetime to the same phase space footing as kinetic gas matter. It couples the full 1PDF to gravity without losing information through averaging. In homogeneous and isotropic symmetry, the Finsler gravity equation takes a similar form as the Friedmann equations. Remarkably we find that this Finsler Friedmann equation possesses solutions describing an accelerated expanding universe without the need of a cosmological constant or any other additional quantities.

GR 4.2 Tue 11:30 KH 01.016

**The Hubble Tension: Overview, Recent Progress, and the Path Forward** — •NILS SCHÖNEBERG — Ludwig-Maximilians-Universität, München, Deutschland

Cosmological observations from the early universe and the late universe have been disagreeing about the value of the Hubble constant for more than one decade now. With the nominal significance of this Hubble tension reaching  $5\sigma$ , it has become one of the most pressing challenges in cosmology. Taken at face value it would signal a breakdown of the  $\Lambda$  + Cold Dark Matter cosmological standard model. Prior to invoking new physics, it is paramount to re-investigate our astrophysical assumptions and to obtain independent confirmations. In this talk I present recent results in the search for the possible causes of the Hubble tension in early- and late-Universe data, including a joint effort from the  $H_0$ DN collaboration of constraining the Hubble constant using local astrophysical probes. I give a critical assessment of possible issues and solutions, and highlight future efforts that will be crucial in clarifying this challenge.

GR 4.3 Tue 11:45 KH 01.016

**Simulation-based inference with the integrated 3PCF** — •DAVID GEBAUER — Universität Bielefeld

We present a simulation-based inference (SBI) framework for analysing a higher-order weak lensing statistic, the integrated 3-point correlation function (i3PCF). Our approach forward-models the cosmic shear field using a suite of N-body simulations, including a comprehensive set of systematic effects such as intrinsic alignment, baryonic feedback, photometric redshift uncertainty, shear calibration bias, and shape noise. Using this, we have produced a set of DES Y3-like syn-

thetic measurements for 2-point shear correlation functions and i3PCFs across 6 cosmological and 11 systematic parameters. Having validated these measurements against theoretical predictions and thoroughly examined for potential systematic biases, we have found that the impact of source galaxy clustering and reduced shear on the i3PCF is negligible for Stage-III surveys. Furthermore, we have tested the Gaussianity assumption for the likelihood of our data vector and found that the likelihood of the combined 2PCF + i3PCF data vector including

filter sizes of 90' and larger can deviate from this assumption. Our SBI pipeline employs masked autoregressive flows to perform neural likelihood estimation and is validated to give statistically accurate posterior estimates. On mock data, we find that including the i3PCF yields a substantial 63.8% median improvement in the figure of merit. These findings are consistent with previous works on the i3PCF and demonstrate that our SBI framework can achieve the accuracy and realism needed to analyse the i3PCF in wide-area weak lensing surveys.

## GR 5: Relativistic Astrophysics I

Time: Tuesday 16:15–17:30

Location: KH 01.016

GR 5.1 Tue 16:15 KH 01.016

**Magnetic field instabilities and late-time equilibria in isolated neutron stars** — •AURORA CAPOBIANCO — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany

The late-time equilibrium geometry of magnetic fields in neutron stars remains poorly constrained, despite its importance for observable signatures. We investigate the development and long-term evolution of strong magnetic fields in isolated neutron stars using the general relativistic magnetohydrodynamics (GRMHD) code AthenaK. Our simulations follow the full general-relativistic evolution of neutron stars with an external dipole-like field and a range of initial internal magnetic-field configurations. We focus on the symmetry properties, stability, and equilibrium structure of the resulting magnetic-field. In particular, we examine the onset and nonlinear evolution of magnetic-field instabilities and assess their role in redistributing magnetic energy. We also discuss the implications of these dynamics for the gravitational-wave emission produced.

GR 5.2 Tue 16:30 KH 01.016

**Curvature invariants and trace anomaly in neutron stars** — •IVÁN GARIBAY<sup>1,2</sup>, CHRISTIAN ECKER<sup>1</sup>, and LUCIANO REZZOLLA<sup>1,3,4</sup> — <sup>1</sup>Institut für Theoretische Physik, Goethe Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — <sup>2</sup>Instituto de Astronomía, Universidad Nacional Autónoma de México, Ciudad de México, CDMX 04510, Mexico — <sup>3</sup>School of Mathematics, Trinity College, Dublin 2, Ireland — <sup>4</sup>Frankfurt Institute for Advanced Studies, Ruth-Moufang-Str. 1, 60438 Frankfurt am Main, Germany

We investigate the behaviour of curvature invariants for a large ensemble of neutron stars built with equations of state (EOSs) that satisfy constraints from nuclear theory and perturbative QCD, as well as measurements of neutron-star masses, radii, and gravitational waves from binary neutron-star mergers. Surprisingly, our analysis reveals that stars with negative Ricci scalar  $\mathcal{R}$  are rather common, and about  $\sim 49\%$  of our EOSs produce one or more stars with Ricci curvature that is negative somewhere inside the star. Furthermore, this negative curvature is found mostly but not exclusively at the highest densities and pressures, and predominantly for stiff EOSs. Furthermore, using a well-known relation between the Ricci scalar and the trace anomaly,  $\Delta$ , our analysis also allows us to determine the general conditions under which the conformal symmetry of matter is broken and restored in neutron stars. Finally, we determine a number of correlations among the different scalar invariants and map the ranges of their allowed values inside neutron stars.

GR 5.3 Tue 16:45 KH 01.016

**Photon phenomenology in the accelerated Schwarzschild black hole** — •EVA HACKMANN<sup>1</sup> and SHOKOUE FARAJI<sup>1,2,3,4</sup> — <sup>1</sup>Center of Applied Space Technology and Microgravity (ZARM), University of Bremen — <sup>2</sup>Department of Physics and Astronomy, University of Waterloo — <sup>3</sup>Waterloo Centre for Astrophysics, University of Waterloo — <sup>4</sup>Perimeter Institute for Theoretical Physics

We analyse null geodesics in an accelerated Schwarzschild black hole sustained by a cosmic string and/or strut (C-metric) in the sub-extremal regime, and investigate if the acceleration and, in particular, the conicity parameter induced by the string/strut can be constrained from observations. For photons the conformal Hamilton-Jacobi equation separates, and we reduce the radial and polar motion to the Bierman-Weierstrass form, yielding new forms of closed analytic solutions. We show that the conicity parameter has no impact on the location of the fixed photon cone that replaces equatorial symmetry when the acceleration is nonzero, or on the single spherical photon surface shared by all latitudes. On the observational side, we prove that the shadow seen by any observer is an exact circle: its screen radius depends on the acceleration and observer distance but not on observer inclination or the conicity, so the local shadow cannot bound the string tension. We also show how a single shadow measurement with known mass-distance relation uniquely infers the dimensionless acceleration. Finally, we provide compact expressions for the photon circle orbital frequency and Lyapunov exponent and use them to obtain eikonal quasinormal estimates.

GR 5.4 Tue 17:00 KH 01.016

**mw-atlas: Bayesian reconstruction of the magnetic field from synchrotron emission** — •RICHA HALDER<sup>1</sup> and PHILIPP MERTSCH<sup>2</sup> — <sup>1</sup>RWTH Aachen University — <sup>2</sup>RWTH Aachen University

This project aims to build a 3D map of the Galactic magnetic field of the Milky Way from synchrotron emission, using a fully Bayesian framework. The magnetic field shapes cosmic-ray propagation, regulates interstellar gas and star formation, and distorts the signals used in precision cosmology, so its 3D structure must be known to interpret many astrophysical observations correctly. We use NIFTy, a variational inference framework, to infer the magnetic field from synchrotron data for a given distribution of cosmic-ray electrons. This provides full posterior distributions instead of single best-fit parameter sets, so uncertainties are explicitly quantified and can be propagated into other, derived quantities. Compared to previous reconstructions based on low-dimensional parametric GMF models fitted to integrated observables, our approach allows far more flexible field geometries, reduces bias from mis-specified parametric forms, and will be tested both on realistic simulations and future observational datasets.

GR 5.5 Tue 17:15 KH 01.016

**Post-Newtonian N-Body Simulations** — •FELIX HEINZE, GERHARD SCHÄFER, and BERND BRÜGMANN — Friedrich-Schiller-Universität Jena, Theoretisch-Physikalisches Institut, Fröbelstieg 1, 07743 Jena

The post-Newtonian formalism is a central tool for constructing approximate solutions of Einstein's field equations in the weak-field, slow-motion regime, in particular for gravitational systems of multiple point masses. This talk gives an overview of the current status of post-Newtonian N-body simulations and focuses on recent developments in the derivation of the N-body Hamiltonian at second post-Newtonian order, as well as on the numerical integration of the resulting equations of motion.

## GR 6: Black Holes I

Time: Tuesday 16:15–17:30

Location: KH 02.012

GR 6.1 Tue 16:15 KH 02.012

**Interplay of evaporating black holes with BSM particle physics** — •JENS BOOS and CHRISTOPH BORSCHENSKY — Karlsruhe Institute of Technology

Evaporating black holes emit Hawking radiation. The precise radiation rate depends on (i) the geometrical backreaction, described by greybody factors, and (ii) the particle spectrum of the universe. We demonstrate that both aspects of modified gravity and beyond-the-standard model particle physics need to be taken into account to model a realistic black hole lifetime. In doing so, we outline the main corrections one thereby obtains to the emitted photon spectrum (including secondary photons) that is relevant to constrain the abundance of such evaporating black holes and links them to (a part of the) dark matter relic density.

GR 6.2 Tue 16:30 KH 02.012

**Microlensing of non-singular black holes at finite size: a ray tracing approach** — •HAO HU and JENS BOOS — Institute for Theoretical Physics, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany

We study the gravitational microlensing of various static and spherically symmetric non-singular black holes (and horizonless, non-singular compact objects of similar size). For pointlike sources we extend the parametrized post-Newtonian lensing framework to fourth order, whereas for extended sources we develop a ray tracing approach via a simple radiative transfer model. Modelling non-relativistic proper motion of the lens in front of a background star we record the apparent brightness as a function of time, resulting in a photometric lightcurve. Taking the star radius to smaller values, our numerical results approach the theoretical predictions for point-like sources. Compared

to the Schwarzschild metric in an otherwise unmodified lensing geometry, we find that non-singular black hole models (and their horizonless, non-singular counterparts) at finite size tend to feature larger magnifications in microlensing lightcurves, contrary to the point-source prediction.

GR 6.3 Tue 16:45 KH 02.012

**On the formation of black-hole mimickers within General Relativity** — •DANIEL JAMPOLSKI<sup>1</sup> and LUCIANO REZZOLLA<sup>1,2,3</sup> — <sup>1</sup>Institut für Theoretische Physik, Max-von-Laue-Str. 1, 60438 Frankfurt, Germany — <sup>2</sup>School of Mathematics, Trinity College, Dublin 2, Ireland — <sup>3</sup>CERN, Theoretical Physics Department, 1211 Geneva 23, Switzerland

Regular black holes and horizonless black-hole mimickers offer mathematically consistent alternatives to address the challenges posed by standard black holes. However, the formation mechanism of these alternative objects is still largely unclear and constitutes a significant open problem since understanding their dynamical formation represents a first step to assess their existence. We here investigate, for the first time and without invoking deviations from general relativity, the dynamical formation of a well-known horizonless black-hole mimicker, namely, a gravastar. More specifically, starting from the collapse of a uniform dust sphere as in the case of the Oppenheimer-Snyder collapse, we demonstrate that, under suitable conditions, a gravastar can form from the nucleation and expansion of a de-Sitter region with initial zero size at the center of the collapsing sphere. Furthermore, the de-Sitter expansion naturally slows down near the Schwarzschild radius, where it meets the collapsing dust surface and gives rise to a static equilibrium. Interestingly, we also find a maximum initial compactness of the collapsing star of  $\mathcal{C} = 3/8$ , above which the collapse to a black hole is inevitable.

GR 6.4 Tue 17:00 KH 02.012

**Formation and Time Evolution of Primordial Black Holes** — HANS-OTTO CARMESIN<sup>1,2,3</sup> and •LINA JARCK<sup>3</sup> — <sup>1</sup>Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — <sup>2</sup>Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — <sup>3</sup>Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

In the very early universe, the density has been sufficiently large, so that black holes have formed. Simultaneously, these can decay as a result of Hawking radiation.

ation.

(1) For various densities, the amount of primordial black holes is derived as a dynamical equilibrium value.

(2) A population-based simulation is developed in Python. The simulation models processes in the early universe: Photons move randomly within a defined space. When two photons meet, they can fall into the Schwarzschild radius and form a black hole. Its lifetime is determined. The black hole then decays back into two photons through Hawking radiation.

(3) The results are compared with primordial black holes observed by the James Webb Space Telescope.

Carmesin, H.-O. (2020): The Universe Developing from Zero-Point Energy - Discovered by Making Photos, Experiments and Calculations. Berlin: Verlag Dr. Köster.

GR 6.5 Tue 17:15 KH 02.012

**The observer-invariant end of spacetime at the horizon of Schwarzschild black holes** — •RENÉ FRIEDRICH — Strasbourg

Time is not absolute but observer-dependent: This groundbreaking insight of Einstein in 1905 has the potential to settle the famous disagreement between external observer Bob and infalling observer Alice:

At first sight, the fact that Alice reaches the event horizon of a black hole within finite proper time prevails over Bob's "mere" observation that infalling matter does never reach the horizon. However, all external observers (even including Alice who is an external observer, too, before reaching the horizon) agree without exception that the horizon represents the ultimate simultaneity line ( $t = \text{infinity}$ ), the temporal border of the spacetime manifold. Since spacetime is observer-dependent and thereby mere observation, this "concordant observation shared by all observers of the universe of spacetime" is perfectly adapted for determining the extent and the boundaries of spacetime.

As a result, there can't exist any spacetime beyond observation, and when Alice - subject to infinite gravitational time dilation - reaches the event horizon, she is leaving our observer-dependent spacetime manifold. Consequently, the mass of a Schwarzschild black hole is not inside the horizon but outside, in the approximate form of a nearby membrane, avoiding the unsolvable dilemma of a central spacetime singularity. More: Quantum gravity without trouble.

## GR 7: Relativistic Astrophysics II

Time: Wednesday 11:00–12:00

Location: KH 01.016

### Invited Talk

GR 7.1 Wed 11:00 KH 01.016

**Electromagnetic jets as strong-gravity probe for rapidly spinning black holes** — •FILIPPO CAMILLONI and LUCIANO REZZOLLA — Goethe University, Frankfurt am Main, Germany

The environment around astrophysical black holes is characterised by an abundance of plasma and intense electromagnetic fields subject to strong-gravity conditions. As indicated from analytic computations and numerical simulations this rich phenomenology range from magnetic reconnection, that can trigger a Penrose process involving structures called plasmoids, to the Blandford-Znajek (BZ) mechanism, an electromagnetic form of energy extraction that is currently considered the best theoretical candidate to explain the launching of powerful relativistic jets. We discuss the quasi-universal nature of the BZ jet power and how the higher-order perturbative corrections bear signatures of the underlying theory of gravity, thus enabling one to use the jet power as a strong-gravity signature to test general relativity on future horizon-scale observations when black holes are rapidly spinning.

GR 7.2 Wed 11:30 KH 01.016

**Construction of a 2d neutrino sky map** — •LUKAS LILAND for the IceCube-Collaboration — TU Dortmund

The IceCube collaboration has during the last 15 years made important discoveries concerning high-energy astrophysical neutrinos. IceCube first presented evidence of the flux of these neutrinos in 2013, and in 2023 the collaboration

presented evidence of an excess neutrino flux from the Milky Way Galaxy. This talk presents a project with the aim of constructing a 2D sky map of the astrophysical neutrino flux. A relatively new sample of IceCube neutrino events are processed with a transformer neural network, a state-of-the-art machine learning algorithm used by the famous large language models, to yield improved reconstructions of the energies and the directions of the neutrinos. A neutrino sky map is then produced using the technique of unfolding, which recovers the real neutrino flux from the calculated estimations with the help of MC simulations.

GR 7.3 Wed 11:45 KH 01.016

**QCD in the cores of Neutron Stars** — •OLEG KOMOLTSEV — Institut für Theoretische Physik, Goethe Universität, Frankfurt am Main

Rapid advancements in neutron-star (NS) observations allow unprecedented empirical access to cold, ultra-dense Quantum Chromodynamics (QCD) matter. The combination of these observations with theoretical calculations reveals previously inaccessible features of the equation of state and the phase diagram of QCD. In this talk, I demonstrate how perturbative-QCD calculations at asymptotically high baryon density provide robust constraints on the equation of state at neutron-star densities, based solely on causality and stability. By comparing the calculations to multimessenger neutron-star observations using a Bayesian framework, I show that QCD input softens the equation of state at neutron-star densities, supporting the hypothesis of a first-order phase transition or a crossover to quark matter cores in the most massive neutron stars.

## GR 8: Gravitational Waves II

Time: Wednesday 13:45–15:15

Location: KH 01.016

GR 8.1 Wed 13:45 KH 01.016

**interaction between gravitational waves and condensed matter systems** — •MICHEL PAULSEN<sup>1</sup>, GUDRID MOORTGAT-PICK<sup>1,2</sup>, ANDREAS RINGWALD<sup>2</sup>, and TOM KROKOTSCH<sup>1</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>DESY

Gravitational waves have established themselves as a key tool for investigating compact astrophysical sources, but so far they have been limited to a lower frequency range.

High-frequency gravitational waves (HFGW) are of particular theoretical interest, as they could potentially provide access to previously unexplored physical processes. The talk covers theoretical investigations of the interaction of gravitational waves with condensed matter systems, with a focus on high-frequency regimes. The focus is on specific physical mechanisms through which HFGW could couple with structured matter, as well as their consequences

for alternative approaches to investigating such signals. Matter systems that are suitable for corresponding theoretical analyses, including superconducting systems, are considered as a frame of reference.

GR 8.2 Wed 14:00 KH 01.016

**Mission Concepts for future space-based Gravitational Wave Detectors** — •JONES ROSARIO — MPI for Gravitational Physics (AEI), Hannover, Germany  
Gravitational waves are ripples in space-time caused by some of the most energetic processes in our universe. Since the first detection by LIGO in 2015, over 200 further signals have been observed. In 2035, the ESA-led space mission LISA is set to launch and will have its highest sensitivity in the mHz band. With this, LISA's sensitivity will lie between the high-frequency window (hertz to kilohertz) of ground based detectors such as LIGO and Virgo, and the nano-hertz regime probed by PTAs. However, these detectors will not cover the gravitational wave spectrum entirely. Particularly, there are gaps in the decihertz and the micro-hertz regime, which could be addressed by future space missions. In the context of ongoing efforts to propose mission concepts to ESA for the 2050s, we will discuss mission concepts proposed in literature that aim to probe these bands. We further extend on this and present current developments towards realistic designs with respect to technical feasibility and affordability.

GR 8.3 Wed 14:15 KH 01.016

**Gravitational wave backgrounds from trapped axion-like particles** — •DANIEL SCHMITT — Goethe University Frankfurt  
Axion-like particles (ALPs) are among the most promising dark matter candidates. While laboratory experiments and astrophysical observations have excluded parts of the viable ALP parameter space, the regime of large ALP decay constants, where the ALP becomes invisible, remains hard to access experimentally. I will discuss the conditions under which such invisible ALPs can generate a sizable primordial gravitational wave (GW) background. In particular, I will focus on ALP production via trapped misalignment, where the oscillations of the pseudoscalar are delayed compared to the conventional misalignment scenario. This can trigger resonances in the equation of motion of both the ALP and a gauge field coupled to the ALP, leading to the exponential growth of horizon-sized fluctuations in the early Universe. Such large anisotropies source stochastic GWs, enabling to probe a large part of the ALP parameter space through future GW observatories.

GR 8.4 Wed 14:30 KH 01.016

**Predicting gravitational wave observations for next-generation detectors** — •PER-INGMAR LAURENS SCHRÄKE<sup>1,2</sup> and FRANK OHME<sup>1,2</sup> — <sup>1</sup>Max Planck Institute for Gravitational Physics — <sup>2</sup>Leibniz University Hannover  
The detection of gravitational waves from merging compact binaries has revolutionized astronomy since the first observation in 2015, with the current GWTC-4.0 catalog containing 161 events. A new generation of significantly more sensitive detectors, such as the Einstein Telescope (ET) and Cosmic Explorer (CE), is already being planned. But what will these future detectors actually be able to measure in detail? This talk examines what predictions about future gravitational wave observations can be derived from the currently available pop-

ulation statistics. To answer this, a synthetic merger population is generated by randomly sampling from the parameter distributions reported in GWTC-4.0. Subsequently, the corresponding gravitational waveforms are generated with state-of-the-art models and evaluated depending on the sensitivity curve of next-generation detectors. The statistical distribution of the resulting signal-to-noise ratio is analyzed to estimate the anticipated occurrence of very strong signals. The framework further enables systematic comparisons among different population models and confusion noise estimates. Under realistic assumptions regarding population properties and detector sensitivities, it becomes apparent that ET enables the near-complete detection of merging compact binaries within the local universe.

GR 8.5 Wed 14:45 KH 01.016

**Vacuum, surface monitoring and cleaning experiment for Einstein Telescope** — •MARKUS SCHULZ-RITZ, JOACHIM WOLF, ADRIAN SCHWENCK, RALPH ENGEL, JUDITH SCHNEIDER, and HENDRIK WEINGART for the Einstein Telescope-Collaboration — Karlsruhe Institute for Technology, Karlsruhe, Germany  
The Einstein Telescope (ET) will be a third generation gravitational wave detector, consisting of a set of low frequency and high frequency interferometers. In order to mitigate thermal noise, the mirrors for the low frequency interferometer are required to be cooled down to cryo temperatures. This leads to freezing of residual gas from the vacuum chamber onto the mirror surface. This will affect the required cooling power and the sensitivity of ET. Hence R&D measurements at cryogenic temperatures are being prepared, investigating the formation of ice layers on the mirror from different gases (CO<sub>2</sub>, water, nitrogen,...) using ellipsometry and quartz micro balances (QMB) for monitoring the thickness of the layer. Further research will include the testing of different in-situ cleaning procedures of silicon surfaces with methods, such as argon plasma cleaning, low-energy electrons and UV light. The talk will be about the setup at KIT and will present first results.

GR 8.6 Wed 15:00 KH 01.016

**Stimulated Emission or Absorption of Gravitons by Light** — •RALF SCHÜTZHOLD — Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany  
We study the exchange of energy between gravitational and electromagnetic waves in an extended Mach-Zehnder or Sagnac type geometry that is analogous to an optical Weber bar. In the presence of a gravitational wave (such as the ones measured by the Laser Interferometer Gravitational Wave Observatory), we find that it should be possible to observe (via interference or beating effects after a delay line) signatures of stimulated emission or absorption of gravitons with present-day technology. Apart from marking the transition from passively observing to actively manipulating such a natural phenomenon, this could also be used as a complementary detection scheme. Nonclassical photon states may improve the sensitivity and might even allow us to test certain quantum aspects of the gravitational field.

[1] R. Schützhold, *Stimulated Emission or Absorption of Gravitons by Light*, Phys. Rev. Lett. **135**, 171501 (2025)

## GR 9: Black Holes II

Time: Wednesday 13:45–15:15

Location: KH 02.012

GR 9.1 Wed 13:45 KH 02.012

**Gravitational lensing in a warm plasma** — BARBORA BEZDEKOVA<sup>1</sup> and •VOLKER PERLICK<sup>2</sup> — <sup>1</sup>Department of Physics, Faculty of Natural Sciences, University of Haifa, Haifa 3498838, Israel — <sup>2</sup>Faculty 1, Universität Bremen, 28359 Bremen, Germany  
We consider gravitational lensing in a warm, non-magnetized electron-ion plasma, thereby extending the rather extensive literature on lensing in a cold plasma. After discussing the general equations for light rays in such a medium on a general-relativistic spacetime, we specify to the axially symmetric and stationary case which includes the spherically symmetric and static case. In particular, we calculate the influence of a warm plasma on the bending angle. In the spherically symmetric and static case, we also calculate the shadow in a warm plasma. We illustrate the general results with a static (respectively corotating) and an infalling warm plasma on Schwarzschild and Kerr spacetimes. A preprint of this work is available at arXiv:2512.09341.

GR 9.2 Wed 14:00 KH 02.012

**Rényi second laws for Charged AdS Black Hole** — ALICE BERNAMONTI<sup>1</sup>, FEDERICO GALLI<sup>1</sup>, and •EMILIANO RIZZA<sup>2</sup> — <sup>1</sup>Università degli Studi di Firenze, Florence, Italy — <sup>2</sup>Jagiellonian University, Krakow, Poland  
Hawking's black hole area theorem offers a geometric interpretation of the second law of thermodynamics, imposing fundamental constraints on gravitational dynamics. By examining entropic inequalities following from the monotonicity

of Rényi entropies, it is shown that these constraints often set stricter bounds than those imposed by the area theorem in asymptotically AdS space.

This work aims to explore in detail the case of charged AdS black holes, which exhibit rich thermodynamic phase structures in the canonical ensemble. In particular, we study the coalescence of charged black holes in AdS, establishing a lower bound on the mass of the final state and an efficiency bound on the amount of gravitational radiation.

GR 9.3 Wed 14:15 KH 02.012

**Bound States of the Schwarzschild Black Hole** — •SEBASTIAN H. VÖLKE — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-14476 Potsdam, Germany  
Understanding the physical significance and spectral stability of black hole quasinormal modes is fundamental to high-precision spectroscopy with future gravitational wave detectors. Inspired by Mashhoon's idea of relating quasinormal modes of black holes with their equivalent bound states in an inverted potential, we investigate, for the first time, energy levels and eigenfunctions of the Schwarzschild black hole quantitatively. While quasinormal modes describe the characteristic damped oscillations of a black hole, the bound states of the inverted potential are qualitatively more similar to those of the hydrogen atom. Although the physical interpretation of these states may initially be of more academic interest, it furthers our understanding of open problems related to quasinormal modes in a similar spirit to Maggiore's interpretation of

the Schwarzschild quasinormal mode spectrum. One surprising insight from the explicit calculation of bound states is that eigenfunctions corresponding to quasinormal mode overtones become rapidly delocalized and extremely loosely bound. This observation raises immediate questions about the common interpretation of quasinormal modes as excitations of the light ring region. Closely related, as a second application, we also explore the spectral stability of bound states and demonstrate that they can provide complementary insights into the quasinormal mode spectrum.

Völkel, Phys. Rev. Lett. 134, 241401, 2025

GR 9.4 Wed 14:30 KH 02.012

**Astrophysical Quantum Matter: Black-Hole and Cosmological Particle Production** — •MICHAEL FLORIAN WONDRAK — Anton Pannekoek Institute for Astronomy/GRAPPA, University of Amsterdam, The Netherlands

Energy extraction from black holes is—at first sight—a counter-intuitive concept. However, black holes are known to lose mass by classical and quantum processes. In recent work, the formal analogy with particle production by electric fields (Schwinger effect) was elaborated.

Building upon this analogy, we will use independent techniques, from canonical to path-integral quantization, to predict quantum particle production in astrophysical settings, from black holes to cosmology. We will present a novel class of time profiles allowing an analytic treatment and allowing an exact prediction of particles produced. We will put the findings into context and comment on the impact of backreaction.

GR 9.5 Wed 14:45 KH 02.012

**Forecasting Ground Motion with Large Sequence Models: Implications for the Einstein Telescope** — •WALEED ESMAIL<sup>1</sup>, ALEXANDER KAPPE<sup>1</sup>, STUART RUSSELL<sup>2</sup>, and CHRISTINE THOMAS<sup>2</sup> — <sup>1</sup>Institut für Kernphysik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149, Münster — <sup>2</sup>Institut für Geophysik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149, Münster

Seismic forecasting is entering a new phase in which data-driven sequence models can learn the complex temporal structure of ground motion directly from waveform records. In this talk, I will discuss a transformer-based approach that treats seismic waveforms as a generative sequence prediction problem, allowing short-horizon forecasting. A key motivation comes from the Einstein Telescope, where seismic noise, especially at low frequencies, can limit detector sensitivity. Accurate, low-latency forecasting enables active noise cancellation, where the detector can anticipate incoming noise and suppress it before it couples into the interferometer. I will show how transformer-based models can support this vision and why a seismic foundation model may become a core component of the next generation of gravitational-wave observatories.

GR 9.6 Wed 15:00 KH 02.012

**Relativistic hydrogen spectrum of the Bopp-Podolsky electrostatic potential** — •ALTIN SHALA<sup>1</sup> and VOLKER PERLICK<sup>2</sup> — <sup>1</sup>ZARM, Bremen, Germany — <sup>2</sup>Faculty 1 University of Bremen, Bremen, Germany

We investigate the relativistic hydrogen spectrum given by the Dirac equation when the electrostatic potential of the nucleus is described by the potential given by Bopp-Landé-Thomas-Podolsky theory of electrodynamics. Employing numerical and analytical methods, we take advantage of known measurement uncertainties in the hydrogen spectrum in order to place new constraints on the introduced parameter.

## GR 10: Poster

Time: Wednesday 16:15–18:45

Location: Redoutensaal

GR 10.1 Wed 16:15 Redoutensaal

**Doubly-periodic Processes in Particle Accelerators, Fusion Reactors and Artificial Photosynthesis** — •OTTO ZIEP — Independent Scholar, 13089, Berlin, Germany

Vacuum energy for a real Lagrangian can be undercut by least squares of complex conformal fields where stress-energy resembles a Schwarzian derivative for a doubly-periodic iteration. The dynamics of zeros of holomorphic functions yields a Newton fractal quadratic in mass  $0=\delta m \delta m'$  with phantom energy  $\rho(\text{dark})$  which resembles spin zero fields. Local stationary states  $\rho-\rho(\text{dark})=0$  are predicted similar to the Dirac model of additive creation of matter  $\rho$ . For particle accelerators, fusion reactors and in artificial photosynthesis a doubly-periodic processing called breathing mode is designed which predicts cooling due to generated complex dark matter  $\rho(\text{dark})$ .

[1] O. Ziep, Cosmic Rays, Aerosol-Photosynthesis and Vegetational Air Ion, Journal of Modern Physics, Bd. 16, p. 1179-1192, 2025, <https://doi.org/10.4236/jmp.2025.168059>

[2] O. Ziep, Doubly-Periodic Processing in Particle Accelerators and Fusion Reactors, submitted to Journal of High Energy Physics, Gravitation and Cosmology, 2025.

[3] O. Ziep, Doubly-Periodic Atmospheric Power Plants, submitted to Discover Energy, 2025.

GR 10.2 Wed 16:15 Redoutensaal

**What was before the Big Bang?** — •JÜRGEN BRANDES — Karlsbad Germany

The considerations of the previous year are continued.

A good overview of the numerous observations that contradict the cosmological principle of GRT can be found in [1]. These include the Hubble Tension [2] as well as the remarkable observation that the expanding universe has angular momentum, as if it were a rotating stellar object. A fundamental *theoretical* objection to the idea of GRT that space expands is its contradiction with the law of conservation of energy. The energy of background radiation (CMB) decreased from 3000°K to 2.7°K over time due to space expansion. *However, it is unclear where the lost energy remains.* The LI of GRT does explain it, given that the source and receiver move relative to each other [3]. A physical theory that contradicts the law of conservation of energy leaves some questions unanswered.

[1] Pavan Kumar Aluri et al. *Is the Observable Universe Consistent with the Cosmological Principle?* arXiv:2207.05765v4 [astro-ph.CO] 27 Feb 2023

[2] J. Brandes, J. Czerniawski, L. Neidhart: *Special and General Theory of Relativity for physicists and philosophers* VRI: 2023, chapter 24.11.2, page 324.

[3] Article (during 2026) on homepage [www.grt-li.de](http://www.grt-li.de): DPG-2025-2026-What was before the Big Bang.

GR 10.3 Wed 16:15 Redoutensaal

**Quantum gravity via Lorentz-invariant gravity** — •RENÉ FRIEDRICH — Strasbourg

Lorentzian spacetime, incredibly, proves to be a 100-year-old optical illusion, an impossible object: The banal fact of the non-zero length of worldlines of lightlike light rays shows us that spacetime diagrams and spacetime manifolds have Euclidean metric, because if they were Lorentzian (pseudo-Riemannian), the length of lightlike phenomena would be zero. Accordingly, spacetime is not fundamental, it is mere observation, and the underlying Lorentz-invariant real universe (compatible with quantum mechanics) consists of worldlines in absolute 3D space, each worldline being parameterized by its respective proper time. - Regarding gravity, we can use the fact that gravity may be described not only as curved spacetime, but also equivalently as gravitational time dilation in three-dimensional flat space: A comparison Schwarzschild metric / Minkowski metric shows that the difference between flat and curved spacetime can be entirely reduced to gravitational time dilation, paving the way to quantum gravity: Gravity in the form of gravitational time dilation slows down the frequency of the proper time of worldlines of massive particles, corresponding to the time evolution  $\exp -imc2\tau/\hbar$  of their respective wave functions. - More: Quantum gravity without trouble, Quantengravitation ohne Mühe, La gravité quantique sans peine.

GR 10.4 Wed 16:15 Redoutensaal

**Constraining the Mass of Ultralight Axions Using the 21-cm Signal During Cosmic Dawn** — •JULIAN ANTONIO KLEFF — Institute for Astrophysics and Geophysics, University of Göttingen, Germany

The aim of my master's thesis is to constrain the mass of a dark matter candidate called ultralight axions (ULAs). Compared to standard cold dark matter ULAs suppress the halo mass function below the scale of the Jeans mass  $M_J(m_\alpha)$  which depends on the mass  $m_\alpha$  of ULAs. Star formation within molecular cooling halos is expected to significantly contribute to the 21-cm signal during cosmic dawn. Efficient molecular cooling, and thus star formation, becomes possible if the critical halo mass  $M_{\text{mol}}(v_{cb})$  is reached, which (among other quantities) is affected by the dark-matter-baryon relative velocity  $v_{cb}$  introduced after recombination. This dependence on  $v_{cb}$  leads to so called velocity acoustic oscillations (VAOs) in the 21-cm power spectrum on scales  $k \sim 0.1 \text{ Mpc}^{-1}$ . However, once  $M_J(m_\alpha) \gg M_{\text{mol}}(v_{cb})$  the dependence of the 21-cm signal on  $v_{cb}$  is effectively removed, and thus the VAOs too. As  $M_J(m_\alpha)$  increases with decreasing  $m_\alpha$ , smoothly decreasing  $m_\alpha$  leads to a smooth decline of the amplitude of the VAOs in the 21-cm power spectrum until they vanish completely. The goal of my master's thesis is to implement the physics of ULAs into the software Zeus21, an analytical tool for the computation of the 21-cm power spectrum, and to utilize the strong dependence of the VAOs on the axion mass to improve current constraints on the axion mass.

GR 10.5 Wed 16:15 Redoutensaal

**New Description of the Big Bang's Approximate Volume and Density in the Universe** — •GH. SALEH — Saleh Research Centre, Amsterdam, Netherlands

In the analysis of an atom, a nucleus is observed at the centre, with electrons orbiting around it. For every element, a specific atomic radius exists, which is certainly a constant value. Essentially, a fixed "identity card" can be defined for each element, containing constant parameters such as volume, mass, density, and so on. Consider a white dwarf: it is defined as a structure composed of a collection of protons situated close together. This creates a relatively small sphere with a high density. Generally, since the material is made of protons, the density of a white dwarf can be estimated to fall within a specific range (around  $10^{17}$ ).

Essentially, this form of matter consists of protons gathered together. A problem arises when attempting to define the primary matter for the Big Bang. If the building blocks were protons or neutrons the result would be a sphere with a radius roughly the distance from the Earth to Jupiter. If the Big Bang is thought to be made of protons, neutrons, or even photons, it results in a massive sphere, which requires a different definition for the Big Bang. Therefore, based on the explanation above, a particle must be defined that is significantly smaller than a photon.

In this paper we are going to show that if photons are viewed as having a structure like an atom, breaking it down yields Cidtonium particles (between one-millionth and one-billionth the size of a photon). With the high density of Cidtonium, the huge mass and tiny volume of the Big Bang can be defined.

GR 10.6 Wed 16:15 Redoutensaal

**Calibration and optimization of Target CTC ASICs for enhanced phase resolution in phase cameras** — •NIKLAS KOTSCHI for the Einstein Telescope-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP) Friedrich-Alexander-Universität Erlangen-Nürnberg Nikolaus-Fiebiger-Str. 2 91058 Erlangen

The Einstein Telescope is a planned gravitational wave observatory designed to detect spacetime distortions with unprecedented sensitivity. This can be achieved with a large michelson-interferometer setup. The laser needs to be well aligned to measure the phase. For this purpose, a new kind of phase camera, which uses an array of optical fibers to capture the laser was introduced. A cost efficient solution to digitize these multi-channel analog inputs are a new set of Application-Specific Integrated Circuits (ASICs), which were originally designed for the readout of signals from photosensors in cameras of Imaging Atmospheric Cherenkov Telescopes for ground-based gamma-ray astronomy. They were optimized for single photon detection. For phase cameras these ASICs need to be optimized for readout of high intensity waveforms. This is why calibration and optimization of TARGET CTC ASICs for application in phase camera systems is important. The resolution is integration time dependent. Therefore reducing the sample speed can increase the resolution by increasing the integration time. Jitter from different GPS clocks was analyzed to optimize the synchronisation stability. The results demonstrate key improvements in data acquisition stability. Testing out different calibration and timing parameters and their impact on the waveforms and phase resolution were done.

GR 10.7 Wed 16:15 Redoutensaal

**Visualization of the curved spacetime of a Morris-Thorn wormhole in a sector model** — •RAHEL GABRIEL — Universität Hildesheim

Sector models, based on Regge calculus, provide an intuitive way to visualize curved spacetimes in general relativity using locally flat sectors. Curvature is encoded at sector boundaries through deficit or excess angles, and geodesics are constructed as straight lines that continue across sector boundaries. This framework is used to explore the topology and phenomenology of hypothetical Morris-Thorn wormholes in an interactive simulation.

GR 10.8 Wed 16:15 Redoutensaal

**Probing Small-Scale Structure during Cosmic Dawn with the 21 cm Forest** — •MONJA BEGAU, MIHIR KULKARNI, and JENS NIEMEYER — Institute for Astrophysics and Geophysics, Göttingen, Germany

Observations of the 21 cm hyperfine transition of neutral hydrogen are expected to significantly improve our understanding of the thermal and structural evolution of the intergalactic medium during cosmic dawn. The 21 cm signal measures deviations of the hydrogen spin temperature from the cosmic microwave background, leading to absorption or emission. In addition to large-scale brightness-temperature fluctuations, neutral hydrogen along individual lines of sight can imprint narrow absorption features in the spectra of distant radio-loud sources. In analogy to the Lyman- $\alpha$  forest, this is referred to as the 21 cm forest. These absorption features probe small-scale density structure.

Modelling the 21 cm signal is challenging due to the nonlinear and non-local relation between matter density, star formation, and the resulting radiative backgrounds. In this work, we employ and extend the Zeus21 framework (arXiv:2302.08506v2, Julian B Munoz), an analytic model for the 21 cm signal during cosmic dawn. This framework is applied here to the description of the 21 cm forest. Since axion dark matter can modify structure formation on small scales, such effects may be reflected in the statistics of the 21 cm forest. We ex-

plore the potential of this approach to probe axion-like dark-matter scenarios through modifications of the predicted 21 cm forest power spectrum.

GR 10.9 Wed 16:15 Redoutensaal

**Bondi mass loss formula for axial symmetric systems in  $f(R) = R + \lambda R^2$  gravity** — •THOMAS GUILLERMO ALBERS RAVIOLA — Universität Bremen, Bremen, Germany

In General Relativity, the Bondi-Sachs formalism is used to study gravitational waves as observed at future null-infinity. It introduces the concept of the Bondi mass, whose decrease is connected to the news tensor through the famous Bondi mass loss formula. This work investigates the changes in the Bondi mass loss formula for axial symmetric systems in  $f(R) = R + \lambda R^2$  gravity, also known as the Starobinsky inflation model. We develop this result in the scalar-tensor representation as a foundation for later applying similar methods for more general scalar-tensor theories of gravity. A priori, it is expected that the addition of further degrees of freedom shall provide a measurable signature, that may manifests itself, for example, in gravitational waves observations. Also closely related to the Bondi-Sachs results is the BMS group, which plays an important role in the search for a quantum theory of gravity. As such, it is highly interesting to understand the modifications to the BMS group in theories of gravity beyond general relativity.

GR 10.10 Wed 16:15 Redoutensaal

**Universe without expansion and big bang** — •ROLAND ALFRED SPRENGER — Herford, Germany

The standard model of cosmology is confronted with a model of a universe which is curved within a five-dimensional spacetime. The redshift of the spectra of galaxies is explained by the curvature; the expansion of the universe and the big bang do not exist in this model. According to this the universe is a four-dimensional hypersphere within the five-dimensional spacetime. Its radius is calculated from the distance of standard candles.

GR 10.11 Wed 16:15 Redoutensaal

**Electron Mass, Charge and Sommerfeld FSC** — •MANFRED GEILHAUPT — Hs Niederrhein Mönchengladbach

Einstein: Ich wüsste gern, was ein Elektron ist. Electron restmass (energy) not zero. Charge Sommerfeld:

$**e^2 = 2 \cdot \alpha \cdot c \cdot \epsilon_0$  (no energy!). Question: What must be known else, able to answer Einsteins question? Restmass & Charge must be derived from a principle theory. Results from GR+TD: rest- mass  $m_e(\alpha, N)$  & charge  $e(\alpha)$ . expectation values, both depend on  $\alpha$ . The  $r(t)$ -generating two differential equations - not like Schrödinger but source for mass and charge - can be found using a common Newton Einstein Equation of Motion:

$**dP/dt = f_1 + f_2 + f_3 + f_4 + f_5$  coming up with 5 internal parts from partial derivation. The second part ( $f_2 = m \cdot ddr/ddt$ ) leads to restmass  $m_e(\alpha, N)$  being an effective value from the solution  $m(t)$  if  $r(t)$  is a generating function same for all 5 parts.  $u(t)$  is a unit vector possible to rotate ( $du/dt$ ). The first equation ( $f_1 = dr/dt \cdot dm/dt$ ) - if  $m(t)$  is known already from part two - leads to charge  $e(\alpha)$  while  $\alpha$  is the Sommerfeld FSC:

$**\alpha = (1/\beta) \cdot (1/\beta) \cdot 1/g_{44} \cdot 3/4 \cdot (1 + \log(1/3)) \cdot (1 + \log(1/3))$  - appears when using  $r(t)$  to get  $m(t)$  from equation  $f_2$ .  $\beta$  is the Einstein SR parameter while  $g_{44}$  is the well known GR-metric number: while within  $(e/m) = 1/\sqrt{r(N)}$  here  $\alpha$  cancels!  $\alpha$  represents the continuum part and  $N$  the quantum part of nature. So GR+TD predicts QMs quantisation phenomena physically - based on causality and TD principles applied.

GR 10.12 Wed 16:15 Redoutensaal

**Dimensional Physics explains the structure of the natural constants  $c$ ,  $G$ , and  $\hbar$  solely based on General Relativity** — •CHRISTIAN KOSMAK — Working Group Dimensional Physics, Würzburg

In the theory of Dimensional Physics, the approach taken is that spacetime density is the source of spacetime curvature. Any mass-energy equivalent is a direct geometric representation in spacetime itself. This gives spacetime boundaries in a higher-dimensional spacetime and in an infinite number of lower-dimensional spacetimes. These boundaries determine the structure of the natural constants  $c$ ,  $G$ , and  $\hbar$ . Planck's quantum of action and, as a result, the Compton wavelength of any object (spacetime density) are necessarily derived from the structure of spacetime. This means that General Relativity dictates how Quantum Field Theory must be structured. Spacetime is not only a dynamic stage, but also the only actor. Website: Dimensionale Physik (dimensionale-physik.de)

GR 10.13 Wed 16:15 Redoutensaal

**Why the theories of relativity are wrong though they are right** — •HANS DEYSENROTH — Holzgasse 28

The two theories of relativity have been confirmed experimentally many times, most recently in spectacular fashion with the verification of the predicted gravitational waves. They must be right.

But unfortunately, the data of the lunar laser ranging project shows clearly that the photons, coming from a mirror on the Moon, appear there where the



Earth was 2.55 seconds before and not - as expected - in the detector next to the laser. That means that there is no oblique light path at the light clock or from the half transparent mirror at the Michelson Morley experiment. Therefore, the time dilation cannot be derived via the Pythagoras form this oblique light path as Einstein it did and the length contraction proposed by H. Lorentz would destroy the null result. With other words: the fundament of both theories of relativity - the Lorentz transformation - is wrong.

Physics should be based on experimental facts. But can physicists accept an experimental fact that contradicts the theories of relativity?

Some other experiments and observations show that gravity can be shielded and controlled by electromagnetic processes. Why have these facts been ignored?

GR 10.14 Wed 16:15 Redoutensaal

**A modified theory of gravity explains the self-interaction of dark matter.** —

•ALBRECHT GIESE — Taxusweg 15, 22605 Hamburg

New investigations using the James Webb telescope have revealed inconsistencies in the explanations for the formation and distribution of dwarf galaxies in the early stages of the universe.

Current cosmological theory suggests that this can be explained by assuming that dark matter particles self-interact. However, according to our current understanding of gravity, such an interaction is impossible.

We will demonstrate that there is a model of gravity based on a different dependence of gravity on mass. This model not only solves the issue of rotation curves, but also that of the self-interaction of dark matter-related particles.

For details: [www.ag-physics.org/gravity](http://www.ag-physics.org/gravity)

GR 10.15 Wed 16:15 Redoutensaal

**CPU - the Cyclic Process Universe** — •THOMAS WÄSCHER — IBW-Engineering, 69231 Rauenberg

Based on my 2022 and 2024 talks which take the fundament of GR, Einstein's equivalence principle into account, it was shown that the accelerated expansion  $a=Hc$  can be equivalently interpreted as a constant isotropic gravitational field, now replacing Dark Matter and eliminating Dark Energy simultaneously. The redshift  $z$  of any radiation originates from accumulating the gravity potential  $\Phi=f(R)$  with  $\Phi_{\max}=c^2$ . The tailored Hubble number  $H$  [km/sMpc] of expansion changes to a natural decay constant [1/s]. The dynamic of expansion is converted to the equilibrium dynamic of in- and outflow of matter and energy by the ubiquitous astrophysical objects like e.g. stars, galaxies, quasars, blazars, pulsars and black-holes. The total mass and energy flows sum up to  $dm/dt=c^3/2G$  [kg/s] and  $P=c^5/2G$  [Watt]. The curved and gravitationally closed universe exhibits a volume of  $V=2\pi^2R^3$  (Einstein 1917), the same as a horn torus with  $r=R$ , a possible topology. This universe allows any individual to be located in the very center by physical justification.

GR 10.16 Wed 16:15 Redoutensaal

**Adequate Coordinate System for Space Navigation and Relativity** — •HANS-OTTO CARMESIN — Univ. Bremen, FB 1, Postfach 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Gymn. Athenaeum, Harsefelder Straße 40, 21680 Stade

The International Astronomical Union (IAU) realized, that the coordinate systems of relativity theory are insufficient for space navigation. Therefore, the IAU proclaimed the problem of finding an adequate coordinate system (ACS) for space navigation and relativity.

Here, that problem is solved:

(1) A measurement procedure is presented. (2) For each Point  $P$  in the universe, an ACS is derived, and its velocity  $\vec{v}_{ACS,CS}$  relative to an arbitrary coordinate sys-

tem (CS) is derived. (3) The ACS is confirmed by an observation at Earth, using two atomic clocks, one at the PTB and one at the MPQ (Max Planck Institute for Quantum Optics). (4) The universal zero of the fractional kinematic time difference  $\delta t_{kin, fractional}$  is derived. (5) For each Point  $P$ ,  $\delta t_{kin, fractional}$  is derived. This is confirmed by observation data at Galileo satellites. As a consequence, the precision of clocks onboard spacecrafts can be improved. This can provide improvements in space navigation, remote sensing or geoinformatics.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster. Carmesin, H.-O. (2025): Construction of a Physically Adequate Coordinate System with Help of an Observation on Earth's Ground. J Geosci Earth Planet Syst, 1(1), pp. 01-12.

GR 10.17 Wed 16:15 Redoutensaal

**Zeitentwicklung der dunklen Energiedichte und der universellen Zeitdilatation** — HANS-OTTO CARMESIN<sup>1,2,3</sup> und •JACKY DAVID YANG<sup>1</sup> — <sup>1</sup>Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — <sup>2</sup>Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — <sup>3</sup>Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

Untersucht wurden das globale Konzept und der globale Verlauf der Zeit. Für ein homogenes Universum ( $\Lambda$ CDM-Modell) und ein heterogenes Universum (Linear Growth Theory, Carmesin 2024) wurde mithilfe kosmologischer Planck-Messdaten (2020) das Weltalter bestimmt, wobei die Hubble-Tension berücksichtigt wurde. Aus der Zeitentwicklung des homogenen Universums wurde die im heterogenen Universum hergeleitet. Daraus wird die Zeitdilatation bestimmt. Die Ergebnisse wurden grafisch, tabellarisch und mathematisch dargestellt. Auch wird nun die Zeitentwicklung der Dunklen Energie  $\Omega_\Lambda$  analysiert und veranschaulicht. Diese kann aus der Zeitentwicklung der globalen/universellen Zeitdilatation berechnet werden. Dabei sagen die von uns hergeleiteten Ergebnisse zukünftige Messwerte vorher und stimmen schon jetzt mit aktuellen Messwerten überein. Hierbei können sich zukünftige Messwerte auf beliebige Rotverschiebungen und entsprechende Zeitpunkte beziehen, da die Dunkle Energie und die globale Zeitdilatation als Funktion der Rotverschiebung hergeleitet wurden.

Planck Collaboration 2020: Astronomy and Astrophysics, pp. 1 - 73. H. - O. Carmesin (2024), Verlag Dr. Köster. H. - O. Carmesin (2025), Verlag Dr. Köster.

GR 10.18 Wed 16:15 Redoutensaal

**A Concept of Worldview** — •BORIS SCHAPIRO — Kluck Str. 25, D-10785 Berlin  
The concept of worldview consists of several hypotheses:

The Space-Time is quantum object. The world consists of several universes. Number of universes and dimensionality of world are related by combinatorics. All universes originated simultaneously and are approximately the same as our own. I call the space in which the universes are located a Metaverse. The Metaverse is also a quantum object. Energy within it shouldn't be conserved because it's an open system; it generates energy through quantum fluctuations and expands due to this energy. Universes expand because they're nested within the Metaverse. Dark matter is the matter of other universes as it is gravitationally perceptible by us.

This leads to the fact that space is a quantum object, while gravity is the curvature of space, which isn't a quantum object, but a classical one. Therefore, there is no need to search for a "theory of quantum gravity", but rather to combine quantum and classical phenomena without merging them into one illogical concept, without distorting the understanding of the fundamental nature of each of them.

Comparison of the obtained formulae with the known observational data allows us to conclude that there are six universes in the Metaverse.

## GR 11: Numerical Relativity II

Time: Thursday 11:00–12:00

Location: KH 01.016

### Invited Talk

GR 11.1 Thu 11:00 KH 01.016

**Numerical Relativity for LISA and the Einstein Telescope** — •NILS VU — California Institute of Technology, Pasadena, USA

The upcoming European gravitational-wave detectors LISA and the Einstein Telescope are bound to revolutionize our understanding of black holes across the Universe, but to make sense of their data we will require extremely accurate numerical simulations of merging black holes and their gravitational waves. This is the realm of numerical relativity and requires solving Einstein's equations of general relativity to extreme precision on large supercomputers. In this talk, I will give an overview of the state-of-the-art in numerical relativity, recent advances in simulating merging binary black holes with highly efficient spectral finite-element methods, and the challenges that lie ahead to reach the requirements for the era of next-generation gravitational-wave astronomy.

GR 11.2 Thu 11:30 KH 01.016

**A novel approach for the systematic study of long-lived merger remnants with neutrino radiation** — •MARIE CASSING<sup>1</sup>, LUCIANO REZZOLLA<sup>1,2,3</sup>, CARLO MUSOLINO<sup>1</sup>, KONRAD TOPOLSKI<sup>1</sup>, HARRY HO-YIN NG<sup>1</sup>, and KENETH MILER<sup>1</sup> — <sup>1</sup>Goethe University Frankfurt, Frankfurt am Main, Germany — <sup>2</sup>CERN, Theoretical Physics Department, Geneva, Switzerland — <sup>3</sup>School of Mathematics, Trinity College, Dublin, Ireland

We introduce a novel hybrid framework for simulating binary neutron star mergers (BNS) with neutrino radiation, developed to explore the long-term evolution of postmerger remnants. The approach combines the strengths of the general-relativistic magnetohydrodynamics (GRMHD) code FIL for modeling the inspiral and merger phase with the advanced code BHAC+, which takes over in the postmerger phase. In BHAC+, we implement an M1 two-moment neutrino transport scheme and solve the stiff source terms with an implicit-explicit (IMEX) time integration strategy. This enables robust simulations of neutrino matter coupling over long timescales. Our primary aim is to study neutrino-

driven winds, changes in remnant structure, and their potential to influence jet launching in scenarios involving long-lived neutron stars or delayed collapse to a black hole. We present results of M1 test problems and physical setups validating our implementation and outline the potential of this hybrid approach to systematically explore ejecta properties and electromagnetic counterparts in BNS mergers.

GR 11.3 Thu 11:45 KH 01.016

**Gravitational Scattering of two Neutron Stars** — •JOAN FONTBUTÉ — Friedrich-Schiller Universität, Jena, Germany

In this talk I'm going to present the first numerical relativity simulations of gravitational scattering between neutron stars and the first comparison of such simulations with analytical predictions as well as the black hole case. Constraint-

satisfying initial data for two equal-mass non-spinning sequences are constructed at fixed energy and various initial angular momenta for two Equations of State. Our results probe extreme strong-field regimes up to the threshold of dynamical capture, revealing both agreement and significant tidal discrepancies with effective-one-body and post-Minkowskian predictions to the scattering angle. Together with these results obtained with the BAM code, I'm also going to present an extension to more realistic scenarios containing magnetic fields, M1 neutrino transport and a better atmosphere treatment with the GR-Athena++ code, where we also study in detail other properties of such events like the final spins, magnetic field properties and mass ejecta. The matter ejected is found to be crucial to explain the decrease in the binding energy that eventually makes the system become bound.

## GR 12: Relativistic Astrophysics III / Gravitational waves III

Time: Thursday 13:45–15:15

Location: KH 01.016

GR 12.1 Thu 13:45 KH 01.016

**The Thermal Index for Interacting Fermi Gases** — •TIMON KLEIBER, ISHFAQ AHMAD RATHER, SELINA KUNKEL, SARAH PITZ, and JÜRGEN SCHAFFNER-BIELICH — Goethe Universität Frankfurt, Institut für Theoretische Physik

We analyze and compare the influence a simple repulsive interaction between particles has on a single component Fermi gas. Our focus is on the thermal part of the equation of state. This model can be used to calculate an EOS at nonvanishing temperature for pure neutron matter or fermionic dark matter. The coupling constant for the interactions uses the scale of strong interactions as a baseline. We additionally look at the effects of higher and lower coupling strengths with respect to the QCD baseline. A special focus is put on the isentropes within the area that is relevant for Proto-Neutron star evolution and or thermal evolution of fermionic dark matter. The inclusion of interactions leads to an increase in pressure compared to energy density along the isentropes and causes their ratio to reach values above the maximum limit without interactions.

GR 12.2 Thu 14:00 KH 01.016

**Impact of in-situ nuclear networks and atomic opacities on neutron star merger ejecta dynamics, nucleosynthesis, and kilonovae** — •FABIO MAGISTRELLI — TPI, FSU Jena

Binary neutron star merger (BNSM) ejecta are key sites of rapid neutron-capture (*r*-process) nucleosynthesis and power kilonovae through the radioactive decay of freshly synthesized nuclei. I will present a systematic study of how nuclear burning, particle thermalization, and atomic opacity treatments impact the nucleosynthesis and electromagnetic emission from BNSM ejecta, starting from ejecta profiles extracted from ab-initio numerical-relativity simulations and evolved up to  $\sim 30$  days with radiation-hydrodynamics calculations with in-situ nuclear reaction networks (NN). I will compare simplified and composition-dependent thermalization schemes, as well as gray opacity models and frequency-dependent, atomic-physics-based opacities. Finally, I will discuss how NN coupling and detailed thermalization and opacity treatments significantly modify the temperature evolution of the ejecta, the structure of the *r*-process peaks, and the brightness and color evolution of the associated kilonova for realistic ejecta profiles.

GR 12.3 Thu 14:15 KH 01.016

**Dynamo processes and jets from long-lived remnants from binary neutron star mergers** — •MICHAEL MUELLER<sup>1</sup>, LUCIANO COMBI<sup>2</sup>, and DANIEL SIEGEL<sup>1</sup> — <sup>1</sup>University of Greifswald, Greifswald, Germany — <sup>2</sup>Perimeter Institute for Theoretical Physics, Waterloo, Canada

Identifying the mechanisms behind the generation of short gamma-ray bursts (GRBs) in compact object mergers, such as the one accompanying GW170817, is necessary to connect the observed GRB and merger populations. Current observations indicate that accreting neutron star remnants are a likely outcome for binary neutron star (BNS) mergers, and it is key to understand whether such systems can give rise to GRB emission. Dynamo processes and magnetic winding have been identified as critical components in producing the necessary large-scale coherent magnetic field to power the jet without a black hole central engine. We present new results from three-dimensional general-relativistic magnetohydrodynamic simulations of equal-mass binary neutron star mergers resulting in a long-lived hypermassive neutron star. The binary system is evolved without symmetry assumptions, employing a tabulated, composition-dependent, finite-temperature equation of state, a vector potential formalism for the magnetic field evolution, and approximate neutrino transport. We demonstrate that the magnetorotational instability is well resolved in the disk, and we study the dynamo action of the resulting turbulence in the disk and at the disk-star interface with new diagnostics to identify the processes involved in generating coherent field structures.

GR 12.4 Thu 14:30 KH 01.016

**Fibre-based Phase Camera for the Einstein Telescope** — •STUTI SHARMA, BENJAMIN SCHWAB, ADRIAN ZINK, and STEFAN FUNK for the Einstein Telescope-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander University

The Einstein Telescope (ET) is a planned third-generation underground gravitational wave observatory. The telescope requires precise monitoring of optical wavefront quality. Mode mismatches and wavefront aberrations in the sidebands used for interferometer control can lead to the excitation of higher order Gaussian modes (HOMs) which reduce detector performance. To address this, a fibre-based 56-pixel proof-of-concept phase camera has been developed. This camera is capable of simultaneously measuring the spatial amplitude and phase of multiple sidebands. Its multimode fibre array provides stable spatial phase relations between pixels at high frame rates. A dedicated digitisation setup is built via the CTC ASIC, that has been adopted from camera readout electronics for CTAO. Commissioning of such a setup at the ET Pathfinder demonstrated reliable visualisation of wavefronts and identification of HOMs.

Future work will build on enhancing the analysis of phase camera images to distinguish and classify higher order Gaussian modes. Therefore, an optical resonator capable of generating arbitrary, well-defined higher-order mode content will be added to the setup for future wavefront studies. The system will be scaled toward a 4096-pixel camera with FPGA based real-time demodulation. These developments aim to establish a robust and scalable wavefront sensing framework for ET.

GR 12.5 Thu 14:45 KH 01.016

**Exploring Machine Learning Techniques for Gravitational-Wave Detection with Einstein Telescope** — •SEBASTIAN WEIN, ALEXANDER KAPPES, and WALEED ESMAIL — Universität Münster, IKP, Wilhelm-Klemm-Str. 9, 48149

Einstein Telescope is a planned third-generation gravitational-wave observatory, that is expected to be more sensitive by at least one order of magnitude compared to current facilities such as LIGO/Virgo. With this increased sensitivity, challenges for signal detection arise due to longer signal duration and frequent signal overlap. Matched filtering, the current standard numerical signal detection algorithm, cannot be easily adapted to meet these challenges: neural networks might be a better fit instead. This talk describes the design of a machine-learning architecture for handling large inputs and detecting multiple, possibly overlapping signals.

GR 12.6 Thu 15:00 KH 01.016

**RealTime Seismic Waveform Prediction Using Low-Latency Transformer-Based Models** — •KYRILL EMANUEL BLÜMER, ALEXANDER KAPPES, and WALEED ESMAIL for the Einstein Telescope-Collaboration — Institut für Kernphysik Uni Münster

The Einstein Telescope (ET) is a planned third-generation gravitational-wave detector, that will be built underground. It is designed to improve the detection sensitivity by up to an order of magnitude relative to existing detectors, especially at low frequencies. Because gravitational waves generates an extremely small strains, seismic and Newtonian noise becomes a limiting factor for the low-frequency sensitivity of the ET. Transformer-based deep learning models are well suited for learning long-range temporal and spatial dependencies in seismic waveform data and can provide accurate short-term forecasts of the 3D ground motion. However, for longer prediction horizons, waveform prediction quality degrades due to the error accumulation, when predictions are produced autoregressively. This talk will explore architectural and algorithmic improvements aimed at achieving stable, real-time, low-latency seismic waveform prediction.

## GR 13: Quantum Gravity and Quantum Cosmology I

Time: Thursday 13:45–15:15

Location: KH 02.012

GR 13.1 Thu 13:45 KH 02.012

**Measurement of the Casimir force during free fall** — •SASCHA KULAS — International University of Applied Sciences (IU), Schiffgraben 49-51, 30175 Hannover, Germany

The Casimir effect is an attractive interaction between two uncharged and perfectly conducting plates held a short distance apart. Its force still has a lot of unknown aspects. Here, this force is measured in a tuning fork experiment during free fall and compared with a measurement on ground. It seems like the Casimir force is strongly suppressed during free fall. This is a hint that the Casimir force does not have its origin in the Van der Waals force, which would not change in weightlessness. In the next step, drop tower experiments have to proof the results. In addition, a physical toy model is introduced, that explains these experimental results and further effects concerning gravity and quantum mechanics.

GR 13.2 Thu 14:00 KH 02.012

**Gravitational collapse in effective loop quantum gravity and the formation of shell-crossing singularities** — FRANCESCO FAZZINI<sup>1</sup>, KRISTINA GIESEL<sup>1</sup>, HONGGUANG LIU<sup>2</sup>, and •ERIC RULLIT<sup>1</sup> — <sup>1</sup>Institute for Quantum Gravity, Friedrich-Alexander-Universität, Erlangen-Nürnberg, Germany — <sup>2</sup>Institute for Theoretical Sciences, Westlake University, Hangzhou, China

In this talk the investigation of the gravitational dust collapse within the framework of effective loop quantum gravity will be addressed, with a special focus on the properties and the formation of shell-crossing singularities in these models. The specific effective model that will be discussed in this talk is based on a cosmological Hamiltonian derived from full LQG by Dapor and Liegener using coherent state techniques, which governs the FLRW-type time evolution of each radial shell in the collapsing dust sphere. This model is characterized by an asymmetric bounce as its central feature where the classical singularity is resolved due to leading-order quantum corrections encoded in the effective description. The investigation of the resulting effective dynamics will be presented in detail and differences and similarities compared to other existing models will be discussed. In a broader context, the question of the existence of shell-crossing singularities is investigated beyond the specific model, including also non-bouncing scenarios such as regular black hole models of Bardeen and Hayward.

GR 13.3 Thu 14:15 KH 02.012

**The perturbative Ricci flow** — ROBERT HARLANDER<sup>1</sup>, YANNICK KLUTH<sup>2</sup>, JONAS KOHNEN<sup>1</sup>, and •HENRY WERTHENBACH<sup>1</sup> — <sup>1</sup>TTK, RWTH Aachen University, 52056 Aachen, Germany — <sup>2</sup>Department of Physics, University of Toronto, Toronto, ON M5S 1A7, Canada

One candidate for a quantum theory of gravity is the Asymptotic Safety conjecture, which postulates the existence of a non-trivial fixed point for the gravitational couplings. We investigate the search for such a fixed point within the framework of perturbation theory.

For this, we employ the Ricci flow as the central tool, pursuing a perturbative scheme analogous to the gradient flow formalism in QCD. In QCD, the gradient flow was introduced to bridge the gap between lattice simulations and perturbative calculations, allowing for a definition of a renormalisation scheme that is accessible in both settings. Applied to gravity the gradient flow is known as ‘Ricci flow’. The core idea is to utilize this framework to compute the beta function of the gravitational coupling by explicitly defining it within the Ricci flow scheme.

In this talk, I will first provide a brief introduction to the gradient flow formalism. I will then present the first steps towards constructing a perturbative implementation of the Ricci flow and the definition of Newton’s coupling in this scheme.

GR 13.4 Thu 14:30 KH 02.012

**Gravitational induced decoherence and the role of reference frames: a quantum mechanical toy model** — •ASHAY SATHE<sup>1</sup> and KRISTINA GIESEL<sup>2</sup> — <sup>1</sup>Friedrich-Alexander-Universität, Erlangen-Nürnberg, Deutschland — <sup>2</sup>Friedrich-Alexander-Universität, Erlangen-Nürnberg, Deutschland

In this talk, we investigate a quantum mechanical toy model of gravitationally induced decoherence, with particular emphasis on the role of reference frames in the description of open quantum systems. We analyse two complementary choices of reference frames: a classical reference frame and a quantum reference frame. For each choice, the master equation governing the effective dynamics is derived. We then compare the resulting models and discuss both their common features and their conceptual and dynamical differences.

GR 13.5 Thu 14:45 KH 02.012

**Area Metric actions and equations on an AdS background** — •MARIO FLORY<sup>1</sup>, ARANYA BHATTACHARYA<sup>1,2</sup>, LAVISH CHAWLA<sup>1,3</sup>, and MATEUSZ KULIG<sup>1</sup> — <sup>1</sup>Jagiellonian University, Cracow, Poland — <sup>2</sup>University of Bristol, Bristol, UK — <sup>3</sup>Friedrich-Schiller-Universität, Jena, Germany

Following the talk by A. Bhattacharya, we study Lagrangians governing linearised area metric fluctuations on an Anti-de Sitter (AdS) background. Our aim is to identify actions whose equations of motion respect the requirements imposed by the holographic principle, with particular emphasis on the allowed boundary behaviour of the solutions. We demonstrate that rewriting area metric fluctuations in terms of Lanczos-like potentials yields a notably elegant model. Interesting parallels with conformal (i.e., Weyl-squared) gravity naturally arise and will be discussed.

GR 13.6 Thu 15:00 KH 02.012

**Exploring physical states of loop quantum gravity using neural networks** — •WALEED SHERIF and HANNO SAHLMANN — Institute for Quantum Gravity, Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 7, 91058, Erlangen, Germany

Loop quantum gravity (LQG) is a canonical approach to the quantisation of general relativity that aims to preserve background independence. The dynamics of the theory is encoded in a set of constraints, among which the Hamiltonian constraint plays a central role. Constructing and analysing general physical states that satisfy this constraint has long remained one of the central open challenges in LQG.

In this talk, we show that this problem can be approached using modern deep learning techniques, specifically neural network quantum states (NQS). We demonstrate that these methods make it possible to construct approximate physical states in simplified models of LQG for the first time in a way that is both flexible and scalable. Using a range of models in Euclidean LQG, we illustrate how this approach enables large-scale numerical investigations of the theory’s quantum dynamics, allowing for the systematic characterisation of physical states and exploring the impact of different operator orderings, regularisation choices and more.

## GR 14: Relativistic Astrophysics IV

Time: Thursday 16:15–17:00

Location: KH 01.016

GR 14.1 Thu 16:15 KH 01.016

**Neutron stars under the influence of dark matter** — •SARAH LOUISA FITZ and JÜRGEN SCHAFFNER-BIELICH — Max-von-Laue-Str. 1 60438 Frankfurt am Main

Neutron stars represent ideal laboratories to test different kinds of matter under the influence of strong gravity and high magnetic fields. Due to their age and their strong gravitational field neutron stars could capture dark matter particles and thus serve indirectly as dark matter detectors. We include bosonic, self-interacting dark matter with a sufficiently stiff self-interaction potential in the form of  $V \propto \phi^n$  and find that these neutron stars become ultra-compact. They are compact enough to have a stable photon orbit at their surface or even above, a property that is otherwise exclusively attributed to black holes or hypothetical boson stars. These ultra-compact neutron stars could be formed by a boson star accreting ordinary matter. We will present results on how a high compactness of the boson star affects the accretion rate and thus the mass of the resulting neutron star.

This work is supported by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) through the CRC-TR 211 Strong-interaction matter under extreme conditions project number 315477589 TRR 211.

GR 14.2 Thu 16:30 KH 01.016

**Neutrino production in blazars with extreme Doppler factors** — •ADITYA TAMAR — Max Planck Institute for Radio Astronomy, Bonn, Germany

There have been recent population studies supporting the idea that radio-loud blazars can be the potential source of high-energy astrophysical neutrinos. The understanding of neutrino production from these sources is intimately connected to explaining their multi-wavelength spectra as well. In this talk, ongoing work will be presented in modelling the lepto-hadronic spectral energy distribution (SED) for PKS 1749+096, a neutrino-candidate blazar with strong Doppler boosting. In the proposed framework, both the bulk properties and the particle distribution in the emission region, are anchored directly using parsec-scale very-long-baseline (VLBI) observations of its jet. When combined with physi-

cally motivated assumptions about jet stratification, this approach allows modeling the SED from radio to gamma-rays without using model-agnostic numerical fitting to archival data, whilst also using VLBI-driven inferences to probe the location and properties of the neutrino production region in the blazar jet. Thus, the talk attempts to motivate using radio observations as an anchor for improving our understanding of multi-messenger emission from neutrino-candidate blazars.

GR 14.3 Thu 16:45 KH 01.016

**Hot Dark Stars: Mass-Radius Curves of an Interacting Fermi Gas at Finite Temperatures and Their Collapse to Black Holes** — •ADIL-MIR ZIA, ISHAQ AHMAD RATHER, SELINA KUNKEL, SARAH PITZ, and JÜRGEN SCHAFFNER-

BIELICH — Institute for Theoretical Physics, Goethe University, Frankfurt am Main

We investigate the mass-radius relations of dark stars using a temperature-dependent equation of state for interacting Fermi gases. Varying the entropy per baryon and the interaction strength allows us to quantify how finite-temperature effects and the underlying couplings influence the structure and stability of hot dark stars. We also compute the particle number along constant-entropy sequences to examine the possibility of a delayed collapse during the early evolution. These results clarify how thermal and interaction effects shape the properties of newly formed dark stars.

## GR 15: Quantum Gravity and Quantum Cosmology II

Time: Thursday 16:15–17:00

Location: KH 02.012

GR 15.1 Thu 16:15 KH 02.012

**Lorentzian Cosmological path integrals in effective spin foams** — •SEBASTIAN STEINHAUS and ALEXANDER JERCHER — Friedrich-Schiller Universität Jena, Theoretisch-Physikalisches Institut, Jena, Germany

Spin foam models, also called covariant loop quantum gravity, are a non-perturbative, Lorentzian path integral approach to quantum gravity. Its expressions are regularised by replacing the continuous manifold by a triangulation, where the sum over geometries is encoded in group-theoretic area and angle variables. However, making contact back with classical, continuum gravity is challenging. In this talk, I will address this question in cosmology from two directions. First, I will solve the discrete (transcendental) equations of motion of cosmological models in Regge calculus and showcase how to relate them to continuum cosmology. Second, I translate this into an oscillatory Lorentzian path integral with effective spin foams and evaluate it numerically, e.g. using acceleration operators. I will discuss under which conditions classical physics (in terms of expectation values of observables) can be recovered and give an outlook to non-classical transitions, e.g. bouncing cosmologies.

GR 15.2 Thu 16:30 KH 02.012

**Einstein equations for Area Metric geometries from entanglement** — •ARANYA BHATTACHARYA<sup>1,2</sup>, LAVISH CHAWLA<sup>1,3</sup>, MARIO FLORY<sup>4</sup>, and MATEUSZ KULIG<sup>1</sup> — <sup>1</sup>Institute of Theoretical Physics, Jagiellonian University, Łojasiewicza 11, 30-348 Krakow, Poland — <sup>2</sup>School of Mathematics, University of Bristol, Fry Building Woodland Road, Bristol BS8 1UG, UK — <sup>3</sup>Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena, Germany

Area metrics provide a generalised notion of geometry, in which areas are fun-

damental but lengths may not be defined at all. They can be motivated from string theory, loop quantum gravity, and entropic gravity alike, which we will briefly touch upon during the talk. In this work, we use the holographic duality and the first law of entanglement as first principles, from which an equation constraining area metric fluctuations around a four dimensional Anti-de Sitter (AdS) background can be derived, thus extending the linearised Einstein equations for these generalised geometries. In the framework of the AdS/CFT correspondence, these area metric fluctuations can be interpreted as encoding the energy-momentum tensor perturbations of a holographically dual three dimensional conformal field theory (CFT). For further implications of these results, see the talk by M. Flory.

GR 15.3 Thu 16:45 KH 02.012

**A Relational Model of Gravitationally induced Decoherence for Photons** — •ROMAN KEMPER<sup>1</sup>, KRISTINA GIESEL<sup>1</sup>, and MAX JOSEPH FAHN<sup>2</sup> — <sup>1</sup>Friedrich-Alexander Universität Erlangen-Nürnberg, Germany — <sup>2</sup>Università di Bologna, Bologna Italy

This talk discusses the formulation of a decoherence model for Maxwell theory coupled to linearised gravity. The resulting dynamics are described by a master equation, which governs the evolution of the electromagnetic subsystem under the effective influence of the gravitational environment. The master equation is derived from the underlying action using the relational formalism to access the physical sector and the open quantum system framework to describe the effective influence of linearised gravity on Maxwell theory at the quantum level. Differences and similarities with existing models in the literature, including approaches based on scalar fields or alternative methods for accessing the physical sector, are discussed.

## GR 16: Members' Assembly

Time: Thursday 17:15–19:00

Location: KH 01.016

**All members of the Gravitation, Relativistic Astrophysics, and Cosmology Division are invited to participate.**

## GR 17: Cosmology II

Time: Friday 9:00–10:00

Location: KH 01.016

### Invited Talk

GR 17.1 Fri 9:00 KH 01.016

**Radio Cosmology and the Cosmic Dawn** — •JONATHAN PRITCHARD — Max Planck Institute for Radio Astronomy

In this talk, I will review the status of experiments attempting to detect the 21cm signal from reionization and the time of the first galaxies. In particular, I will discuss 21cm global experiments, especially REACH - a global 21 cm experiment deployed in the the Karoo in South Africa. I will also discuss some of the preparation work for epoch of reionization studies with the Square Kilometre Array and describe applications of machine learning algorithms for inferring science from 21cm observations.

GR 17.2 Fri 9:30 KH 01.016

**Early growth of structure with warm wave dark matter** — •SIMON MAY — Universität Bielefeld, Universitätsstraße 25, 33615 Bielefeld, Germany

I will present unique features in the growth of structure in wave dark matter models with warm white noise, where the power spectrum is peaked at sub-horizon wavenumbers. The post-inflationary production of bosonic particles, such as axions or axion-like particles, leads to an enhanced isocurvature density power spectrum on small scales. Moreover, when dark matter is extremely light, these inhomogeneities result in a non-negligible velocity dispersion and hence

free-streaming suppression of the adiabatic power spectrum. Starting with the Schrödinger-Poisson system of equations as the relevant equations of motion, I will present results from analytic calculations and numerical simulations of cosmic structure formation. The results show the enhancement and evolution of the small-scale power spectrum and the formation of non-linear collapsed objects, including wave dark matter halos and Bose stars (solitons), shortly after matter-radiation equality. Using hydrodynamical simulations of warm wave dark matter with baryons, I will further show how this affects the early clustering of baryonic matter. Probes of the small-scale power spectrum (e.g. dynamical heating of stars, Ly- $\alpha$  forest, gravitational lensing, 21cm-line intensity mapping) can be sensitive to these effects on quasi-linear scales, making this broad class of dark matter models accessible to observations.

GR 17.3 Fri 9:45 KH 01.016

**Comparing Gravitational Wave Spectra of Inflation Models** — •ALEXANDER SCHNEIDER<sup>1</sup>, TOM KROKOTSCH<sup>1</sup>, GUDRID MOORTGAT-PICK<sup>1,2</sup>, and ANDREAS RINGWALD<sup>2</sup> — <sup>1</sup>University of Hamburg, Hamburg, Germany — <sup>2</sup>Desy, Hamburg Germany

Inflation is currently among the most favored explanations for the horizon and the flatness problem, and there are several plausible models.

Many of them are predicted to have produced a gravitational wave background, the measurement of which could be a direct way of probing inflation.

In this talk, we present simulations of two inflation models and subsequent reheating processes with a focus on their respective gravitational wave spec-

tra. Among the questions discussed are the prospects to measure the primordial gravitational wave backgrounds from these processes today, and how such a measurement could be used to differentiate between models.

## GR 18: Cosmology III

Time: Friday 11:00–11:45

Location: KH 01.016

GR 18.1 Fri 11:00 KH 01.016

**Effective Pressure and Viscosity Analogies in Schrödinger\*Poisson Models of Structure Formation** — •AOIBHINN GALLAGHER — Bielefeld University, Universitätsstraße 25, 33615 Bielefeld, Germany

Recent advances in wave-mechanical approaches to cosmic structure formation have highlighted the usefulness of the Schrödinger\*Poisson (or Schrödinger\*Newton) system as an alternative description of collisionless matter. Beyond its role in models of ultra-light dark matter, this framework offers a compact way to capture gravitational dynamics across linear and non-linear regimes, motivating renewed interest in how its behaviour relates to familiar concepts from classical physics.

In this talk, I explore how certain features of Schrödinger\*Newton evolution can be reinterpreted through the lens of classical fluid dynamics, in particular through effective \*pressure\* and \*viscosity\* analogies. I show that the parameter  $\lambda_{\text{nu}}$ , often introduced in practical implementations of the formalism, can play a role akin to a kinematic viscosity, and I assess when a pseudo-Reynolds number description becomes meaningful. This reinterpretation provides intuitive insight into non-linear structure formation, especially beyond shell-crossing where standard fluid approaches fail. At the same time, I outline the fundamental limitations of the analogy: a full classical fluid correspondence would require additional physical ingredients (such as dissipation and entropy production) that do not arise in strictly unitary Schrödinger\*Newton dynamics. The resulting picture is therefore not a complete fluid model, but a useful heuristic framework that clarifies the behaviour of wave-mechanical cosmological systems.

GR 18.2 Fri 11:15 KH 01.016

**Exotic compact binary mergers at ultra-high redshift - parameter estimation with pulsar timing array data** — •WOO-SEOK YIM and JÜRGEN SCHAFFNER-BIELICH — Institut für Theoretische Physik, Goethe University, Frankfurt am Main, Germany

The origin of the nanohertz stochastic gravitational-wave background (SGWB) reported in 2023 remains under active discussion, with supermassive black hole binaries (SMBHBs) still being the leading astrophysical explanation. However, a discrepancy between the predicted SMBH abundance and the measured SGWB amplitude remains. This could be explained by a sub-dominant group of merging exotic compact objects (ECO), which are compact objects formed from dark matter at ultra-high redshift. We find and present combinations of binary parameters of such ECOs, namely the binary mass and merger redshift, that could significantly contribute to the total gravitational-wave energy density spectrum  $\Omega_{\text{gw}}$  at nanohertz scales.

This project is supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) through the CRC-TR211 "Strong-interaction matter under extreme conditions" under the project number 315477589 - TR 211.

GR 18.3 Fri 11:30 KH 01.016

**Cumulants in the Cosmos: Tools for Compressing the Universe** — •CORA UH-LEMANN — Bielefeld University

Central nonlinear physics problems in cosmology can be characterized by an infinite hierarchy of cumulants. For a simple one-dimensional probability density function, the first cumulant is the mean, the second cumulant is the variance, and the higher-order cumulants capture non-Gaussian information. Cumulants thus serve as useful compression of the underlying probability density function. I will explain why characterising the higher-order cumulants is essential for beyond 2-point statistics of dark matter and show how they can be predicted by leveraging symmetries and large-deviation theory. I will then connect this to key observables in galaxy clustering and weak lensing and discuss challenges related to their survey applications.

## GR 19: Numerical Relativity III

Time: Friday 11:00–12:00

Location: KH 02.012

GR 19.1 Fri 11:00 KH 02.012

**Improved Moving-Puncture Techniques for Binary Black-Hole Simulations** — •LINSHEG LI — Institut für Theoretische Physik, Goethe Universität, Frankfurt am Main, Germany

To fully exploit current and upcoming gravitational-wave observations, accurate numerical-relativity simulations of compact binaries require tight control of constraint violations in moving-puncture evolutions. We present a moving-puncture scheme in the CCZ4 formulation within the Einstein Toolkit that incorporates both a slow-start lapse (SSL) condition and a curvature-adjusted Hamiltonian-constraint damping (CAHD) prescription, aimed at reducing constraint violations and improving the quality of the extracted waveforms. By exploiting the constraint-propagation and damping properties of CCZ4, we re-tune the Z4 damping and gauge parameters to improve constraint control through inspiral, merger, and ringdown. For equal-mass, nonspinning binary black-hole simulations, the SSL+CAHD+CCZ4 scheme significantly reduces Hamiltonian and momentum-constraint violations in both the strong-field region and the wave-extraction zone.

GR 19.2 Fri 11:15 KH 02.012

**Black hole spectroscopy of collapsing and merging neutron stars** — •OLIVER STEPPHOHN<sup>1</sup>, SEBASTIAN H. VÖLKE<sup>2</sup>, and TIM DIETRICH<sup>1</sup> — <sup>1</sup>Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — <sup>2</sup>Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, 14476 Potsdam, Germany

Black hole spectroscopy is an important pillar when studying gravitational waves from black holes and enables tests of general relativity. Most of the gravitational wave signals observed over the last decade originate from binary black hole systems. Binary neutron star or black hole-neutron star systems are rarer but of particular interest for the next-generation ground-based gravitational wave detectors. These events offer the exciting possibility of studying matter effects on the ringdown of "dirty black holes". In this work, we ask the question: Does

matter matter? Using numerical relativity, we simulate a wide range of collapsing neutron stars producing matter environments, both in isolated scenarios and in binary mergers. Qualitatively, the resulting ringdown signals can be classified into "clean", "modified", and "distorted" cases, depending on the amount of matter that is present. We apply standard strategies for extracting quasinormal modes of clean signals, using both theory-agnostic and theory-specific assumptions. Even in the presence of matter, possible modifications of quasinormal modes seem to be typically dominated by ringdown modeling systematics.

GR 19.3 Fri 11:30 KH 02.012

**Numerical relativity with NRPy+ and dealii** — •GÖRAN RATZ<sup>1,2</sup> and FRANK OHME<sup>1,2</sup> — <sup>1</sup>Max Planck Institute for Gravitational Physics, Hannover, Germany — <sup>2</sup>Leibniz University Hannover, Hannover, Germany

Numerical Relativity has been an insightful and irreplaceable part of understanding the nonlinear dynamics of spacetime. It is also known for being a little inaccessible mainly due to its magnificent computational costs and specialisation. In my talk, I want to give a brief introduction to NRPy+ (<https://nrpyplus.net/>), a well documented and beginner-friendly NR python library which makes, by some smart coordinate choices, certain black-hole merger simulations accessible for the "everyday user". I will also discuss the application of the C++ FEM-library dealii (<https://dealii.org/>) for generating Bowen-York-Brandt-Brügmann initial data slices for numerical relativity.

GR 19.4 Fri 11:45 KH 02.012

**Machine Learning-Accelerated HLLD Riemann Solver for GRMHD** — •KENETH MILER — Institut für Theoretische Physik, Goethe Universität, Max-von-Laue-Str. 1, D-60438

We present a machine-learning-enhanced HLLD Riemann solver for GRMHD simulations that significantly reduces computational cost. The primary bottleneck in HLLD schemes is the iterative pressure recovery from conserved variables. We replace this expensive root-finding procedure with a trained neural network that directly predicts primitive pressure.

## Hadronic and Nuclear Physics Division Fachverband Physik der Hadronen und Kerne (HK)

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### Overview of Invited Talks and Sessions

(Lecture halls AM 00.011, AM 00.014, AM 00.017, AM 00.021, PHIL A 301, PHIL B 302, PHIL C 301,  
PHIL A 401, PHIL A 602, PHIL B 604, PHIL C 601, and MED 00.915; Poster Redoutensaal)

### Plenary Talk of the Hadronic and Nuclear Physics Division

PV IX    Wed    9:00– 9:45    AudiMax    **Status and perspectives for science at FAIR (Facility for Antiproton and Ion Research)**  
— •THOMAS NILSSON

### Invited Talks

|         |     |             |            |                                                                                                                                 |
|---------|-----|-------------|------------|---------------------------------------------------------------------------------------------------------------------------------|
| HK 1.1  | Mon | 14:45–15:15 | MED 00.915 | <b>ALICE Run 3 Physics Highlights</b> — •IGOR ALTSYBEEV                                                                         |
| HK 1.2  | Mon | 15:15–15:45 | MED 00.915 | <b>Ab initio studies on muon capture and rare decays</b> — •LOTTA JOKINIEMI                                                     |
| HK 10.1 | Tue | 11:00–11:30 | MED 00.915 | <b>Baryon scattering amplitudes from lattice QCD</b> — •JOHN BULAVA                                                             |
| HK 10.2 | Tue | 11:30–12:00 | MED 00.915 | <b>Exploring Triaxial Deformation in Neutron-rich Nuclei</b> — •KATHRIN WIMMER,<br>BYUL MOON, WOLFRAM KORTEN                    |
| HK 10.3 | Tue | 12:00–12:30 | MED 00.915 | <b>Jet Targets for Nuclear and Hadron Physics Experiments</b> — •ALFONS KHOUKAZ                                                 |
| HK 10.4 | Tue | 12:30–13:00 | MED 00.915 | <b>Probing neutrinos with the KATRIN and LEGEND experiments</b> — •SUSANNE<br>MERTENS                                           |
| HK 19.1 | Wed | 11:00–11:30 | MED 00.915 | <b>Nucleosynthesis of heavy elements in explosive astrophysical environments</b> —<br>•DANIEL SIEGEL                            |
| HK 19.2 | Wed | 11:30–12:00 | MED 00.915 | <b>Recent results from laser spectroscopy with CRIS at ISOLDE: nuclear structure<br/>studies and beyond</b> — •JESSICA WARBINEK |
| HK 19.3 | Wed | 12:00–12:30 | MED 00.915 | <b>QCD at FAIR: Strong QCD Across Communities</b> — •JOHAN MESSCHENDORP,<br>FRANK NERLING                                       |
| HK 19.4 | Wed | 12:30–13:00 | MED 00.915 | <b>New Directions in Micropattern Gaseous Detector Technologies</b> — •PHILIP<br>HAUER                                          |
| HK 28.1 | Thu | 11:00–11:30 | MED 00.915 | <b>Toward the Island of Stability</b> — •KHUYAGBAATAR JADAMBAA                                                                  |
| HK 28.2 | Thu | 11:30–12:00 | MED 00.915 | <b>From stars to underground labs: Nuclear astrophysics measurements at<br/>Felsenkeller</b> — •ELIANA MASHA                    |
| HK 28.3 | Thu | 12:00–12:30 | MED 00.915 | <b>Hunting exotic mesons in the light-quark sector at GlueX</b> — •FARAH AFZAL                                                  |
| HK 28.4 | Thu | 12:30–13:00 | MED 00.915 | <b>Dispersive analyses of Primakoff reactions with kaons</b> — •BASTIAN KUBIS                                                   |
| HK 47.1 | Fri | 9:00– 9:30  | MED 00.915 | <b>Supernova signatures on Earth and beyond</b> — •JENNY FEIGE                                                                  |
| HK 47.2 | Fri | 9:30–10:00  | MED 00.915 | <b>ALICE 3 - The next-generation heavy-ion experiment at the LHC</b> — •LARS DÖP-<br>PER                                        |
| HK 47.3 | Fri | 10:00–10:30 | MED 00.915 | <b>Towards Physics Operation of the CBM Experiment at FAIR</b> — •ADRIAN RO-<br>DRÍGUEZ RODRÍGUEZ                               |
| HK 48.1 | Fri | 11:00–11:30 | MED 00.915 | <b>Probing confinement and string-breaking with quantum simulations</b> —<br>•TORSTEN ZACHE                                     |
| HK 48.2 | Fri | 11:30–12:00 | MED 00.915 | <b>Exploring stochastic aspects of nuclear gamma decays with photonuclear reac-<br/>tions</b> — •JOHANN ISAAK                   |
| HK 48.3 | Fri | 12:00–12:30 | MED 00.915 | <b>Precision QCD with ePIC at the Electron-Ion Collider</b> — •TYLER KUTZ                                                       |

## Sessions

|               |     |             |              |                                                |
|---------------|-----|-------------|--------------|------------------------------------------------|
| HK 1.1–1.2    | Mon | 14:45–15:45 | MED 00.915   | <b>Invited Talks</b>                           |
| HK 2.1–2.7    | Mon | 16:15–18:30 | PHIL C 301   | <b>Hadron Structure and Spectroscopy I</b>     |
| HK 3.1–3.7    | Mon | 16:15–18:15 | PHIL A 401   | <b>Hadron Structure and Spectroscopy II</b>    |
| HK 4.1–4.7    | Mon | 16:15–18:30 | AM 00.011    | <b>Structure and Dynamics of Nuclei I</b>      |
| HK 5.1–5.7    | Mon | 16:15–18:30 | AM 00.021    | <b>Structure and Dynamics of Nuclei II</b>     |
| HK 6.1–6.7    | Mon | 16:15–18:15 | PHIL C 601   | <b>Heavy-Ion Collisions and QCD Phases I</b>   |
| HK 7.1–7.7    | Mon | 16:15–18:15 | PHIL A 602   | <b>Nuclear Astrophysics I</b>                  |
| HK 8.1–8.7    | Mon | 16:15–18:15 | PHIL A 301   | <b>Instrumentation I</b>                       |
| HK 9.1–9.7    | Mon | 16:15–18:15 | PHIL B 302   | <b>Instrumentation II</b>                      |
| HK 10.1–10.4  | Tue | 11:00–13:00 | MED 00.915   | <b>Invited Talks</b>                           |
| HK 11.1–11.7  | Tue | 16:15–18:30 | PHIL C 301   | <b>Hadron Structure and Spectroscopy III</b>   |
| HK 12.1–12.7  | Tue | 16:15–18:30 | PHIL A 401   | <b>Hadron Structure and Spectroscopy IV</b>    |
| HK 13.1–13.8  | Tue | 16:15–18:45 | AM 00.011    | <b>Structure and Dynamics of Nuclei III</b>    |
| HK 14.1–14.9  | Tue | 16:15–18:45 | AM 00.021    | <b>Structure and Dynamics of Nuclei IV</b>     |
| HK 15.1–15.10 | Tue | 16:15–18:45 | PHIL C 601   | <b>Heavy-Ion Collisions and QCD Phases II</b>  |
| HK 16.1–16.7  | Tue | 16:15–18:30 | PHIL A 602   | <b>Nuclear Astrophysics II</b>                 |
| HK 17.1–17.7  | Tue | 16:15–18:15 | PHIL A 301   | <b>Instrumentation III</b>                     |
| HK 18.1–18.8  | Tue | 16:15–18:15 | PHIL B 302   | <b>Instrumentation IV</b>                      |
| HK 19.1–19.4  | Wed | 11:00–13:00 | MED 00.915   | <b>Invited Talks</b>                           |
| HK 20.1–20.6  | Wed | 13:45–15:45 | AM 00.014    | <b>Focus Session: QCD@FAIR</b>                 |
| HK 21.1–21.7  | Wed | 13:45–15:45 | AM 00.011    | <b>Structure and Dynamics of Nuclei V</b>      |
| HK 22.1–22.6  | Wed | 13:45–15:45 | AM 00.021    | <b>Structure and Dynamics of Nuclei VI</b>     |
| HK 23.1–23.7  | Wed | 13:45–15:45 | PHIL C 301   | <b>Heavy-Ion Collisions and QCD Phases III</b> |
| HK 24.1–24.7  | Wed | 13:45–15:45 | PHIL A 401   | <b>Heavy-Ion Collisions and QCD Phases IV</b>  |
| HK 25.1–25.6  | Wed | 13:45–15:30 | PHIL A 602   | <b>Nuclear Astrophysics III</b>                |
| HK 26.1–26.7  | Wed | 13:45–15:30 | PHIL A 301   | <b>Instrumentation V</b>                       |
| HK 27.1–27.32 | Wed | 16:15–18:30 | Redoutensaal | <b>Poster Session</b>                          |
| HK 28.1–28.4  | Thu | 11:00–13:00 | MED 00.915   | <b>Invited Talks</b>                           |
| HK 29.1–29.6  | Thu | 13:45–15:30 | PHIL C 301   | <b>Hadron Structure and Spectroscopy V</b>     |
| HK 30.1–30.6  | Thu | 13:45–15:45 | PHIL A 401   | <b>Hadron Structure and Spectroscopy VI</b>    |
| HK 31.1–31.6  | Thu | 13:45–15:45 | AM 00.011    | <b>Structure and Dynamics of Nuclei VII</b>    |
| HK 32.1–32.7  | Thu | 13:45–15:45 | PHIL C 601   | <b>Heavy-Ion Collisions and QCD Phases V</b>   |
| HK 33.1–33.8  | Thu | 13:45–15:45 | PHIL A 602   | <b>Nuclear Astrophysics IV</b>                 |
| HK 34.1–34.3  | Thu | 13:45–15:00 | AM 00.021    | <b>Fundamental Symmetries I</b>                |
| HK 35.1–35.7  | Thu | 13:45–15:45 | PHIL A 301   | <b>Instrumentation VI</b>                      |
| HK 36.1–36.7  | Thu | 13:45–15:45 | PHIL B 302   | <b>Instrumentation VII</b>                     |
| HK 37.1–37.6  | Thu | 16:15–18:00 | PHIL C 301   | <b>Hadron Structure and Spectroscopy VII</b>   |
| HK 38.1–38.6  | Thu | 16:15–18:00 | PHIL A 401   | <b>Hadron Structure and Spectroscopy VIII</b>  |
| HK 39.1–39.7  | Thu | 16:15–18:00 | AM 00.011    | <b>Structure and Dynamics of Nuclei VIII</b>   |
| HK 40.1–40.7  | Thu | 16:15–18:00 | PHIL C 601   | <b>Heavy-Ion Collisions and QCD Phases VI</b>  |
| HK 41.1–41.6  | Thu | 16:15–18:00 | PHIL A 602   | <b>Heavy-Ion Collisions and QCD Phases VII</b> |
| HK 42.1–42.3  | Thu | 16:15–17:30 | AM 00.021    | <b>Fundamental Symmetries II</b>               |
| HK 43.1–43.3  | Thu | 16:15–17:00 | PHIL B 604   | <b>Computing and Outreach</b>                  |
| HK 44.1–44.7  | Thu | 16:15–18:00 | PHIL A 301   | <b>Instrumentation VIII</b>                    |
| HK 45.1–45.6  | Thu | 16:15–17:45 | PHIL B 302   | <b>Instrumentation IX</b>                      |
| HK 46         | Thu | 18:00–19:30 | AM 00.017    | <b>Members' Assembly</b>                       |
| HK 47.1–47.3  | Fri | 9:00–10:30  | MED 00.915   | <b>Invited Talks</b>                           |
| HK 48.1–48.3  | Fri | 11:00–12:30 | MED 00.915   | <b>Invited Talks</b>                           |

## Members' Assembly of the Hadronic and Nuclear Physics Division

Thursday 18:00–19:30 AM 00.017

- Approval of the minutes and the agenda
- Report from HK division chair
- Report from KHuK
- Aob



## Sessions

– Invited Talks, Group Reports, Contributed Talks, and Posters –

### HK 1: Invited Talks

Time: Monday 14:45–15:45

Location: MED 00.915

#### Invited Talk

HK 1.1 Mon 14:45 MED 00.915

**ALICE Run 3 Physics Highlights** — •IGOR ALTSYBEEV for the ALICE Germany-Collaboration — Technische Universität München, Garching bei München, Germany

The ALICE experiment at the LHC is designed to study the properties of the quark-gluon plasma (QGP) formed in relativistic heavy-ion collisions. The QGP is a hot, dense state of QCD matter in which quarks and gluons are no longer confined within hadrons and can propagate over distances larger than the hadronic scale.

During Run 3 of the LHC (2022–2026), ALICE has collected data across a variety of collision systems, including pp, Pb-Pb, as well as – for the first time – light-ion systems such as pO, OO and Ne-Ne. Compared to Runs 1 and 2, the experiment operates at significantly higher interaction rates, made possible by major detector upgrades that enable continuous readout rather than a trigger-based data acquisition.

In this talk, an overview of recent physics results from ALICE will be presented, with a particular emphasis on the high-statistics data collected during Run 3.

#### Invited Talk

HK 1.2 Mon 15:15 MED 00.915

**Ab initio studies on muon capture and rare decays** — •LOTTA JOKINIEMI — Technische Universität Darmstadt, Darmstadt, Germany — ExtreMe Matter Institute EMMI, Darmstadt, Germany

Neutrinoless double-beta decay, in which a nucleus decays by two simultaneous beta decays without emitting neutrinos, is a sensitive probe for new physics. The decay would be the first signal of lepton number violation, since only two beta particles without antiparticles are created. It would also prove that neutrinos have Majorana nature and shed light on their unknown masses. However, interpreting the experiments requires reliable nuclear-theory predictions.

Muon capture is a nuclear-weak process in which a negatively charged muon, initially in an atomic bound state, is captured by the atomic nucleus, resulting in atomic number reduction by one and emission of a muon neutrino. Thanks to the high momentum transfer involved in the process, it can be used to probe the weak currents at the momentum regime relevant for the neutrinoless double-beta decay.

I will discuss recent advances in the theory predictions for neutrinoless double-beta decay. Then, I will talk about ab initio studies on muon capture in light nuclei, focusing in particular on the ab initio no-core shell model. These systematically improvable calculations are based on nuclear interactions derived from chiral effective field theory. The computed rates are found to be in good agreement with available experimental counterparts, motivating future experimental and theoretical explorations in light nuclei.

\* Funded by the LOEWE Top Professorship LOEWE/4a/519/05.00.002(0014)98.

### HK 2: Hadron Structure and Spectroscopy I

Time: Monday 16:15–18:30

Location: PHIL C 301

#### Group Report

HK 2.1 Mon 16:15 PHIL C 301

**Accessing transition Generalized Parton Distributions with the  $N \rightarrow N^*$  DVCS and DVMP processes** — •STEFAN DIEHL for the CLAS-Collaboration — II. Physikalisches Institut, JLU Gießen, Gießen, Germany — University of Connecticut, Storrs, CT, USA

The understanding of the internal structure of baryon resonances is of essential important for many fields of nuclear physics. It is known, that Generalized Parton Distributions (GPDs) are a well established tool for characterizing the QCD structure of the ground-state nucleon based on 3D tomographic images of the quark/gluon structure. Transition GPDs extend these concepts to  $N \rightarrow N^*$  transitions and can be used to characterize the 3D structure and mechanical properties of baryon resonances. They can be probed for example in high-momentum transfer exclusive electroproduction processes with resonance transitions  $eN^* \rightarrow eMN^*$ , such as deeply virtual Compton scattering ( $M = \gamma$ ) or meson production ( $M = \pi, K, \dots$ ). Based on the high-intensity, 10.6 GeV electron beam at JLAB and the large acceptance CLAS12 spectrometer, it becomes possible to study these processes in a large kinematic range. The talk will present results of the deeply virtual  $ep \rightarrow e\Delta^{++}\pi^-$  process, providing a first measurement sensitive to transition GPDs and discuss the feasibility of the study of further  $N \rightarrow N^*$  DVMP processes with CLAS12. Furthermore, first results for beam spin asymmetries of the  $N \rightarrow N^*$  DVCS process ( $ep \rightarrow eN^{*+}\gamma$ ) will be presented and compared to transition GPD based theory predictions. \*The work is partly supported by Deutsche Forschungsgemeinschaft (Project No. 508107918).

#### Group Report

HK 2.2 Mon 16:45 PHIL C 301

**Measurement of the proton charge radius at AMBER** — •MARTIN HOFFMANN for the AMBER-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn

The AMBER collaboration plans to perform a new precision measurement of the proton electric form factor at low values of the negative squared four-momentum transfer by elastic scattering of high-energy muons off protons. This experiment features a high-intensity 100 GeV muon beam at the M2 beam line of CERN's Super Proton Synchrotron, leading to reduced and different systematic uncertainties compared to low-energy lepton-proton elastic scattering experiments. A high-pressure hydrogen-filled Time Projection Chamber serves as an active target and measures the energy transferred to the recoil proton. The muon trajectories and momenta are reconstructed by high-precision vertex detectors surrounding this chamber and a magnetic spectrometer. In this way, the measurement is over-constrained to cleanly select elastic scattering events.

The completely new free-streaming data acquisition was successfully tested under realistic conditions in 2025. First detectors of each type were installed in the setup and included in this new readout scheme. This talk will present first insights from this measurement and an overview of further developments towards the main experiment, which will be in the commissioning phase during the conference.

Supported by BMFTTR.

HK 2.3 Mon 17:15 PHIL C 301

**The PRIMA Experiment@MAMI: Simulation work for the pion acceptance determination** — •OSCAR ANDÚJAR SABÁN<sup>1</sup>, NING CAO<sup>1</sup>, LUIGI CAPOZZA<sup>1</sup>, JONAS GEISBÜSCH<sup>1</sup>, RAVI GOWDRU MAJUNATA<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, ANTOINE MARTINET<sup>1</sup>, OLIVER NOLL<sup>1,2</sup>, PAUL SCHÖNER<sup>1</sup>, CHRISTOPH ROSNER<sup>1</sup>, PIERRE VIJAYAN<sup>1</sup>, and SAHRA WOLFF<sup>1</sup> for the PANDA-Collaboration — <sup>1</sup>Helmholtz-Institut Mainz, Mainz, Germany — <sup>2</sup>Institute of Nuclear Physics, Mainz, Germany — <sup>3</sup>PRISMA+ Cluster of Excellence, Mainz, Germany

The significant discrepancy among data-driven models for the pion electromagnetic transition form factor (TFF)  $F_{\pi^0\gamma^*\gamma^*}$  must be resolved, as this factor provides a main contribution to the hadronic light-by-light scattering (HLbL) process, which is essential for calculating the hadronic correction to the muon anomalous magnetic moment ( $a_\mu^{QCD}$ ). The PRIMA Experiment is measuring  $F_{\pi^0\gamma^*\gamma^*}$  in the low momentum transfer ( $Q^2$ ) region at the MAMI accelerator in Mainz, utilizing an Electromagnetic Calorimeter (EMC) and an Electron Veto Detector.

Determining the pion acceptance of the calorimeter is essential for this experiment. Consequently, simulation studies are being performed. This talk presents the current work-in-progress and the initial results regarding the pion acceptance.

HK 2.4 Mon 17:30 PHIL C 301

**Feasibility studies of hyperon transition form factors with CBM at FAIR** — •SHREYA ROY for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH Planckstraße 1 64291 Darmstadt

Electromagnetic transition form factors (eTFFs) probe the internal structure of baryons. In the timelike region ( $q^2 > 0$ ), they are accessible, for example via Dalitz decays  $Y^* \rightarrow Y e^+ e^-$ . Previous results from HADES exist for light baryons (e.g.  $\Delta(1232)$ ,  $N^*(1520)$ ) that tested vector-meson dominance and revealed meson-cloud effects. To take the studies to the next level, the feasibility of extending this program to the strange sector with the Compressed Baryonic Mat-

ter (CBM) experiment at FAIR, Darmstadt, has been investigated. This contribution will cover details of the analysis strategy for exclusive  $\Lambda$  reconstruction in the  $pp \rightarrow pK^+\Lambda$  channel using CBM tracking, PID, and kinematic fitting in the simulation. We then extend the study to the Dalitz channel  $pp \rightarrow pK^+\Lambda(1520)$  with  $\Lambda(1520) \rightarrow \Lambda e^+e^-$  to assess the sensitivity to timelike eTFFs and the possible kaon-cloud dynamics. Background simulation is under investigation. The obtained invariant-mass resolution, acceptance $\times$ efficiency, expected signal rates at CBM luminosities, form-factor sensitivity, and the accessible baryon radius will be presented.

HK 2.5 Mon 17:45 PHIL C 301

**Beam rastering system for P2 collaboration at MESA** — •SUMEDH KULKARNI and TYLER KUTZ for the P2-Collaboration — KPH, Johannes Gutenberg University of Mainz

The P2 collaboration at the MESA facility aims for a high precision measurement of the parity violating asymmetry in the elastic scattering of polarized electrons off of unpolarized protons. The expected asymmetry is on the order of 40 parts per billion (ppb), with a precision goal of better than 1 ppb. Thus, the experiment requires very high event rates to achieve the necessary statistical precision. Achieving such rates demands an intense, continuous electron beam incident on a thick target. P2 will carry out the measurement with a 150  $\mu$ A electron beam on a 60 cm liquid hydrogen target. The resulting large power deposition can damage or destabilize the target without proper precautions. One way to mitigate this risk is to raster the electron beam with fast steering magnets, in order to distribute the power over a larger area of the target. For this, P2 will develop a rastering system that uses two electromagnetic dipoles to steer the electron beam by the desired angle. We used computer simulation to optimize ferrite yoke geometries and to determine the coil specifications for the required magnetic field strength. From these simulations, the most suitable yoke design and coil specifications were chosen. Here we present results of these simulations and further construction steps of the rastering system for the P2 experiment at MESA.

HK 2.6 Mon 18:00 PHIL C 301

**Sieve optimization for calibration of the MAGIX spectrometers** — •ALEN GAJER for the MAGIX-Collaboration — KPH, JGU, Mainz, Germany

The MAGIX experiment, currently under development at the MESA accelerator in Mainz, will enable a broad range of precision measurements using electron scattering on fixed targets. The core component are two high-resolution magnetic spectrometers that separate scattered particles according to their momentum and detect them at the focal plane.

To extract scattering variables at the target, accurate reconstruction of the particle trajectories from focal-plane measurements is required. This is achieved through spectrometer optics, using a matrix formalism method that relates measured and target variables. Determining the corresponding transport tensor components demands a dedicated calibration run with a sieve collimator placed in front of the spectrometers entrance.

Since the performance of the calibration directly depends on the sieve geometry, designing it is a nontrivial task. We present a simulation-based optimization approach, which evaluates the sieve pattern based on the quality of the reconstruction.

HK 2.7 Mon 18:15 PHIL C 301

**Investigation of initial Antiproton Polarization** — •VINCENT VERHOEVEN for the P371-Collaboration — Ruhr-University Bochum — GSI

The preparation of a polarized antiproton beam, useful for experiments aiming at exploring new physics topics, remains a challenge. No simple and efficient polarization method has yet been established. The CERN P371 experiment aims to investigate whether antiprotons produced in a high-energy proton beam collision with an unpolarized solid target are initially polarized. The polarization can be determined by measuring the asymmetry of elastic  $\bar{p}p$ -scattering with a known analyzing power in the Coulomb-Nuclear Interference region. The experiment was carried out in July and August 2025 using the T11 beam line of the Proton Synchrotron in the East Area. As a track reconstruction is required even to determine the number of antiprotons in the beam, the data analysis is challenging and currently ongoing.

### HK 3: Hadron Structure and Spectroscopy II

Time: Monday 16:15–18:15

Location: PHIL A 401

#### Group Report

HK 3.1 Mon 16:15 PHIL A 401

**Light-Meson Spectroscopy at COMPASS** — •STEFAN WALLNER for the COMPASS-Collaboration — Max Planck Institute for Physics, Garching, Germany

We studied the excitation spectrum of non-strange and strange light mesons with unparalleled precision using the world's largest sample of diffractive scattering of 190 GeV/c negative pions and kaons recorded at the COMPASS experiment at CERN. We performed partial-wave analyses of data on various final states to identify the produced light-meson resonances and to measure their properties, including spin, parity, mass, and width.

We report on recent results for the  $\omega\pi^-\pi^0$ ,  $\eta\pi^-\pi^+\pi^+$ , and  $K_S^0K^-$  final states, which map out a wide range of the non-strange light-meson spectrum. We present measurements of excited  $a_1$  and  $\pi_1$  states at high masses, a partly unexplored regime. We also discuss the exotic  $\pi_1(1600)$ , the lightest hybrid meson, which we found in various decay channels in these final states. Finally, we present the most comprehensive measurement to date of the strange-meson spectrum in the  $K^-\pi^+\pi^0$  final state. There, we found the first candidate for an exotic strange meson with  $J^P = 0^-$ .

HK 3.2 Mon 16:45 PHIL A 401

**Pseudoscalar meson-pair production beyond the resonance region at COMPASS** — •HENRI PEKELER for the COMPASS-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, Germany

The COMPASS experiment at CERN's SPS provides a uniquely large data set to study the light-meson spectrum in diffractive production reactions of 190 GeV/c beam pions with protons. Among the many different final states accessible,  $\eta\pi^-$  and  $\eta'\pi^-$  are clean channels to investigate the lightest hybrid-meson candidate, the  $\pi_1(1600)$ . One challenge in identifying meson resonances is the separation of resonant and non-resonant processes.

To better constrain the non-resonant production mechanism of these final states, we analyze the high-mass region, i.e.  $4\text{ GeV}/c^2 < m_{\eta(\eta')\pi^-} < 6\text{ GeV}/c^2$ , using the double-Regge exchange model by Shimada et al., [Nucl. Phys. B 142 (1978)]. The model describes the dependence of the amplitude of a given double-Regge exchange on the invariant variables in terms of Regge trajectories. In addition, form factors are introduced at every vertex to parameterize the  $t$ -dependence of the coupling. For the first time, we perform an event-based likelihood fit to the COMPASS data set and show that the high-mass data can be described by only 13 parameters.

Supported by BMFTR.

HK 3.3 Mon 17:00 PHIL A 401

**Studying Light-Meson Resonances in  $\tau^- \rightarrow \pi^+\pi^-\pi^-\nu_\tau$  Decays at Belle (II)** — •GODO KURTEN, HANS-GÜNTHER MOSER, STEPHAN PAUL, CLAUDIA PEREZ-ORIVE, STEFAN WALLNER, and MIRIAM WEISKOPF — Max Planck Institute for Physics, Boltzmannstr. 8, 85748 Garching, Germany

We study mainly the  $a_1$  resonances occurring in  $\tau^- \rightarrow \pi^+\pi^-\pi^-\nu_\tau$  decays. To this end, we develop a two-step partial-wave analysis using simulated samples from the Belle II experiment. First, we perform a partial-wave decomposition fit that disentangles the data into partial-wave amplitudes with well-defined quantum numbers and measure their dependence on the invariant mass of the three pion system  $m_{3\pi}$ . Secondly, we search for resonances in these amplitudes with a resonance-model fit to the measured partial-wave amplitudes. Thereby, we extract mass and width of the resonances.

We present simulation-based input-output studies for the resonance-model fit, validating the resonance-model fit and assessing sensitivity to signals, such as the  $a_1(1420)$ .

HK 3.4 Mon 17:15 PHIL A 401

**Studying the meson photoproduction mechanism through spin-density matrix elements at GlueX** — •NIKLAS HERRMANN and FARAH AFZAL for the GlueX-Collaboration — Institut für Experimentalphysik I, Ruhr-Universität Bochum, Bochum, Germany

The primary goal of the GlueX experiment is the search for exotic mesons, states that are forbidden within the quark model but permitted by quantum chromodynamics. GlueX located at Jefferson Lab employs a linearly polarized photon beam in the energy range from 8.2 to 8.8 GeV on a liquid hydrogen target. Current searches for exotic hybrid mesons within the meson spectrum require an understanding of the production mechanism. An important experimental tool to study the production mechanism is the measurement of polarization observables as the Spin-Density Matrix Elements (SDMEs) with a linearly polarized photon beam. In this talk, I present the measurement of the polarized SDMEs in the photoproduction of  $\rho^-\Delta^{++}$ , using GlueX data from 2017 - 2018. The new GlueX data has significantly better statistical precision compared to the existing SLAC data and provides a precise measurement of the  $t$ -dependence of the SDMEs for the range 0.025 to 1.4 GeV<sup>2</sup>.

HK 3.5 Mon 17:30 PHIL A 401

**Particle Identification ( $e\gamma\gamma$ ) of Primakoff-Electroproduction  $\pi^0$ -Events for PRIMA FAIR Phase-0** — •OSCAR ANDÚJAR SABÁN<sup>1</sup>, NING CAO<sup>1</sup>, LUIGI CAPOZZA<sup>2</sup>, JONAS GEISBÜSCH<sup>1</sup>, RAVI GOWDRU MANJUNATA<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>,

•ANTOINE MARTINET<sup>1</sup>, OLIVER NOLL<sup>1,2</sup>, PAUL SCHÖNER<sup>1</sup>, CHRISTOPH ROSNER<sup>1</sup>, PIERRE VIJAYAN<sup>1</sup>, and SAHRA WOLFF<sup>1</sup> — <sup>1</sup>Helmholtz-Institut Mainz, Mainz, Germany — <sup>2</sup>Institute of Nuclear Physics, Mainz, Germany — <sup>3</sup>PRISMA+ Cluster of Excellence, Mainz, Germany

The FAIR Phase-0 experiment PRIMA, conducted at the Mainzer Mikrotron (MAMI), aims at measuring the  $\pi^0$  transition form factor (TFF) in doubly-virtual Primakoff kinematics. Improving the TFF uncertainty is crucial, as it contributes a large uncertainty to the Standard Model prediction of the anomalous magnetic moment of the muon. The TFF represents the leading order of the hadronic light-by-light scattering (HLbL) correction. To achieve this, a modified version of the homogeneous PbWO<sub>4</sub>-based PANDA backward-electromagnetic-calorimeter is used to measure the final state of the scattered electron and the  $\pi^0$ -decay photons. Key to this analysis is the particle identification for the  $e\gamma\gamma$  final state. This can be done using the invariant mass of the detected particles, but potentially also using a neural network. This talk presents the current progress on particle identification of electrons and photons using a neural network.

HK 3.6 Mon 17:45 PHIL A 401

**Background Modelling in Partial-Wave Analysis of  $\tau^- \rightarrow \pi^+ \pi^- \pi^- \nu_\tau$  decays at Belle II** — •MIRIAM WEISKOPF, GODO KURTEN, HANS-GÜNTHER MOSER, STEPHAN PAUL, CLAUDIA PEREZ-ORIVE, and STEFAN WALLNER — Max Planck Institut für Physics, Boltzmannstraße 8, Garching 85748, Germany

We study light mesons appearing as intermediate resonances in the  $\tau^- \rightarrow \pi^+ \pi^- \pi^- \nu_\tau$  decays at the Belle II experiment where  $\tau$  pairs are produced in  $e^+ e^-$  collisions. A detailed partial wave-analysis is performed to identify resonances that appear in the  $3\pi$  system and to measure their properties including spin,

parity, mass and width.

We will present our neural-network based approach that is used to model the distributions of backgrounds, such as  $\tau^- \rightarrow \pi^+ \pi^- \pi^- \pi^0 \nu_\tau$  or  $e^+ e^- \rightarrow q\bar{q}$ , in our data sample. We address challenges such as the high dimensionality of the phase space, limited data coverage, sharp background features, and background distributions that vary across different kinematic regions. The modelled background distributions and their integration into the partial-wave analysis will be presented.

HK 3.7 Mon 18:00 PHIL A 401

**Polarization in the two-photon production of pion pairs and how to use it** — •MAX LELLMANN, ACHIM DENIG, JAN MUSKALLA, and CHRISTOPH FLORIAN REDMER — Johannes Gutenberg Universität Mainz

The accuracy of the Standard Model prediction for the hadronic light-by-light contribution to the muon's anomalous magnetic moment  $a_\mu$  is strongly limited by the knowledge of two-photon couplings of axial and tensor mesons. The coupling of the lightest tensor state,  $f_2(1270)$ , can be conveniently studied in the process  $e^+ e^- \rightarrow e^+ e^- \pi^0 \pi^0$ , in which the pion pair is produced through the fusion of two virtual photons emitted by the leptons.

A reliable extraction of the tensor state's two-photon coupling requires proper corrections for reconstruction efficiency and other detector effects, which in turn demand accurate Monte Carlo simulations of the process. By implementing such a generator that, for the first time, includes a fully exclusive description of the  $e^+ e^- \rightarrow e^+ e^- \pi^0 \pi^0$  reaction, additional features of the cross section become accessible and can be used to extract further information from the same data.

This talk will outline the method and introduce the corresponding Monte Carlo generator, HADROTOPS.

## HK 4: Structure and Dynamics of Nuclei I

Time: Monday 16:15–18:30

Location: AM 00.011

### Group Report

HK 4.1 Mon 16:15 AM 00.011

**Implementation of the recoil distance Doppler-shift technique at the radioactive beam facility ISOLDE** — •CHRISTOPH FRANSEN<sup>1</sup>, ALINA DIDIK<sup>1</sup>, ANDREY BLAZHEV<sup>1</sup>, ROB BARK<sup>2</sup>, MAX DROSTE<sup>1</sup>, CASPER-DAVID LAKENBRINK<sup>1</sup>, PETER REITER<sup>1</sup>, CARLOTTA PORZIO<sup>3</sup>, and NIGEL WARR<sup>1,4</sup> for the IS 656-Collaboration — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Germany — <sup>2</sup>iThemba LABS, South Africa — <sup>3</sup>CERN, Switzerland — <sup>4</sup>University of Liverpool, UK

Absolute transition strengths between excited states yield fundamental information on nuclear structure and can be determined from level lifetimes. The recoil distance Doppler-shift (RDDS) technique employing so-called plunger devices is valuable to measure lifetimes in the picosecond range and has been in the focus of our Cologne group for many years. In this talk, we will present the first RDDS campaign at ISOLDE. Particular emphasis will be paid to the special conditions for such experiments at ISOLDE, e.g., with respect to radioactive beams, the sophisticated plunger device, the reaction kinematics, and the special requirements for targets. As a main example, we will focus on an experiment on <sup>144</sup>Ba done recently by our group aiming for the implementation of the RDDS technique at ISOLDE and the search for octupole correlations. Further, RDDS experiments on <sup>162</sup>Yb and <sup>207</sup>Tl performed within the same campaign will be briefly discussed that support the high potential of this technique for investigations of exotic nuclei. Supported by the BMFTR, Joint Project 05P2024 - ISOLDE, Grant No. 05P24PK2.

### Group Report

HK 4.2 Mon 16:45 AM 00.011

**Employing Coincidence Doppler-Shift Attenuation Method approaches to inelastic ion-scattering experiments in the  $A \approx 100$  mass region** — •ANNA BOHN, ELIAS BINGER, TOBIAS LANGE, MARKUS MÜLLENMEISTER, SARAH PRILL, MICHAEL WEINERT, and ANDREAS ZILGES — University of Cologne, Institute for Nuclear Physics, Germany

The  $A \approx 100$  mass region is a major focus of current research on various nuclear structure phenomena, such as shape evolution and proton-neutron symmetry mixing. Several inelastic ion-scattering experiments have been performed on stable even-even nuclei [1–4], including Te, Sn, Pd, Ru, Mo, and Zr isotopes, at the SONIC@HORUS [5] setup at the University of Cologne. Fundamental properties such as nuclear-level lifetimes, level schemes, and spin information could be investigated. This contribution provides an overview of the most recent results and different analysis approaches employing the Coincidence Doppler-Shift Attenuation Method [1,4].

Supported by the DFG (ZI 510/9-2).

- [1] A. Hennig *et al.*, Phys. Rev. C **92** (2015) 064317.
- [2] S. Prill *et al.*, Phys. Conf. Ser. **1643** (2020) 012157.
- [3] S. Prill *et al.*, Phys. Rev. C **105** (2022) 034319.
- [4] A. Bohn *et al.*, EPJ Web Conf. **329** (2025) 03004.
- [5] S. Pickstone *et al.*, Nucl. Instr. Meth. A **875** (2017) 104.

HK 4.3 Mon 17:15 AM 00.011

**Multi-method analysis of the dipole response in the tin isotopic chain** — •MARKUS MÜLLENMEISTER<sup>1</sup>, JOHANN ISAAK<sup>2</sup>, MICHAEL WEINERT<sup>1</sup>, FLORIAN KLUWIG<sup>1</sup>, TANJA SCHÜTTLER<sup>1</sup>, PAULA BEHRENDT<sup>1</sup>, and ANDREAS ZILGES<sup>1</sup> — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Germany — <sup>2</sup>Technische Universität Darmstadt, Institute for Nuclear Physics, Germany

Model-independent determination of nuclear properties provides essential benchmarks for both statistical observables, and the assumptions underlying several experimental methods. Such approaches are central to constraining quantities relevant for stellar nucleosynthesis [1] and nuclear structure phenomena [2].

This contribution presents a set of continuum and state-to-state methods applied to the tin isotopes <sup>116,118,120</sup>Sn, especially the  $A^{-1}\text{Sn}(d, p\gamma)^A\text{Sn}$  reactions as seen in [3], to extract information in a consistent manner. The combination of selective electromagnetic [4] and hadronic probes and modern analysis techniques [5] enables direct determination of nuclear structure properties, like nuclear level densities (NLDs).

This work is supported by the DFG under (ZI 510/10-2) and (Project-ID 499256822 \* GRK 2891 'Nuclear Photonics').

- [1] M. Wiedeking *et al.*, Phil. Trans. R. Soc. A **382** (2024), 20230125.
- [2] A. Bracco *et al.*, Prog. Part. Nucl. Phys. **106** (2019), 360.
- [3] M. Weinert *et al.*, Phys. Rev. Lett. **127** (2021), 242501.
- [4] M. Müscher *et al.*, Phys. Rev. C **102** (2020), 014317.
- [5] O. Papst *et al.*, Phys. Rev. Lett. **135** (2025), 052501.

HK 4.4 Mon 17:30 AM 00.011

**Lifetime measurements of excited states in <sup>101</sup>Pd** — •SVEN WAGNER, MAX-IMILIAN DROSTE, PETER REITER, RAMONA BURGGRAB, CHRISTOPH FRANSEN, HANNAH KLEIS, and CASPER-DAVID LAKENBRINK — Institut für Kernphysik, Universität zu Köln, Zülpicher Straße 77 D-50937 Köln, Germany

The nucleus <sup>101</sup>Pd lies four protons and five neutrons away from the doubly magic <sup>100</sup>Sn. Nuclei in this region of the nuclear chart have traditionally been regarded as prototypical vibrational systems, exhibiting characteristic level structures in their low-lying excited states. However, precise lifetime measurements for even-even Pd isotopes have revealed notable deviations from this vibrational behaviour [1]. Experimental information on <sup>101</sup>Pd remains limited, with earlier studies reporting discrepant lifetimes for the first excited state [2] and for higher-lying members of the  $\nu h_{11/2}$  band [3,4]. Excited states in <sup>101</sup>Pd were populated via the fusion-evaporation reaction <sup>92</sup>Zr(<sup>12</sup>C,3n)<sup>101</sup>Pd using a 50 MeV beam. A precise lifetime measurement was performed at the FN Tandem accelerator of the IKP Cologne employing the recoil-distance Doppler-shift (RDDS) technique to extract reduced transition strengths. New lifetimes for states in the  $\nu d_{5/2}$ ,  $\nu g_{7/2}$ , and  $\nu h_{11/2}$  bands have been obtained. The results will be discussed in the context of nuclear structure in the vicinity of <sup>100</sup>Sn.

- [1] M. Droste et al., Phys. Rev. C 106, 024329 (2022) [2] D. Ivanova et al., Phys. Rev. C 105, 034337 (2022) [3] M. Sugawara et al., Phys. Rev. C 92, 024309 (2015) [4] V. Singh et al., J. Phys. G 44, 075105 (2017)

HK 4.5 Mon 17:45 AM 00.011

**Lifetime Measurements Excited States in  $^{99}\text{Pd}$**  — •RAMONA BURGGRAF, PETER REITER, RAINER ABELS, TIMO BIESENBAACH, ANDREY BLAZHEV, MAXIMILIAN DROSTE, ARWIN ESMAYLZADEH, CHRISTOPH FRANSEN, KAI HENSELER, HANNAH KLEIS, MARIO LEY, AARON PFEIL, JOE ROOB, ALESSANDRO SALICE, TIMON SÜLTENFUSS, and DAVID WERNER — IKP, Universität zu Köln

Excited states in  $^{99}\text{Pd}$  were populated in the  $^{90}\text{Zr}(^{12}\text{C},3n)$  fusion-evaporation reaction at a beam energy of 55 MeV using the Cologne plunger setup in combination with the CATHEDRAL  $\gamma$ -ray spectrometer, which consists of 24 HPGe and eight LaBr<sub>3</sub> detectors. The setup enabled simultaneous recoil-distance Doppler-shift and fast-timing measurements. The lifetimes of the first excited state and several previously unknown higher-lying levels were extracted using the differential decay-curve method. Longer-lived states were additionally characterised using  $\gamma$ - $\gamma$  fast timing. Transitional nuclei located south-east of the doubly magic  $^{100}\text{Sn}$  have long been considered as prototypical vibrational systems, although recent lifetime data have questioned this interpretation [1]. For  $^{99}\text{Pd}$ , however, experimental information on excited states remains scarce. Prior to the present work, only a single lifetime had been reported by Ivanova et al. [2], which disagreed with the results obtained in this study. The new set of level lifetimes, including those for higher-lying states, will be presented and compared with large-scale shell-model calculations.

[1] M. Droste et al., Phys. Rev. C 106, 024329 (2022)

[2] D. Ivanova et al., Phys. Rev. C 105, 034337 (2022)

HK 4.6 Mon 18:00 AM 00.011

**The isovector spin-M1 response of  $^{90}\text{Zr}$  and  $^{92}\text{Mo}$**  — •A. GUPTA<sup>1</sup>, V. WERNER<sup>1</sup>, A. D. AYANGEAKAA<sup>2,3</sup>, M. BEUSCHLEIN<sup>1</sup>, S. W. FINCH<sup>3,4</sup>, U. F. GAYER<sup>3,4,5</sup>, D. GRIBBLE<sup>2,3</sup>, J. HAUF<sup>1</sup>, K. E. IDE<sup>1</sup>, J. ISAAK<sup>1</sup>, X. JAMES<sup>2,3</sup>, R. V. F. JANSSENS<sup>2,3</sup>, S. R. JOHNSON<sup>2,3</sup>, J. KLEEMANN<sup>1</sup>, P. KOSEOGLOU<sup>1</sup>, T. KOWALEWSKI<sup>2,3</sup>, B. LÖHER<sup>6</sup>, O. PAPST<sup>1</sup>, N. PIETRALLA<sup>1</sup>, A. SARACINO<sup>2,3</sup>, D. SAVRAN<sup>6</sup>, and N. SENSHARMA<sup>2,3</sup> — <sup>1</sup>IKP, TU Darmstadt — <sup>2</sup>UNC, Chapel Hill, NC, USA — <sup>3</sup>TUNL, Durham, NC, USA — <sup>4</sup>Duke U., Durham, NC, USA — <sup>5</sup>ESS, Lund, SE — <sup>6</sup>GSI, Darmstadt

Electron-capture rates in medium-heavy nuclei are crucial for deleptonization

in late core-collapse supernovae. These rates depend strongly on Gamow-Teller (GT) strength [1], though direct measurements remain difficult. The isovector spin-flip M1 (IVSM1) response, an isospin analogue of GT transitions, provides an alternative probe, which we investigate in the  $N = 50$  isotones  $^{90}\text{Zr}$  and  $^{92}\text{Mo}$ . The two extra protons in  $^{92}\text{Mo}$ 's  $g_{9/2}$  orbital beyond the closed  $pf$  shell may enhance its IVSM1 strength relative to  $^{90}\text{Zr}$ . The dipole response of both nuclei was studied via nuclear resonance fluorescence using a new hybrid HPGe Clover-LaBr<sub>3</sub> array at the Hl $\gamma$ S facility. Ground-state transition asymmetries will be used to extract the total  $M1/E1$  strength up to 10 MeV. The experimental details and preliminary results for the total  $M1$  strength distribution will be presented.

Supported by DFG Project No. 279384907-SFB 1245 and the U.S. DOE Grant No. DE-FG02-97ER41041 and No. DE-FG02-97ER41033.

[1] K. Langanke et al., Rep. Prog. Phys. **84**, 066301 (2021)

HK 4.7 Mon 18:15 AM 00.011

**Lifetime Determination in  $^{98}\text{Ru}$  using the Reverse Coincidence Doppler-Shift Attenuation Method** — •TOBIAS LÄNGEL, ELIAS BINGER, ANNA BOHN, SARAH PRILL, MICHAEL WEINERT, and ANDREAS ZILGES — University of Cologne, Institute for Nuclear Physics, Germany

The Coincidence Doppler-Shift Attenuation Method (CDSAM) is a powerful tool to determine nuclear level lifetimes in the sub-picosecond regime [1–2]. At the SONIC@HORUS detector array [3], located at the University of Cologne, both HPGe  $\gamma$ -detectors and silicon particle-detectors are used to enable coincident detection of inelastically scattered protons and subsequently emitted photons. This significantly suppresses background and feeding contributions, allowing for high-precision lifetime measurements.

The newly developed Reverse CDSAM approach [4] improves the accessibility of lower-intensity transitions. In addition to other experiments conducted in the  $A \approx 100$  mass region, a  $^{98}\text{Ru}(p,p'\gamma)$  experiment was performed and analyzed using both the standard CDSA method and the new reverse approach. This contribution presents the experimental results and discusses the differences between the approaches.

Supported by the DFG (ZI 510/9-2).

[1] A. Hennig et al., Nucl. Instr. Meth. A **758**, 171 (2015)

[2] S. Prill et al., Phys. Rev. C **105**, 034319 (2022)

[3] S. G. Pickstone et al., Nucl. Instr. Meth. A **875**, 104 (2017)

[4] A. Bohn et al., EPJ Web Conf. **329**, 03004 (2025)

## HK 5: Structure and Dynamics of Nuclei II

Time: Monday 16:15–18:30

Location: AM 00.021

### Group Report

HK 5.1 Mon 16:15 AM 00.021

**Emulators for Hartree-Fock and In-Medium Similarity Renormalization Group** — •MARGARIDA COMPANYS FRANZKE<sup>1,2,3</sup>, TOM PLIES<sup>1,2</sup>, ALEXANDER TICHAI<sup>1,2,3</sup>, KAI HEBELER<sup>1,2,3</sup>, and ACHIM SCHWENK<sup>1,2,3</sup> — <sup>1</sup>Technische Universität Darmstadt, Department of Physics — <sup>2</sup>ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — <sup>3</sup>Max-Planck Institut für Kernphysik, Heidelberg

Emulation techniques have become a popular tool in nuclear physics to study Hamiltonians with an explicit parametric dependence. An important example is given by two- and three-nucleon interactions derived from chiral effective field theory that depend linearly on low-energy couplings (LECs). To extensively explore the LEC parameter space even simpler methods like Hartree Fock can become computationally costly, which makes the use of emulators necessary. While methods like Hartree-Fock can be emulated with reduced basis methods like eigenvector continuation, the problem is more complex for in-medium similarity renormalization group calculations. For this, more data-driven approaches like Gaussian Processes are more promising. Funded by the ERC Grant Agreement No. 101020842 and by the DFG - Project-ID 279384907 - SFB 1245.

HK 5.2 Mon 16:45 AM 00.021

**A Bayesian approach to the Coulomb breakup of  $^{19}\text{C}$**  — •QUENTIN BOZET and PIERRE CAPEL — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany

The breakup of weakly bound nuclei is a key probe of nuclear structure at the limits of stability. In this work, we investigate the breakup of the one-neutron halo nucleus  $^{19}\text{C}$  on a lead target at 69 MeV using the Coulomb-Corrected Eikonal approximation (CCE). To rigorously quantify uncertainties and constrain model parameters, we employ a Bayesian analysis framework for the description of  $^{19}\text{C}$ , more specifically on its binding energy and asymptotic normalization constant (ANC). Posterior distributions on these two quantities are inferred from the comparison of precise reaction calculations to experimental cross sections measured at RIKEN as a function of the  $^{18}\text{C}$ -n relative energy. Using these posteriors leads also to a good agreement with the cross sections measured as a function of the scattering angle. These experimental cross section as a function of the center of mass energy are indeed used during the computa-

tion of the posteriors. Comparison between the posteriors and the experimental cross sections as a function of the scattering angle. Our results demonstrate that Bayesian inference, when combined with the CCE, provides a powerful methodology for interpreting breakup data of exotic nuclei. It enables us to infer reliable estimates of structure observables with meaningful uncertainties.

HK 5.3 Mon 17:00 AM 00.021

**Correlated mass models for calcium isotopes from ab initio calculations** — •MAX CINCAR<sup>1,2,3</sup>, ZHEN LI<sup>1,2,3</sup>, TOM PLIES<sup>1,2</sup>, URBAN VERNIK<sup>1,2</sup>, MATTHIAS HEINZ<sup>4,5</sup>, TAKAYUKI MIYAGI<sup>6</sup>, and ACHIM SCHWENK<sup>1,2,3</sup> — <sup>1</sup>Technische Universität Darmstadt, Department of Physics — <sup>2</sup>ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — <sup>3</sup>Max-Planck-Institut für Kernphysik, Heidelberg — <sup>4</sup>National Center for Computational Sciences, ORNL — <sup>5</sup>Physics Division, ORNL — <sup>6</sup>Center for Computational Sciences, University of Tsukuba

Neutron-rich nuclei offer an opportunity to investigate exotic nuclear structure phenomena and properties of the underlying nuclear forces. We present ab initio calculations for neutron-rich calcium isotopes, quantifying various sources of theoretical uncertainties. Based on these calculations we construct correlated mass models for different interactions from chiral effective field theory. Conditioning these models on experimentally known data, we make predictions for unknown two-neutron separation energies.

\* Funded by the ERC Grant Agreement No. 101020842, by the DFG - Project-ID 279384907 - SFB 1245, and by the LOEWE Top Professorship LOEWE/4a/519/05.00.002(0014)98.

### Group Report

HK 5.4 Mon 17:15 AM 00.021

**Exploring the Nuclear Structure and Collectivity of Neutron-Rich Tin Isotopes around  $^{132}\text{Sn}$**  — MAXIMILIAN DROSTE<sup>1</sup>, •PETER REITER<sup>1</sup>, and THORSTEN KRÖLL<sup>2</sup> — <sup>1</sup>IKP, Universität zu Köln — <sup>2</sup>IKP, TU Darmstadt

Evolution of nuclear collectivity and structure in the region surrounding the doubly-magic nucleus  $^{132}\text{Sn}$  remains a central open question in nuclear structure physics. Recent large-scale shell-model calculations, employing realistic interactions, predict an enhancement of collectivity in the even-even isotopes adjacent to  $^{132}\text{Sn}$ . However, a long-standing discrepancy between experimen-

tal data for  $^{130}\text{Sn}$  and  $^{134}\text{Sn}$  and corresponding theoretical predictions has persisted. Two safe Coulomb excitation experiments were conducted at ISOLDE. Post-accelerated radioactive ion beams of  $^{130}\text{Sn}$  and  $^{134}\text{Sn}$ , delivered by the HIE-ISOLDE accelerator at 4.4 MeV/u, were incident on  $^{206}\text{Pb}$  and  $^{194}\text{Pt}$  targets. The first excited states of  $^{130}\text{Sn}$  and  $^{134}\text{Sn}$  were selectively populated and the de-exciting  $\gamma$  rays were measured using the Miniball high-resolution  $\gamma$ -ray spectrometer in coincidence with scattered particles. The newly extracted  $B(E2)$  values provide significantly improved experimental constraints and resolve the previously observed tension between theory and experiment, offering a clearer picture of the evolution of collectivity around the  $N = 82$  shell closure. Supported by BMBF Projects 05P21PKC11, 05P24PKC11, 05P21RDC12. This project has received funding from the European Unions Horizon Research and Innovation programme under Grant Agreement No. 101057511

HK 5.5 Mon 17:45 AM 00.021

**Low-Lying Dipole Response of  $^{42}\text{Ca}$  via Real-Photon Scattering** — •TANJA SCHÜTTLER<sup>1</sup>, FLORIAN KLUWIG<sup>1</sup>, RONALD SCHWENGNER<sup>2</sup>, and ANDREAS ZILGES<sup>1</sup> — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Germany — <sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf, Germany

Systematic investigations along isotopic and isotonic chains are of key importance for understanding the influence of shell structure, neutron excess, or nuclear deformation on the low-lying dipole strength of atomic nuclei. In the medium-mass region, the calcium ( $Z=20$ ) isotopic chain is particularly well suited for such studies, comprising four stable even-even isotopes with  $N/Z$  ratios ranging from 1.0 to 1.4. Furthermore, the occurrence of two doubly magic isotopes ( $^{40,48}\text{Ca}$ ) allows probing the evolution of the dipole response with changing shell structure. While the isotopes  $^{40,44,48}\text{Ca}$  have already been studied in real-photon scattering experiments [1-4], the low-abundance isotope  $^{42}\text{Ca}$  has not yet been investigated. Hence, two ( $\gamma,\gamma'$ ) bremsstrahlung experiments on  $^{42}\text{Ca}$  were conducted up to the neutron separation threshold  $S_n = 11.5$  MeV at the  $\gamma\text{ELBE}$  facility of the Helmholtz-Zentrum Dresden-Rossendorf [5]. The first results of these measurements will be presented. Supported by the DFG (ZI510/10-2).

[1] T. Hartmann *et al.*, Phys. Rev. Lett. **85** (2000) 274.

[2] T. Hartmann *et al.*, Phys. Rev. C **65** (2002) 034301.

[3] T. Hartmann *et al.*, Phys. Rev. Lett. **93** (2004) 192501.

[4] J. Isaak *et al.*, Phys. Rev. C **83** (2011) 034304.

[5] R. Schwengner *et al.*, Nucl. Instr. and Meth. A **555** (2005) 211.

HK 5.6 Mon 18:00 AM 00.021

**Nuclear resonance fluorescence study of  $^{70}\text{Zn}$  as a probe for nuclear structure at  $N = 40$**  — •J. HAUF<sup>1</sup>, V. WERNER<sup>1</sup>, N. PIETRALLA<sup>1</sup>, R. V. F. JANSSENS<sup>2,3</sup>, A. D. AYANGEAKAA<sup>2,3</sup>, D. BALABANSKI<sup>4</sup>, M. BEUSCHLEIN<sup>1</sup>, R. BEYER<sup>5</sup>, S. W. FINCH<sup>2,6</sup>,

A. GUPTA<sup>1</sup>, D. GRIBBLE<sup>2,3</sup>, T. HENSEL<sup>5</sup>, M. HEUMÜLLER<sup>1</sup>, F. E. IDOKU<sup>2,3</sup>, J. ISAAK<sup>1</sup>, X. JAMES<sup>2,3</sup>, S. R. JOHNSON<sup>2,3</sup>, A. JUNGHANS<sup>5</sup>, J. KLEEMANN<sup>1</sup>, P. KOSEOGLOU<sup>1</sup>, T. KOWALEWSKI<sup>2,3</sup>, A. KUSOGLU<sup>4</sup>, E. MASHA<sup>5</sup>, C. M. NICKEL<sup>1</sup>, O. PAPST<sup>1</sup>, M. PICHOTTA<sup>5</sup>, K. PRIFTI<sup>1</sup>, K. RÖMER<sup>5</sup>, A. SARACINO<sup>2,3</sup>, L. SHAEEDING<sup>2,3</sup>, P.-A. SÖDERSTRÖM<sup>4</sup>, K. SCHMIDT<sup>5</sup>, R. SCHWENGNER<sup>5</sup>, A. THEES<sup>5</sup>, N. TSONEVA<sup>4</sup>, S. TURKAT<sup>5</sup>, A. WAGNER<sup>5</sup>, and A. YADAV<sup>5</sup> — <sup>1</sup>TU Darmstadt, IKP — <sup>2</sup>TUNL — <sup>3</sup>University of North Carolina — <sup>4</sup>ELI-NP — <sup>5</sup>Helmholtz-Zentrum Dresden-Rossendorf — <sup>6</sup>Duke University

Properties of nuclei at the  $N = 40$  subshell closure are strongly influenced by several nuclear-structure effects, such as shape coexistence originating in Type-II shell evolution. This study aims to achieve a better understanding of these effects by investigating the  $N = 40$  nucleus  $^{70}\text{Zn}$  using the nuclear resonance fluorescence method with bremsstrahlung and quasi-monoenergetic photon beams at  $\gamma\text{ELBE}$  and  $\text{HI}\gamma\text{S}$ , respectively. Preliminary results for the average  $E1$ - and  $M1$ -strength distributions and decay branches of  $^{70}\text{Zn}$  are shown and discussed. This work is supported by DFG under Project-IDs 499256822 GRK 2891, 279384907 SFB 1245, ELI-RO under ELI-RO/RDI/2024 002, ELI-RO/RDI/2024 007 and US DOE by No. DE-FG02-97ER41041 (UNC), No. DE-FG02-97ER41033 (TUNL).

HK 5.7 Mon 18:15 AM 00.021

**Low-Lying Dipole Strength in  $^{144}\text{Nd}$  and  $^{142}\text{Ce}$  studied via Nuclear Resonance Fluorescence** — •FLORIAN KLUWIG<sup>1</sup>, DENIZ SAVRAN<sup>2</sup>, TANJA SCHÜTTLER<sup>1</sup>, RONALD SCHWENGNER<sup>3</sup>, and ANDREAS ZILGES<sup>1</sup> — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Germany — <sup>2</sup>GSi, Darmstadt, Germany — <sup>3</sup>Helmholtz-Zentrum Dresden-Rossendorf, Germany

The Pygmy Dipole Resonance (PDR) constitutes a low-energy excitation component within the electric dipole response of atomic nuclei. Despite extensive experimental and theoretical efforts over several decades [1-3], the structure and precise origin of the PDR remain subjects of ongoing investigation. Systematic studies, particularly along isotopic and isotonic chains, serve to resolve these open questions. Our work focuses on the  $N = 84$  isotones,  $^{144}\text{Nd}$  and  $^{142}\text{Ce}$ , situated near the  $N = 82$  magic shell closure. These nuclei were probed using the Nuclear Resonance Fluorescence (NRF) technique, based on real-photon scattering. Given their low-angular-momentum transfer capability, real photons are uniquely effective probes for isolating and characterizing the PDR strength [4]. This contribution presents and compares NRF data obtained for  $^{144}\text{Nd}$  and  $^{142}\text{Ce}$ , thereby contributing to the understanding of the PDR systematics in this mass region. Supported by the DFG (ZI510/10-2).

[1] D. Savran *et al.*, Prog. Part. Nucl. Phys. **70** (2013) 210.

[2] A. Bracco *et al.*, Prog. Part. Nucl. Phys. **106** (2019) 360.

[3] E.G. Lanza *et al.*, Prog. Part. Nucl. Phys. **129** (2023) 104006.

[4] A. Zilges *et al.*, Prog. Part. Nucl. Phys. **122** (2022) 103903.

## HK 6: Heavy-Ion Collisions and QCD Phases I

Time: Monday 16:15–18:15

Location: PHIL C 601

### Group Report

HK 6.1 Mon 16:15 PHIL C 601

**Thermalization of heavy quarks in heavy-ion collisions: a fluid-dynamic perspective** — •FEDERICA CAPELLINO — GSI Helmholtzzentrum Darmstadt

Heavy quarks (i.e. charm and beauty) are powerful tools to characterize the quark-gluon plasma (QGP) produced in heavy-ion collisions at the LHC and at RHIC top energies. Although they are initially produced out of kinetic equilibrium via hard partonic scattering processes, recent measurements of the anisotropic flow of charmed hadrons pose the question of a possible thermalization of heavy quarks in the medium. By exploiting a mapping between transport theory and hydrodynamics, we developed in recent years a fluid-dynamic description of heavy-quark diffusion in the QCD plasma. In this contribution, I will report the latest results on heavy-quark thermalization in the QGP from our fluid-dynamic perspective. First, we compute the out-of-equilibrium corrections to the heavy-quark phase-space distribution, enabling a consistent description of both integrated yields and momentum spectra of charm hadrons. Second, we explore a 2+1-dimensional fluid-dynamic treatment of charm diffusion to study the development of charm anisotropic flow in both heavy- and light-ion collision systems. Finally, we investigate the universality of the fluid-dynamic description of heavy quarks by searching for attractor solutions that are insensitive to the details of the initial conditions.

This work is funded via the DFG ISOQUANT Collaborative Research Center (SFB 1225).

HK 6.2 Mon 16:45 PHIL C 601

**Heavy-quark dynamics in the QGP \* attractors, thermalization, and universality** — •RUWEN SCHULZ — Physikalisches Institut, Universität Heidelberg

Heavy quarks are produced in hard scatterings at the very beginning of a heavy-ion collision. Consequently, heavy-quarks experience all stages of a heavy-ion collision, and their dynamics are highly sensitive to the properties of the

quark\*gluon plasma (QGP) phase in particular. Recent studies have demonstrated that a fluid-dynamical description of heavy-quark transport in the QGP, combined with a realistic hadronization and freeze-out procedure, can successfully reproduce experimental particle spectra with remarkable precision. While this success is widely acknowledged, the underlying reasons are not yet fully understood. In this talk, I will discuss the dynamics of heavy-quarks in the QGP, with a focus on possible signs of thermalization\*or hydrodynamization\*within the finite lifetime of the QGP. Special emphasis will be placed on pre-thermal universal behavior, including scaling features and (hydrodynamic) attractors that may govern heavy-quark evolution even far from equilibrium.

HK 6.3 Mon 17:00 PHIL C 601

**Measurement of directed flow ( $v_1$ ) of  $D^0$  mesons in Pb-Pb collisions at  $\sqrt{s_{NN}} = 5.36$  TeV** — •ALICA MARIE ENDERICH for the ALICE Germany-Collaboration — Physikalisches Institut, Heidelberg, Germany

Directed flow is the first harmonic of the azimuthal particle distribution in ultra-relativistic heavy-ion collisions. It is sensitive to the spatial profile of the initial conditions and the pre-equilibrium early time dynamics. Recent predictions indicate that the slope of the directed flow at mid-rapidity for  $D^0$  mesons, driven by the transport of charm quarks in a tilted medium, can be several times larger than the one for light-flavor hadrons. Heavy-ion collisions also generate extremely strong electromagnetic fields, primarily induced by spectator protons. Unlike light quarks, the formation time of charm quarks is comparable to the time at which the magnetic field reaches its maximum strength. As a result, charm quarks are expected to exhibit a much larger charge-dependent directed flow than light quarks.

During Run 2, ALICE provided the first measurement of the charge-dependent  $v_1$  for  $D^0$  mesons in Pb-Pb collisions at LHC. As the experimental measurement was limited by statistics, it is now repeated in Run 3. The reconstruction of the

decay topology is improved via ML techniques and the measurement is extended to lower  $p_T$ .

In this talk, current results on the charge-integrated and charge-dependent  $v_1$  for  $D^0$  mesons are presented. The measurements are compared with theoretical model calculations and results from other experiments.

HK 6.4 Mon 17:15 PHIL C 601

**Exploring charm and beauty hadronisation, collectivity, and final-state interactions at the LHC with ALICE** — •BIAO ZHANG for the ALICE Germany-Collaboration — Physikalisches Institut Im Neuenheimer Feld 226 69120 Heidelberg Germany

Beauty and charm quarks, produced in initial hard scatterings, offer an effective probe to test perturbative QCD (pQCD). We present the first ALICE measurement of B-meson production in pp collisions at  $\sqrt{s} = 13.6$  TeV, providing new constraints on pQCD calculations and beauty-quark fragmentation. Charm hadronisation shows striking deviations from universal fragmentation expectations, with charm baryon production posing a persistent puzzle for QCD-based models. In this context, measuring higher-mass excited charm-baryon states provides essential insight into the mechanisms that govern baryon formation. We report the first ALICE reconstruction of excited  $\Xi_c^0$  states via the  $D^0\Lambda$  decay channel, enabled by the large Run 3 pp dataset. This new reconstruction strategy offers enhanced sensitivity to the non-universal nature of charm-quark hadronisation.

Charm-quark collectivity is studied via the first  $D^0$  elliptic-flow measurement in O-O collisions, bridging pp and Pb-Pb systems and constraining heavy-quark transport coefficients.

Finally, new analyses of correlations between  $\Lambda_c^+$  and  $D^+$  with protons in pp collisions at  $\sqrt{s} = 13.6$  TeV, using the large-statistics Run 3 dataset, will also be presented. These measurements open a new avenue for exploring charm\*hadron interactions and their role in the formation of charm-bearing bound states.

HK 6.5 Mon 17:30 PHIL C 601

**Analysis strategy for a  $\Xi_c^+$  lifetime measurement with ALICE at the LHC** — •SIMON PIJAHN for the ALICE Germany-Collaboration — Physikalisches Institut, Universität Heidelberg

Experimentally measured charm-baryon lifetime ratios from LHC and Fermilab were long understood to be well described within the Heavy Quark Expansion (HQE) framework. However, in 2018 LHCb reported an  $\Omega_c^0$  lifetime almost four times larger than previous measurements, inverting the expected lifetime hierarchy. This result has since been supported by measurements from BELLE II and by more precise LHCb determinations of the  $\Omega_c^0$  and  $\Xi_c^0$  lifetimes. These persistent discrepancies highlight the need for additional, precise lifetime measurements for an accurate treatment of higher order terms in the HQE framework and to clarify the experimental situation. As the HQE is strong in predicting lifetime ratios, corresponding measurements of all charm baryons are of interest. To complement ongoing measurements of charm-baryon lifetimes with the ALICE detector, this contribution presents the analysis strategy and performance for a measurement of the  $\Xi_c^+$  baryon lifetime in pp collisions at  $\sqrt{s} = 13.6$  TeV.

The analysis employs the Kalman Filter Particle package for secondary vertex reconstruction, boosted decision trees for candidate selection, and a data-driven approach to disentangle prompt from non-prompt contributions.

HK 6.6 Mon 17:45 PHIL C 601

**Evolution of perturbations of the energy-momentum tensor during the pre-equilibrium phase of HIC** — •LENNART WEBER<sup>1</sup>, JIE ZHU<sup>1,2,3</sup>, and SÖREN SCHLICHTING<sup>1</sup> — <sup>1</sup>Bielefeld University — <sup>2</sup>CCNU, Wuhan, Inst. Part. Phys. — <sup>3</sup>Hua-Zhong Normal University

Non-eq. Green's functions provide a powerful framework for describing the pre-equilibrium evolution of the QGP created in HICs. They enable a systematic transition from initial state model to hydrodynamic simulations. Previous studies have calculated the Green's functions which propagate initial energy and transverse momentum perturbations on top of a homogeneous background. In this work, we generalize the formalism to include initial transverse tensor perturbations, computed analytically in the free-streaming regime and numerically within the conformal relaxation time approximation from moments of the distribution. The non-eq. Green's functions exhibit damping behavior similar to that found for the energy and momentum perturbations studied in earlier works. The derived Green's functions are further benchmarked against hydrodynamic constitutive relations at late times and then Fourier transformed into coordinate space for practical use in the pre-eq. dynamics package, KoMPoST. Furthermore, we run hydrodynamic simulations and investigate the effects of the pre-eq. evolution on generation of momentum anisotropy. In summary, this work completes the description of transverse perturbations and provides a consistent framework for evolving the full energy-momentum tensor from the initial time to the onset of hydrodynamics.

HK 6.7 Mon 18:00 PHIL C 601

**Validating the Pre-equilibrium Evolution of Heavy Ion Collisions in KoMPoST** — •JENS HÜGEL<sup>1</sup>, SÖREN SCHLICHTING<sup>1</sup>, CLEMENS WERTHMANN<sup>2</sup>, and VICTOR AMBRUS<sup>3</sup> — <sup>1</sup>Universität Bielefeld, Germany — <sup>2</sup>Universiteit Gent, Belgium — <sup>3</sup>Universitatea de Vest din Timișoara, Romania

We explicitly verify the validity of the open source package KoMPoST [1] for modelling the early time dynamics of the QGP in heavy ion collisions. Since KoMPoST is based on the dynamics of a kinetic theory description to implement a macroscopic evolution of the energy-momentum tensor, we assess its applicability by comparing KoMPoST results to fully microscopic calculations in kinetic theory in the relaxation time approximation (RTA) [2]. We find that KoMPoST accurately describes the full 2+1D evolution of the energy-momentum tensor in the pre-equilibrium stage with the exception of the components related to elliptic flow. We investigate possible error sources and attempt to modify KoMPoST in order to bring it into agreement with the full kinetic theory solution.

[1] KoMPoST, Phys.Rev.C 99 (2019) 3, 034910 [2] Ambrus, Werthmann, Schlichting, "Opacity dependence of transverse flow, preequilibrium, and applicability of hydrodynamics in heavy-ion collisions" Phys.Rev.D 107 (2023) 9, 094013

## HK 7: Nuclear Astrophysics I

Time: Monday 16:15–18:15

Location: PHIL A 602

### Group Report

HK 7.1 Mon 16:15 PHIL A 602

**Equation of State: From Ultracompact Objects to Color Superconductivity in Proto-Neutron Stars** — •ISHFAQ AHMAD RATHER, SELINA KUNKEL, SARAH PITZ, and JÜRGEN SCHAFFNER-BIELICH — Institute of Theoretical Physics, Goethe University, Frankfurt am Main

We present a comprehensive overview of our group's recent research on the properties of compact stars, probing the equation of state (EoS) across dark matter, hadronic, and quark matter regimes. We explore the impact of scalar fields and dark sector, showing that modified scalar potentials and self-interacting bosonic dark matter can lead to the formation of ultracompact boson stars and alter the macroscopic properties of neutron stars, potentially mimicking black holes. We utilize EoS constrained by chiral effective field theory to analyze the early evolution of compact stars, determining the minimal masses of proto-neutron stars (PNS) and highlighting the role of thermal effects on stability limits. Employing a renormalization group consistent NJL model, we analyze the stability windows of color-superconducting (CSC) phases, demonstrating that stable color-flavor-locked (CFL) cores are consistent with current astrophysical constraints. Furthermore, we investigate the phase diagram and analyze the trajectories of constant entropy per baryon to identify which CSC phases are accessible at maximum central densities throughout various evolutionary stages of PNS characterized by different entropies and lepton fractions.

Funded by DFG through the CRC-TR 211-Project No. 315477589 TRR 21, and the Alexander von Humboldt Foundation.

HK 7.2 Mon 16:45 PHIL A 602

**Proto-Neutron Stars with Color Superconductivity** — •SELINA KUNKEL<sup>1</sup>, ISHFAQ AHMAD RATHER<sup>1</sup>, MARCO HOFMANN<sup>2</sup>, HOSEIN GHOLAMI<sup>2</sup>, and JÜRGEN SCHAFFNER-BIELICH<sup>1</sup> — <sup>1</sup>Institut für Theoretische Physik, Goethe Universität, Frankfurt am Main, Germany — <sup>2</sup>Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany

At high densities and low temperatures, hadronic matter is expected to undergo a first-order phase transition into a color-superconducting state. While such conditions occur in neutron stars, studies focusing only on cold neutron stars are not fully conclusive because they neglect the evolutionary processes that may influence the appearance of color-superconducting phases. A proto-neutron star, however, describes the earliest evolutionary stages during the first seconds to minutes after core collapse and therefore has different thermodynamic properties compared to a cold neutron star - in particular higher temperatures and trapped neutrinos. To address this, we incorporate proto-neutron star conditions into the equation of state. Since the total baryon number of a neutron star is conserved during its early evolution, tracking stellar configurations from the maximum mass of the hot proto-neutron star to the final cold neutron star allows us to investigate whether color-superconducting phases can form at any point along this trajectory.

Funded by DFG through the CRC-TR 211-Project No. 315477589\*TRR 21.

HK 7.3 Mon 17:00 PHIL A 602

**Experimental Studies of Proton Capture Reactions on Stable Rb Isotopes** — •SVENJA WILDEN, BENEDIKT MACHLINER, MARTIN MÜLLER, and ANDREAS ZILGES — University of Cologne, Institute for Nuclear Physics, Germany  
The p nuclei - stable neutron-deficient isotopes not produced via neutron-capture - are synthesized through photodisintegration reactions in the  $\gamma$  process. Since many of the relevant reactions involve unstable nuclei and cannot be measured directly, Hauser-Feshbach calculations are essential, and experimental data are needed to constrain the nuclear inputs. Proton-induced reactions therefore play a central role in improving  $\gamma$ -process models.

In this work, the cross sections for the  $^{85}\text{Rb}(p, \gamma)^{86}\text{Sr}$  and  $^{87}\text{Rb}(p, \gamma)^{88}\text{Sr}$  reactions were measured using the in-beam method at the HORUS spectrometer at the University of Cologne. The results extend the database of proton-capture reactions around  $A \approx 85$ , and the  $^{87}\text{Rb}$  study nearly completes the systematic investigation of the stable  $N = 50$  isotones [1].

Comparisons with Hauser-Feshbach calculations show significant deviations for both isotopes, indicating deficiencies in the proton optical model potential, while variations in nuclear level densities and  $\gamma$ -strength functions have only minor effects. The new data provide constraints for improving statistical-model predictions and refining reaction rates.

Supported by the DFG (ZI 510/12-1).

[1] S. Wilden *et al.*, Eur. Phys. J. A 61 (2025) 142.

HK 7.4 Mon 17:15 PHIL A 602

**Stacked target experiments for nuclear astrophysics** — •MARTIN MÜLLER, BENEDIKT MACHLINER, SVENJA WILDEN, and ANDREAS ZILGES — University of Cologne, Institute for Nuclear Physics, Germany

The study of nucleosynthesis processes brings together cutting-edge science performed in a wide variety of fields. One of the main contributions from experimental nuclear physics is the determination of reaction cross sections and reaction rates. While many different techniques exist, the activation technique is among those that have been used the most over the decades, due to the relative simplicity with which high precision results can be obtained. However, since cross sections at energies relevant to nuclear astrophysics are tiny, long irradiation times at high intensities are required. This can be remedied by using the stacked target technique, in which multiple targets are irradiated at the same time. The energy projectiles loose while passing through each target layer enables cross section measurements at multiple energies at once. The price to pay for this is an increased energy uncertainty. In order to reduce these uncertainties, precise knowledge of target thicknesses are needed. This contribution will introduce a new setup for Rutherford Backscattering spectrometry commissioned at the University of Cologne, a Geant4 based simulation of energy losses, that is capable of propagating the uncertainties in the target thicknesses, as well as cross sections determined using the stacked target method. Studied reactions include  $^{170,172}\text{Yb}(\alpha, \gamma)$ ,  $^{170,172}\text{Yb}(p, \gamma)$ ,  $^{55}\text{Mn}(\alpha, (2)n)$ , and  $^{58}\text{Fe}(p, n)$ . Supported by the DFG (ZI 510/12-1).

HK 7.5 Mon 17:30 PHIL A 602

**Nuclear two-photon decay investigation of  $^{98}\text{Mo}$  in the ESR Heavy Ion Storage Ring** — •CARLO FORCONI for the E0018 Experiment-Collaboration — GSI Darmstadt, Germany

The nuclear two-photon or double gamma ( $2\gamma$ ) decay is a rare second-order electromagnetic process in which an excited nucleus emits two gamma rays simultaneously. Its branching ratio is significantly lower than that of competing first-order processes such as internal conversion, pair creation, or single-photon emission, making its experimental observation extremely challenging. However,

in the ESR at GSI, these competing decay modes can be suppressed by storing fully ionised ions and selecting a  $0+ - 0+$  transition with excitation energy below the electron-positron pair creation threshold (1022 keV). Under these conditions, the two-photon decay becomes the only available decay channel. In this talk, I will report on the current status of the analysis of an experiment investigating the  $2\gamma$  decay of  $^{98}\text{Mo}$ , which has a first excited  $0+$  state at 734.75 keV. The experiment was performed at the GSI facility in Darmstadt, where fully stripped  $^{98}\text{Mo}$  ions were produced using the projectile fragmentation of  $^{100}\text{Mo}$  primary beam on  $^9\text{Be}$  target in the transfer line. These ions were then transported and stored in the ESR, operated in the isochronous mode. Two non-destructive Schottky detectors were used, allowing for precision measurement of the ions revolution frequencies and extraction of both the nuclear half-life and mass. Preliminary results indicate that the measured half-life of  $^{98}\text{Mo}$  is consistent with the expected theoretical extrapolation estimates from previously studied  $0+ - 0+$  nuclear transitions.

HK 7.6 Mon 17:45 PHIL A 602

**Towards including hyperons in many-body perturbation theory calculations of dense matter** — •SAMET DOKUR<sup>1,2</sup>, KAI HEBELER<sup>1,2,3</sup>, and ACHIM SCHWENK<sup>1,2,3</sup> — <sup>1</sup>Department of Physics, Technische Universität Darmstadt — <sup>2</sup>ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — <sup>3</sup>Max-Planck-Institut für Kernphysik, Heidelberg

We investigate the so-called “hyperon puzzle” by systematically analyzing the impact of hyperons on the properties of dense matter. To this end, we employ systematically improvable interactions derived from chiral effective field theory and compute the corresponding equation of state using many-body perturbation theory. Our aim is to incorporate hyperon-nucleon and hyperon-nucleon-nucleon interactions up to next-to-leading order using the decuplet saturation approximation in our current many-body framework, which is already capable of describing dense matter with nucleon-nucleon and three-nucleon interactions up to next-to-next-to-next-to-leading order. We will outline the many-body approach, address the conceptual and technical challenges associated with hyperonic forces and present first results for the equation of state of neutron-rich matter including calculations of chemical potentials in beta equilibrium.

\* Funded by the LOEWE Top Professorship LOEWE/4a/519/05.00.002(0014)98.

HK 7.7 Mon 18:00 PHIL A 602

**Dark matter effects on the properties of hybrid and twin stars** — •HARISH CHANDRA DAS — Goethe-Universität Frankfurt am Main, Institut für Theoretische Physik, Frankfurt, 60438, Germany

We investigate the influence of dark matter (DM) on the structure and stability of hybrid and twin stars within a two-fluid framework in which DM interacts with baryonic matter purely through gravity. The baryonic sector is described using relativistic mean-field theory for nucleonic matter and a constant sound-speed parametrization for quark matter, while the DM component is modeled as self-interacting fermions. We find that the presence of DM suppresses the emergence of hybrid and twin star branches compared with DM-free configurations. The degree of suppression depends sensitively on the phase-transition pressure and the energy-density discontinuity for fixed sound speed, as well as on the DM particle mass and fractional abundance. Stars featuring DM-dominated cores or halos are governed primarily by DM properties, whereas the emergence of twin or hybrid configurations remains controlled by the quark-matter equation of state. Incorporating current observational constraints further narrows the allowed parameter space for twin stars in both scenarios.

## HK 8: Instrumentation I

Time: Monday 16:15–18:15

Location: PHIL A 301

### Group Report

HK 8.1 Mon 16:15 PHIL A 301

**Status report on the CBM-TRD** — •DENNIS SPICKER for the CBM-Collaboration — Institut für Kernphysik, Goethe-Uni, Max von Laue Str. 1, 60438, Frankfurt am Main

At the Facility for Antiproton and Ion Research (FAIR), the Compressed Baryonic Matter experiment (CBM) is designed to measure particles resulting from heavy-ion collisions at exceedingly high interaction rates. The Transition Radiation Detector (TRD), a subsystem of the CBM experiment, will comprise four layers of Multi-Wire-Proportional-Chambers (MWPC), each equipped with a foam radiator enabling the generation of transition radiation. The principal objective of the TRD is to distinguish between electrons and pions, to augment the light nuclei identification, and to provide tracking information.

This report gives an overview of the current status of the TRD project. Series production of detector modules is commencing. Various quality assurance procedures have been developed for use during series production and on finished detector modules. A new software framework is intended to facilitate the

management of the results of these procedures. Also, an improved version of the readout front-end electronics is currently undergoing testing.

Supported by:

German BMFTR-grants 05P24PM1 and 05P24RF2

HFHF: Helmholtz Forschungssakademie Hessen für FAIR

NRW-FAIR-Netzwerk

HK 8.2 Mon 16:45 PHIL A 301

**Development of a gas system for the Transition Radiation Detector of the CBM experiment** — •NIKOLAI PODGORNOV<sup>1,2</sup>, JAMES RITMAN<sup>1,2,3</sup>, and PETER WINTZ<sup>3</sup> for the CBM-Collaboration — <sup>1</sup>Ruhr-Universität Bochum — <sup>2</sup>GS — <sup>3</sup>Forschungszentrum Jülich

The Transition Radiation Detector (TRD) of the Compressed Baryonic Matter (CBM) experiment is essential to identify electrons with a momentum  $p > 1$  GeV/c with an efficiency of over 90%. The TRD uses a mixture of the noble gas xenon and the quenching gas CO<sub>2</sub>. Since xenon is an expensive gas, a critical part



of the TRD is its gas system, which must maintain a stable and optimal gas mixture to ensure efficient detection of charged particles and transition radiation. Gas mixture purity is also an important factor. This requires a constant flow for purging of the TRD chambers with precisely controlled overpressure maintained within a range of 0.3 - 0.7 mbar. In addition, the system must be closed and ensure complete xenon recovery and purification. This report discusses the status of a gas system prototype and plans for its upgrade toward the full-size system. This includes reassembling the prototype on a new chassis and conducting subsequent long-term leak-tightness and stability tests. An updated piping and instrumentation diagram will be presented, and the control logic will be discussed in the context of migration to a new Programmable Logic Controller suitable for a full-size system. Additionally, a concept for system monitoring based on the Experimental Physics and Industrial Control System (EPICS) will be presented.

HK 8.3 Mon 17:00 PHIL A 301

**Measuring the gas tightness of CBM-TRD wire chambers in Node-RED flows** — •PHILIPP KÄHLER — Institut für Kernphysik, Universität Münster

The Transition Radiation Detector (TRD) in the CBM experiment at FAIR will provide electron identification, enabling the study of the hot and dense medium created in heavy-ion collisions via the measurement of di-electrons at intermediate masses. Furthermore, the TRD will serve as an intermediate tracking station and, moreover, augments the identification of light nuclei for the hypernuclei programme of CBM.

As gaseous detector using a Xe/CO<sub>2</sub> 85:15 gas mixture, the gas loss per detector chamber has to be minimised to not exceed an accepted upper limit of 1 ml/h. To test the corresponding gas tightness is a crucial QA step during serial chamber production for this detector.

In this talk, a new QA test stand for gas tightness assessment based on a direct gas loss measurement is presented. The data acquisition is implemented in *Node-RED* flows on a *Raspberry Pi*-based platform, which includes ADCs of corresponding required precision as well as a high automation level of the measurement routines.

HK 8.4 Mon 17:15 PHIL A 301

**Construction of the Cherenkov-Detector for the P2-Experiment** — SEBASTIAN BAUNACK<sup>1</sup>, MAARTEN BOONEKAMP<sup>4</sup>, BORIS GLÄSER<sup>1</sup>, SHRUTI GUDLA<sup>1</sup>, •FRANZ HALTER<sup>1</sup>, JAYANTA NAIK<sup>1</sup>, RAHIMA KRINI<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, MORAN NEHER<sup>1</sup>, TOBIAS RIMKE<sup>1</sup>, PAUL SCHÖNER<sup>2</sup>, SIDDHARTH TAKKER<sup>1</sup>, and MALTE WILFERT<sup>1</sup> for the P2-Collaboration — <sup>1</sup>Institute of Nuclear Physics, Mainz, Germany — <sup>2</sup>Helmholtz-Institut Mainz, Mainz, Germany — <sup>3</sup>PRISMA+ Cluster of Excellence, Mainz, Germany — <sup>4</sup>IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

The P2 experiment at the MESA accelerator facility in Mainz aims at a precise determination of the weak mixing angle  $\sin^2 \theta_W$ . The Weinberg angle will be extracted from parity violating asymmetry in elastic electron-proton scattering at low  $Q^2$ . Therefore the measurement verifies a fundamental parameter of the Standard Model and may open a door to new physics with a target relative accuracy of 0.16%.

The key detector element will be a Cherenkov detector ring, in which Cherenkov light is detected by photomultiplier tubes. To ensure an accurate measurement, the detectors must be carefully aligned and shielded.

This talk will present the design challenges, current status, and recent progress of the detector components.

HK 8.5 Mon 17:30 PHIL A 301

**Design of a luminosity monitor for the P2 parity violating experiment at MESA** — SEBASTIAN BAUNACK<sup>1</sup>, MAARTEN BONNEKAMP<sup>2,4</sup>, BORIS GLÄSER<sup>1</sup>, SHRUTI GUDLA<sup>1</sup>, RAHIMA KRINI<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, JAYANTA NAIK<sup>1</sup>, MORAN NEHER<sup>1</sup>, •TOBIAS RIMKE<sup>1</sup>, PAUL SCHÖNER<sup>2</sup>, SIDDHARTH THAKKER<sup>1</sup>, and MALTE WILFERT<sup>1</sup> — <sup>1</sup>Institut für Kernphysik, Johannes Gutenberg-Universität

Mainz — <sup>2</sup>Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — <sup>3</sup>PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz — <sup>4</sup>IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

The P2 experiment at the future MESA accelerator in Mainz plans to measure the weak mixing angle  $\sin^2(\theta_W)$  in parity violating elastic electron-proton scattering. The aim of the experiment is a very precise measurement of the weak mixing angle with an accuracy of 0.15% at a low four-momentum transfer of  $Q^2 = 4.5 \cdot 10^{-3} \text{ GeV}^2$ . In order to achieve this accuracy, it is necessary to monitor the stability of the electron beam and the liquid hydrogen target. Any helicity correlated fluctuation of the target density leads to false asymmetries.

Therefore, it is planned to install a luminosity monitor in forward direction close to the beam axis. The motivation and challenges for designing an air Cherenkov luminosity monitor will be discussed. Furthermore, I show the current prototype design with results from promising test runs with the electron beam of the MAMI accelerator and detailed simulation studies.

HK 8.6 Mon 17:45 PHIL A 301

**Magnetic-field mapping requirements and strategy for the P2 parity violating experiment at MESA** — SEBASTIAN BAUNACK<sup>1</sup>, MAARTEN BONNEKAMP<sup>2,4</sup>, BORIS GLÄSER<sup>1</sup>, •SHRUTI GUDLA<sup>1</sup>, RAHIMA KRINI<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, JAYANTA NAIK<sup>1</sup>, MORAN NEHER<sup>1</sup>, TOBIAS RIMKE<sup>1</sup>, PAUL SCHÖNER<sup>2</sup>, SIDDHARTH THAKKER<sup>1</sup>, and MALTE WILFERT<sup>1</sup> for the P2-Collaboration — <sup>1</sup>Institut für Kernphysik, Johannes Gutenberg-Universität Mainz — <sup>2</sup>Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — <sup>3</sup>PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz — <sup>4</sup>IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

The P2 experiment at the upcoming MESA accelerator aims to perform a high-precision determination of the weak mixing angle by measuring the parity-violating asymmetry in elastic electron-proton scattering at low momentum transfer ( $Q^2 \approx 4.5 \times 10^{-3} \text{ GeV}^2$ ). To reach the targeted uncertainty, the experiment relies on a solenoid-based spectrometer providing full  $2\pi$  azimuthal acceptance and controlled transport of scattered electrons to the integrating Cherenkov detector system. Precise knowledge of the magnetic field distribution inside the solenoid is essential for  $Q^2$  reconstruction, systematic-uncertainty control, and background separation. Therefore, a dedicated magnetic-field mapping approach is planned to characterize the 3D field response under operating conditions. The talk will outline requirements of mapping a high-current, large-aperture solenoid and discuss strategies for establishing a validated magnetic-field model for the P2 spectrometer.

HK 8.7 Mon 18:00 PHIL A 301

**Mirror System and Mirror Alignment Monitoring of the CBM RICH** — •SVEN PETER for the CBM-Collaboration — Justus Liebig University, Gießen

The CBM (Compressed Baryonic Matter) experiment at FAIR (Facility for Antiproton and Ion Research) will study extremely dense matter resulting from heavy ion collisions starting in 2028. The CBM Ring Imaging Cherenkov Detector (RICH) uses CO<sub>2</sub> as radiator and multi-anode photomultiplier tubes as readout. The mirrors (R=3 m) consist of 80 individual mirror tiles (about 40 cm×40 cm). A prototype of the mirror wall has been built and a gluing procedure has been developed that does not cause harmful distortion of the mirror. The RICH is planned to be periodically exchanged with the MUCH (Muon Chamber) detector by craning. This carries the risk of mirror misalignment but only misalignment upto 1 mrad can be tolerated. Potential misalignment must be detected and accounted for during data analysis to ensure accurate ring diameters, locations, and subsequent ring-track matching. The CLAM method (Continuous Line Alignment and Monitoring, originally developed for the COMPASS RICH-1) was adapted for the CBM RICH. A ray-optics simulation of the mirror system was used to compare different approaches for misalignment quantification. Supported by BMBF grant no. 05P24RG6.

## HK 9: Instrumentation II

Time: Monday 16:15–18:15

Location: PHIL B 302

### Group Report

HK 9.1 Mon 16:15 PHIL B 302

**Status of the CBM Micro Vertex Detector\*** — •FRANZ MATEJCEK for the CBM-MVD-Collaboration — Goethe-Universität Frankfurt

The Micro Vertex Detector (MVD) is the first downstream detector of the fixed-target CBM Experiment at the future Facility for Antiproton and Ion Research (FAIR). It enables high-precision tracking of low-momentum particles in direct proximity of the target with the first of four stations being placed only 8 cm downstream the interaction point in the target vacuum. ~300 MIMOSIS (TJ-180 nm) CMOS Monolithic Active Pixel Sensors (MAPS) provide >99% detection efficiency and a 5–6  $\mu\text{m}$  spatial resolution (5  $\mu\text{s}$  frame time), also after irradiation to 5 Mrad and  $1 \times 10^{14} n_{\text{eq}}/\text{cm}^2$  (TID+NIEL), fulfilling the requirements and preparing for final sensor submission. Sensors are wire-bonded to thin flex

cables and glued onto both sides of Thermal Pyrolytic Graphite (380  $\mu\text{m}$ ) carriers, which provide stiff, low- $X_0$  support with excellent thermal conductivity. Actively cooled aluminum heat sinks outside the acceptance extract the heat.

In this contribution, we present the detector concept, highlights from the CBM-compatible readout validated in mCBM, and results from the final MIMOSIS prototype under CBM-like conditions. A focus will be the challenges associated with vacuum operation, stringent material budget constraints (0.3–0.5%  $X_0$ ), and double-sided integration as we progress toward station assembly and readiness for first beam in 2028.

\*This work has been supported by BMFT (05H24RF5), HGS-HiRe, HFHF, GSI and Eurizon.

HK 9.2 Mon 16:45 PHIL B 302

**Results of Recent Testing Campaigns of the Analogue Pixel Test Structure** — •MAXIMILIAN SPORS<sup>1,2</sup>, MALTE GRÖNBECK<sup>1,2</sup>, ALEXANDER RACHEV<sup>1,2</sup>, LARS DÖPPER<sup>1,2</sup>, PHILIP HAUER<sup>1,2</sup>, and BERNHARD KETZER<sup>1,2</sup> for the ALICE Germany-Collaboration — <sup>1</sup>Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, Germany — <sup>2</sup>Forschungs- und Technologiezentrum Detektorphysik

For the Long Shutdown 4 of the LHC, the ALICE Collaboration is planning a major upgrade of its detectors, known as ALICE 3. The tracking system of ALICE 3 will be entirely based on Monolithic Active Pixel Sensors (MAPS), fabricated using TPSCo's 65 nm CMOS imaging process. Dedicated small-scale Analogue Pixel Test Structures (APTS), originally developed for the Inner Tracking System 3 project, are used to study the analogue response to incident radiation. As this technology is also planned to be used for the ALICE3 tracking system, the APTS measurements provide insights into the characteristics of sensors fabricated in this process, such as detection efficiency, spatial resolution and in-pixel efficiencies.

This presentation summarizes the results of recent testing campaigns, consisting of test beam measurements at ELSA, as well as laboratory experiments using X-ray sources.

This work is supported by BMFTR.

HK 9.3 Mon 17:00 PHIL B 302

**Status of the MANTA project** — •MICHAEL DEVEAUX — GSI, Darmstadt, Germany

Building a next generation of ultra-light particle tracking detector calls for sensors combining good ( $\sim 10 \mu\text{m}$ ) spatial resolution with fast ( $\sim 10 \text{ ns}$ ) time stamping, very light material budget and low power dissipation.

Thanks to their fine granularity, their low ( $0.05\% X_0$ ) material budget and the possibility of achieving a low energy consumption well below  $\sim 50 \text{ mW/cm}^2$ , next generation CMOS Monolithic Active Pixel Sensors are considered as valuable technology candidate for this application. On the other hand, their time stamping capability and rate capability have still to be improved in order to handle reliably particle fluxes of  $10 - 100 \text{ MHz/cm}^2$ .

Being formed under the umbrella of the DRD3, the MANTA collaboration aims to respond to this challenge by developing a versatile sensor design. This design is intended to yield a single ASIC, which may be configured by slow control to the needs of different tracking detectors.

The presentation introduces the vision of MANTA and discusses the underlying technological concept.

HK 9.4 Mon 17:15 PHIL B 302

**Status of the MIMOSIS sensor for the CBM Micro Vertex Detector\*** — •BENEDICT ARNOLDI-MEADOWS for the CBM-MVD-Collaboration — Goethe-Universität Frankfurt

The CMOS Monolithic Active Pixel Sensor (MAPS) MIMOSIS will be used as the sensor of the Micro Vertex Detector (MVD) of the CBM experiment, which is foreseen to receive beam on target in 2028. The sensor is currently being developed by IPHC Strasbourg in cooperation with University Frankfurt and GSI, with the MIMOSIS-2.1 sensor being its latest and last prototype.

Both in-beam performance studies validating changes in the sensor, and studies related to the selection, preparation, and operation of suitable sensors in the experiment have been conducted with MIMOSIS-2.1 prototype sensors. This contribution will present the recent progress made towards the final sensor for the experiment.

\*This work has been supported by BMFTR (05H24RF5), GSI, Eurizon, HGS-HIRE, and HFHE.

HK 9.5 Mon 17:30 PHIL B 302

**Asynchronous Readout for Pixel Detectors** — •TIM STELLHORN for the ALICE Germany-Collaboration — Wilhelm-Klemm Straße 9, 48149 Münster

ALICE 3 is a next-generation high-energy physics experiment for the LHC Run 5. The Outer Tracker (OT) of ALICE 3 will be the largest tracker consisting solely of silicon sensors based on Monolithic Active Pixel Sensors (MAPS) with an active area of  $60 \text{ m}^2$ . To meet its requirement of an improved timing resolution of 100 ns, new readout models are investigated. The asynchronous readout approach is based on Asynchronous Priority Arbiters (APAs) and is implemented in the Sensor Pixel Asynchronous Readout CMOS (SPARC) chiplet.

This talk will focus on simulations of the asynchronous readout with the prototyping framework PixESL. A network in PixESL consists of front-end nodes as well as readout nodes and the communication between these nodes is based on the Transaction Level Modelling (TLM) framework of SystemC. The input to PixESL is a list of pixels with recorded hits and the related Time-of-Arrival (ToA) and the Time-over-Threshold (ToT), which is generated in an Allpix-squared simulation. As a result of the PixESL simulation, readout delays of recorded hits from the pixels to the memory of the chip will be analysed depending on different APA tree architectures.

HK 9.6 Mon 17:45 PHIL B 302

**Status of the Readout of the CBM Micro Vertex Detector\*** — •BENEDIKT GUTSCHE for the CBM-MVD-Collaboration — Goethe-Universität Frankfurt

The Compressed Baryonic Matter (CBM) Experiment will be one of the main experiments at the future FAIR facility. Its Micro Vertex Detector (MVD) will be composed of four sensor planes in vacuum and will be equipped with Monolithic Active Pixel Sensors (MIMOSIS). The sensor is being developed by IPHC Strasbourg and will run with a sustained rate of up to  $80 \text{ MHz/cm}^2$ . Like other parts of CBM, the detector will be read out using radiation hard electronics (GBTx) and PCIe based FPGA boards (CRI).

In this contribution, we report on the integration of a CRI-based readout for a setup consisting of two MIMOSIS sensors, which was the first time the setup was used in the common CBM readout chain. The operation and data consistency has been validated by using correlations with other subsystems of CBM during an experimental run in May 2025. We will present the first in-beam results of this test setup.

\*This work has been supported by BMFTR (05H24RF5), GSI, and HFHE.

HK 9.7 Mon 18:00 PHIL B 302

**The MADHAT module - A prototype structure for the ALICE 3 Outer Tracker** — •MALTE GRÖNBECK for the ALICE Germany-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn — Forschungs- und Technologiezentrum Detektorphysik

ALICE 3 is a novel heavy-ion experiment foreseen to be installed during the Long Shutdown 4 of the Large Hadron Collider. Its key feature will be a  $60 \text{ m}^2$  silicon MAPS-based tracking detector, with the active area of the Outer Tracker spanning up to  $45 \text{ m}^2$ . The sensor technology will be based on the 65 nm production node of TPSCo. The material-budget target of less than  $1\% X_0$  per layer requires investigations into different cooling systems, electrical interconnections and the mechanical stability. Therefore a prototype sensor called MADHAT (Mechanical Assessment Design for Heat And Thermal solutions) and an associated detector module carrying 8 sensors was designed and built. These simple microchips are capable of emulating the heat dissipation, while simultaneously measuring the surface temperature with an integrated temperature probe.

This talk will discuss the MADHAT module design and its readout electronics. Supported by BMFTR.

## HK 10: Invited Talks

Time: Tuesday 11:00–13:00

Location: MED 00.915

### Invited Talk

HK 10.1 Tue 11:00 MED 00.915

**Baryon scattering amplitudes from lattice QCD** — •JOHN BULAVA — Ruhr Universität Bochum

Lattice QCD computations of baryon scattering amplitudes are continually improving. As a first-principles Monte Carlo approach, such simulations elucidate the quark mass dependence of baryon interactions, providing useful input to chiral effective theories. I will review computations of the nucleon-nucleon interaction at unphysically heavy quark masses, for which agreement has been recently attained between several independent groups. I will then present first results for light quark masses, which make contact to chiral effective theories for the first time.

### Invited Talk

HK 10.2 Tue 11:30 MED 00.915

**Exploring Triaxial Deformation in Neutron-rich Nuclei** — •KATHRIN WIMMER<sup>1</sup>, BYUL MOON<sup>2</sup>, and WOLFRAM KORTEN<sup>3</sup> — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Germany — <sup>2</sup>Center for Exotic Nuclear Studies, Institute for Basic Science, Daejeon 34126, Republic of Korea — <sup>3</sup>IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France

Understanding nuclear shapes far from stability is key to refining nuclear models. While many deformed nuclei are well described by axial symmetry, some isotopes require a triaxial description, where the nucleus lacks a single axis of symmetry. This triaxiality has long been debated, with contrasting theoretical models offering different interpretations. Neutron-rich Zr and Mo isotopes are ideal candidates to explore this question due to predicted shape coexistence and evolving collective structure.

To probe this, we performed a high-resolution in-beam  $\gamma$ -ray spectroscopy experiment at RIBF using the HiCARI array. Nucleon-removal reactions populated

$^{108,110}\text{Zr}$  and  $^{110,112}\text{Mo}$ . Excited-state lifetimes were extracted via the line-shape method, and new level schemes were established, revealing characteristic signatures associated with triaxial deformation. The results, interpreted using modern theoretical models, provide new constraints on deformation in this mass region.

In this talk, I will present the experiment, discuss the results in detail, and provide an outlook for further studies of triaxial deformation in neutron-rich nuclei.

**Invited Talk** HK 10.3 Tue 12:00 MED 00.915

**Jet Targets for Nuclear and Hadron Physics Experiments** — •ALFONS KHOUKAZ — Institut für Kernphysik, Universität Münster, 48149 Münster  
Jet beams are widely used as targets in many fields of physics. Prominent examples are scattering experiments at hadron and lepton accelerators or at high-power laser facilities, where pure and windowless targets with adjustable thickness are required in vacuum. Depending on the specific experimental situation, different types of targets such as gas-jets, cluster-jets or pellet streams can be used to fulfil the required properties. However, in recent years new experimental challenges have emerged that require a significant improvement in the performance of existing target technologies and the development of new target beam gener-

ation and monitoring techniques. Inspired by this, new research projects have been initiated, focusing on the development of state-of-the-art jet targets. This talk gives an overview of the developments on cryogenic gas-jet, cluster-jet and frozen pellet/filament targets at the University of Münster.

**Invited Talk** HK 10.4 Tue 12:30 MED 00.915  
**Probing neutrinos with the KATRIN and LEGEND experiments** — •SUSANNE MERTENS — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The absolute mass scale and fundamental nature of the neutrino remain among the most pressing open questions in astroparticle physics today. Beta decay experiments provide unique laboratory probes of these properties. In particular, the kinematics of single beta decay allow for a model-independent determination of the absolute neutrino mass. The KATRIN experiment currently sets the most stringent direct limit on this quantity. The observation of neutrinoless double beta decay would demonstrate that neutrinos are their own antiparticles. The LEGEND experiment is designed to achieve unprecedented sensitivity to this rare process. This talk will present the KATRIN and LEGEND experiments, highlighting recent results and outlining future prospects.

## HK 11: Hadron Structure and Spectroscopy III

Time: Tuesday 16:15–18:30

Location: PHIL C 301

**Group Report** HK 11.1 Tue 16:15 PHIL C 301

**Recent results from the CBELSA/TAPS experiment and plans for a new experiment at ELSA: INSIGHT** — •TOBIAS SEIFEN for the CBELSA/TAPS-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, Nussallee 14-16, 53115 Bonn

Based on the high quality photoproduction data, our understanding of the spectrum and the properties of  $N^*$ - and  $\Delta^*$ -baryons has substantially improved. Polarization data, as taken by the CBELSA/TAPS experiment for various final states, are a key to resolve the baryon spectrum. The measurement of polarization observables is indispensable for performing an unambiguous partial wave analysis to extract the resonances from the data.

In contrast to the non-strange baryon sector, so far, little is known about the excited  $\Lambda$  and  $\Sigma$  spectrum. For decades, progress in the strange baryon sector has been hampered by the lack of data.

Here, the new INSIGHT experiment at ELSA will provide high quality data and therefore crucial information on  $\Lambda^*$  and  $\Sigma^*$  resonances and will also investigate the possible existence of multi-quark states in the strange quark sector.

INSIGHT features a unique combination of an almost complete angular coverage for high-resolution photon measurements, charged-particle detection and the ability to perform measurements using a transversally or longitudinally polarized target.

This talk will discuss recent results from the CBELSA/TAPS experiment as well as the plans for the future INSIGHT experiment at ELSA.

**Group Report** HK 11.2 Tue 16:45 PHIL C 301

**The study of unconventional baryon structure in the light quark sector with the BGOOD and INSIGHT experiments** — •THOMAS JUDE for the BGOOD-Collaboration — Physikalisches Institut, Universität Bonn

The existence of exotic multi-quark states beyond valence three quark and quark-antiquark systems has been unambiguously confirmed in the heavy quark sectors and equivalent structures may be evidenced in the light,  $uds$  sector. The BGOOD photoproduction experiment at ELSA is ideal to study spatially extended, molecular-like structure which may manifest in reaction mechanisms. BGOOD is comprised of a central calorimeter for neutral meson momentum reconstruction and complemented by a magnetic spectrometer in forward directions for charged particle identification.

Our published results in the strangeness sector suggest a dominant role of meson-baryon dynamics which may have an equivalence to the  $P_c$  states in the charmed sector. This includes structure in  $K^0\Sigma^0$  and  $K^+\Sigma^+$  photoproduction at the  $K^*Y$  thresholds.

The new INSIGHT experiment at ELSA will be an important upgrade for both the BGOOD and CBELSA/TAPS experiments and will feature a unique combination of almost complete angular coverage for high-resolution photon identification and charged-particle detection with polarised beams and targets.

I will present BGOOD results and anticipated INSIGHT measurements using simulated data.

HK 11.3 Tue 17:15 PHIL C 301

**Production Mechanism Studies of the  $N^*$  and  $\Delta$  Resonances in Proton-Proton Collisions** — •SAKET KUMAR SAHU<sup>1,2</sup>, AHMED MARWAN FODA<sup>2</sup>, JOHAN MESSCHENDORP<sup>2</sup>, JAMES RITMAN<sup>1,2,3</sup>, and DEBORAH RÖNCHEN<sup>3</sup> — <sup>1</sup>Ruhr University Bochum — <sup>2</sup>GSF Helmholtzzentrum für Schwerionenforschung GmbH — <sup>3</sup>Forschungszentrum Jülich

Excited nucleon states ( $N^*$  and  $\Delta$  resonances) help us to probe the non-perturbative regime of Quantum Chromodynamics (QCD) and baryon structure. One way to access their internal properties is through their coupling to virtual photons produced in elementary reactions. Our long-term goal is to study Dalitz transitions of  $N^*$  and  $\Delta$  resonances generated in proton-proton collisions. In this work, we study the production mechanisms of these resonances which will also serve as a baseline measurement for interpreting data from heavy-ion collisions. The High Acceptance Di-Electron Spectrometer (HADES) at GSI Darmstadt, which is a versatile magnetic spectrometer designed for measuring wide range of particles across large angular acceptance, is ideal for performing these studies. This analysis aims to extract differential cross-sections for the exclusive production of  $N^*$  and  $\Delta$  channels in proton-proton collisions at  $\sqrt{s} = 3.47$  GeV and also their coupling strengths in proton-proton collisions. This talk will present results of the analysis of proton-proton scattering data collected in February 2022 by the HADES collaboration, along with preliminary comparisons to fits using the Jülich\*Bonn (JüBo) dynamical coupled\*channel model.

HK 11.4 Tue 17:30 PHIL C 301  
 **$K^+\Sigma(1385)^-$  photoproduction at the BGOOD experiment** — •MARTIN LUDWIG for the BGOOD-Collaboration — Physikalisches Institut, Universität Bonn

In the past twenty years, many exotic multi-quark states have been discovered in the heavy-quark sector. Although their exact binding mechanism is still under discussion, their proximity to certain thresholds suggests they may be molecular-like states. If so, one may expect similar states to appear in the light (uds) sector as well.

One way to search for such states is via photoproduction off the proton or neutron. The BGOOD experiment at the ELSA facility is ideally suited for these studies, as it combines a central calorimeter with a forward spectrometer that enables charged-particle reconstruction at extreme forward angles. These forward angles correspond to low momentum transfer to the recoil baryon, which may be a favourable condition for the formation of loosely bound molecular states.

Previous studies of strangeness-photoproduction channels at BGOOD have provided hints that exotic hadrons similar to the  $P_c$  pentaquarks may actually exist in the light-quark sector. In this context, another interesting channel to investigate is  $\gamma p \rightarrow K^+\Sigma(1385)^-$ . Preliminary results for its differential cross section for beam energies ranging from threshold up to 2050 MeV will be presented.

HK 11.5 Tue 17:45 PHIL C 301  
 **$K^{*+}\Lambda$  and  $K^{*+}\Sigma^0$  photoproduction at the BGOOD experiment** — •AMELIA CARINA DE LOPE FEND for the BGOOD-Collaboration — Physikalisches Institut, Universität Bonn

In recent years exotic multi-quark states such as the XYZ mesons and the  $P_c$  pentaquark states have been discovered in the charm quark sector. Structures in  $\gamma p \rightarrow K^+\Sigma^0$  and  $\gamma p \rightarrow K^0\Sigma^+$  cross sections may be evidence of an equivalence in the light quark sector where  $(K^*\Sigma)^+$  and  $K^{*+}\Lambda$  dynamically generated states may exist.

The BGOOD experiment at the ELSA facility is especially suited to investigate this, as it provides a unique forward spectrometer for  $K^+$  identification and momentum reconstruction and a central calorimeter for neutral hadron decays.

Current studies of the photoproduction reactions  $\gamma p \rightarrow K^{*+}\Lambda$  and  $\gamma p \rightarrow K^{*+}\Sigma^0$  are achieved via the identification of the decay  $K^{*+} \rightarrow K^+\pi^0$  and focus on measuring the differential cross section with high statistical precision at forward  $K^{*+}$  angles. Preliminary results will be presented.

HK 11.6 Tue 18:00 PHIL C 301

**$K^0\Sigma^0$  photoproduction at the BGOOD experiment** — •ADRIAN SONNENSCHNEN for the BGOOD-Collaboration — Physikalisches Institut, Nussallee 12, 53115 Bonn, Germany

The BGOOD experiment at the ELSA accelerator facility uses an energy tagged bremsstrahlung photon beam to investigate hadronic excitations in meson photoproduction in the light quark sector.

The associated photoproduction of  $K_S^0$  and hyperons is of particular interest. A cusp-like structure observed in the  $\gamma p \rightarrow K_S^0 \Sigma^+$  reaction at the  $K^*$  threshold is described by models including multi-quark resonances through dynamically generated vector meson-baryon interactions. This is the same model which predicted the  $P_C$  pentaquark states observed at LHCb through  $D^* \Sigma_c$  interactions and if proven correct, would provide evidence of molecular-like states in the strangeness sector. The model predicts a peak like structure in  $K_S^0 \Sigma^0$  photoproduction at the  $K^*$  threshold, which is the motivation for the measurement present here.

The reaction  $\gamma n \rightarrow K_S^0 \Sigma^0$  has been measured at BGOOD from threshold to a beam energy of 2600 MeV. The analysis procedure is based upon a previous BGOOD publication, however employing additional kinematic fitting techniques with improved statistical precision. Preliminary differential cross section measurements will be presented.

HK 11.7 Tue 18:15 PHIL C 301

**Energy Calibration of an Electromagnetic Calorimeter for the PRIMA Experiment at MAMI** — OSCAR ANDÚJAR SABÁN<sup>1</sup>, NING CAO<sup>1</sup>, LUIGI CAPOZZA<sup>1</sup>, JONAS GEISBÜSCH<sup>1</sup>, RAVI GOWDRU MANJUNATA<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, ANTOINE MARTINET<sup>1</sup>, OLIVER NOLL<sup>1,2</sup>, PAUL SCHÖNER<sup>1</sup>, CHRISTOPH ROSNER<sup>1</sup>, •PIERRE VIJAYAN<sup>1</sup>, and SAHRA WOLFF<sup>1</sup> for the PANDA-Collaboration — <sup>1</sup>Helmholtz-Institut Mainz, Mainz, Germany — <sup>2</sup>Institute of Nuclear Physics, Mainz, Germany — <sup>3</sup>PRISMA+ Cluster of Excellence, Mainz, Germany

The PRIMA experiment which was conducted at the MAMI accelerator facility in Mainz aims to measure the doubly virtual transition form factor (TFF) of the  $\pi^0$  via the  $\pi^0$ -electroproduction in the Primakoff kinematics. A modified version of the PANDA backward calorimeter (EMC) was installed in the A1 spectrometer hall at MAMI, for detecting both the scattered electron and the  $\pi^0$  decay  $\gamma$ -particles. The experiment will give new input to the hadronic corrections of the anomalous magnetic moment of the muon ( $g_\mu - 2$  puzzle). In order to achieve a precise measurement of the TFF, the kinematics of this process needs to be determined with high precision.

For this purpose, a reliable energy calibration procedure of the EMC is mandatory. The talk therefore gives insight into the energy calibration of the electromagnetic calorimeter for the PRIMA-setup at MAMI.

## HK 12: Hadron Structure and Spectroscopy IV

Time: Tuesday 16:15–18:30

Location: PHIL A 401

### Group Report

HK 12.1 Tue 16:15 PHIL A 401

**Search for exotic states in  $\eta_c$  decays at BESIII** — TESSA BERTELSMEIER<sup>1</sup>, JANS BÖING<sup>1</sup>, ANJA BRÜGGEMANN<sup>1</sup>, NILS HÜSKEN<sup>2</sup>, NIKOLAI IN DER WIESCHE<sup>1</sup>, LOIS KRÖGER<sup>1</sup>, HANNAH NEUWIRTH<sup>1</sup>, •FREDERIK WEIDNER<sup>1</sup>, and ALFONS KHOUKAZ<sup>1</sup> — <sup>1</sup>Universität Münster, Germany — <sup>2</sup>Johannes Gutenberg-Universität Mainz, Germany

The BESIII detector at the  $e^+e^-$  collider BEPCII in Beijing, China, provides the world's largest data sample of the charmonium  $J/\psi$  with more than 10 billion events collected from 2009 to 2019.

Starting from the radiative  $J/\psi$  decay into  $\gamma\eta_c$ , we analyse the reactions  $\eta_c \rightarrow \eta' h\bar{h}$  (with  $h\bar{h} = \pi\pi, 2(\pi\pi), K\bar{K}, \eta\eta$ ) to determine the corresponding branching ratios as well as the mass and width of the  $\eta_c$ . Moreover, these  $\eta_c$  decays provide the opportunity to investigate possible exotic content in  $h\bar{h}$  intermediate states that lie in the mass region below  $2 \text{ GeV}/c^2$ , where the lightest scalar glueball is predicted.

Our studies are based on a partial wave analysis approach that gives access to the partial decay widths of contributing resonances decaying into the  $h\bar{h}$  subsystems. By coupling the considered channels multi-channel effects can be correctly incorporated. The extracted widths are directly comparable to theoretical predictions, which assume glueball admixtures carried by certain considered resonances.

This work is supported by the DFG under project numbers 443159800, 547123630 and GRK 2149/2 and by the Ministry for Culture and Science of the State North Rhine-Westphalia under funding code NW21-024-E.

### Group Report

HK 12.2 Tue 16:45 PHIL A 401

**Search for the Lightest Glueball via the Reactions  $\psi(2S) \rightarrow \phi + \pi\pi, 4\pi, K\bar{K}, \eta\eta$  and  $\eta\eta'$  at BESIII** — •NIKOLAI IN DER WIESCHE, FREDERIK WEIDNER, ANJA BRÜGGEMANN, LOIS KRÖGER, TESSA BERTELSMEIER, JANS BÖING, HANNAH NEUWIRTH, and ALFONS KHOUKAZ for the BESIII-Collaboration — Universität Münster, Germany

The self-interaction of gluons is one of the most fundamental features of QCD, which implies the existence of purely gluonic bound states, called glueballs. However, to this day, no unambiguous experimental evidence of such state has been found. Theoretical calculations predict the mass of the lightest glueball, with quantum numbers  $J^{PC} = 0^{++}$ , to be between 1.6 GeV and 1.7 GeV. Therefore, the three experimentally observed isoscalar  $0^{++}$  states  $f_0(1370)$ ,  $f_0(1500)$  and  $f_0(1710)$ , are promising candidates to contain admixtures of this glueball. Due to many contradictory measurements of their properties, the assignment of these states is still controversial.

In this talk, the current progress of a large-scale coupled-channel analysis project investigating the reactions  $\psi(2S) \rightarrow \phi + \pi\pi, 4\pi, K\bar{K}, \eta\eta$  and  $\eta\eta'$  will be presented. Using the world's largest  $\psi(2S)$  data set obtained at BESIII, this project aims at extracting the properties of the  $f_0$  states, which are produced as intermediate resonances in the recoil systems of the  $\phi$  meson.

This work is supported by the DFG under the project number 547123630 and by the Ministry for Culture and Science of the State North Rhine-Westphalia under funding code NW21-024-E.

HK 12.3 Tue 17:15 PHIL A 401

**Partial-Wave Analysis of  $B^0 \rightarrow J/\psi K^+ \pi^-$  at Belle (II)** — •MARTIN BARTL, HANS-GÜNTHER MOSER, and STEFAN WALLNER — Max-Planck-Institut für Physik, München

We will present Monte Carlo studies for a partial-wave analysis (PWA) of  $B^0 \rightarrow J/\psi K^+ \pi^-$  at Belle and Belle II. The PWA disentangles contributions from numerous intermediate resonances, e.g.  $K^*$  mesons in the  $K\pi$  subsystem. Background components are described using neural network techniques. We will discuss the search for exotic, i.e. non- $q\bar{q}$ , states, which can appear in the  $J/\psi\pi$  and  $J/\psi K$  subsystems, complementing recent observations by LHCb.

HK 12.4 Tue 17:30 PHIL A 401

**Light Hybrid Mesons with Functional Methods** — •FRANZISKA MÜNSTER<sup>1</sup>, CHRISTIAN FISCHER<sup>2</sup>, and MARKUS HUBER<sup>3</sup> — <sup>1</sup>Institute for theoretical physics, JLU, Gießen, Germany — <sup>2</sup>Institute for theoretical physics, JLU, Gießen, Germany — <sup>3</sup>Institute for theoretical physics, JLU, Gießen, Germany

In my talk, I discuss the theoretical description of light hybrid mesons\*hadrons composed of a quark, an antiquark, and a gluon. Their explicit gluonic degree of freedom makes them particularly interesting for studying the nonperturbative dynamics of QCD. Unlike ordinary mesons, hybrid mesons can carry exotic quantum numbers that simple quark\*antiquark configurations cannot access in the nonrelativistic quark model. Their study is further motivated by some possible experimental candidates reported in recent years. The most prominent candidate for a light hybrid meson is the isovector state  $\pi_1(1600) 1^{--}$ . To investigate such systems, we employ a functional approach based on Dyson\*Schwinger and Bethe\*Salpeter equations. Hybrid mesons are treated as genuine three-body bound states, which requires solving a three-body Bethe\*Salpeter equation that explicitly includes quark, antiquark, and gluon degrees of freedom. I outline the structure of this framework and discuss its implications for the spectrum and internal dynamics of hybrid mesons.

HK 12.5 Tue 17:45 PHIL A 401

**First steps towards the mixing of Glueballs and Mesons using the Dyson-Schwinger and Bethe-Salpeter equations** — •JONATHAN YIGZAW, CHRISTIAN FISCHER, and MARKUS HUBER — Justus-Liebig-Universität Gießen Germany

The spectrum of Quantum Chromodynamics (QCD) contains not only conventional quark-antiquark mesons but also purely gluonic bound states, the glueballs. While glueball masses have been studied extensively in pure Yang-Mills theory, their mixing with mesons of identical quantum numbers remains a largely open question. While in recent years functional methods have been successfully used to produce mass spectra for pure Yang-Mills theory, and the ongoing study of mesons in this framework has led to a fuller understanding of their properties, the effects of their mixing have not been studied yet.

As a first step towards a fully mixed spectrum of mesons and glueballs, I use the Dyson-Schwinger and Bethe-Salpeter equations to calculate the coupled set of equations in the scalar and pseudoscalar channels. I will present the resulting impact on the spectra and discuss the possible implications.

HK 12.6 Tue 18:00 PHIL A 401

**Partial Wave Analysis for Baryonic Resonances for the HADES Experiment** — •AHMED MARWAN FODA — GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany

The HADES collaboration at GSI investigates baryonic resonances and their decay channels using exclusive channels with pion and proton beams, which enable direct resonance formation at fixed center-of-mass energy ( $\sqrt{s}$ ). This approach complements photo-induced studies and, combined with Partial Wave Analysis (PWA), provides crucial insights into resonance couplings, particularly in two- and three-pseudoscalar meson production. A central focus is the role and medium modification of vector mesons in baryon-dense matter, with pion-induced reactions and PWA offering unprecedented access to  $\rho N$  and  $\omega N$  final states, relevant for phenomena such as  $\rho$  meson melting and dilepton emissions in heavy-ion collisions.

To advance resonance exploration, a modular PWA software package is being developed, incorporating frameworks such as K-Matrix, N/D methods, and a baryon pseudoscalar fit based on the JuBo coupled-channel model. This enables comparison of electro- and photoproduction predictions with proton-proton data, refining resonance contributions. The effort coincides with recently analyzed proton-induced data together with approved pion beam time at GSI targeting the third resonance region, and a complementary experiment at J-PARC. Current results include illustrative fits from pion-proton reactions in the second resonance region, and proton-proton reactions at 4.5 GeV, demonstrating the framework's potential for upcoming campaigns.

HK 12.7 Tue 18:15 PHIL A 401

**Coupled-Channel Partial-Wave Analysis of the Decays  $\psi(2S) \rightarrow \omega + KK, \pi\pi, \eta\eta, \eta\eta', 4\pi$**  — •LOIS KRÖGER, TESSA BERTELSMEIER, JANS BÖING, ANJA BRÜGGEMANN, NIKOLAI IN DER WIESCHE, HANNAH NEUWIRTH, FREDERIK WEIDNER, and ALFONS KHOUKAZ for the BESIII-Collaboration — University of Münster

The BESIII experiment provides a datasample of 2.7 billion events of the vector charmonium  $\psi(2S)$  produced in electron-positron collisions. This high-statistics data sample is utilised to perform a coupled-channel partial-wave analysis of the decays  $\psi(2S) \rightarrow \omega + KK, \pi\pi, \eta\eta', \eta\eta, 4\pi$ . The resonance parameters and the partial widths of the isoscalar, scalar resonances  $f_0(1370)$ ,  $f_0(1500)$  and  $f_0(1710)$  produced as intermediate states in the analysed decay chains are studied. As these resonances lie in the same mass range as the lightest predicted glueball and also share the same quantum numbers, they are candidates to have an admixture of this predicted purely gluonic state. Therefore, this analysis aims to gain insight on the composition of the  $f_0$  states below 2 GeV via the extracted resonance information in search for the lightest glueball. As a fundamental prediction of QCD, experimental evidence for the lightest glueball would greatly contribute to the understanding of the strong interaction. First results of the analysis will be presented in this talk. This work is supported by the DFG under the project number 547123630.

## HK 13: Structure and Dynamics of Nuclei III

Time: Tuesday 16:15–18:45

Location: AM 00.011

### Group Report

HK 13.1 Tue 16:15 AM 00.011

**Fast-Timing Lifetime Measurements Following Thermal-Neutron Capture: Probing Shape Coexistence in Mid-Shell Sn Isotopes** — •V. KARAYONCHEV<sup>1</sup>, F. WU<sup>2</sup>, C. ANDREOIU<sup>2</sup>, C. PETRACHE<sup>3</sup>, J.-M. RÉGIS<sup>4</sup>, C. MICHELAGNOLI<sup>5</sup>, M. BEUSCHLEIN<sup>6</sup>, J. JOLIE<sup>4</sup>, and C.R. DING<sup>7</sup> — <sup>1</sup>ANL, Lemont, IL, USA — <sup>2</sup>SFU, Burnaby, BC, Canada — <sup>3</sup>Université Paris-Saclay, CNRS/IN2P3, IJCLab, Orsay, France — <sup>4</sup>IKP, Köln, Germany — <sup>5</sup>ILL, Grenoble, France — <sup>6</sup>IKP, Darmstadt, Germany — <sup>7</sup>School of Physics and Astronomy, Sun Yat-sen University, Zhuhai, China

Thermal-neutron capture reactions produce high-energy primary  $\gamma$  rays that can be used as clean and selective gates, greatly reducing background in  $\gamma$ - $\gamma$  coincidence measurements. When combined with the fast-timing technique using LaBr<sub>3</sub> detectors, this approach enables precise lifetime measurements of excited states populated through very weak decay branches — states that are often inaccessible with conventional methods. These measurements provide unique insight into the structure of stable nuclei.

This talk will present the methodology of fast timing following thermal-neutron capture and illustrate its capabilities through recent studies of mid-shell tin isotopes. In particular, lifetime and monopole ( $E0$ ) strength measurements of low-lying  $0^+$  states shed new light on shape coexistence phenomena in <sup>116,118,120</sup>Sn. The experimental results will be compared with predictions from Multi-Reference Covariant Density Functional Theory (MR-CDFT).

### Group Report

HK 13.2 Tue 16:45 AM 00.011

**$\gamma$ -ray spectroscopy of neutron-rich radioactive isotopes using two-neutron transfer reactions** — •C.M. NICKEL<sup>1</sup>, V. WERNER<sup>1</sup>, G. RAINOVSKI<sup>2</sup>, A. BLAZHEV<sup>3</sup>, A. ESMAYLZADEH<sup>3</sup>, C. FRANSEN<sup>3</sup>, K.E. IDE<sup>1</sup>, J. JOLIE<sup>3</sup>, K. GLADNISHKI<sup>2</sup>, V. KARAYONCHEV<sup>3</sup>, D. KOICHEVA<sup>2</sup>, R. LICÁ<sup>4</sup>, N.M. MÄRGINEAN<sup>4</sup>, H. MAYR<sup>1</sup>, C. MIHAI<sup>4</sup>, R.E. MIHAI<sup>4</sup>, S. PASCU<sup>4</sup>, N. PIETRALLA<sup>1</sup>, F. VON SPEE<sup>3</sup>, T. STETZ<sup>1</sup>, and R. ZIDAROVA<sup>1</sup> — <sup>1</sup>TU Darmstadt — <sup>2</sup>U Sofia — <sup>3</sup>U Cologne — <sup>4</sup>IFIN-HH

Moderately neutron-rich radioactive nuclei can be efficiently populated by the (<sup>18</sup>O,<sup>16</sup>O) two-neutron transfer reaction. It allows measurements of  $\gamma$ -ray coincidences and angular correlations as well as excited-states' lifetimes, hence, electromagnetic matrix elements. We have recently applied it to Zr, Te, Sm, Er, Yb, Pt and Pb isotopes [1]. Lifetime data on the neutron rich isotopes <sup>210</sup>Pb [2] and <sup>200</sup>Pt [3] were obtained from recoil-distance Doppler-shift experiments at the Cologne and IFIN-HH tandem facilities. Data on <sup>210</sup>Pb solidify a discrepancy in shell-model descriptions of  $2_1^+$  and  $4_1^+$  states around <sup>208</sup>Pb, whereas the expected transition of  $\gamma$ -softness to sphericity towards  $N=126$  is probed in <sup>200</sup>Pt.

[1] T. Stetz, H. Mayr *et al.*, Phys. Rev. C **112**, 034325 (2025).

[2] C.M. Nickel, V. Werner *et al.*, Phys. Rev. C. (2025, accepted).

[3] C.M. Nickel, V. Werner *et al.*, Phys. Rev. C. (2025, submitted).

\*Supported by BMBF (Grant Nos. 05P21RDCI2 and 05P24RD3) and by DFG (GRK 2128 'Accelence', IRTG 2891 'Nuclear Photonics' and INST 216/988-1 FUGG).

HK 13.3 Tue 17:15 AM 00.011

**Lifetime measurement of excited states of <sup>172</sup>W** — •K. E. IDE<sup>1</sup>, V. WERNER<sup>1</sup>, R. ABELS<sup>2</sup>, U. AHMED<sup>1</sup>, D. BITTNER<sup>2</sup>, T. BIESENBACH<sup>2</sup>, A. BLAZHEV<sup>2</sup>, A. ESMAYLZADEH<sup>2</sup>, C. FRANSEN<sup>2</sup>, J. JOLIE<sup>2</sup>, H. KLEIS<sup>2</sup>, C. -D. LAKENBRINK<sup>2</sup>, M. LEY<sup>2</sup>, H. MAYR<sup>1</sup>, M. MÜLLENMEISTER<sup>2</sup>, C. M. NICKEL<sup>1</sup>, R. NOVAK<sup>2</sup>, A. PFEIL<sup>2</sup>, N. PIETRALLA<sup>1</sup>, J. ROOB<sup>2</sup>, F. VON SPEE<sup>2</sup>, T. STETZ<sup>1</sup>, T. SÜLTENFUSS<sup>2</sup>, and R. ZIDAROVA<sup>1</sup> — <sup>1</sup>IKP, TU Darmstadt — <sup>2</sup>IKP, Uni Köln

Nuclear quadrupole collectivity is identified from enhanced  $E2$  decay rates. A sudden increase of the  $E2$  strength of the  $2_1^+ \rightarrow 0_1^+$  transition from  $N=96$  (<sup>170</sup>W) to  $N=98$  (<sup>172</sup>W) in the W isotopic chain is unexpected compared to the neighboring Hf isotopic chain. This discrepancy was investigated by lifetime measurements of <sup>170</sup>W [1] which confirmed the low  $B(E2; 2_1^+ \rightarrow 0_1^+)$  value. In this work we investigate yrast  $B(E2)$  values of <sup>172</sup>W to study the structural evolution of the yrast band in comparison to <sup>170</sup>W. The experiment was performed at the Cologne 10 MV FN-tandem accelerator facility and used the Cologne plunger device [2] and the CATHEDRAL spectrometer. The fast-timing method and the RDDS method are used complementarily to determine the lifetimes of yrast states. First results will be presented and compared to the confined  $\beta$ -soft (CBS) rotor model [3].

[1] K. E. Ide *et al.*, LNL report 2019 (2020).

[2] A. Dewald, O. Möller, and P. Petkov, PNP **67** (2012) 786.

[3] N. Pietralla and O. M. Gorbachenko, PRC **70** (2004) 011304. Supported by DFG (GRK 2128, GRK 2891 'Nuclear Photonics', INST 216/988-1 FUGG) and by BMBF under Grant No. 05P21RDCI2.

HK 13.4 Tue 17:30 AM 00.011

**First measurement of lifetimes of excited states in <sup>176</sup>Hg** — •C.-D. LAKENBRINK<sup>1</sup>, C. MÜLLER-GATERMANN<sup>2</sup>, C. FRANSEN<sup>1</sup>, M. P. CARPENTER<sup>2</sup>, A. DIDIK<sup>1</sup>, C. HEYMER<sup>1</sup>, J. JOLIE<sup>1</sup>, D. SEWERNIAK<sup>2</sup>, and K. WIMMER<sup>1</sup> — <sup>1</sup>Institute for Nuclear Physics, University of Cologne — <sup>2</sup>Physics Division, Argonne Nat'l Laboratory

The neutron-deficient mercury isotopes are known to exhibit shape coexistence between a weakly-deformed oblate  $\pi(0p-2h)$  and a prolate  $\pi(4p-6h)$  configuration [1]. For the very neutron-deficient nucleus <sup>176</sup>Hg the excitation energies of the  $4_1^+$  and  $6_1^+$  states lie at the crossing of these two configurations making an assignment from energy systematics ambiguous [1,2]. Also from the kinematic moments of inertia a structural change is expected between the  $2_1^+$  and  $8_1^+$  states. Transition strengths in the neighboring <sup>178</sup>Hg suggest a configuration mixing in the  $2_1^+$  state and different theoretical models predict this to be the onset of a shape transition with decreasing neutron number [3].

Thus an investigation of transition strengths between the low-lying yrast states in <sup>176</sup>Hg was conducted. The experiment was performed at ANL employing the recoil distance method and recoil-decay tagging.

This work was supported by the German Research Foundation (DFG) under contract number FR 3276/3-1 and by the U.S. Department of Energy under contract number DE-AC02-06CH11357. It used resources of ANL's ATLAS facility, which is a DOE User Facility.

[1] R. Julin *et al.*, J. Phys. G **27**, R109 (2001)

[2] L.P. Gaffney *et al.*, Phys. Rev. C **89**, 024307 (2014)

[3] C. Müller-Gattermann *et al.*, Phys. Rev. C **99**, 054325 (2019)

HK 13.5 Tue 17:45 AM 00.011

**Lifetimes of Excited States in the Normal and Superdeformed Bands of Doubly Magic  $^{40}\text{Ca}$**  — •TIMON SÜLTENFUSS<sup>1</sup>, MAXIMILIAN DROSTE<sup>1</sup>, PETER REITER<sup>1</sup>, ANDREY BLAZHEV<sup>1</sup>, DUY DUC DAO<sup>2</sup>, FRÉDÉRIC NOWACKI<sup>2</sup>, KONRAD ARNSWALD<sup>1</sup>, ANNA BOHN<sup>1</sup>, RAMONA BURGGRAB<sup>1</sup>, HANNAH KLEIS<sup>1</sup>, SARAH PRILL<sup>1</sup>, MICHAEL WEINERT<sup>1</sup>, and DAVID WERNER<sup>1</sup> — <sup>1</sup>Institut für Kernphysik, Universität zu Köln, Zùlpicher Straße 77, 50937 Köln, Germany — <sup>2</sup>Université de Strasbourg, IPHC, 23 rue du Loess, 67037 Strasbourg, France

Lifetimes of excited states in the doubly magic nucleus  $^{40}\text{Ca}$  have been measured in an experiment performed at the FN tandem accelerator of the University of Cologne. Excited states were populated via the  $(p, p'\gamma)$  reaction at a proton beam energy of 15 MeV. The detector array SONIC@HORUS, comprising 12 silicon detectors for charged-particle identification and 14 HPGe detectors for high-resolution  $\gamma$ -ray spectroscopy, was used to measure scattered protons and emitted  $\gamma$ -rays, respectively. Lifetimes of the first excited  $2^+$ ,  $4^+$ , and  $6^+$  states were extracted using the Doppler-Shift Attenuation Method. The new results were compared with recent large-scale shell model calculations, showing excellent agreement for the level scheme as well as the new lifetimes which are identified as members of a normal-deformed structure in  $^{40}\text{Ca}$ . In addition, preliminary lifetime results for states in the superdeformed band of  $^{40}\text{Ca}$  will be presented and compared with state-of-the-art shell-model predictions.

HK 13.6 Tue 18:00 AM 00.011

**RDDS Lifetime Measurements in Neutron-Deficient  $^{172}\text{Os}$**  — •ALINA DIDIK<sup>1</sup>, CHRISTOPH FRANSEN<sup>1</sup>, CASPER-DAVID LAKENBRINK<sup>1</sup>, DANIA AL DAAS<sup>1</sup>, ANDREY BLAZHEV<sup>1</sup>, JAN JOLIE<sup>1</sup>, CARINA HEYMER<sup>1</sup>, FRANZISKUS VON SPEE<sup>1</sup>, KATARZYNA HADYNSKA-KLEK<sup>2</sup>, GRZEGORZ JAWORSKI<sup>2</sup>, MICHALINA KOMOROWSKA<sup>2</sup>, MICHAL KOWALCZYK<sup>2</sup>, ADAM NALECZ-JAWECKI<sup>2</sup>, PAWEŁ NAPIORKOWSKI<sup>2</sup>, MARCIN PALACZ<sup>2</sup>, KRYSZTOF RUSEK<sup>2</sup>, and KATARZYNA WRZOSEK-LIPSKA<sup>2</sup> — <sup>1</sup>IKP, University of Cologne, Germany — <sup>2</sup>Heavy Ion Laboratory, University of Warsaw, Poland

In the lighter isotopes  $^{168,170}\text{Os}$  the  $B_{4/2} = B(E2; 4_1^+ \rightarrow 2_1^+)/B(E2; 2_1^+ \rightarrow 0_1^+)$  ratios drop far below the values expected for collective nuclei, indicating a rapid structural change, explained only very recently to result from strong band mixing including triaxiality. The nucleus  $^{172}\text{Os}$  appears to lie just at the boundary of this evolution. Earlier data on transition strengths [1] suggest rotor-like behavior for the  $2_1^+$  and  $4_1^+$  states, but a sharp increase of the  $B(E2)$  values from the  $6_1^+$  and  $8_1^+$  states hints for structural changes within the lower yrast states. However, the latter is not expected from the level energy systematics. To clarify this discrepancy, we performed a new RDDS experiment on  $^{172}\text{Os}$  at HIL using the Cologne plunger combined with the EAGLE  $\gamma$ -ray spectrometer. For the first time, level lifetimes were determined from a  $\gamma\gamma$  coincidence analysis to eliminate the need for assumptions on delayed feeding in contrast to the earlier dataset. Supported by the DFG, Grant No. FR 3276/3-1.

[1] A. Virtanen et al., Nucl. Phys. A591, 145 (1995)

HK 13.7 Tue 18:15 AM 00.011

**Determination of ground-state decay level width in  $^{27}\text{Al}$  using the temperature-dependent self-absorption technique** — •K. PRIFTI<sup>1</sup>, V. WERNER<sup>1</sup>, N. PIETRALLA<sup>1</sup>, U. AHMED<sup>1</sup>, M. BAUMANN<sup>1</sup>, M. BEUSCHLEIN<sup>1</sup>, J. BORMANS<sup>1,2</sup>, I. BRANDHERM<sup>1</sup>, M. L. CORTES<sup>1</sup>, B. GÖTZ<sup>1</sup>, A. GUPTA<sup>1</sup>, J. HAUF<sup>1</sup>, B. HESBACHER<sup>1</sup>, M. HEUMÜLLER<sup>1</sup>, K. E. IDE<sup>1</sup>, J. ISAAK<sup>1</sup>, I. JUROSEVIC<sup>1</sup>, J. KLEEMANN<sup>1</sup>, P. KOSEOGLOU<sup>1</sup>, J. LU<sup>1</sup>, H. MAYR<sup>1</sup>, C. M. NICKEL<sup>1</sup>, O. PAPST<sup>1</sup>, T. RAMAKER<sup>1</sup>, M. RECH<sup>1</sup>, D. M. RICHTER<sup>1</sup>, T. M. SEBE<sup>3,4</sup>, T. STETZ<sup>1</sup>, and R. ZIDAROVA<sup>1</sup> — <sup>1</sup>IKP, TU Darmstadt — <sup>2</sup>GSI, Darmstadt — <sup>3</sup>ELI-NP, IFIN-HH, Romania — <sup>4</sup>Politehnica Bucharest, Romania

The first temperature-dependent relative self-absorption (TRSA) measurement was conducted at the Darmstadt High-Intensity Photon Setup (DHIPS) at the superconducting Darmstadt linear electron accelerator (S-DALINAC) on the nucleus  $^{27}\text{Al}$  using a bremsstrahlung photon beam with an endpoint energy of 5.5 MeV. This technique enables the separation of the natural linewidth of the nuclear transition from the Doppler broadening caused by the thermal motion of atoms in the solid target. The present work aims to measure the ground-state decay width of the 3957 keV level with high precision. Measurements were performed with and without an absorbing target at three different temperatures: 77 K, 320 K, and 600 K. The technique and its connection to both nuclear and atomic theory will be presented with a discussion of the results. This work was supported by the DFG under Project-ID 279384907-SFB 1245 and Project-ID 499256822-GRK 2891 "Nuclear Photonics".

HK 13.8 Tue 18:30 AM 00.011

**Results and recent updates for electron-gamma coincidence experiments at the S-DALINAC** — •BASTIAN HESBACHER<sup>1</sup>, J. BIRKHAN<sup>1</sup>, J. ISAAK<sup>1</sup>, D. H. JAKUBASSA-AMUNDSEN<sup>2</sup>, O. MÖLLER<sup>1</sup>, N. PIETRALLA<sup>1</sup>, T. RAMAKER<sup>1</sup>, D. RICHTER<sup>1</sup>, X. ROCA-MAZA<sup>3</sup>, D. SCHNEIDER<sup>1</sup>, and G. STEINHILBER<sup>1</sup> — <sup>1</sup>Institut für Kernphysik, TU Darmstadt, Germany — <sup>2</sup>Mathematisches Institut, LMU München, Germany — <sup>3</sup>INFN, Sezione di Milano, Italy

The all-electromagnetic  $(e, e'\gamma)$  reaction had first been used for nuclear structure measurements in the 1980s [1]. Since then very few experiments were based on this reaction. In 2021 first successful  $(e, e'\gamma)$  measurements were performed at the S-DALINAC with improved resolution of electron energy, gamma energy and coincidence time by two orders of magnitude [2]. The scattered electrons were registered with the QCLAM spectrometer. The  $\gamma$ -radiation was detected by  $\text{LaBr}_3\text{:Ce}$  detectors. Measurements on  $^{12}\text{C}$  and  $^{96}\text{Ru}$  targets were performed and demonstrated the superior performance of the new facility over previous attempts to study  $(e, e'\gamma)$  reactions. Results on the  $\gamma$ -decay behaviour and angular distributions of  $^{96}\text{Ru}$  will be presented. In addition, recent updates for the experimental setup will be presented which enhance the performance for upcoming experimental campaigns.

This work is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 279384907 - SFB 1245

[1] C. N. Papanicolas et al., Phys. Rev. Lett. **54**, 26 (1985).[2] B. Hesbacher et al., Nucl. Instrum. Methods Phys. Res. A **1078**, 170574 (2025).

## HK 14: Structure and Dynamics of Nuclei IV

Time: Tuesday 16:15–18:45

Location: AM 00.021

### Group Report

HK 14.1 Tue 16:15 AM 00.021

**Collinear laser spectroscopy reveals signatures of triaxial deformation in neutron-rich Ru** — •KRISTIAN KÖNIG for the ATLANTIS-Collaboration — TU Darmstadt

The region of refractory metals below tin exhibits a diverse spectrum of nuclear phenomena, i.e. quickly changing deformations and shape coexistence. Particularly, in the neutron-rich Ru isotopes, there are indications for triaxial ground state deformations. This was explored at a new collinear laser spectroscopy setup (ATLANTIS) installed at the low-energy branch of CARIBU at Argonne National Laboratory. There, a californium-252 fission source can uniquely produce sufficiently intense low-energy ion beams of neutron-rich isotopes in this part of the nuclear chart. Laser spectroscopy was performed in  $^{96,98-102,104,106-114}\text{Ru}$  and charge radii as well as electromagnetic moments were extracted. The findings are compared to the latest BSkG models, which are energy density functionals of the Skyrme type. These comparisons reveal clear signatures of triaxial ground states in the neutron-rich Ru isotopes.

This work was supported by DFG Project-ID 279384907-SFB 1245, BMBF 05P19RDFN1 and NSF Grant No. PHY-21-11185, and by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357, with resources of ANL's ATLAS facility, an Office of Science User Facility.

HK 14.2 Tue 16:45 AM 00.021

**Investigating the GDR of  $^{164}\text{Dy}$  using NRF** — •M. HEUMÜLLER<sup>1</sup>, J. KLEEMANN<sup>1</sup>, N. PIETRALLA<sup>1</sup>, A. D. AYANGEAKA<sup>2,3</sup>, S. W. FINCH<sup>2,4</sup>, D. GRIBBLE<sup>2,3</sup>, J. HAUF<sup>1</sup>, J. ISAAK<sup>1</sup>, X. K.-H. JAMES<sup>2,3</sup>, R. V. F. JANSSENS<sup>2,3</sup>, S. R. JOHNSON<sup>2,3</sup>, T. KOWALEWSKI<sup>2,3</sup>, B. LÖHER<sup>5</sup>, O. PAPST<sup>1</sup>, K. PRIFTI<sup>1</sup>, A. SARACINO<sup>2,3</sup>, D. SAVRAN<sup>5</sup>, N. SENSHARMA<sup>2,3</sup>, and V. WERNER<sup>1</sup> — <sup>1</sup>IKP, TU Darmstadt — <sup>2</sup>TUNL, Durham, NC, USA — <sup>3</sup>U. of NC, Chapel Hill, USA — <sup>4</sup>Duke U., Durham, USA — <sup>5</sup>GSI, Darmstadt

The GDR's geometrical model provides predictions for the  $\gamma$ -decay behavior in elastic photon and  $2_1^+$  Raman scattering reactions. To rigorously test these for the first time, a photonuclear experiment was recently performed on the GDRs of the spherical and deformed nuclides  $^{140}\text{Ce}$  and  $^{154}\text{Sm}$ , respectively, at the High Intensity  $\gamma$ -ray Source (HiγS) at TUNL, USA [1]. HiγS's quasi-monochromatic, polarized, and tunable photon beam was employed to selectively photoexcite energy slices of the GDR and subsequently measure their  $\gamma$ -decay. The results are in stunning agreement with the geometrical model predictions. A similar NRF experiment was conducted on the GDR of the strongly deformed  $^{164}\text{Dy}$  at HiγS.  $^{164}\text{Dy}$  is of particular interest due to its suspected higher degree of triaxiality. Experimental  $\gamma$ -ray spectra and the current status of the data analysis will be presented.

This work is supported by the DFG under Project-ID 499256822 – GRK 2891 "Nuclear Photonics" – and US DOE under No. DE-FG02-97ER41041 (UNC), No. DE-FG02-97ER41033 (TUNL).

[1] J. Kleemann et al., Phys. Rev. Lett. **134**, 022503 (2025).

HK 14.3 Tue 17:00 AM 00.021

**Vibrations, rotations and single-particle excitations in  $^{168}\text{Dy}$**  — •JOHAN EMIL LINNÉSTAD LARSSON<sup>1,2,3</sup>, HELENA ALBERS<sup>3</sup>, JEROEN BORMANS<sup>1,2,3</sup>, MAGDALENA GÓRSKA<sup>3</sup>, TUOMAS GRAHN<sup>4</sup>, COSTEL M. PETRACHE<sup>5</sup>, NORBERT PIETRALLA<sup>1</sup>, and VOLKER WERNER<sup>1,2</sup> — <sup>1</sup>Technische Universität Darmstadt, 64289 Darmstadt, Germany — <sup>2</sup>Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI, 64289 Darmstadt, Germany — <sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — <sup>4</sup>University of Jyväskylä and Helsinki Institute of Physics, P.O. Box 35, FI-40014 Jyväskylä, Finland — <sup>5</sup>Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France

The low excitation energies of first excited  $2^+$  states in the rare-earth nuclei close to the mid-shell are an indicator of their degree of deformation, and it reveals more complicated dependencies on neutron number [1].

In order to further study these isotopes, we performed the first ever projectile-fragmentation of  $^{170}\text{Er}$  with an energy of 1 GeV/u at the GSI Helmholtzzentrum für Schwerionenforschung GmbH. The key isotope of  $^{168}\text{Dy}$  was cleanly separated, identified and implanted in the DESPEC setup [2]. The newly observed transitions and transition probabilities reveal novel structures in  $^{168}\text{Dy}$ , as well as providing a new interpretation of the isotope.

References: [1] Z. Patel et al., PRL 113, 262502 (2014). [2] A. Mistry et al., NIM A 1033, 166662 (2022).

HK 14.4 Tue 17:15 AM 00.021

**Nuclear structure in heavy neutron-rich nuclei in the vicinity of  $N=126$  and northwest of  $^{132}\text{Sn}$  via multinucleon-transfer reactions** — •RAINER ABELS and PETER REITER for the AGATA22.04-Collaboration — IKP, Universität zu Köln, Germany

Multinucleon-transfer (MNT) reactions offer a powerful tool to access to access exotic neutron-rich nuclei. Excited reaction products from the  $^{136}\text{Xe} + ^{208}\text{Pb}$  system at 1 GeV were investigated using the high-resolution  $\gamma$ -ray tracking array AGATA coupled to the mass spectrometer PRISMA at LNL, Italy positioned at the grazing angle. For the beam-like fragments, energy  $E$ , atomic number  $Z$ , velocity  $\beta$ , charge state  $q$ , and mass number  $A$  were measured over the range  $Z = 52-58$ , enabling a clean selection of the nuclei of interest. Kinematic coincidences were exploited to enhance the identification of the hard-to-reach neutron-rich lead isotopes on the target-like side. Mass-yield distributions have been extracted and compared with calculations from the GRAZING model for MNT reactions. Based on the relative cross-section systematics for different transfer channels, the capabilities and limitations for the production of the hard-to-reach neutron-rich isotopes with this experimental method will be discussed. Preliminary results on excited states of beam-like nuclei in the Xe-Ba mass region will also be presented.

Supported by the German BMBF under 05P21PKFN9 and ENSAR2-TNA.

HK 14.5 Tue 17:30 AM 00.021

***Ab initio* description of deformed nuclei from angular-momentum projection** — •MUALLA AYTEKIN<sup>1</sup>, BENJAMIN BALLY<sup>1</sup>, THOMAS DUGUET<sup>2</sup>, and ALEXANDER TICHAI<sup>1,3,4</sup> — <sup>1</sup>Technische Universität Darmstadt, Department of Physics — <sup>2</sup>IRFU, CEA, Université Paris-Saclay — <sup>3</sup>ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — <sup>4</sup>Max-Planck-Institut für Kernphysik, Heidelberg

Atomic nuclei are complex quantum many-body systems that exhibit rich emergent collective behavior. To understand how such phenomena arise from the underlying nuclear forces, we investigate neon and magnesium isotopes using *ab initio* methods. We will present axially deformed mean-field calculations based on chiral two- and three-nucleon interactions and, via angular-momentum projection, explore the low-lying spectroscopy of the ground-state rotational bands. Finally, we will outline recent developments towards a projected coupled-cluster framework aimed at providing a unified description of both nuclear bulk properties and collective features. These developments open the door to a systematic and consistent treatment of deformed nuclei across the nuclear chart.

\* Funded by the ERC Grant Agreement No. 101162059.

HK 14.6 Tue 17:45 AM 00.021

**Electromagnetic response of nuclei using Gogny energy density functionals** — •NITHISH KUMAR COVALAM VIJAYAKUMAR<sup>1,2</sup>, GABRIEL MARTÍNEZ-PINEDO<sup>2,1</sup>, LUIS MIGUEL ROBLEDO MARTÍN<sup>3</sup>, and SAMUEL ANDREA GIULIANI<sup>3</sup> — <sup>1</sup>Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>3</sup>Universidad Autónoma de Madrid, Madrid, Spain

Electromagnetic response of nuclei plays an important probe in the understanding of nuclear structure. This quantity is fundamental for the description of neutron capture and photodissociation rates for r-process nucleosynthesis. R-process studies require calculations of many nuclei and typically the response is extracted by using linear response approaches such as quasiparticle random phase approximation (QRPA). But the standard QRPA approach is computationally expensive. A more efficient way of solving the QRPA equations based

on Finite amplitude method (FAM) was introduced and thus making its applications more advantageous for heavy nuclei. In this work, we have developed a FAM computer code using the finite range Gogny energy density functionals and axial symmetry preserving Hartree-Fock-Bogoliubov framework. Various test calculations of the new code and the comparison of electromagnetic response results with standard QRPA calculations and available experimental data was performed. We also plan to extend the approach of FAM in the context of nuclear fission for evaluating collective inertias.

HK 14.7 Tue 18:00 AM 00.021

**Coulomb excitation of  $^{212}\text{Ra}$  at HIE-ISOLDE** — •H. MAYR<sup>1</sup>, G. RAINOVSKI<sup>2</sup>, N. PIETRALLA<sup>1</sup>, and V. WERNER<sup>1</sup> for the ISOLDE IS748-Collaboration — <sup>1</sup>TU Darmstadt — <sup>2</sup>Sofia University, Bulgaria

The generalised seniority scheme is a truncated version of the nuclear shell model [1] applicable to the structure of atomic nuclei in the vicinity of shell closures. The number of unpaired nucleons, the seniority  $\nu$ , is considered an approximate quantum number. The region of the even-even Po-Rn-Ra nuclei with  $N=124$  exhibits strong signs of seniority-like behaviour, e.g. the energy spacing between yrast states decreases with increasing angular momentum. However, no data is available to confirm or falsify the anticipated parabolically increasing trend in the absolute  $E2$  transition strength with the filling of the  $j$ -shell for the  $\Delta\nu = 2$  seniority-changing  $2_1^+ \rightarrow 0_1^+$  transition [2]. Therefore, a Coulomb-excitation experiment was conducted at HIE-ISOLDE in 2024 in order to obtain the  $B(E2; 2_1^+ \rightarrow 0_1^+)$  value of  $^{212}\text{Ra}$ . The  $^{212}\text{Ra}$  beam was impinged on a  $^{120}\text{Sn}$  target with 4.5 MeV/u.  $\gamma$  rays of deexciting  $^{212}\text{Ra}$  nuclei were observed by the Miniball array [3]. Particles were recorded by a DSSD. The  $B(E2; 2_1^+ \rightarrow 0_1^+)$  value is deduced from  $\gamma$ -ray yields. The status of the analysis will be presented.

[1] I. Talmi, Nucl. Phys. A **172**, 1 (1971).

[2] J. J. Ressler et al., Phys. Rev. C **69**, 034317 (2004).

[3] N. Warr et al., Eur. Phys. J. A **49**, 40 (2013).

Supported by the BMFTR (05P24RD3, 05P24PKC11), Horizon Europe (101057511), the ELI-RO programme (RDI/2024-007 ELITE) and the Romanian Ministry of Research and Innovation (PN23210106).

HK 14.8 Tue 18:15 AM 00.021

**The vanishing  $\nu 11/2^- [505]$  extruder orbital** — •JEROEN PETER BORMANS<sup>1,2,3</sup>, JOHAN EMIL LINNÉSTAD LARSSON<sup>1,2,3</sup>, MAGDALENA GÓRSKA<sup>2</sup>, HELENA ALBERS<sup>2</sup>, TUOMAS GRAHN<sup>4</sup>, COSTEL MARIAN PETRACHE<sup>5</sup>, NORBERT PIETRALLA<sup>1</sup>, and VOLKER WERNER<sup>1</sup> — <sup>1</sup>Technische Universität Darmstadt, 64289 Darmstadt, Germany — <sup>2</sup>Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI, 64289 Darmstadt, Germany — <sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — <sup>4</sup>University of Jyväskylä and Helsinki Institute of Physics, P.O. Box 35, FI-40014 Jyväskylä, Finland — <sup>5</sup>Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France

The single-particle structure of neutron-rich odd- $N$  Sm isotopes is of interest for judging the structural role of the  $\nu 11/2^- [505]$  orbital in describing the sudden onset of deformation. In the mass  $A \sim 150$  region, this sudden onset has been attributed to the interplay between the spherical-driving extruder ( $h_{11/2}$ ) orbital and deformation-driving intruder orbital(s) ( $i_{13/2}$ ) [1]. We have conducted a gamma-ray spectroscopy experiment with the DESPEC setup at GSI, where excited states of the neutron-rich rare-earth nuclei were populated with the projectile fragmentation of a  $^{170}\text{Er}$  beam impinging on a thick  $^9\text{Be}$  target. The results of the measurement on  $^{157,159}\text{Sm}$  will be presented and discussed.

[1] P. Kleinheinz et al., PRL **32**, 68 (1974).

HK 14.9 Tue 18:30 AM 00.021

**Shell Evolution towards  $N = 32$ : Inelastic Scattering of  $^{49}\text{K}_{30}$  and  $^{51}\text{K}_{32}$**  — •DEBAJYOTI DAS<sup>1,2</sup>, KATHRIN WIMMER<sup>2,3</sup>, SIDONG CHEN<sup>4</sup>, TING GAO<sup>4</sup>, and MARINA PETRI<sup>4</sup> for the RIBF249-Collaboration — <sup>1</sup>IKP, TU Darmstadt, Darmstadt, Germany — <sup>2</sup>GSI, Darmstadt, Germany — <sup>3</sup>IKP, Universität zu Köln, Germany — <sup>4</sup>University of York, UK

The evolution of nuclear shell structure far from stability provides key insights into nuclear forces. In recent years, significant experimental and theoretical efforts have been focused on the emergence of sub-shell closures at neutron numbers  $N = 32$  and 34 in neutron-rich Ca isotopes. In particular, the strength of the shell gap and the extent of the validity of these new magic numbers for neighboring proton numbers have been under investigation. In neutron-rich potassium isotopes, the proton  $1s_{1/2}$  and  $0d_{3/2}$  single-particle orbitals are inverted compared to the normal ordering. At  $^{51}\text{K}$ , with  $N = 32$ , the ground state re-emerges as  $3/2^+$ . How this re-inversion of proton single-particle levels between  $^{49}\text{K}$  and  $^{51}\text{K}$  influences the development of the neutron sub-shell closure at  $N = 32$  remains an open question. To address this, we investigate the collective nature of  $^{49,51}\text{K}$  and compare it with  $^{50,52}\text{Ca}$  nuclei studied in the same experiment. Inelastic scattering in inverse kinematics at relativistic beam energies was performed at the RNC/RIBF facility.  $\gamma$  rays from excited states were detected using the DALI2<sup>+</sup> array together with the newly developed HYPATIA detectors. In this talk, I will present an overview of the experiment and show preliminary results for  $^{49,51}\text{K}$  Coulomb and nuclear excitations.



## HK 15: Heavy-Ion Collisions and QCD Phases II

Time: Tuesday 16:15–18:45

Location: PHIL C 601

HK 15.1 Tue 16:15 PHIL C 601

**Flow phenomena at high nuclear densities with HADES** — •BEHRUZ KARDAN for the HADES-Collaboration — Goethe-Universität, Frankfurt am Main  
Heavy-ion collisions in the few-GeV energy range create strongly interacting matter at extreme baryon densities, comparable to those in neutron star mergers. Precise measurements of the dense-matter *Equation-of-State* in this regime are therefore essential for the understanding of neutron stars.

We present new results from HADES (*High-Acceptance Dielectron Spectrometer*) located at the SIS18, GSI Darmstadt, the only current setup capable of measuring rare and penetrating probes at the high- $\mu_B$  frontier of the QCD phase diagram.

High-statistics measurements of collective flow for protons and light nuclei are reported in Au+Au and Ag+Ag collisions at  $\sqrt{s_{NN}} = 2.42$  and 2.55 GeV, along with recent Au+Au data at  $\sqrt{s_{NN}} = 1.98, 2.07, 2.16$ , and 2.24 GeV, extending the excitation function to lower beam energies (200 – 800 AMeV).

Beyond directed and elliptic flow, flow coefficients  $v_n$  up to 6<sup>th</sup> order are measured for the first time in this energy range, enabling a 3D characterization of angular particle emission in momentum space. Furthermore, the event-by-event flow fluctuations can be explored via correlations between the different flow coefficients, providing even stronger constraints on the *Equation-of-State*, and will also be presented.

This work was supported by the Helmholtz Forschungsakademie HFHF and GSI F&E.

HK 15.2 Tue 16:30 PHIL C 601

**Low-mass, low-momentum virtual photon measurement with HADES** — •IULIANA-CARINA UDREA for the HADES-Collaboration — TU Darmstadt/GSI GmbH  
Collisions of heavy nuclei at relativistic energies create a hot and dense medium, offering a unique environment to explore its microscopic properties using electromagnetic probes.

Dileptons are particularly advantageous for this purpose, as they do not interact strongly with the surrounding matter, allowing them to carry undisturbed information about the QCD matter produced during the reaction.

In particular, low-invariant-mass and low-momentum dileptons are highly sensitive to the transport properties of the system, providing a means to identify signatures of novel phases, such as precursor phenomena of color superconductivity, in dense QCD matter.

In this contribution, we outline the key steps towards investigating soft dileptons. For this purpose data from Ag+Ag collisions at 1.23A GeV with a nominal magnetic field strength are compared with a reduced magnetic field (5% of  $B_{max}$ ), the latter increasing the acceptance for low-momentum leptons. Additionally, we will present the new data collected in 2025 for Au+Au collisions at 0.8A GeV with a lower magnetic field strength, allowing us to study the low-mass and low-momentum dileptons in more detail.

This work is supported by: GSI F&E and HGS-HIRE.

HK 15.3 Tue 16:45 PHIL C 601

**Characterising the hot and dense fireball with virtual photons at HADES** — •NIKLAS SCHILD for the HADES-Collaboration — TU Darmstadt, Darmstadt, Germany

The High-Acceptance Di-Electron Spectrometer (HADES) at GSI, Darmstadt, investigates heavy-ion and elementary collisions at beam energies of a few GeV, providing valuable insights into QCD matter at high densities and moderate temperatures. One key aspect of HADES is the study of these collisions via rare electromagnetic probes, which offer unique access to the evolution of the system due to their penetrating nature.

In this contribution, we present recent measurements of dielectron production from Ag+Ag collisions at  $\sqrt{s_{NN}} = 2.55$  GeV and  $\sqrt{s_{NN}} = 2.42$  GeV. Expanding on previous results, we aim to study dielectron spectra in a multi-differential manner, considering observables such as invariant mass, centrality, rapidity, and transverse momentum. This not only provides detailed information about the properties of the hot and dense medium created in the collisions, but also allows for a more refined and differential comparison with theoretical models. This will be crucial for advancing our understanding of the thermal radiation emitted by the medium and, as such, can help to further constrain and improve existing descriptions.

This work has been supported by BMFTR and HGS-HIRE.

HK 15.4 Tue 17:00 PHIL C 601

**Dielectron analysis in p+p collisions at 1.58 GeV beam energy with HADES** — •KARINA SCHARMANN for the HADES-Collaboration — Justus-Liebig-Universität Gießen

In this contribution we present preliminary results on the dielectron production in p+p interactions at 1.58 GeV beam energy measured with the High

Acceptance DiElectron Spectrometer (HADES). The HADES RICH detector has been upgraded with a new photon detection camera which strongly enhances the electron efficiency and conversion pair rejection. With this upgrade, a signal-to-background ratio above 1 is achieved over the entire dielectron spectrum. 0.5 billion collisions have been analyzed showing a contribution of  $\pi^0$  and  $\eta$  Dalitz decays in a signal up to an invariant mass of 600 MeV/c<sup>2</sup>. Furthermore, by analyzing elastic  $p + p$  collisions, a normalization procedure for differential cross sections has been established. Additionally, collisions with the empty target (target mounting) provide a p+Mylar spectrum and allow the extraction of a p+n reference spectrum.

The p+p and p+n dielectron spectra can serve as a baseline for the understanding and interpretation of Ag+Ag collisions which have been measured in HADES at the same energy. A precise understanding of the dielectron production in elementary reactions is needed to disentangle the various contributions to the measured dielectron yield in Ag+Ag collisions.

HK 15.5 Tue 17:15 PHIL C 601

**Dissecting the moat regime at low energies** — •SHI YIN and FABIAN RENNECKE — Justus Liebig University Giessen, Heinrich-Buff-Ring 16 D-35392 Giessen

Dense QCD matter can feature a moat regime, where the static energy of mesons is minimal at nonzero momentum. Valuable insights into this regime can be gained using low-energy models. This, however, requires a careful assessment of model artifacts. We therefore study the effects of renormalization and in-medium modifications of quark-meson interaction on the moat regime. To capture the main effects, we use a two-flavor quark-meson model at finite temperature and baryon density in the random phase approximation. We put forward a convenient renormalization scheme to account for the nontrivial momentum dependence of meson self-energies and discuss the role of renormalization conditions for renormalization group consistent results on the moat regime. In addition, we demonstrate that its extent in the phase diagram critically depends on the interaction of quarks and mesons.

HK 15.6 Tue 17:30 PHIL C 601

**Hydrodynamic attractors in periodically driven weakly and strongly coupled systems** — •SIMON SCHNEIDER<sup>1</sup>, SÖREN SCHLICHTING<sup>2</sup>, ALEKSAS MAZELIAUSKAS<sup>3</sup>, LOUIS ONWUKA<sup>4</sup>, MARTIN VRDOLJAK<sup>5</sup>, and TOSHALI MITRA<sup>6</sup>  
— <sup>1</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>2</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>3</sup>Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg, Germany — <sup>4</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>5</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>6</sup>Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg, Germany

We study equilibration and hydrodynamic response in systems undergoing periodic expansion and contraction in one spatial direction. We use strongly coupled holographic, weakly coupled kinetic and hydrodynamic frameworks to study the shear response to periodic drive for different amplitudes and frequencies. Unlike the monotonic Bjorken expansion, the system does not approach equilibrium or even Navier-Stokes behavior. For small drive amplitudes and frequencies, the late time cyclic attractor is universal across systems and is described by MIS theory. For large drive amplitudes, the non-linear heating induces the drift in the system properties and the attractor behaviour.

HK 15.7 Tue 17:45 PHIL C 601

**Numerical simulations of stochastic fluids via the Metropolis algorithm** — •MATTIS HARHOFF<sup>1</sup>, SÖREN SCHLICHTING<sup>1</sup>, and LORENZ VON SMEKAL<sup>2,3</sup>  
— <sup>1</sup>Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, Bielefeld, 33615, Germany — <sup>2</sup>Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392, Gießen, Germany — <sup>3</sup>Helmholtz Forschungsakademie Hessen für FAIR (HFHF), Campus Gießen, 35392, Gießen, Germany

Stochastic hydrodynamics provides a dynamical framework for the evolution of fluctuations in heavy-ion collisions, but poses significant challenges in numerical simulations. We present an algorithm for the simulation of non-relativistic stochastic hydrodynamics in two spatial dimensions in a box, both in the cases of compressible and incompressible fluids. We use the robust Metropolis algorithm, handling fluctuations and dissipation at once by systematically replacing dissipative terms in the hydrodynamic equations by random forces. The algorithm can easily be modified for numerical simulations of other hydrodynamic theories. We present test cases as well as numerical calculations of the renormalization of shear viscosity, and give an outlook to critical dynamics and relativistic theories.

HK 15.8 Tue 18:00 PHIL C 601

**Event Generator Comparison for Centrality Studies in Heavy-Ion Collisions at FAIR Energies** — •BEATRIZ ARTUR — IKF, Goethe-Universität Frankfurt

The initial geometry of a relativistic heavy-ion collision greatly influences important observables of the strongly interacting matter, such as collective flow or event-by-event fluctuations of conserved quantities. Experimentally, it cannot be measured directly, so other observables have to be used as a proxy. The multiplicity of produced charged particles at mid-rapidity or the energy deposition of the forward-going spectator particles can be used, for instance. In this work, we compare different event generators, such as PHQMD, DCM-QGSM-SMM and SMASH+afterburner for centrality studies. We look specifically into the fragment production in the forward direction, since all models employ different methods for cluster production. Implications on an optimized strategy for centrality determination and consequent definition of the reaction volume will be discussed.

HK 15.9 Tue 18:15 PHIL C 601

**Monte-Carlo sampling of nucleon positions in the nuclear shell model for heavy-ion collisions** — •LISA KRÖGER<sup>1</sup>, OSCAR GARCIA-MONTERO<sup>2</sup>, and SÖREN SCHLICHTING<sup>1</sup> — <sup>1</sup>Bielefeld University — <sup>2</sup>University of Santiago de Compostela

Recently, it has been shown that investigating the structure of atomic nuclei is essential for correct description of fluctuations imprinted into the initial stage of a heavy-ion collision event. In fact, the examination of the  $N$ -body density distributions has shown to be crucial for better understanding deeply inelastic scattering (DIS) and nucleus-nucleus collisions [1]. Motivated by the recent interest to represent quantitatively the structure properties of the incoming nuclei, we present a new sampling algorithm which takes on account quantum correlations of the nuclear many-body wave function. Using the nuclear shell model (NSM) as a proof of concept model, a Markov Chain Monte Carlo method algorithm was implemented in order to generate nucleon positions, according to the full  $N$ -nucleon probability distribution. We benchmark it by comparing our numer-

ical results to the analytic one- and two-body densities. By using this algorithm, quantum correlations in the nucleus are then imprinted into the positions. Additionally, the usage of the NSM permits the extension of this algorithm to large systems, such as Au and Pb, which are still prohibitively expensive for full *ab-initio* computations. We explore the impact of these new sources of fluctuation on the creation of long-range correlations by exploring initial state observables sensitive to the  $N$ -body densities, such as the initial eccentricities, extracted from the novel McDIPPER model [2].

HK 15.10 Tue 18:30 PHIL C 601

**Dependence of resonance parameters on the pion momentum spectra** — •TIM WEINREICH — Physikalisches Institut, Universität Heidelberg

Ultrarelativistic heavy-ion collisions, which are studied at the Large Hadron Collider and Relativistic Heavy Ion Collider, are believed to create a deconfined state of matter called the Quark-Gluon-Plasma. It has been demonstrated that this state can be adequately described by relativistic viscous hydrodynamics. However, some of the measured observables or features observed in experimental data remain to be fully understood.

For instance, the pion spectrum at low transverse momentum indicates a discrepancy between experimental data and hydrodynamic models. One potential explanation for this phenomenon is the insufficient treatment of resonances that contribute to the total particle spectra. In fact, heavy-ion collision models typically neglect or omit uncertainties in all resonance parameters, e.g., resonance masses, decay widths, and branching ratios.

This talk presents a systematic study investigating the dependence of resonance parameter uncertainties on the pion production. This study is conducted using the FASTRESO [1] framework to calculate the irreducible spectral components for resonance decays.

This work is funded via the DFG ISOQUANT Collaborative Research Center (SFB 1225).

[1] Mazeliauskas, A. *et al.* Eur. Phys. J. C 79, 284 (2019)

**HK 16: Nuclear Astrophysics II**

Time: Tuesday 16:15–18:30

Location: PHIL A 602

**Group Report**

HK 16.1 Tue 16:15 PHIL A 602

**Constraining the s-Process Path Using Indirect Methods at MESA and FAIR** — •TANJA HEFTRICH<sup>1</sup>, JAN BUTZ<sup>1</sup>, PIERRE CAPEL<sup>2</sup>, LEON FÄHNRIK<sup>1</sup>, ALINA GOTTSCHALK<sup>1</sup>, CAROLIN GRÜN<sup>1</sup>, MICHAEL HEIL<sup>3</sup>, FELIX PANHOLZER<sup>1</sup>, RENÉ REIFARTH<sup>4</sup>, CONCETTINA SFIENTI<sup>2</sup>, MONICA ALEJANDRA SANJINEZ ORTIZ<sup>2</sup>, and DAVUD SOKOLOVIC<sup>1</sup> — <sup>1</sup>Goethe University Frankfurt — <sup>2</sup>Johannes Gutenberg University Mainz — <sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung — <sup>4</sup>Los Alamos National Laboratory

The slow neutron-capture process (s-process) is responsible for the synthesis of about half of the elements heavier than iron in stellar environments. Its modeling relies critically on precise neutron-capture cross sections, in particular for unstable nuclei that are not directly accessible to conventional measurements.

In this contribution, we present indirect approaches to determine  $(n, \gamma)$  reaction rates relevant for the s-process. In Mainz at the future MESA accelerator, neutron-capture cross sections are constrained via the inverse reaction using electron-induced processes, using  $(e, e'n)$  reaction to access the nuclear response to virtual photons. Complementarily, experiments at FAIR employ Coulomb breakup measurements of the type  $(\gamma^*, n)$  at the R3B setup, where electromagnetic excitation in the Coulomb field of a heavy target provides access to the radiative capture process by detailed balance.

HK 16.2 Tue 16:45 PHIL A 602

**Results for the  $(n, \gamma)$ -reaction on natural Krypton via the activation method.** — •JAN BUTZ, LEON FÄHNRIK, CAROLIN GRÜN, ALINA GOTTSCHALK, TANJA HEFTRICH, SAMIRA IKERKOURN, FELIX PANHOLZER, and DAVUD SOKOLOVIC — Goethe-Universität, Frankfurt am Main, Germany

An important step in understanding the origin of life is to study stellar nucleosynthesis. The abundance of elements up to iron is produced almost exclusively through nuclear fusion, whereas most heavy elements are formed via neutron-capture in the s- and r-processes. The s-process occurs inside the shell burning of massive and asymptotic giant branch stars, while the r-process, however, requires extreme conditions, like type II supernovae or neutron star mergers.

Krypton plays a vital role in the s-process due to the branching points of <sup>81</sup>Kr and <sup>85</sup>Kr. These branching points are nuclei where the decay rate is of the same order of magnitude as the neutron capture rate,  $r_\beta \approx r_n$ . To gain insight into these points, it is crucial to study the  $(n, \gamma)$  reaction and how these nuclei behave under stellar conditions. The cross sections for the <sup>78</sup>Kr( $n, \gamma$ ), <sup>79</sup>Kr and <sup>84</sup>Kr( $n, \gamma$ )<sup>85m</sup>Kr reactions could be determined at various temperatures using a natural krypton sample and the activation method. The resulting values and outlook will be presented.

HK 16.3 Tue 17:00 PHIL A 602

**Updates on constraining the <sup>95</sup>Zr( $n, \gamma$ ) cross section via the Oslo-method** — •TOM SITTIG<sup>1</sup>, ABDALLAH KARAKA<sup>1</sup>, ANNA BOHN<sup>1</sup>, ARTEMIS SPYRO<sup>2</sup>, DEVIN HYMER<sup>1</sup>, MARKUS MÜLLENMEISTER<sup>1</sup>, MICHAEL WEINERT<sup>1</sup>, SARAH PRILL<sup>1</sup>, SEBASTIAN SCHRÖDER<sup>1</sup>, and DENNIS MÜCHER<sup>1</sup> — <sup>1</sup>Institute of Nuclear Physics, University of Cologne, Cologne, Germany — <sup>2</sup>Facility for Rare Isotope Beams, Michigan State University, East Lansing, Michigan, USA

The <sup>95</sup>Zr( $n, \gamma$ ) cross section is of pivotal understanding for the slow neutron capture process (s-process) as the long-lived <sup>95</sup>Zr isotope is a branching point at which  $\beta$ -decay is in competition with the production of <sup>96</sup>Zr.

In the case of the unstable isotope <sup>95</sup>Zr, a direct measurements of the neutron capture cross section is currently not possible. Using the Oslo method, we have constrained the neutron capture cross section of <sup>95</sup>Zr( $n, \gamma$ ) experimentally, for the first time. We utilized the <sup>96</sup>Zr( $p, p'$ ) reaction at the 10 MV FN-Tandem accelerator of the Institute for Nuclear Physics at the University of Cologne using the SONIC@HORUS detector array. We have successfully used the newly developed "Shape" method to significantly reduce the model uncertainties of our result by extracting the absolute nuclear level density at the neutron separation energy.

The preliminary results of these measurements and their impact on the s-process will be presented.

**Group Report**

HK 16.4 Tue 17:15 PHIL A 602

**Study of the <sup>14</sup>N( $\alpha, \gamma$ )<sup>18</sup>F reaction at Felsenkeller underground lab with the gas-jet target setup** — •ANUP YADAV<sup>1,2</sup>, DANIEL BEMMERER<sup>1</sup>, KONRAD SCHMIDT<sup>1</sup>, ELIANA MASHA<sup>1</sup>, AXEL BOELTZIG<sup>1</sup>, PETER HEMPEL<sup>1,2</sup>, and KAI ZUBER<sup>2</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf (HZDR) — <sup>2</sup>Technische Universität Dresden

A precise reaction rate for <sup>14</sup>N( $\alpha, \gamma$ )<sup>18</sup>F is required for modeling stellar evolution. The <sup>14</sup>N( $\alpha, \gamma$ )<sup>18</sup>F reaction takes place during the helium-burning phase in asymptotic giant branch (AGB) stars other helium-burning sites. This reaction influences different nucleosynthesis pathways and is part of the reaction chains <sup>14</sup>N( $\alpha, \gamma$ )<sup>18</sup>F( $\beta^+$ )<sup>18</sup>O( $\alpha, \gamma$ )<sup>22</sup>Ne and <sup>14</sup>N( $\alpha, \gamma$ )<sup>18</sup>F( $\beta^+$ )<sup>18</sup>O( $p, \alpha$ )<sup>15</sup>N( $\alpha, \gamma$ )<sup>19</sup>F, which are important for the production of <sup>22</sup>Ne and <sup>19</sup>F, respectively. However, at helium-burning energies the cross section is dominated by low-energy resonances whose properties remain insufficiently constrained. The reaction was studied at the Felsenkeller shallow-underground laboratory using a newly developed gas-jet target setup, in which an  $\alpha$  beam was directed onto a nitrogen gas jet and the emitted  $\gamma$  rays were

detected with high-purity germanium detectors. Precise angular distributions, branching ratios, resonance energies, and strengths were measured for three selected resonances at  $E_r = 573, 1136, \text{ and } 1618 \text{ keV}$ , with the lowest-energy resonance being relevant for helium-burning temperatures. We will present the new experimental results and discuss their astrophysical impact. Future measurements using the gas-jet target at the Felsenkeller underground laboratory will also be outlined.

HK 16.5 Tue 17:45 PHIL A 602

**Low energy resonances in the  $^{15}\text{N}(\alpha, \gamma)^{19}\text{F}$ -reaction** — •PETER HEMPEL<sup>1,2</sup>, DANIEL BEMMERER<sup>1</sup>, AXEL BOELTZIG<sup>1</sup>, ELIANA MASHA<sup>1</sup>, FELIX MAYER<sup>1,2</sup>, KONRAD SCHMIDT<sup>1</sup>, SIMON VINCENT<sup>2,3</sup>, ANUP YADAV<sup>1,2</sup>, and KAI ZUBER<sup>2</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf (HZDR) — <sup>2</sup>TU Dresden — <sup>3</sup>Deutsches Zentrum für Astrophysik (DZA)

The  $^{15}\text{N}(\alpha, \gamma)^{19}\text{F}$ -reaction contributes to fluorine production in several astrophysical sites including AGB stars, type II supernovae, and Wolf Rayet stars. The reaction occurs during the helium burning phase. However, the reaction rate at astrophysical energies is still poorly known. Here we report on data from a measurement of astrophysically relevant resonances in the 0.5 - 1.1 MeV center of mass energy range. The experiment has been carried out at the Felsenkeller 5 MV shallow-underground accelerator in Dresden using tantalum nitride solid targets enriched in  $^{15}\text{N}$  and the new FelicitAS  $4\pi$  BGO  $\gamma$ -ray calorimeter.

HK 16.6 Tue 18:00 PHIL A 602

**Constraining r-process nucleosynthesis with multi-objective Galactic chemical evolution models** — •MARTA MOLERO — Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 2, Darmstadt 64289, Germany

The astrophysical site(s) of the r-process are uncertain, with candidates such as neutron star mergers and magneto-rotational supernovae predicting different event rates, delay times, and heavy-element yields. Galactic chemical evolution models constrain these properties by comparing model predictions with observed abundances. We explore, in a systematic and data-driven way, the astrophysical conditions under which r-process enrichment can reproduce the observed trends of multiple neutron-capture elements in the Milky Way. Rather

than assuming a fixed site, we adopt a flexible, parametric approach to test whether a common set of r-process parameters can explain the chemical evolution of several heavy elements. We compute a grid of one-infall, homogeneous models varying: Eu yield per event, r-process event rate, enrichment delay time, and progenitor mass range. For each of the  $\sim 10^5$  models, we predict  $[\text{X}/\text{Fe}]$  vs.  $[\text{Fe}/\text{H}]$  trends by scaling Eu yields with the solar r-process pattern. A multi-objective optimisation based on Pareto fronts identifies models that best reproduce the abundance trends. In this talk, I will present and discuss best fitting Eu models as well as the limitations in reproducing, at the same time, both light and heavy neutron-capture elements, reflecting how the solar r-process scaling relation becomes less robust towards lightest elements.

HK 16.7 Tue 18:15 PHIL A 602

**Constraining neutron capture rates for the r-process** — •CHRISTIAN SCHLAIER<sup>1</sup>, JESSICA BERKMAN<sup>2</sup>, KONSTANTINOS BOSMOTINIS<sup>2</sup>, SEAN LIDDICK<sup>2</sup>, ANDREA RICHARD<sup>2</sup>, ARTEMIS SPYROU<sup>2</sup>, and DENNIS MUECHER<sup>1</sup> — <sup>1</sup>Institute for Nuclear Physics, University of Cologne, Cologne, Germany — <sup>2</sup>FRIB, Michigan State University, USA

The formation of the second r-process peak ( $A \approx 130$ ) depends critically on neutron capture rates of nuclei below  $^{132}\text{Sn}$ . Current theoretical predictions for these rates vary by orders of magnitude.

In 2025, an experiment at the Facility for Rare Isotope Beams (FRIB) at the Michigan State University was performed, aiming to experimentally constrain the neutron capture rates of these key nuclei for r-process nucleosynthesis, for the first time. The measurement utilized the  $\text{SuN}^{++}$  setup, which consists of the Summing NaI and CeBr3 ( $\text{SuN}^{++}$ ) detector coupled with an Double Sided Strip Detector (DSSD) for particle identification and beam correlation. A cocktail beam of neutron-rich isotopes centered around  $^{128}\text{Ag}$  was implanted into the setup to measure  $\beta$ -decay properties. The high efficiency and  $4\pi$  coverage of  $\text{SuN}^{++}$  allow for the precise determination of  $\beta$ -decay intensities and the extraction of statistical nuclear properties, such as nuclear level densities and  $\gamma$ -ray strength functions. This contribution will discuss the experimental procedure and present preliminary results.

## HK 17: Instrumentation III

Time: Tuesday 16:15–18:15

Location: PHIL A 301

### Group Report

HK 17.1 Tue 16:15 PHIL A 301

**The MAGIX Experiment at MESA** — •DAVID MARKUS — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

At the new high-intensity, low-energy electron accelerator MESA, construction of the multi-purpose MAGIX experiment is in the final phases and preparations for the first physics run are underway. This first run with beam is planned to both provide a new more precise measurement of the transition form factor between the Hoyle state and the ground state of carbon-12 and to provide data to calibrate the new detectors, using a thin diamond foil as target.

In the future, MAGIX will use a gas jet target, which will be capable of operating with a variety of gases and enable a new frontier in high precision electron scattering experiments. Combined with MESA's high intensity electron beam and two high precision magnetic spectrometers, these experiments aim to contribute to the study of hadron structure and few-body systems, as well as investigations of reactions relevant to nuclear astrophysics and into the dark sector.

In the focal plane of the spectrometers, which are connected windowlessly to the scattering chamber, the two detector systems of MAGIX are installed, a time projection chamber for particle tracking and a trigger veto system combining plastic scintillation detectors and passive lead absorbers for particle identification and triggering.

This contribution outlines the physics program at MAGIX and provides an overview of both the setup of MAGIX and the planned first physics experiment.

HK 17.2 Tue 16:45 PHIL A 301

**GEM detectors for AMBER - Production and streaming readout** — •SHANIA MÜLLER<sup>1,2</sup>, PASCAL HENKEL<sup>1</sup>, MAX KNAUSEDER<sup>1,2</sup>, JAKOB KRAUSS<sup>1,2</sup>, JONATHAN KUNECKE<sup>1,2</sup>, JAN PASCHEK<sup>1,2</sup>, and BERNHARD KETZER<sup>1,2</sup> — <sup>1</sup>Helmholtz-Institut für Strahlen- und Kernphysik, University of Bonn, Germany — <sup>2</sup>Forschungs- und Technologiezentrum Detektorphysik

The AMBER experiment at CERN's Super Proton Synchrotron is a facility that explores how the fundamental properties of mesons and baryons emerge from the underlying quark and gluon dynamics. In its first physics runs in 2023 and 2024, the experiment measured cross-sections for antiproton production in hadron-hadron collisions. The run in 2025 has been a preparation run for the upcoming proton electric form-factor measurement using a high-energy muon beam, showing the feasibility of the planned experimental program.

To measure the trajectories of scattered muons downstream of the target close

to the beam, a new generation of  $30 \times 30 \text{ cm}^2$  triple-GEM detector stations are being produced and integrated into the setup. These detectors are constructed and characterized in the laboratories at the University of Bonn. To fulfill the requirements for this physics program a new free-streaming data acquisition system was established. To match the free-streaming mode, the self-triggering VMM3a front-end chip was implemented to readout the GEM detectors.

This talk will present the construction procedure of the detectors, their quality assurance and the characterization using the new readout system. Supported by BMFTR.

HK 17.3 Tue 17:00 PHIL A 301

**Drift-field distortion corrections of the ALICE TPC in LHC Run 3** — •JANIS JÄGER for the ALICE Germany-Collaboration — Institut für Kernphysik, Goethe-Universität Frankfurt

At CERN's Large Hadron Collider (LHC), the Time Projection Chamber (TPC) of the ALICE experiment provides an excellent tracking and particle identification performance. For LHC Run 3, the Multiwire Proportional Chambers (MWPCs) were replaced with stacks of four Gas Electron Multiplier (GEM) foils to cope with the high interaction rates of up to 50 kHz and enabling a continuous data acquisition. Despite the low intrinsic ion-backflow properties of the 4-GEM setup, a residual amount of ions, produced during the amplification process, drift back into the active volume of the TPC, leading to space-charge distortions of the drift field. Further effects such as geometric imperfections and interaction rate variations lead to additional static and time-dependent drift-field distortions. These drift-field distortions need to be corrected to preserve the intrinsic particle tracking precision of the ALICE TPC.

This talk will give an overview of the observed drift-field distortions in the ALICE TPC in Run 3, together with the correction procedure and its precision.

Supported by BMFTR and the Helmholtz Association.

HK 17.4 Tue 17:15 PHIL A 301

**A New Automatised Wire Tension Measurement for the CBM-TRD Chambers** — •HANNES OLBRING for the CBM-Collaboration — Institut für Kernphysik, Universität Münster

At the Facility for Antiproton and Ion Research (FAIR) in Darmstadt the Compressed Baryonic Matter (CBM) experiment is currently being built. The goal of the experiment is to study the QCD phase diagram at high net baryon densities using heavy ion collisions at interaction rates of up to 10 MHz.

The Transition Radiation Detector (TRD) of CBM is based on Multi-wire Proportional Chambers (MWPCs). The wire electrodes of the MWPCs will be produced with a well-controlled mechanical wire tension, dictated by the requirements on the electrostatic deflection caused by high voltages applied to the wires. To check the proper tension prior and after the wire gluing, a wire tension measurement device needs to be built. The wires will be brought to (harmonic) oscillation by an air blast, such that the actual measurement of the tension can be achieved by measuring the oscillation frequency. This talk will focus on commissioning and first performance measurements of a newly constructed wire tension measurement device and its automatisations.

We thank our colleagues from IFIN-HH, Măgurele, Romania, in particular Marian Olteanu, for the collaboration on developing this new device. This work is supported by BMFTR grant 05P24PM1.

HK 17.5 Tue 17:30 PHIL A 301

**Hit Position Reconstruction and Tracking with the CBM-TRD in mCBM Beam Data** — •HENNING PAUELS for the CBM-Collaboration — Institut für Kernphysik, Universität Münster

The Compressed Baryonic Matter (CBM) experiment is a fixed-target experiment currently under construction at FAIR in Darmstadt. It is designed to investigate the QCD phase diagram at high net-baryon densities using heavy-ion beams from the SIS100 accelerator.

The Transition Radiation Detector (TRD) will play an important role in both the identification and the tracking of particles in CBM. To further confirm its performance as part of the future full CBM experiment, TRD modules were included in the in-beam measurements of the mCBM setup at the SIS18 facility at GSI. Consisting of modules of almost all of CBM's subdetectors, mCBM performed data taking and reconstruction under high-rate conditions. This talk will focus on the TRD hit and track reconstruction using two TRD modules operated in mCBM runs.

This work is supported by BMFTR grant 05P24PM1.

HK 17.6 Tue 17:45 PHIL A 301

**Developing radiopurity screening with alpha spectrometry for the LEGEND experiment** — •CHRISTOPH SEIBT, BJÖRN LEHNERT, STEFFEN TURKAT, and KAI ZUBER for the LEGEND-Collaboration — TU Dresden

LEGEND is one of the leading experiments in the search for neutrinoless double-beta ( $0\nu\beta\beta$ ) decay. With its second phase, LEGEND-1000, the experiment uses one ton of germanium crystals enriched in  $^{76}\text{Ge}$  to reach a discovery potential of half-lives greater than  $10^{28}$  years.

However, to reach this sensitivity, an extremely low background level of  $10^{-5}$  cts/(keV kg yr) at  $Q_{\beta\beta}$  is necessary. One step towards this goal is to minimize the radioactivity of all components and to classify them with material screening methods.

We report on our recent efforts in developing alpha spectrometry with improved sensitivity beyond commercial low background solutions. Using an Frisch-gridded ionization chamber offers a high resolution and allows an analysis on individual radionuclides of one decay chain. In addition, we are sensitive to surface contaminations of less than  $0.5 \text{ mBq/m}^2$  for  $^{238}\text{U}$  and  $^{232}\text{Th}$ . This presentation will show the optimization of the energy resolution, efforts in background reduction and first screening measurements with test samples.

This work is supported by: U.S. DOE, NSF, LANL, ORNL and LBNL LDRD programs; European ERC and Horizon programs; German DFG, BMBF, and MPG; Italian INFN; Polish NCN and MNiSW; Czech MEYS; Slovak RDA; Swiss SNF; UK STFC; Canadian NSERC and CFI; LNGS and SURF facilities.

HK 17.7 Tue 18:00 PHIL A 301

**LHCb OT Straw-Tube Modules in mCBM: Integration and First Beam-Time Results** — •LUCA SCHRÄMM for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt

Several of the former LHCb Outer Tracker (OT) straw tube modules were successfully installed and evaluated in the mini CBM (mCBM) test environment. The CERN-LHCb collaboration donated the OT straw tube detector to GSI. The aim is to install it as part of the Forward Tracking Systems in FAIR experiments such as PANDA and recently also as part of the Muon Detector of the CBM.

During the spring of 2025, the LHCb modules were operated under varied high-voltage and threshold settings during heavy-ion beam tests at GSI to assess performance stability. The contribution will present the beam-test setup and results obtained. A joint PANDA-CBM cooperation developed simulation and reconstruction software to enable the analysis of beam-test data. The results demonstrate consistent straw tube performance across the tested conditions, confirming the detector's readiness for integration into either experiment.

## HK 18: Instrumentation IV

Time: Tuesday 16:15–18:15

Location: PHIL B 302

HK 18.1 Tue 16:15 PHIL B 302

**The LowRAD project: achieving ultra-low background for the future liquid xenon experiments** — •YING-TING LIN, CHRISTIAN WEINHEIMER, VOLKER HANNEN, CHRISTIAN HUHMANN, LUTZ ALTHÜSER, DANIEL WENZ, ROBERT BRAUN, DAVID KOKE, PHILIPP SCHULTE, and PATRICK UNKHOFF — Universität Münster, Institut für Kernphysik

Liquid xenon (LXe) has become a cornerstone medium for rare event detection, including searches for dark matter and neutrino physics. To achieve an order of magnitude improvement in sensitivity for the next generation LXe experiment such as XLZD, the requirement of having ultra-low background must be satisfied, as even a trace amount of radioactive impurity can impact the sensitivity of the detector. The LowRAD project aims to establish the guidelines for the construction of cryogenic distillation systems capable of reducing the concentrations of the most critical radioactive impurities,  $^{222}\text{Rn}$  and  $^{85}\text{Kr}$ , to unprecedented levels. Demonstrators are actively under construction with their performance systematically evaluated. This talk will present the working principles and design choices of each system, including a multi-column configuration that maximizes xenon recovery and a novel heat pump dedicated to LXe distillation. Furthermore, online diagnostic systems are planned to enable continuous monitoring of, crucially, the level of background reduction. The emphasis will be placed not only on the performance, but also on the integrative design philosophy that ensures scalability and long-term operation.

Supported by the ERC Advanced Grant "LowRad" (101055063).

HK 18.2 Tue 16:30 PHIL B 302

**Measuring the nuclear spin polarization of a pulsed  $\text{H}^-$  ion source** — •SIMON JAKOB PÜTZ<sup>1,2,4</sup>, TAREK EL-KORDY<sup>5</sup>, RALF ENGELS<sup>2</sup>, NICOLAS FAATZ<sup>1,2,6</sup>, RALF GEBEL<sup>1</sup>, KIRILL GRIGORYEV<sup>1</sup>, CHRYSOVALANTIS KANNIS<sup>3</sup>, YURY VALDAU<sup>1</sup>, JAN WIRTZ<sup>1</sup>, and YURY LITVINOV<sup>1</sup> — <sup>1</sup>GSI, Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt — <sup>2</sup>Institut für Kernphysik, Forschungszentrum Jülich, Wilhelm-Johnen-Straße, 52428 Jülich — <sup>3</sup>Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf — <sup>4</sup>Institut für Kernphysik, Universität zu Köln, Zùlpicherstraße 77, 50937 Köln — <sup>5</sup>FH Aachen, University of Applied Sciences, Bayernallee 11, 52066 Aachen — <sup>6</sup>RWTH Aachen, Otto-Blumenthal-Straße 19, 52074 Aachen

At the Forschungszentrum Jülich, the COSY accelerator was fed with polarized

$\text{H}^-$  /  $\text{D}^-$  ions for stripping injection into the ring. For polarized beamtimes, knowing the initial polarization directly behind the source is essential before conducting experiments. An automated and reliable data acquisition system was developed to improve the time and energy efficiency of the process. For this purpose, the applicability of the Lamb-shift polarimeter was expanded to include pulsed  $\text{H}^-$  and  $\text{D}^-$  ion beams. Unlike other methods, the LSP is capable of measuring the nuclear spin polarization of particle beams in the keV energy range. The presented study addresses the optimization of nuclear spin polarimetry for upcoming polarized sources of the COSY type without pre-acceleration.

HK 18.3 Tue 16:45 PHIL B 302

**Design of a High-Power Liquid Hydrogen Target for the P2 Experiment at MESA using CFD** — SEBASTIAN BAUNACK<sup>1</sup>, MAARTEN BONNEKAMP<sup>2,4</sup>, BORIS GLÄSER<sup>1</sup>, SHRUTI GUDLA<sup>1</sup>, RAHIMA KRINI<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, JAYANTA NAIK<sup>1</sup>, MORAN NEHER<sup>1</sup>, TOBIAS RIMKE<sup>1</sup>, PAUL SCHÖNER<sup>2</sup>, •SIDDHARTH THAKKER<sup>1</sup>, and MALTE WILFERT<sup>1</sup> for the P2-Collaboration — <sup>1</sup>Institut für Kernphysik, Johannes Gutenberg-Universität Mainz — <sup>2</sup>Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — <sup>3</sup>PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz — <sup>4</sup>IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

The upcoming P2 experiment at the MESA accelerator in Mainz aims to detect parity-violating asymmetries in elastic electron-proton scattering. It is designed for a determination of the weak mixing angle,  $\sin^2 \theta_W$ , to a high precision of 0.16% at low momentum transfer.

To measure this small asymmetry with high precision, the experiment requires a high-luminosity, 60 cm liquid hydrogen ( $\text{IH}_2$ ) target cell, which is designed using Computational Fluid Dynamics (CFD). The total heat deposited by the electron beam into the target cell materials is estimated to be over 3100 W, with a total loop heat load of 4000 W. The  $\text{IH}_2$  flowing through the cell is cooled by a heat exchanger coupled to a helium coolant supply. Additionally, a dedicated gas system is being constructed to manage all required operational gases. This talk presents the CFD simulations of the target cell, the design of the target loop and gas system, and an introduction to the P2 experiment itself.

HK 18.4 Tue 17:00 PHIL B 302

**Completion of the  $\bar{\text{PANDA}}$  cluster-jet target setup** — •HANNA EICK, DANIEL BONAVENTURA, PHILIPP BRAND, LIRIDON DEDA, FRIEDERIKE RUMMLER, MICHAEL WEIDE, and ALFONS KHOUKAZ for the PANDA-Collaboration — Institute for Nuclear Physics, University of Münster, Germany

Cluster-jet targets offer a wide range of potential applications, due to their unique windowless and internal design, making them an attractive choice for various experimental settings. A powerful state-of-the-art cluster target source, specifically designed and constructed for the future  $\bar{\text{PANDA}}$  experiment at FAIR, has been successfully assembled and integrated with a dedicated target setup at COSY/Jülich. This target system will play a decisive role in the upcoming KOALA experiment at the GSI in Darmstadt over the next years. To optimize its performance, a comprehensive study has been conducted to investigate the target's properties, focusing on vacuum pressure distributions along the target beam line and target jet density at different stagnation conditions. Furthermore, a newly commissioned beam dump, equipped with multiple diagnostic tools, has undergone intensive testing. This presentation highlights the key findings, with particular emphasis on achieving a high target density of up to  $10^{15}$  atoms/cm<sup>2</sup> at the interaction point and  $> 2.1$  m behind the jet nozzle, while maintaining minimal residual pressure background, through careful adjustment of the orifice system within the beam dump. This project has received funding from GSI F&E (MSKHOU2023, MSKHOU2527), NRW Netzwerke (NW21-024-E), BMBF (05P21PMFP1).

HK 18.5 Tue 17:15 PHIL B 302

**New nozzle production method and vacuum simulations for the  $\bar{\text{PANDA}}$  cluster-jet target** — •MICHAEL WEIDE, DANIEL BONAVENTURA, PHILIPP BRAND, HANNA EICK, SOPHIA VESTRICK, and ALFONS KHOUKAZ for the PANDA-Collaboration — Institut für Kernphysik, Universität Münster, 48149 Münster, Germany

In antiproton-proton annihilation experiments such as the upcoming  $\bar{\text{PANDA}}$  experiment at FAIR, internal targets have a key role as they allow the accelerator beam to be utilized for multiple interactions with the target. Initially, this target will be realized by a cluster-jet target (CJT) operated with H<sub>2</sub>, that produces clusters of sizes  $\leq 20$  microns in diameter.

Due to the costly production of antiprotons, a challenge of such an experiment is minimizing background reactions. Thus, good vacuum conditions are mandatory. To predict the vacuum conditions for an experimental setup, a vacuum simulation model is developed and compared with experimental data recorded at a similar experimental setup at COSY (FZ Jülich).

The core piece of a CJT is a copper de-Laval nozzle, for which a new in-house production process is being developed at the Institute of Nuclear Physics at the University of Münster. This allows to perform detailed analysis on the influence of the geometry and shape of the nozzle. The current status as well as beam studies of the new nozzle design are presented.

The research project was supported by BMBF (05P21PMFP1) and NRW Netzwerke (NW21-024-E).

HK 18.6 Tue 17:30 PHIL B 302

**The cryogenic windowless jet target for e-p scattering experiments at MAGIX at MESA** — •LIRIDON DEDA, PHILIPP BRAND, JOST FRONING, and ALFONS KHOUKAZ — Institut für Kernphysik, Universität Münster, 48149 Münster, Germany

MAGIX experiment will provide a versatile physics program, ranging from studies of baryonic matter structure to searches for dark sector particles. By combining the high-intensity, energy-recovering electron beam of MESA with a state-of-

the-art windowless jet target, MAGIX aims to perform high-precision e-p scattering experiments without target background. The MAGIX jet target is designed to be operated with various gases, including hydrogen, helium, and almost all heavier gases. A target thickness of more than  $10^{18}$  atoms/cm<sup>2</sup> is delivered at the interaction point when using hydrogen. Achieving such high target thickness requires a high gas flow rate at cryogenic temperatures, which is then pressed through a de Laval nozzle. The nozzle geometry defines how the target expands, thus numerical simulations of the jet's formation and propagation are necessary to understand and optimize the target performance. In this contribution, the setup, performance, and development of the MAGIX jet target including various simulations for different gases will be presented and discussed. Additionally, the adaptation for the generation of a frozen filament jet structure will be described.

This project has received funding from CRC1660 (project number 514321794).

HK 18.7 Tue 17:45 PHIL B 302

**Development and Commissioning of an RFQ Cooler-Buncher for Laser Spectroscopy** — •FINN KÖHLER<sup>1</sup>, JULIAN PALMES<sup>1</sup>, BERNHARD MAASS<sup>2</sup>, KRISTIAN KÖNIG<sup>1</sup>, and WILFRIED NÖRTERSHÄUSER<sup>1</sup> — <sup>1</sup>Institut für Kernphysik, TU Darmstadt, Germany — <sup>2</sup>Physics division, Argonne National Laboratory, USA

At rare-isotope beam facilities, radio-frequency-based beam cooler-bunchers (RFQCB) are particularly used to prepare ion beams for high-precision experiments at low energies ( $< 50$  keV). They can accumulate rare beams for up to several seconds, cool them through collisions with a buffer gas, and emit ion bunches with a short time and energy width. This contribution will report on the development of a new, compact RFQCB that produces ion bunches well suited for laser spectroscopy measurements at the Collinear Apparatus for Laser Spectroscopy and Applied Physics (COALA) in Darmstadt. A two level differential pumping scheme allows for a high-pressure region at the entrance of the RFQCB to efficiently capture incoming ions despite its short length. A laser ablation ion source is included at the injection side of the device to give access to a wide variety of ion species. We will report on the first commissioning results at COALA. As a next step, the device will serve as an injector, paving the way for laser-spectroscopy studies of ion bunches separated and extracted directly from a multi-reflection time-of-flight (MR-ToF) mass spectrometer. This project was supported by DFG (Project-ID 279384907 - SFB 1245) and BMBFTR (05P24RD8).

HK 18.8 Tue 18:00 PHIL B 302

**Characterization of hydrogen clusters using shadowgraphy measurements** — •ANNA LUNA HANNEN, HANNA EICK, and ALFONS KHOUKAZ — Institute for Nuclear Physics, University of Münster, Germany

Cluster-jet targets can be used in accelerator beam experiments that require high event rates and precise measurements of the resulting particles, for example the upcoming  $\bar{\text{PANDA}}$  experiment or MAGIX the experiment.

The properties of a cluster beam and the individual clusters can be studied using e.g. shadowgraphy measurements. The cluster beam is created using a cluster-jet source. The clusters are then illuminated with a short-pulsed laser, allowing the shadow of the clusters to be photographed. Through the analysis of the resulting shadowgraphy images, the size and velocity distributions of the clusters can be determined.

Measurements were taken at the Münster cluster-jet target using shadowgraphy, and size distributions were already measured as a result. Future goals are to refine the measurements and analysis of the shadowgraphy images.

This talk provides an overview of the shadowgraphy experiment and the new developments in the shadowgraphy measurements. This research project was supported by BMBF (05P21PMFP1) and NRW Netzwerke (NW21-024-E).

## HK 19: Invited Talks

Time: Wednesday 11:00–13:00

Location: MED 00.915

### Invited Talk

HK 19.1 Wed 11:00 MED 00.915

**Nucleosynthesis of heavy elements in explosive astrophysical environments** — •DANIEL SIEGEL — Institut für Physik, Universität Greifswald

The astrophysical origin of about half of the elements heavier than iron - those synthesized via rapid neutron capture (the r-process) - remains an open problem. Multimessenger astronomy with gravitational waves has revolutionized the way we observe the Universe and linked neutron-star mergers to r-process nucleosynthesis via emission from the radioactive decay of r-process nuclei (a kilonova). However, ample evidence ranging from first-principle arguments to observations of stellar spectra of metal-poor stars and Galactic archeology indicate that a significant if not dominant fraction of r-process nucleosynthesis should be associated with the death of massive stars. Starting from neutron-star mergers, I will discuss recent theoretical and observational developments on heavy-element formation in the death of (massive) rotating stars (collapsars, magnetorotational supernovae, and the accretion-induced collapse of white dwarfs). As new observational capabilities such as the James Webb Space Telescope yield first exquisite

results, multi-messenger astronomy may soon lead to new and perhaps surprising answers to the long-standing, fundamental question of how the Universe creates its heaviest elements.

### Invited Talk

HK 19.2 Wed 11:30 MED 00.915

**Recent results from laser spectroscopy with CRIS at ISOLDE: nuclear structure studies and beyond** — •JESSICA WARBIENEK for the CRIS-Collaboration — CERN, Switzerland — KU Leuven, Belgium

Over the past decade, collinear resonance ionization spectroscopy (CRIS) has developed into a versatile platform for studying atomic and nuclear properties of rare and short-lived quantum systems. CRIS enables high-precision measurements of trends in nuclear charge radii, electromagnetic moments, and the determination of nuclear spins across the nuclear chart, even for isotopes produced at rates as low as a few tens of ions per second. Recent advances have significantly improved the sensitivity toward the most exotic isotopes and expanded the scope and versatility of the technique.

CRIS has opened a new experimental frontier through the first study of short-lived radioactive molecules, in particular RaF, which provide promising platforms for precision tests of fundamental symmetries and searches for physics beyond the standard model at low energies. The production and studies of negative molecular ions further lay the groundwork for proposed future cooling and trapping approaches.

This contribution highlights recent results from CRIS and experimental developments instrumental in achieving them. Future opportunities for precision studies of exotic nuclei at ISOLDE will be outlined.

**Invited Talk** HK 19.3 Wed 12:00 MED 00.915

**QCD at FAIR: Strong QCD Across Communities** — •JOHAN MESSCHENDORP<sup>1</sup> and FRANK NERLING<sup>1,2</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — <sup>2</sup>Institut für Kernphysik, Goethe-Universität Frankfurt, Frankfurt, Germany

Hadron physics lies at the intersection of several communities, linking QCD theory and effective approaches to emergent phenomena in hadrons and nuclei, the behavior of strongly interacting matter under extreme conditions, and the macroscopic properties of compact stars. In this plenary talk, we will highlight the synergy and added value of a coherent mid- and long-term hadron-physics agenda at GSI/FAIR ("QCD at FAIR") as a common language, leveraging shared facilities across fields – from precision studies of hadron-hadron interactions and hadron spectroscopy to in-medium modifications and electromagnetic transition form factors – thereby connecting hadron and nuclear structure, heavy-ion physics, and astro(particle) physics. We outline a staged roadmap from SIS18 to SIS100 and, ultimately, high-intensity antiproton beams at HESR, and discuss the resulting impact on 'strong QCD'.

**Invited Talk**

HK 19.4 Wed 12:30 MED 00.915

**New Directions in Micropattern Gaseous Detector Technologies** — •PHILIP HAUER — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn — Forschungs- und Technologiezentrum Detektorphysik, Universität Bonn

Micropattern Gaseous Detectors (MPGDs) have become a cornerstone technology in modern particle, hadron, and nuclear physics experiments, providing charged-particle tracking over large areas with high spatial resolution, exceptional rate capability, and a minimal material budget. The next generation of experiments demands even greater performance regarding high-rate and low material budget.

This talk will review the research and development activities driving this evolution. A crucial step is to further improve on the amplification stage by using novel approaches including optimized geometries or advanced materials. Concurrently, the research path extends beyond these core advancements to address systemic challenges. This includes the development of stable high-voltage powering schemes for large-area detectors, and the design of highly integrated, radiation-tolerant readout electronics.

This talk reviews recent advancements and directions in MPGD technologies. The practical realization will be illustrated through their implementation in exemplary current detectors and their role in the design of upcoming experiments, underlining how continued MPGD innovation is essential to unlock the physics potential of future experiments.

Supported by BMFT.

## HK 20: Focus Session: QCD@FAIR

Time: Wednesday 13:45–15:45

Location: AM 00.014

**Group Report** HK 20.1 Wed 13:45 AM 00.014

**"QCD at FAIR" – A hadron physics driven campaign towards FAIR completion** — •FRANK NERLING — GSI Helmholtz Centre for Heavy Ion research, Darmstadt, Germany, Helmholtz Research Academy Hesse for FAIR, Campus Frankfurt — Goethe University Frankfurt

A newly established initiative has successfully been launched to strengthen the First Science(+) programme of the upcoming FAIR accelerator facility, also in view of anti-protons delivered by the High Energy Storage Ring in the future. While investigating fundamental questions related to the strong interaction in the non-perturbative regime, the overarching goal is to keep the expertise and interest of the community in hadron physics at FAIR. In this Focus Session, the hadron physics opportunities at the existing and upcoming experiments at SIS18/SIS100 of GSI/FAIR as summarised in the corresponding White Paper are discussed.

**Group Report** HK 20.2 Wed 14:05 AM 00.014

**Physics opportunities for hadron physics at FAIR** — •CHRISTOPH HANHART — IAS-4, Forschungszentrum Jülich, 52428 Jülich

In this talk I will discuss the physics program planned for proton and pion induced reactions at FAIR. In particular I will highlight two cases: The perspectives to measure hyperon-nucleon and hyperon-hyperon scattering lengths and to study the hidden charm pentaquarks, so far seen only at LHCb.

**Group Report** HK 20.3 Wed 14:25 AM 00.014

**Hadron physics studies at the pion beams facility with HADES** — •MANUEL LORENZ for the HADES-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI) — Goethe University Frankfurt

We present the physics program of  $\pi$ -N and  $\pi$ -A reactions up to  $\sqrt{s} \approx 2.35$  GeV at the GSI pion-beam facility in combination with the HADES spectrometer. On proton targets, the program enables systematic studies of baryon resonances and their electromagnetic structure up to the third resonance region. Differential cross sections and polarization observables are used in Partial-Wave Analyses to tightly constrain baryon-meson and baryon-virtual-photon couplings, in particular  $\rho N$  and  $\omega N$ . Moreover,  $e^+e^-$  measurements probe the electromagnetic transition form factors in the time-like region and clarify the role of vector mesons. On nuclear targets, pion beams provide excellent kinematic conditions, with small relative momenta in the final state, enhancing sensitivity to medium effects. This allows us to explore vector-meson propagation in cold nuclear matter and to study the production of hidden- and open-strangeness particles. The same kinematics are ideally suited to investigate hypernuclei formation from low-relative-momentum strange baryons. In addition, these measurements provide a crucial connection to neutrino-nucleus interaction modeling by delivering high-precision hadronic baselines that constrain the reaction dynamics underlying long-baseline neutrino-oscillation experiments.

**Group Report**

HK 20.4 Wed 14:45 AM 00.014

**Spectroscopy of  $\eta'$ -mesic nuclei at GSI and FAIR** — •KENTA ITAHASHI<sup>1</sup> and YOSHIKI TANAKA<sup>2</sup> for the Super-FRS Experiment-Collaboration — <sup>1</sup>Department of Physics, The University of Osaka, Japan — <sup>2</sup>High Energy Nuclear Physics Laboratory, RIKEN, Saitama, Japan

We have conducted experimental search for  $\eta'$ -nuclei, a bound system of an  $\eta'$ -meson and a carbon 11 nucleus, using FRS at GSI as a high-resolution spectrometer. We measured the missing mass of the  $^{12}\text{C}(p, d)$  reaction near the  $\eta'$ -emission threshold and selected formation events of the  $\eta'$ -mesic nuclei by tagging a high-momentum proton emitted in the two nucleon absorption channel,  $\eta' NN \rightarrow NN$ , where  $N$  denotes a nucleon. The measured excitation spectrum may indicate first experimental observation of the bound systems of an  $\eta'$  and a  $^{11}\text{C}$  nucleus. We deduced the real part of the  $\eta'$ - $^{11}\text{C}$  potential to be  $-61 \pm 1 \pm 5$  MeV with the local and global statistical significance of  $3.5 \sigma$  and  $2.1 \sigma$ , respectively. We plan a new experiment to improve the statistical sensitivity and extend the excitation-energy region of the measurement. We make use of a new solenoidal magnet to be transferred from SPring-8, Japan, which has larger geometry and higher magnetic field to achieve better tagging efficiency. We also discuss possibilities to utilize secondary beams such as pions or antiprotons, using the combination of SIS100 and the SuperFRS.

**Group Report**

HK 20.5 Wed 15:05 AM 00.014

**Hadron physics with proton and deuteron beams at the CBM experiment** — •JAMES RITMAN for the CBM-Collaboration — GSI mbH, Darmstadt — Ruhr-Uni-Bochum

The high-intensity 30 GeV/c proton and deuteron beams soon available at FAIR will enable a rich program of hadron and QCD studies. These beams will be directed towards the large acceptance CBM detector, which provides an excellent basis for fully exclusive reconstruction of all final-state reaction products. These data will not only play a crucial role in contextualising the results from heavy-ion reactions, but will also provide great opportunities in the realm of hadron physics. The physics program includes investigations of hadron-hadron interactions and the composition of hadrons, as well as the mapping of baryon and meson spectra, including exotic states and quantifying hadron structure. This talk will present an overview of both, the detector set-up and expected performance for the related measurements.

**Group Report**

HK 20.6 Wed 15:25 AM 00.014

**QCDatFAIR Round Table Discussion** — •FRANK NERLING<sup>1,2</sup> and JOHAN MESSCHENDORP<sup>3</sup> — <sup>1</sup>GSI Helmholtz Research Academy Hesse for FAIR, Campus Frankfurt — <sup>2</sup>Goethe University Frankfurt — <sup>3</sup>GSI Helmholtz Centre for Heavy Ion research, Darmstadt, Germany

We discuss the contributions of this Focus Session including the status and perspectives of the newly established initiative.

## HK 21: Structure and Dynamics of Nuclei V

Time: Wednesday 13:45–15:45

Location: AM 00.011

## Group Report

HK 21.1 Wed 13:45 AM 00.011

**Towards high-precision laser spectroscopy of trapped radioactive ions**

— •PHILLIP IMGRAM<sup>1,2</sup>, STEFANOS PELONIS<sup>1</sup>, TOBIAS CHRISTEN<sup>1</sup>, JULIEN GRONDIN<sup>1</sup>, ANGELOS KARADIMAS<sup>1</sup>, ARDA KAYAALP<sup>1</sup>, SANDRO KRAEMER<sup>1</sup>, AGOTA KOSZORUS<sup>1</sup>, PIERRE LASSEGUES<sup>1</sup>, ROBBE VAN DUYSSE<sup>1</sup>, and RUBEN DE GROOTE<sup>1</sup> — <sup>1</sup>Department of Physics and Astronomy, Instituut voor Kern-en Stralingsfysica, KU Leuven, 3001, Leuven, Belgium — <sup>2</sup>Facility for Antiproton and Ion Research in Europe GmbH, Darmstadt, Germany

Benchmarking nuclear models through precise measurements of nuclear observables such as nuclear charge radii and electromagnetic moments in exotic, short-lived nuclei is crucial, and most precise and nuclear-model-independent results are achieved through laser spectroscopy. Here, well-established in-source or collinear laser spectroscopy techniques are usually limited in precision by either the temperature of the ions or the interaction time of the ions with the laser light. To overcome both limitations, a new offline beamline has been commissioned at KU Leuven to develop laser spectroscopy on trapped ions at radioactive ion beam (RIB) facilities [1]. This contribution will give an overview of the project and present the first results from our linear Paul trap, which includes the deceleration, trapping, and laser cooling of  $\text{Sr}^+$  ions from a 10 keV beam energy to a few 10 mK in temperature and first laser spectroscopy measurements. Finally, an outlook on the upcoming developments in Leuven will be provided and prospects for implementation of this setup at RIB facilities will be explored. [1] P. Imgram et al., Rev. Sci. Instr. 96, 093302 (2025)

HK 21.2 Wed 14:15 AM 00.011

**POSEIDON: A new setup for collinear laser spectroscopy at the N=126 factory**

— •JULIAN PALMES<sup>1</sup>, GUY SAVARD<sup>2</sup>, and JASON CLARK<sup>2</sup> for the POSEIDON-Collaboration — <sup>1</sup>Institut für Kernphysik der Technischen Universität Darmstadt, Darmstadt, Germany — <sup>2</sup>Argonne National Laboratory, Lemont, USA

The nuclear charge radius is a fundamental nuclear observable and a sensitive probe of the forces and correlations that shape atomic nuclei. While for stable isotopes, absolute radii can be determined by muonic spectroscopy and electron scattering, the extraction of differential charge radii of exotic nuclei relies on optical isotope shift measurements. In the neutron-rich region near the N=126 shell closure, which is of special interest for astrophysical processes, our knowledge of those fundamental properties is sparse. These isotopes are difficult to produce due to limited cross-sections for conventional methods. Multi-nucleon transfer (MNT) reactions provide sufficiently large cross sections but have large momentum transfers, making beam collection challenging.

At the N=126 factory at the Argonne National Laboratory, a gas catcher directly after the target will collect these exotic nuclei and allow spectroscopy on MNT reaction products. We present POSEIDON, our newly designed collinear laser spectroscopy beamline and present plans to measure the charge radius of platinum isotopes across N=126.

This project is supported by the German Research Foundation (Project-ID 279384907 - SFB1245).

HK 21.3 Wed 14:30 AM 00.011

**Precision mass measurement of n-deficient cadmium isotopes at ISOLTRAP**

— •CHRISTOPH SCHWEIGER for the ISOLTRAP-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

ISOLTRAP [1] is a multi-ion-trap mass spectrometer located at ISOLDE/CERN dedicated to high-precision mass measurements of artificially produced, short-lived, exotic radionuclides far from stability. Experimentally, ISOLTRAP employs multi-reflection time-of-flight and Penning-trap mass spectrometry techniques for direct mass measurements. Following the mass-energy equivalence, the measured masses can be related to nuclear binding energies, reflecting the underlying interactions and structure in the nucleus. Knowledge of the binding energies therefore allows the study of nuclear structure and nuclear astrophysics. To this end mass filters are employed. In addition, precision mass data have applications in fundamental physics such as neutrino or weak interaction studies.

Following an introduction of the experimental setup, recent mass measurements of neutron-deficient cadmium isotopes in vicinity of the self-conjugate doubly-magic  $^{100}\text{Sn}$  will be presented. The contribution will also include technical developments that improved the experimental setup significantly.

[1] Lunney, D. et al., J. Phys. G: Nucl. Part. Phys. 44, 064008 (2017)

HK 21.4 Wed 14:45 AM 00.011

**Progress towards Collinear Laser Spectroscopy of stable Phosphorus Atoms**

— •IMKE LOPP, KRISTIAN KÖNIG, DANIELA TANDARA, and WILFRIED NÖRTERS-HÄUSER — Institut für Kernphysik, Technische Universität Darmstadt

Phosphorus is of special interest for collinear laser spectroscopy, since it offers a proton-halo candidate,  $^{26}\text{P}$ , at the proton dripline. By measuring isotope shifts, collinear laser spectroscopy provides access to changes in the nuclear charge radii

along the isotopic chain, enabling a sensitive probe of halo structures. In the case of phosphorus, experimental challenges have prevented laser spectroscopy so far. There are no laser-accessible transitions from the ionic or atomic ground state. However, from meta-stable atomic states, transitions in the deep UV at 215 nm and 255 nm can be accessed with state-of-the-art laser systems. Therefore, a charge exchange cell is used to populate these states using in-flight charge exchange reactions. Preparation studies on stable  $^{31}\text{P}$  are performed at the COALA setup at TU Darmstadt, where a new charge exchange cell and Penning Ionisation Gauge ion source are commissioned for this purpose. The status of the new charge exchange cell and ion source, as well as the progress towards collinear laser spectroscopy of stable phosphorus atoms will be presented.

This project is supported by BMFTR (05P24RD8) and the German Research Foundation (Project-ID: 279384907 - SFB 1245)

HK 21.5 Wed 15:00 AM 00.011

**Laser Spectroscopy of neutron-rich and neutron-deficient Tm isotopes with RADRIS at GSI/HIM and RISIKO at JGU Mainz**

— •JANA WEYRICH for the RADRIS-Collaboration — GSI, Darmstadt, DE — Helmholtz-Institut, Mainz, DE — Johannes Gutenberg-Universität, Mainz, DE

Nuclear shell effects stabilize the nuclei of heavy and superheavy elements against spontaneous fission, counteracting the Coulomb repulsion of the protons in the nucleus. Thus, studying physical properties in that region of the nuclear chart enhances our understanding of the nuclear structure. These elements, however, are radioactive, often short-lived, and generally produced only in limited quantities. As a result, the technique of Resonance Ionization Spectroscopy (RIS) plays a crucial role in studying atomic spectra to determine atomic and nuclear properties, as it features high sensitivity, efficiency, and selectivity. As on-line studies of the rare species are time- and cost-intensive, it is advisable to investigate lighter atomic homologues in advance.

In this work, studies of  $^{169}\text{Tm}$  and  $^{170}\text{Tm}$  were performed with the RISIKO mass separator at JGU Mainz, Germany, to study the sensitivity of ionization schemes. Further on-line studies with the Radiation Detected Resonance Ionization Spectroscopy (RADRIS) apparatus at GSI-FAIR in Darmstadt, Germany, included  $^{152\text{m}}\text{Tm}$ ,  $^{153}\text{Tm}$ , and  $^{154\text{m}}\text{Tm}$ . In this contribution, the results will be discussed, which include isotope shift measurements in three optical transitions and a first determination of the magnetic moment of  $^{152\text{m}}\text{Tm}$ .

HK 21.6 Wed 15:15 AM 00.011

**Investigating molecular formation and breakup towards measurements of the halo candidate  $^8\text{B}$** 

— •JULIEN SPAHN<sup>1</sup>, JASON CLARK<sup>2</sup>, BERNHARD MAASS<sup>2</sup>, PETER MÜLLER<sup>2</sup>, WILFRIED NÖRTERS-HÄUSER<sup>1</sup>, and GUY SAVARD<sup>2</sup> — <sup>1</sup>Institute for nuclear physics, TU Darmstadt, Germany — <sup>2</sup>Physics division, Argonne National Laboratory, USA

Since the first discovery of halo nuclei, neutron halos in particular have been characterized using nuclear reactions and laser spectroscopy. A measurement of the nuclear charge radius of the more exotic proton halo in the isotope  $^8\text{B}$ , however, is still pending. An ongoing effort at Argonne's ATLAS facility aims to investigate  $^8\text{B}$  via collinear laser spectroscopy. However,  $^8\text{B}$  ions readily form molecules with residual contaminants in the He buffer gas of the gas catcher used to cool and extract the ions. These molecular species reduce the yield of the pure (bunched)  $^8\text{B}$  beam. This contribution will focus on the commissioning of a new setup allowing investigation of the beam composition in continuous and bunched mode, relying on neural network based analysis of alpha decays detected via an MCP behind a velocity filter. Additionally, first results from on-line experiments investigating the molecular formation in the gas catcher and the breakup of the formed molecules in the RFQ will be presented.

This project was supported by DFG (Project-ID 279384907 - SFB 1245) and by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357, with resources of ANL's ATLAS facility, an Office of Science User Facility.

HK 21.7 Wed 15:30 AM 00.011

**Production and Collinear Laser Spectroscopy of Helium-like Boron Ions**

— •EMILY BURBACH, HENDRIK BODNAR, FINN KÖHLER, KRISTIAN KÖNIG, IMKE LOPP, WILFRIED NÖRTERS-HÄUSER, and JULIEN SPAHN — Institut für Kernphysik, Technische Universität Darmstadt

Nuclear ground state properties of short-lived isotopes can be studied using collinear laser spectroscopy (CLS). Differential root-mean-square charge radii can be derived from isotope shifts of atomic transitions between different isotopes. For light systems, also the absolute charge radius can be determined by applying NRQED calculations and high-precision absolute frequency measurements. The Collinear Apparatus for Laser Spectroscopy and Applied Sciences (COALA) at TU Darmstadt is suitable for high-precision transition frequency measurements at the ppb-level that are required for light isotopes. There, highly charged boron ions were produced in an electron beam ion source. We present



experimental details on the efficient production of helium-like boron ions in the metastable  $^3S_1$  state, where laser-accessible atomic transitions occur at 283 nm and the subsequent laser spectroscopy measurements. The absolute charge radius of  $^{11}\text{B}$  can be determined from the transition frequency and NRQED cal-

culations, which was previously demonstrated for  $^{12}\text{C}$  [1]. An overview of the current status of the analysis is given.

This project is supported by DFG (Project-ID 279384907 - SFB 1245).

[1] P. Imgram et al., Phys. Rev. Lett. **131**, 243001 (2023).

## HK 22: Structure and Dynamics of Nuclei VI

Time: Wednesday 13:45–15:45

Location: AM 00.021

### Group Report

HK 22.1 Wed 13:45 AM 00.021

**Momentum-dependent electroweak currents in deformed nuclei** — •RUI HAN<sup>1</sup>, BETÁNIA BACKES<sup>2</sup>, JACEK DOBACZEWSKI<sup>2,3</sup>, WEIGUANG JIANG<sup>4</sup>, MARKUS KORTELAINE<sup>5,6</sup>, GABRIEL MARTÍNEZ-PINEDO<sup>1,7,8</sup>, and HERLIK WIBOWO<sup>2</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — <sup>2</sup>Department of Physics, University of York, York, United Kingdom — <sup>3</sup>Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland — <sup>4</sup>Institut für Kernphysik und PRISMA+ Cluster of Excellence, Johannes Gutenberg-Universität, Mainz, Germany — <sup>5</sup>Department of Physics, University of Jyväskylä, Jyväskylä, Finland — <sup>6</sup>Helsinki Institute of Physics, University of Helsinki, Helsinki, Finland — <sup>7</sup>Institut für Kernphysik (Theoriezentrum), Fachbereich Physik, Technische Universität Darmstadt, Darmstadt, Germany — <sup>8</sup>Helmholtz Forschungsakademie Hessen für FAIR, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

For weak processes such as neutrino-nucleus scattering and muon capture, the momentum transfer can be large enough that long-wavelength approximations break down, and chiral EFT two-body currents may contribute significantly. A framework is presented to evaluate momentum-dependent one- and two-body electroweak currents in deformed open-shell nuclei within nuclear DFT. Magnetic dipole moments serve as a benchmark for validating the consistent implementation of chiral two-body currents, and current progress toward a unified finite- $q$  treatment for weak processes is outlined.

### Group Report

HK 22.2 Wed 14:15 AM 00.021

**Two-body currents at finite momentum transfer and WIMP-nucleus scattering** — •CATHARINA BRASE<sup>1,2,3</sup>, ZHEN LI<sup>1,2,3</sup>, YUKIYA CHIBA<sup>4</sup>, TAKAYUKI MIYAGI<sup>4</sup>, JAVIER MENÉNDEZ<sup>5,6</sup>, and ACHIM SCHWENK<sup>1,2,3</sup> — <sup>1</sup>Technische Universität Darmstadt, Department of Physics — <sup>2</sup>ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — <sup>3</sup>Max-Planck-Institut für Kernphysik, Heidelberg — <sup>4</sup>Center for Computational Sciences, University of Tsukuba — <sup>5</sup>Departament de Física Quàntica i Astrofísica, Universitat de Barcelona — <sup>6</sup>Institut de Ciències del Cosmos, Universitat de Barcelona

We study two-body currents (2BCs) in scattering processes off medium-heavy nuclei. The inclusion of 2BCs at finite momentum transfer is important for various electroweak processes. In this work, we calculate structure factors for spin-dependent WIMP-nucleus scattering, which are needed for dark matter direct detection experiments. The structure factors encode the nuclear response and have to be calculated theoretically. We investigate the effects of 2BCs with full momentum transfer dependence on the structure factors for  $^{19}\text{F}$ ,  $^{29}\text{Si}$ ,  $^{129,131}\text{Xe}$ . Our results are compared to previous calculations that used approximation schemes to include 2BCs.

HK 22.3 Wed 14:45 AM 00.021

**Searching for signatures of the possible resonant neutrinoless double electron capture in  $^{152}\text{Gd}$  at the Felsenkeller shallow-underground laboratory** — •LARS RUDERT, BJÖRN LEHNERT, STEFFEN TURKAT, and KAI ZUBER — TU Dresden

The hypothesized Majorana nature of neutrinos is a key motivation for many large-scale research projects in contemporary particle physics. While neutrinoless double-beta decay plays a central role in the experimental search for this property, double electron capture (EDEC) has gained increasing attention as an alternative probe. The two-neutrino mode of EDEC was first experimentally observed in 2019 by the XENON1T collaboration in  $^{124}\text{Xe}$ . However, the observation of neutrinoless double electron capture remains an open experimental challenge.

A long-term measurement is currently being conducted using a  $^{152}\text{Gd}$ -enriched gadolinium oxide sample, which is considered the most promising candidate for a resonance-enhanced neutrinoless double electron capture. This contribution focuses on an experiment employing an ultra-low-background well-type HPGe detector at the Felsenkeller shallow-underground laboratory, operated by the Nuclear Physics group at TU Dresden. During the ongoing measurement campaign, further optimizations of the background sensitivity are being performed and are currently under discussion. This includes an extended characterization of the detector with respect to the expected X-ray emissions from the theoretical decay.

HK 22.4 Wed 15:00 AM 00.021

**Electron-capture decay of Tc-98** — •DOMINIK ELCHINE<sup>1</sup>, MARTIN MÜLLER<sup>2</sup>, MARKUS SCHIFFER<sup>3</sup>, and ERIK STRUB<sup>1</sup> — <sup>1</sup>Division of Nuclear Chemistry, University of Cologne, Zùlpicher Str. 45, 50674 Cologne, Germany — <sup>2</sup>Institute for Nuclear Physics, University of Cologne, Zùlpicher Str. 77, 50937 Cologne, Germany — <sup>3</sup>Faculty of Arts and Humanities, Department of Prehistoric Archaeology, Laboratory of Isotope Archaeology

From simple symmetry and energy considerations it can be concluded that  $^{98}\text{Tc}$  might undergo electron capture decay (EC). In this work we provide evidence for an EC decay of  $^{98}\text{Tc}$  measuring 2.67 g  $[\text{TcO}_4]$  that contains approximately 1 GBq of  $^{99}\text{Tc}$ . By use of a lead shielding for the sample, it was possible to identify the coincident  $4^+ \rightarrow 2^+$  and  $2^+ \rightarrow 0^+$   $\gamma$  transitions in the daughter nuclide  $^{98}\text{Mo}$  at the clover setup of the Institute for Nuclear Physics at the University of Cologne. For the first time, the  $\text{EC}/\beta^-$  branching ratio of 0.29(3)% was determined directly. With a log ft of 14.21(7) this decay does almost tie with the log ft of the  $^{36}\text{Cl}$  EC decay [14.23(1)] for the same highest second forbidden nonunique transition.

HK 22.5 Wed 15:15 AM 00.021

**Chasing the elusive nuclear two-photon decay in  $^{72}\text{Ge}$**  — •MICHAEL WEINERT<sup>1</sup>, WOLFRAM KORTEN<sup>2</sup>, YURY LITVINOV<sup>1,3</sup>, MARKUS MÜLLENMEISTER<sup>1</sup>, PETER REITER<sup>1</sup>, and ANDREAS ZILGES<sup>1</sup> — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Germany — <sup>2</sup>IRFU, CEA, Université Paris-Saclay, France — <sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

A recent study at the ESR storage ring at GSI, Darmstadt, allowed to indirectly observe the nuclear two-photon ( $2\gamma$ ) decay of the first excited state in  $^{72}\text{Ge}$  [1]. By storing the excited and fully ionized nucleus in the ESR, conventional electron conversion can no longer depopulate the  $0^+$  isomer and the rare second-order electromagnetic process becomes the dominant decay path. It could be shown that the isomeric state has a much longer, yet finite lifetime in the ESR system, serving as an indirect observation of the  $2\gamma$  decay. This contribution presents the current endeavors on complementary  $^{72}\text{Ge}(p, p'\gamma)$  experiments, hunting for the direct observation of this extremely rare decay process. Besides finding a way to strongly populate the isomeric state, several orders of magnitude of natural and beam induced  $\gamma$ -ray background have to be suppressed. An overview of the latest experiments with the SONIC@HORUS setup in Cologne [2] and with the ELIFANT array [3] at IFIN-HH, Bucharest, will be given.

[1] D. Freire-Fernández et al., Phys. Rev. Lett. **133**, 022502 (2024)

[2] S. G. Pickstone et al., Nucl. Inst. Meth. A **875** (2017) 104–110

[3] D. L. Balabanski et al., EPJ Web Conf. **342**, 01002 (2025)

HK 22.6 Wed 15:30 AM 00.021

**Studies of the  $^{76}\text{Ge}$  level scheme via neutron activation and  $\gamma$ - $\gamma$  coincidence spectroscopy for germanium-based  $0\nu\beta\beta$  decay experiments** — •MARIE PICHOTTA<sup>1</sup>, TORALF DÖRING<sup>2</sup>, BJÖRN LEHNERT<sup>1</sup>, MAX OSSWALD<sup>1</sup>, RONALD SCHWENGER<sup>2</sup>, CHRISTOPH SEIBT<sup>1</sup>, STEFFEN TURKAT<sup>1</sup>, and KAI ZUBER<sup>1</sup> — <sup>1</sup>Technische Universität Dresden (IKTP), Germany — <sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf, Germany

The still undetected neutrinoless double beta ( $0\nu\beta\beta$ ) decay would prove the Majorana nature of neutrinos and thus provide clear evidence for physics beyond the Standard Model.  $^{76}\text{Ge}$  is one of the most promising nuclides for its detection and is employed in several large-scale experiments, such as LEGEND. For a distinct identification of a potential  $^{76}\text{Ge}$   $0\nu\beta\beta$  signal, a detailed understanding of all background contributions within the signal region is essential.

In a first experimental campaign at the DT neutron generator of TU Dresden, germanium isotopically enriched in  $^{76}\text{Ge}$  was activated with 14 MeV neutrons, and the resulting  $\gamma$  radiation from the  $\beta^-$  decay of  $^{76}\text{Ga}$  into excited states of  $^{76}\text{Ge}$  was measured. The spectra from multiple irradiation cycles revealed several  $\gamma$ -ray peaks located in the vicinity of the  $0\nu\beta\beta$  signal region, of partially unknown origin.

This talk focuses on a follow-up study, where multiple HPGe detectors equipped with active anti-Compton suppression were employed to perform  $\gamma$ - $\gamma$  coincidence measurements. This enables a detailed reconstruction of decay cascades and aims at identifying unknown  $\gamma$ -ray transitions, thereby closing remaining gaps in the level scheme of  $^{76}\text{Ge}$ .

## HK 23: Heavy-Ion Collisions and QCD Phases III

Time: Wednesday 13:45–15:45

Location: PHIL C 301

## Group Report

HK 23.1 Wed 13:45 PHIL C 301

**Probing charm and quarkonium dynamics in pp and OO collisions with ALICE** — •SAMRANGY SADHU, ANKUR YADAV, LUBNA AL-RIFAIE, and BERNHARD KETZER for the ALICE Germany-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, University of Bonn

We present recent and ongoing heavy-flavour measurements with the ALICE experiment at the CERN LHC, focusing on charm production in pp and quarkonium collectivity in OO collisions. We discuss recent open-charm results, including the  $D^{*+}$  production cross section in pp collisions at  $\sqrt{s} = 5.36$  TeV and  $D^0$  meson-charged particles azimuthal correlations in pp at  $\sqrt{s} = 13.6$  TeV. Together, these measurements constrain charm-quark production, fragmentation, and charm-jet properties, and at the same time provide essential baselines for future heavy-ion studies at the corresponding energies. In addition, we present the first  $J/\psi$  flow measurement in OO collisions at  $\sqrt{s_{NN}} = 5.36$  TeV. The observed azimuthal anisotropy offers insight into possible collective behaviour and charm transport in a small, short-lived QCD medium. These results strengthen the understanding of heavy-flavour dynamics across collision systems and support the characterisation of QCD phenomena from pp to intermediate-size nuclei. Supported by BMFTR.

HK 23.2 Wed 14:15 PHIL C 301

**Charm-baryon lifetime measurement in pp collisions at  $\sqrt{s} = 13.6$  TeV with ALICE** — •OLEKSI LUBYNETS for the ALICE Germany-Collaboration — Heidelberg university, Physics institute

The lifetimes of heavy-flavour hadrons provide a sensitive benchmark for the heavy-quark expansion (HQE) approach, in which the total decay width is expressed as a power series of heavy-quark mass. Different treatments of higher-order terms can lead to sizable variations in predicted lifetimes, making precise measurements of charm-baryon lifetimes crucial for validating and refining HQE approaches.

We present the implementation of a lifetime measurement for the  $\Lambda_c^+$  baryon reconstructed via its decay channel  $pK^- \pi^+$  with data collected at ALICE during Run 3 of the LHC. Charmed hadrons are reconstructed by their decay topology via a Kalman filter algorithm. The measured yield as a function of proper decay time is corrected for detector and reconstruction inefficiencies using dedicated Monte-Carlo simulations implemented with the Geant4 transport model. The effect of feed-down from beauty-hadron decays is corrected in a data-driven way. It allows us to build a corrected proper decay time distribution of prompt  $\Lambda_c^+$  from which its lifetime is determined.

The described procedure demonstrates the capability of ALICE to deliver a competitive lifetime measurement of charm baryons, contributing to the global effort to constrain HQE parameters and improve theoretical understanding of charm-hadron decays.

HK 23.3 Wed 14:30 PHIL C 301

**Measurement of  $\psi(2S)$  production at midrapidity in Pb-Pb Collisions at  $\sqrt{s_{NN}} = 5.36$  TeV with ALICE** — •JINJO SEO for the ALICE Germany-Collaboration — Heidelberg University

Quarkonium is a sensitive probe of the quark-gluon plasma (QGP) created in ultra-relativistic heavy-ion collisions. In the QGP, color screening leads to the suppression of all charmonium states. However, the large charm production cross-section at LHC energies can also cause enhanced charmonium production at the phase boundary or (re-)generation throughout the QGP evolution. The interplay between suppression and (re-)generation mechanisms reflects the underlying charm-quark dynamics in the QGP and during hadronization. Studying the  $\psi(2S)$  is particularly interesting because of its weaker binding energy, larger spatial size, and smaller feed-down contribution compared to the  $J/\psi$ . Previous measurements have shown a stronger suppression of  $\psi(2S)$  relative to  $J/\psi$  and are compatible with both statistical hadronization at the phase boundary as well as a model with continuous breakup and formation in the QGP. To clarify the situation, data at low transverse momentum and midrapidity are necessary. In this contribution, we present the first results of inclusive  $\psi(2S)$  production at midrapidity in Pb-Pb collisions at  $\sqrt{s_{NN}} = 5.36$  TeV with the ALICE detector, together with the corresponding  $J/\psi$  measurements.

HK 23.4 Wed 14:45 PHIL C 301

**$J/\psi$  measurement at midrapidity in Pb-Pb collisions at  $\sqrt{s_{NN}} = 5.36$  TeV with the ALICE central barrel** — •JONATHAN WITTE for the ALICE Germany-Collaboration — Universität Heidelberg

The interaction of heavy flavour quarks in the quark-gluon plasma has been under investigation for more than two decades. After the melting of bound charmonium states have been firmly established, the focus moved towards regeneration effects at higher collision energies. First results from Pb-Pb collisions at the LHC provided strong support for this picture, offering important experimental constraints for both thermal and transport hadronisation models. The newest ALICE data collected in LHC Run 3 - featuring a new time projection cham-

ber and higher interaction rate - opens the door to precision measurements of  $J/\psi$  production at midrapidity. The  $J/\psi$  is reconstructed in the dielectron decay channel, with the two electrons measured in the central barrel. While the data taking is still in progress, the final analysis is under development. The current focus here is on the optimisation on the electron identification and the description of the background, increased due to the high interaction rates. In the talk I will present the analysis status and show the first stable  $J/\psi$  signals from the Run 3 Pb-Pb data.

HK 23.5 Wed 15:00 PHIL C 301

**Charmonium production as a function of multiplicity in pp collisions** — •ALEXANDER TIEKÖTTER for the ALICE Germany-Collaboration — Institut für Kernphysik, Münster, Deutschland

Charmonium production happens at different energy scales.  $c\bar{c}$  production occurs at perturbative energies, while the hadronization into colorless charmonium is a soft process. Models like the Improved Color Evaporation Model or Non-relativistic QCD describe the charmonium cross-section well, but fail at  $p_T < 3$  GeV/c. The color glass condensate (CGC) approach extends NRQCD to better describe the low  $p_T$  regime and implies a non-linear multiplicity dependence of charmonium production.

To investigate this effect, we measure the production of  $J/\psi$  and  $\psi(2S)$  mesons at  $\sqrt{s} = 13.6$  TeV as a function of charged-particle multiplicity with the ALICE detector at mid-rapidity in the  $e^+e^-$  decay channel. The multiplicity is measured by using an iterative Bayesian unfolding algorithm to convert the number of tracks to a charged-particle distribution. Results are presented via self-normalized ratios so that experiment-dependent quantities cancel. Results of the inclusive  $J/\psi$  production as function of multiplicity show a stronger-than-linear increase and are in good agreement with the NRQCD+CGC model, while predictions from PYTHIA8 fail to describe the data. Measuring  $N_{\psi(2S)}/N_{J/\psi}$  even shows a more complex behavior, where the CGC alone fails. Considering dissociation mechanisms for charmonium can qualitatively explain the shape of the ratio. Supported by BMFTR

HK 23.6 Wed 15:15 PHIL C 301

**$J/\psi$  elliptical-flow  $v_2$  analysis in O-O collisions at mid-rapidity using ALICE Run-3 data** — •ANKUR YADAV, SAMRANGY SADHU, LUBNA AL-RIFAIE, and BERNHARD KETZER for the ALICE Germany-Collaboration — Helmholtz-Institut für Strahlen und Kernphysik, Universität Bonn

The Large Hadron Collider (LHC) at CERN had first oxygen-oxygen (O-O) collisions at  $\sqrt{s_{NN}} = 5.36$  TeV in 2025. This dataset provides a unique opportunity to study collectivity and quark-gluon-plasma (QGP) signatures in a smaller collision system compared to the heavy-ion systems such as Pb-Pb. The ALICE experiment has recorded this dataset with excellent precision, enabling the investigation of quarkonium production with a focus on the  $J/\psi$  meson.

This talk will present the first measurement of the azimuthal-anisotropy coefficient  $v_2$  of inclusive  $J/\psi$  in O-O collisions at mid-rapidity. The  $v_2$  values are extracted in several transverse-momentum and centrality intervals using the scalar product method. Comparing this measurement to existing results from larger collision systems allows us to probe the scaling of quarkonium collectivity with system size.

The talk will cover the analysis procedure, including signal extraction, and flow determination, as well as the resulting  $J/\psi$  elliptic flow values.

Supported by BMFTR.

HK 23.7 Wed 15:30 PHIL C 301

**Collective effects in O-O and Ne-Ne collisions from a hybrid approach** —

•LUCAS CONSTANTIN<sup>1</sup>, CARL B. ROSENKVIST<sup>1</sup>, NIKLAS GOETZ<sup>1</sup>, and HANNAH ELFNER<sup>3,1,2,4</sup> — <sup>1</sup>Goethe University Frankfurt, Department of Physics, Institute for Theoretical Physics, 60438 Frankfurt, Germany — <sup>2</sup>Frankfurt Institute for Advanced Studies, 60438 Frankfurt am Main, Germany — <sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — <sup>4</sup>Helmholtz Research Academy Hesse for FAIR (HFHF), GSI Helmholtz Center, Campus Frankfurt, 60438 Frankfurt am Main, Germany

Many features of heavy-ion collisions are well described by hybrid approaches, where the droplet of strongly coupled quark gluon plasma (QGP) is modeled by hydrodynamics and the subsequent dilute stage is performed with a hadronic transport model. Conventionally, the formation of a QGP is well established in larger collision systems like Lead and Gold. However, hints of collectivity were found even in proton-proton collisions, raising the question where the onset of QGP formation lays. This study aims at making predictions for the light ions run at the LHC in July 2025, in order to explore the applicability of hybrid approaches in smaller collision systems. We employ three different models, the SMASH-vHLE-hybrid approach, the pure hadronic cascade of SMASH and Angantyr to simulate O-O collisions at a center of mass energy of  $\sqrt{s_{NN}}=5.36$  TeV. This setup allows us to compare evolutions with and without a hydrodynamic description on an equal basis, while Angantyr serves as a baseline for no collective effects.

## HK 24: Heavy-Ion Collisions and QCD Phases IV

Time: Wednesday 13:45–15:45

Location: PHIL A 401

## Group Report

HK 24.1 Wed 13:45 PHIL A 401

**Diquark Properties from First Principles and Their Impact on Color Superconducting Matter** — HOSEIN GHOLAMI<sup>1</sup>, •UGO MIRE<sup>2</sup>, FABIAN RENNECKE<sup>2,3</sup>, BERND-JOCHEN SCHAEFER<sup>2,3</sup>, and SHI YIN<sup>2</sup> — <sup>1</sup>Technische Universität Darmstadt, Fachbereich Physik, Institut für Kernphysik, Theoriezentrum, Darmstadt, Germany — <sup>2</sup>Institut für Theoretische Physik, Justus-Liebig-Universität Gießen, Gießen, Germany — <sup>3</sup>Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Campus Gießen, Gießen, Germany

Recent neutron star observations demand increasingly precise equations of state at extreme densities where exotic phases of matter may appear. An intriguing candidate is color superconductivity, in which quarks pair into diquarks that condense, making a first-principles understanding of diquark dynamics essential for interpreting astrophysical data. In this talk I will present results for the vacuum properties of the scalar diquark in a self-consistent and first-principle approach to QCD. Using the functional renormalization group, I will show how the high energy quark and gluon degrees of freedom can be smoothly integrated resulting in a low-energy description in terms of mesons and diquarks. I will show that our approach predict a scalar diquark bound state, consistent with the quark-diquark picture of the nucleon. Finally, I will demonstrate how these results can constrain low-energy models of color superconductivity, yielding new insights into the equation of state of cold and dense quark matter.

HK 24.2 Wed 14:15 PHIL A 401

**Renormalization-Group Invariant Parity-Douplet Model for Nuclear and Neutron-Star Matter** — •MATTIA RECCHI<sup>1</sup>, LORENZ VON SMEKAL<sup>1,2</sup>, and JOCHEN WAMBACH<sup>3</sup> — <sup>1</sup>Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — <sup>2</sup>Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Campus Giessen — <sup>3</sup>Technische Universität Darmstadt, 64289, Darmstadt, Germany

The Parity-Douplet Model (PDM) is a chirally invariant effective theory for nuclear matter that incorporates a chirally invariant mass through opposite-parity partners. We develop a multiplicatively renormalizable mean-field approach to include baryonic vacuum contributions in the grand-canonical potential in a manifestly renormalization-group invariant form. We study the chiral dynamics and equation of state of the model, focusing on the restoration of spontaneously broken chiral symmetry at baryon densities and temperatures relevant for neutron-star astrophysics and heavy-ion collisions. We find that baryonic vacuum fluctuations have a crucial impact on the evolution of the chiral condensate and are essential for a realistic description of neutron-star structure.

HK 24.3 Wed 14:30 PHIL A 401

**Neutron Star Properties with Skyrme Potentials from Relativistic Heavy-Ion Physics** — •ELEONORA FOERSTER, SARAH PITZ, SELINA KUNKEL, ISHFAQ RATHER, and JÜRGEN SCHAFFNER-BIELICH — Goethe Universität, Frankfurt am Main, Germany

The study of ultra-dense matter created in relativistic heavy-ion collisions provides important constraints on the nuclear equation of state (EoS), which is a key input for modeling neutron stars. In this contribution, we explore the mutual interplay between EoS constraints extracted from heavy-ion flow measurements and observational mass-radius constraints of neutron stars. Using a Skyrme-based EoS constrained by heavy-ion data, mass-radius relations for symmetric nuclear matter and pure neutron matter are calculated and compared to current neutron-star observations. The focus is on investigating how specific properties of the nuclear interaction, in particular the nuclear incompressibility  $K$ , influence neutron-star observables such as the maximum mass and radius. Variations of  $K$  lead to noticeable changes in the predicted maximum mass, demonstrating the connection between neutron star observables and constraints on the EoS by heavy-ion physics.

HK 24.4 Wed 14:45 PHIL A 401

**Global Lambda Polarization in Au+Au collisions at 0.8 AGeV measured with HADES** — •FLORIAN ALEF for the HADES-Collaboration — TU Darmstadt, Darmstadt, Germany

In heavy-ion collisions, large angular momenta are generated which might translate to a spin polarization of the produced particles. Extracting the spin orientation of an outgoing proton from a weakly decaying  $\Lambda$  hyperon with respect to the reaction plane could probe a global polarization and be a hint for high vorticities in the early stages of the collision. Measurements of the  $\Lambda$  polarization by HADES and STAR collaboration both indicate a strong enhancement towards

lower beam energies, reaching  $\langle P_\Lambda \rangle (\%) = 4.4 \pm 0.3 \text{ (stat.)} \pm 0.4 \text{ (sys.)}$  in Ag+Ag collisions at  $\sqrt{s_{NN}} = 2.55 \text{ GeV}$ , which corresponds to the free NN  $\Lambda$  production threshold.

This contribution will report on the status of the  $\Lambda$  polarization in Au+Au collisions at  $\sqrt{s_{NN}} = 2.25 \text{ GeV}$  measured with HADES, which is the first  $\Lambda$  polarization measurement below the production threshold.

HK 24.5 Wed 15:00 PHIL A 401

**Strangeness fluctuations in the HADES experiment\*** — •ATHIRA SREEJITH for the HADES-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

Fluctuations of conserved charges such as baryon number, electric charge, and strangeness are effective probes of the QCD phase diagram. Their higher-order cumulants are particularly sensitive to critical phenomena and remain an important focus of current heavy-ion research.

In this work, an exploratory study of strangeness fluctuations in Ag+Ag collisions at  $\sqrt{s_{NN}} = 2.55 \text{ GeV}$ , measured with the High Acceptance Di-Electron Spectrometer (HADES), a fixed-target experiment at GSI, Germany, is presented. Operating in the 1\*2A GeV regime, HADES accesses QCD medium at high net-baryon density and low temperature, providing complementary coverage to higher-energy programs. The very low strange-hadron yields at these energies, especially for kaons, necessitate robust particle identification. Therefore, a fuzzy-logic-based probabilistic technique is employed to reconstruct strange-hadron multiplicity moments.

This contribution focuses on the feasibility study of strangeness fluctuations at HADES, including the identification and reconstruction performance for strange particles, and the resulting cumulants of their multiplicity distributions.

\*This work is supported by “Netzwerke 2021”, an initiative of the Ministry of Culture and Science of the State of Northrhine Westphalia and BMBF (05P24PX1).

HK 24.6 Wed 15:15 PHIL A 401

**Proton and light nuclei yields and E-by-E fluctuations measured at HADES** — •MARVIN NABROTH — Goethe-University Frankfurt

Low energy heavy-ion collisions in the 1 AGeV regime, as studied by the HADES experiment at SIS18/GSI, allow to probe QCD matter under highest net-baryon densities and moderate temperatures.

In this contribution we present refined efficiency corrected transverse and longitudinal yield spectra of protons, deuterons, tritons, He3 reconstructed from Ag+Ag collisions at  $\sqrt{s_{NN}} = 2.55 \text{ GeV}$  and  $\sqrt{s_{NN}} = 2.42 \text{ GeV}$  measured at HADES in 2019. We discuss the spectral shape properties and the coalescence behavior as a function of centrality, as well as the beam-energy dependence. These results contribute to a better understanding of the formation of light nuclear clusters, and help constrain the freeze-out conditions via thermal-model fits. Furthermore, we present an update of the analysis of higher order moments of the e-by-e fluctuations of the proton yields in different rapidity windows. Such fluctuation observables are essential for exploring signs of criticality expected from the conjectured first-order phase transition or critical end point.

This work has been supported by BMBF (05P21RFFC2, 05H24RF5), GSI and HGS-Hire.

HK 24.7 Wed 15:30 PHIL A 401

**Lambda reconstruction at SIS18: a mCBM campaign** — •ABHISHEK ANIL DESHMUKH for the CBM-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

The production of strange hadrons, such as the  $\Lambda$  particle, serves as a standard candle for probing the properties of dense nuclear matter created in heavy-ion collisions at SIS18 energies at GSI, Darmstadt. The mini-CBM (mCBM) experiment, a prototype for the upcoming CBM experiment, allows for these measurements. Its narrow acceptance, combined with the lack of magnetic field present a unique challenge, rendering the reconstruction of multi-particle decay topologies particularly difficult.

This contribution presents the reconstruction of  $\Lambda$  particles via their dominant charged hadronic decay channel  $\Lambda \rightarrow p + \pi^-$  (63.9%). The method has been successfully developed, tested, and optimized on Monte Carlo simulations, where its performance and selection criteria have been thoroughly characterized.

The mCBM collaboration conducted beamtime campaigns in 2024 and 2025, collecting a total of six datasets with various beam and energy combinations. This contribution will present the status of applying the validated analysis technique to experimental data from the Ni+Ni collisions at 1.93A GeV. A first look at the  $\Lambda$  signal will be provided, and the preliminary performance of the reconstruction algorithm on real data will be discussed in comparison to the simulation.

\*Work supported by BMBF (05P24PX1)

## HK 25: Nuclear Astrophysics III

Time: Wednesday 13:45–15:30

Location: PHIL A 602

## Group Report

HK 25.1 Wed 13:45 PHIL A 602

**Collisional Radiative Data for non-LTE Kilonova Radiative Transfer** — •ANDREAS FLÖRS<sup>1</sup>, RICARDO SILVA<sup>2</sup>, and GABRIEL MARTÍNEZ-PINEDO<sup>1</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — <sup>2</sup>Laboratório de Instrumentação e Física Experimental de Partículas (LIP), Lisboa, Portugal

Recent infrared spectroscopy from the James Webb Space Telescope (JWST) has transformed kilonova studies, with detailed nebular-phase spectra now available for AT 2023vfi, the second spectroscopically observed kilonova and the counterpart to GRB 230307A. Observations reveal rich mid-infrared emission, with features tentatively attributed to r-process elements such as tellurium. These data extend well beyond what was possible for the first kilonova AT2017gfo and highlight the need for robust atomic and collisional data to interpret kilonova spectra in the non-local thermodynamic equilibrium (non-LTE) regime.

Non-LTE radiative transfer modelling of kilonovae relies on comprehensive collisional-radiative datasets, including electron impact excitation and forbidden transitions for heavy ions. In this talk, I will present calibrated large-scale collisional-radiative atomic structure calculations for lanthanide ions, and show how their inclusion in radiative transfer models improves agreement with JWST observations of AT2023vfi. These results enable more robust elemental abundance determinations and provide new constraints on r-process nucleosynthesis.

AF and GMP acknowledge support by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (ERC Advanced Grant KILONOVA No. 885281).

HK 25.2 Wed 14:15 PHIL A 602

**Analysis of Coulomb Breakup of Clustered Nuclei for the Determination of Radiative Capture Cross Sections: The case of  $\alpha(d, \gamma)^6\text{Li}$**  — •MONICA SANJINEZ ORTIZ and PIERRE CAPEL — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany

In the study of nucleosynthesis, the cross section of radiative capture reactions involving charged particles plays a fundamental role. However, the direct experimental measurement of these cross sections is difficult at low energy. Coulomb breakup of nuclei on a heavy target has been considered as an alternative method to infer the low-energy cross sections in an indirect way, as it can be understood as the time reversed process of radiative captures. Two Coulomb breakup experiments to infer the  $\alpha(d, \gamma)^6\text{Li}$  radiative capture cross section have been performed in the past. With a fully dynamical reaction model, we report here on a new theoretical analysis of these experiments. Our results indicate that the breakup of  $^6\text{Li}$  onto  $^{208}\text{Pb}$  at 150 A MeV and 26 A MeV is characterized by marked Coulomb-nuclear interferences. Moreover, the analysis points towards a nuclear dominated process at forward angles as Coulomb breakup is suppressed due to the  $\alpha$ -d clustered structure of  $^6\text{Li}$ . Consequently, extracting radiative capture cross sections from data at these energies is unfeasible. The forward Coulomb breakup suppression may be a general feature of breakup processes involving  $N=Z$  clustered nuclei. We underscore the importance of alternative indirect methods for the determination of cross sections for astrophysics such as photodissociation induced by electrons.

HK 25.3 Wed 14:30 PHIL A 602

**Simulation and Analysis of Three- $\alpha$  Decay in  $^{12}\text{C}$  with GEANT4** — •TIMO BIESENBAACH<sup>1</sup>, DAVID WERNER<sup>1</sup>, PETER REITER<sup>1</sup>, ALESSANDRO SALICE<sup>1</sup>, JOE ROOB<sup>1</sup>, KONRAD ARNSWALD<sup>1</sup>, MAXIMILIAN DROSTE<sup>1</sup>, MADALINA ENCIU<sup>3</sup>, PAVEL GOLUBEV<sup>2</sup>, HANNAH KLEIS<sup>1</sup>, NIKOLAS KÖNIGSTEIN<sup>1</sup>, DIRK RUDOLPH<sup>2</sup>, and LUIS SARMIENTO<sup>2</sup> — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Cologne — <sup>2</sup>Lund University, Department of Physics, Lund, Sweden — <sup>3</sup>TU Darmstadt, Institute of Nuclear Physics, Darmstadt

The branching ratios of direct and sequential three- $\alpha$  decay modes of the  $0_2^+$  Hoyle state in  $^{12}\text{C}$  provide a sensitive probe of its internal structure and play a key role in our understanding of stellar nucleosynthesis. A high-statistics experiment was conducted at the 10 MV FN Tandem Accelerator at the University of Cologne using inelastic scattering via the  $^{12}\text{C}(\alpha, \alpha')$  reaction at an incident energy of 27 MeV. The decay products were detected with the Lund–York–Cologne Calorimeter, which combines high angular resolution with large acceptance of Si strip detector arrays. To enable a precise interpretation of the data, the experiment was modelled within the GEANT4 Monte Carlo framework. The simulation incorporates the full experimental geometry, detector response, beam characteristics, target properties, and relevant physical processes. By performing a detailed comparison between the measured observables and the simulated

decay scenarios, the branching ratio of the direct decay component is extracted. These results provide constraints on the three-body decay dynamics of the Hoyle state.

HK 25.4 Wed 14:45 PHIL A 602

**Proof-of-principle neutron photo-dissociation measurement in the  $^7\text{Li}(e, e' n)^6\text{Li}$  reaction** — •DAVUD SOKOLOVIC<sup>1</sup>, JAN BUTZ<sup>1</sup>, PIERRE CAPEL<sup>2</sup>, TANJA HEFTRICH<sup>1</sup>, MICHAEL HEIL<sup>3</sup>, CAROLIN GRÜN<sup>1</sup>, SAMIRA IKERKOURN<sup>1</sup>, FELIX PANHOLZER<sup>1</sup>, and CONCETTINA SFIENTI<sup>2</sup> — <sup>1</sup>Goethe-Universität, Frankfurt am Main, Deutschland — <sup>2</sup>Johannes Gutenberg-Universität, Mainz, Deutschland — <sup>3</sup>GSI, Darmstadt, Deutschland

As neutron capture processes are fundamental to our understanding of the element abundance distribution in the universe, measurements of  $(n, \gamma)$  in direct kinematics are essential. For many nuclei, these measurements are not easily accessible due to low reaction rates or strong backgrounds from competing channels. Thus, time-reversed reactions induced by virtual photons provide a complementary approach to determine neutron capture cross sections via detailed balance.

In this talk, the concept and first steps of a proof-of-principle neutron photo-dissociation measurement in the  $^7\text{Li}(e, e' n)^6\text{Li}$  reaction at the Mainz Microtron (MAMI) are presented including GEANT4 simulation studies used to map electromagnetic and photonuclear backgrounds and to optimise the placement of a lithium-glass neutron detector.

The kinematic strategy is chosen to mimic an  $s$ -wave entrance channel into a  $p$ -wave bound state, favouring an  $E1$  transition to the ground state. In view of these requirements, DICEBOX simulations are performed to estimate ground-state branching ratios and identify further target candidates. The status of the analysis will be reported.

HK 25.5 Wed 15:00 PHIL A 602

**Investigating BBN cross sections: Characterization of the DT neutron generator in Dresden and the new ASTRO beam line** — •MAX OSSWALD<sup>1</sup>, DANIEL BEMMERER<sup>2</sup>, BJÖRN LEHNERT<sup>1</sup>, STEFFEN TURKAT<sup>1</sup>, FREDERIK UHLEMANN<sup>1</sup>, and KAI ZUBER<sup>1</sup> — <sup>1</sup>TU Dresden — <sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

The Deuterium-Tritium neutron generator of TU Dresden can provide several milliamperes of proton and deuteron beams with energies of up to 350 keV. So far the accelerator was used to generate monoenergetic 14 MeV neutrons for fusion research via the  $^3\text{H}(d, n)^4\text{He}$  reaction with up to  $10^{12}$  n/s.

This contribution will present the feasibility studies and modifications required to transform this neutron production facility into a laboratory, which in addition will also be used for nuclear astrophysics, i.e. investigations of reactions relevant for Big Bang Nucleosynthesis (BBN). Key parameters such as beam characterization, energy calibration, and operational limits will be reported, providing the basis for future high-precision cross-section measurements. In addition, the new ASTRO beam line and the collaborative effort to use the ELISSA silicon strip detector array in Dresden will be introduced for the first time. These upgrades enable forthcoming studies of the  $d(d, p)^3\text{H}$  and  $d(d, n)^3\text{He}$  reactions, which currently limit our understanding of the primordial deuterium abundance in BBN models.

HK 25.6 Wed 15:15 PHIL A 602

**Geant4 simulation towards the measurements of  $^2\text{H}(d, p)^3\text{H}$  and  $^2\text{H}(d, n)^3\text{He}$  reactions at the DT generator of TU Dresden** — •FREDERIK UHLEMANN, BJÖRN LEHNERT, MAX OSSWALD, STEFFEN TURKAT, and KAI ZUBER — Institut für Kern- und Teilchenphysik, TU Dresden

The  $^2\text{H}(d, p)^3\text{H}$  and  $^2\text{H}(d, n)^3\text{He}$  reactions are critical for determining the primordial deuterium abundance D/H after Big Bang nucleosynthesis. Improved cross section data for these channels would reduce the uncertainty on the cosmic baryon density  $\Omega_b h^2$ . The resulting value could reach a precision comparable to that of the CMB, while remaining fully independent. This would improve our understanding of early universe physics and provides a powerful cross-check for entirely independent fields of (astro-)physics.

The Deuterium-Tritium neutron generator of TU Dresden is a unique facility in Europe that was mainly used for fusion research so far. Based on its new ASTRO beam line, this facility will be capable to measure these two reaction channels from 10 keV to 350 keV, which covers the entire energy range relevant for BBN. Measurements of the two deuterium reactions using solid targets are planned. This talk will focus on Geant4 simulations for this campaign, with a focus on the setup, utilized targets and detectors.

## HK 26: Instrumentation V

Time: Wednesday 13:45–15:30

Location: PHIL A 301

HK 26.1 Wed 13:45 PHIL A 301

**Development of a Scintillating Fiber Hodoscope for the Proton Radius Measurement at AMBER** — •KARL EICHHORN<sup>1</sup>, JAN MICHAEL FRIEDRICH<sup>1</sup>, JAROSŁAW GRZYB<sup>2</sup>, IGOR KONOROV<sup>1</sup>, MARTIN J. LOSEKAMM<sup>3</sup>, TIM MAEHRHOLZ<sup>1</sup>, FELIX MINDL<sup>1</sup>, STEPHAN PAUL<sup>1</sup>, MARCIN STOLARSKI<sup>2</sup>, and FROWIN WILD<sup>1</sup> — <sup>1</sup>TUM School of Natural Sciences - Technical University of Munich, 85748 Garching, Germany — <sup>2</sup>National Centre for Nuclear Research, 02-093 Warsaw, Poland — <sup>3</sup>European Space Agency, ESTEC, 2201 AZ Noordwijk, Netherlands

The AMBER experiment will measure the proton charge radius using elastic muon-proton scattering at the M2 beam line at CERN. Four Scintillating Fiber Hodoscopes (SFHs) will be used in combination with ALPIDE pixel sensors to reconstruct the incoming beam particles, as well as the muons that have been scattered off the active hydrogen target. Each SFH consists of four 9x9 cm<sup>2</sup> large planes of square scintillating fibers, which are read out individually with SiPM arrays. Keeping the material budget to a minimum, they provide precise timing information using custom readout electronics based on the Citiroc 1A ASIC and the AMBER iFTDC. The first SFH detector was built and successfully tested with a high-energy muon beam in 2025. We will present the results of this beam test and provide an outlook on further developments.

We acknowledge funding from BMBF (grant number 05P24WO1) and MNiSW (grant number 2025/WK/03).

HK 26.2 Wed 14:00 PHIL A 301

**Heavy-ion tracking detector at R<sup>3</sup>B** — •ISABELLE BRANDHERM<sup>1</sup>, CHRISTOPH CAESAR<sup>2</sup>, PABLO GARCÍA-GIL<sup>2,3,4</sup>, MICHAEL HEIL<sup>2</sup>, DENIZ SAVRAN<sup>2</sup>, and ANDREAS ZILGES<sup>1</sup> for the R3B-Collaboration — <sup>1</sup>Institute for Nuclear Physics, University of Cologne, Germany — <sup>2</sup>GSI Helmholtzzentrum, Darmstadt, Germany — <sup>3</sup>Universidad de Vigo, Vigo, Spain — <sup>4</sup>Institute for Nuclear Physics, Technical University of Darmstadt, Germany

The R<sup>3</sup>B (Reactions with Relativistic Radioactive Beams) experiment at GSI is a versatile setup that enables kinematically complete measurements. Tracking detectors are used at R<sup>3</sup>B to reconstruct the trajectories of charged particles as they pass through the magnetic field of the GSI Large Acceptance Dipole (GLAD) magnet. This allows the magnetic rigidity of the particles to be determined.

This talk presents the design and performance of a position-sensitive scintillation-fiber detector that will be a part of the tracking system for heavy ions. The detector is constructed from ultra-thin scintillation fibers with a thickness of 200 μm. Thin fibers are used to minimize the material budget in the particle trajectory and thus reduce straggling within the detector material. The fibers are read out with silicon photomultipliers, allowing the detector to operate in magnetic fields while maintaining high detection efficiency.

Gefördert durch das Ministerium für Kultur und Wissenschaft des Landes Nordrhein-Westfalen

HK 26.3 Wed 14:15 PHIL A 301

**Study of a low-temperature SiPM readout system for DarkMESA** — •CHRISTIAN STOSS for the MAGIX-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

The existence of dark matter remains one of the most significant open questions in particle physics. The DarkMESA experiment aims to search for light dark matter (LDM) in an unexplored mass and coupling regime. This parasitic beam dump experiment will be located downstream of the P2 experiment at the new MESA accelerator in Mainz. It is planned to operate for several thousands of hours in extracted beam mode, using a 150 μA electron beam with an energy of 155 MeV. In the simplest model of LDM, the electrons might produce the dark photon as a massive vector particle via a Bremsstrahlung-like process in the beam dump, which then decay into dark matter particles. If LDM exists within the targeted parameter space, a fraction of the produced LDM will scatter off electrons in one of the calorimeters' Cherenkov crystals, generating a measurable signal.

Given the low probability of such an event, dark counts can significantly overlay the interesting signal. This presentation will focus on a feasibility study for a readout system consisting of one PMT with additional 5 cooled SiPMs per crystal as a small test setup. Initial measurements with a constant overvoltage and temperature dependent breakdown voltage will be presented. The aim is the reduction of dark counts while maintaining high detector efficiency for different temperatures.

HK 26.4 Wed 14:30 PHIL A 301

**Feasibility Study on a Backward Angle Sampling Calorimeter for the P2 Experiment at MESA** — ÓSCAR ANDÚJAR SABÁN<sup>1</sup>, NING CAO<sup>1</sup>, LUIGI CAPOZZA<sup>1</sup>, •JONAS GEISBÜSCH<sup>1</sup>, RAVI GOWDRU MANJUNATA<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, ANTOINE MARTINET<sup>1</sup>, OLIVER NOLL<sup>1,2</sup>, PAUL SCHÖNER<sup>1</sup>, CHRISTOPH ROSNER<sup>1</sup>, PIERRE VIJAYAN<sup>1</sup>, and SAHRA WOLFF<sup>1</sup> — <sup>1</sup>Helmholtz-Institut Mainz, Mainz, Germany

— <sup>2</sup>Institute of Nuclear Physics, Mainz, Germany — <sup>3</sup>PRISMA+ Cluster of Excellence, Mainz, Germany

A sampling calorimeter with SiPM read-out for the detection of high energy particles is under development. Such a calorimeter can be well suited for many experiment applications where space limitations apply. The main focus is on choosing the right material, as well as the right arrangement of active and passive material. Different mechanical options will be explored. The detector prototype design will be prepared by doing detector response simulations to ensure a high energy resolution, as well as a high spatial resolution. A possible application for such a calorimeter is the P2 experiment at the upcoming MESA accelerator in Mainz. The talk will give an update on the progress of this project.

HK 26.5 Wed 14:45 PHIL A 301

**A new Liquid Scintillator Veto System for Rare Event Searches** — •MICHAEL KONTIGOULAS for the MAGIX-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

In the ongoing search for light dark matter, the DarkMESA and NuDoubt<sup>++</sup> experiments have combined their efforts to probe a new region of parameter space. DarkMESA is a forthcoming electron beam dump experiment to be located in the new MESA accelerator facility in Mainz, designed to detect light dark matter particles using a PbF<sub>2</sub> crystal calorimeter. The NuDoubt<sup>++</sup> experiment will utilize an opaque liquid scintillator detector to investigate the double beta decay ( $2\beta^+$ ) and the neutrinoless double beta decay ( $0\nu\beta\beta$ ). Due to the expected rarity of these interactions, exceptional background rejection is crucial for identifying potential events. Therefore, both experiments plan to use passive and active shielding layers against background radiation.

This contribution will focus on the development of a liquid scintillator veto prototype for use in both experiments. The prototype will feature a hexagonal geometry with an active volume of approximately 0.351 m<sup>3</sup>, filled with a linear alkylbenzene (LAB) scintillator, doped with 0.2wt.% Gadolinium for enhanced neutron tagging. The scintillator will be read out by seven 5-inch PMTs mounted on the top surface of the volume. A comparative analysis will be presented, comparing simulation results with initial tests of the prototype to evaluate veto efficiency, with particular emphasis on neutron rejection, given their significance as a background in dark matter searches.

HK 26.6 Wed 15:00 PHIL A 301

**Construction of the crystal Zero Degree Detector for BESIII** — •FREDERIC STIELER, ACHIM DENIG, PETER DREXLER, WERNER LAUTH, MAX LELLMANN, JAN MUSKALLA, JANNIK PETERSEN, SASKIA PLURA, CHRISTOPH FLORIAN REDMER, YASEMIN SCHELHAAS, and HANG ZHOU — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

The crystal Zero Degree Detector (cZDD) is an addition to the BESIII experiment in China. In order to measure hadronic cross sections with the Initial State Radiation (ISR) method for a more precise calculation of the hadronic vacuum polarization contribution to the anomalous magnetic moment of the muon, ISR photons have to be detected. Since these photons are mostly emitted at small angles in relation to the colliding particles, the cZDD will measure these photons at angles of about 1.5 mrad to 10.4 mrad, which are not covered yet by the already existing detectors at BESIII.

Following its installation at BESIII, first commissioning data have been taken. The detector is now being used to perform relative-luminosity measurements, allowing an evaluation of its performance and stability under real experimental conditions.

This contribution discusses the current status of the cZDD, covering its installation, commissioning, and the first results of the relative-luminosity measurements.

HK 26.7 Wed 15:15 PHIL A 301

**Studies of Cosmogenic Backgrounds in a Shielded Crystal Calorimeter for DarkMESA** — •SHUMIT MITRA — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

DarkMESA is a planned electron beam-dump experiment at the MESA accelerator facility in Mainz, designed to search for light dark matter particles mediated by a hypothetical dark photon  $\gamma'$  using a compact crystal calorimeter. Due to the extremely low expected interaction rates of beyond-the-Standard-Model processes, efficient background suppression is essential. DarkMESA therefore relies on a combination of passive and active shielding to mitigate cosmogenic and beam-related backgrounds. This contribution presents the development and characterization of a prototype calorimeter composed of  $5 \times 5$  PbWO<sub>4</sub> crystals of dimensions  $2 \times 2 \times 20$  cm<sup>3</sup> with single-sided SiPM readout per crystal. The calorimeter is hermetically surrounded by inner and outer plastic scintillator veto layers and passive lead shielding. The detector performance with respect to cosmogenic muon- and gamma-induced backgrounds in the relevant energy

range around 5 MeV and above is discussed and compared to detailed simulations. First results from long-term background measurements with the full detector setup are presented. Possible contributions from cosmogenic neutrons are

briefly addressed. Finally, an outlook on the implications of these studies for a PbWO<sub>4</sub>-based DarkMESA detector is given.

## HK 27: Poster Session

Time: Wednesday 16:15–18:30

Location: Redoutensaal

HK 27.1 Wed 16:15 Redoutensaal

**Latest Progress Concerning the Front-End Electronics Prototype for the PANDA Barrel EMC** — •ANIKO TIM FENSKE, KAI-THOMAS BRINKMANN, HANS-GEORG ZAUNICK, and KARL SIMON HABERMEHL for the PANDA-Collaboration — 2<sup>nd</sup> Physics Institute, Justus Liebig University, Giessen, Germany

The barrel section of the PANDA electromagnetic calorimeter (EMC) at the future FAIR facility is designed to precisely measure photon and charged particle energies over a wide dynamic range. Achieving the targeted performance requires not only a carefully engineered detector system but also a detailed understanding of its operational behavior under realistic conditions.

Therefore, recent efforts have concentrated on an in-depth analysis of calibration data and functional tests of the readout and front-end electronics. Building on results from the current prototype setup, a comprehensive evaluation of in-beam measurements and laboratory studies has been carried out, with particular attention to the stability, linearity, and noise characteristics of the system. This contribution summarizes the latest findings of these analyses and discusses their implications for the final configuration of the Barrel EMC.

*Supported by the BMFTR, GSI and HFHF.*

HK 27.2 Wed 16:15 Redoutensaal

**Accessing transverse momentum dependent distribution functions with semi-inclusive deep inelastic single pion and kaon production** — •STEFAN DIEHL<sup>1,2</sup> and ARON KRIPKO<sup>1</sup> for the CLAS-Collaboration — <sup>1</sup>II. Physikalisches Institut, JLU Gießen, Gießen, Germany — <sup>2</sup>University of Connecticut, Storrs, CT, USA

Semi-inclusive deep inelastic scattering is a well-established tool to study TMDs and fragmentation functions. With the CLAS12 detector at Jefferson Laboratory (JLab), precise, multidimensional measurements of cross sections and asymmetry observables become possible in the valence quark regime for the first time. Based on the new high statistics data, the polarized structure-function ratio  $F_{LU}^{\sin\phi}/F_{UU}$ , as well as the un-polarized cross section modulations  $F_{UU}^{\cos\phi}$  and  $F_{UU}^{\cos 2\phi}$  were studied for single pion and kaon SIDIS. The contribution will present a comprehensive multidimensional study for all three pions as well as positive kaons and discuss the connection of the observable to TMDs and the impact of the new data on our understanding of the involved TMDs and their flavour separation. \*The work is supported by Deutsche Forschungsgemeinschaft (Project No. 508107918).

HK 27.3 Wed 16:15 Redoutensaal

**Correction of the recoil attenuation in a plunger stopper foil** — •DENIZ OYAN, VOLKER WERNER, HANNES MAYR, CLEMENS NICKEL, KATHARINA IDE, and NORBERT PIETRALLA — IKP, TU Darmstadt

Measurements applying the recoil-distance Doppler-shift method [1] at high recoil velocities of around 5 %  $v/c$  are prone to suffer from partially overlapping stop and flight components, due to the slowing-down process in the stopper. The Doppler-shifted  $\gamma$ -ray energy of the de-excitation is governed by the ion's velocity distribution. Thus, the flight component cannot be distinguished from the Doppler tail of the (usually denoted "unshifted") component from ions having reached the stopper by simple Gaussian fits. To disentangle both components a simulation using the DSAM analysis software APCAD [2] is performed.

Accurate knowledge on lifetimes of excited states of <sup>104,106,108</sup>Pd is necessary to precisely determine E2 transition strengths and  $g$  factors in this region of the nuclear chart. Therefore, our simulation is conducted on a dataset of the Pd isotopes from WNSL, Yale University [3]. This contribution presents the applicability of our method to correct for the attenuation in the stopper foil.

[1] A. Dewald *et al.*, Prog. Part. Nucl. Phys. **67**, 786-839 (2012)

[2] C. Stahl *et al.*, Comput. Phys. Commun. **214**, 174-198 (2017)

[3] V. Werner *et al.*, J. Phys.: Conf. Ser. **366**, 012048 (2012)

HK 27.4 Wed 16:15 Redoutensaal

**The young High Energy Physicists Association (yHEP)** — FARAH AFZAL<sup>1</sup>, JUDITA BEINORTAITE<sup>2</sup>, JULIAN GETHMANN<sup>3</sup>, SIMRAN GURDASANI<sup>4</sup>, MEIKE KÜSSNER<sup>1,5</sup>, •MICHAEL LUPBERGER<sup>5,6</sup>, LEONEL MOREJON<sup>7</sup>, LEONIEDAS RESCHKE<sup>8</sup>, and SRIJAN SEHGAL<sup>7</sup> — <sup>1</sup>Ruhr University Bochum — <sup>2</sup>DESY — <sup>3</sup>Karlsruhe Institute of Technology — <sup>4</sup>University of Berlin — <sup>5</sup>University of Bonn — <sup>6</sup>University of Freiburg — <sup>7</sup>University of Wuppertal — <sup>8</sup>University of Giessen

The young High Energy Physicists Association(yHEP) represents non-permanent scientists within the German and international particle, astroparticle,

hadron, nuclear, and accelerator physics communities. Its members range from bachelor and master students to PhD candidates, postdocs, and junior group leaders. The association works to improve working conditions, research support, and career perspectives for early-career researchers. yHEP strengthens the involvement of young scientists in scientific and political decision-making processes, aiming to build broad consensus and to ensure that every voice is heard. This poster introduces the structure and goals of yHEP and provides information on how interested researchers can engage with the community. Meet your yHEP management board representatives at the poster to discuss your topics or to hear what yHEP does for you and how you can get involved.

HK 27.5 Wed 16:15 Redoutensaal

**Triple Nuclear Collisions in SMASH** — •LUIS MIGUEL VÉLEZ<sup>2</sup>, LUCAS CONSTANTIN<sup>2</sup>, and HANNAH ELFNER<sup>1,2,3,4</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt, Germany — <sup>2</sup>Institute for Theoretical Physics, Goethe University, Max-von-Laue-Strasse 1, 60438 Frankfurt am Main, Germany — <sup>3</sup>Frankfurt Institute for Advanced Studies, Ruth-Moufang-Strasse 1, 60438 Frankfurt am Main, Germany — <sup>4</sup>Helmholtz Research Academy Hesse for FAIR (HFHF), GSI Helmholtz Center, Campus Frankfurt, Max-von-Laue-Strasse 12, 60438 Frankfurt am Main, Germany

One goal of binary heavy-ion collisions is to study strongly interacting matter under extreme conditions e.g. at a high baryon density. Nevertheless, an even higher density can be accomplished by colliding three nuclei instead of two in a Triple Nuclear Collision (TNC). In this work, the process of simulating a TNC with the use of the hadronic transport approach SMASH (Simulating Many Accelerated Strongly-interacting Hadrons) is presented. Furthermore, the observables for particle production of central Pb+Pb+Pb TNCs at energies between 3 GeV and 20 GeV are examined. Simultaneously, these findings are compared with those of binary Pb+Pb collisions with the same respective energy and centrality. Finally, it is shown that a TNC leads to a higher baryon and energy density than in binary collisions, thus exposing a promising method to better understand QCD matter.

HK 27.6 Wed 16:15 Redoutensaal

**Advances in Readout Electronics and Calibration for the PANDA Micro Vertex Detector** — •MARVIN PETER<sup>1</sup>, KAI-THOMAS BRINKMANN<sup>1</sup>, RAPHAEL RATZ<sup>1</sup>, HANS-GEORG ZAUNICK<sup>1</sup>, MICHELE CASELLE<sup>2</sup>, DANIELA CALVO<sup>3</sup>, and GIOVANNI MAZZA<sup>3</sup> for the PANDA-Collaboration — <sup>1</sup>2<sup>nd</sup> Physics Institute Justus Liebig university Giessen — <sup>2</sup>Karlsruhe Institute of Technology — <sup>3</sup>Istituto Nazionale di Fisica Nucleare - Sezione di Torino

The Micro Vertex Detector (MVD) forms the innermost tracking layer of the PANDA experiment, positioned closest to the interaction point. Silicon strip sensors are read out by the Torino Amplifier for silicon Strip detectors (ToAST) ASIC, a 64-channel self-triggered chip based on the Time-over-Threshold principle, developed by INFN Turin. In this contribution, we present recent advancements including the implementation of a new test bench and a comprehensive calibration framework for the ToAST ASIC based on the readout system provided by KIT. Results from calibration measurements with radioactive sources are discussed. *Supported by BMFTR.*

HK 27.7 Wed 16:15 Redoutensaal

**Simulation study of  $\pi^0$  flow contribution to direct photon HBT measurement** — •LUIS ESCALANTE — Institut für Kernphysik, Goethe-Universität Frankfurt

In heavy-ion collisions at the CERN-LHC, a new state of matter, the quark-gluon plasma (QGP), can be created to examine its properties, such as the temperature and spatio-temporal evolution. One approach to probe these properties is the measurement of Bose-Einstein correlations of direct photons using HBT interferometry. The measurement of direct-photon HBT correlations, however, requires a highly accurate determination of background contributions. Previous studies have shown that one of the dominant background sources is contamination from the elliptic flow ( $v_2$ ) of  $\pi^0$  mesons. Providing a reliable estimate of this flow contribution is therefore essential for extracting the direct-photon signal.

In this poster, a simulation framework for assessing flow-induced correlations of decay photons originating from  $\pi^0$  mesons is presented. The study incorporates measured  $\pi^0$  yields and flow coefficients from ALICE Pb-Pb data and investigates the centrality dependence of flow contributions from decay photons. In addition, the impact of flow using the Bertsch-Pratt parametrization is explored. Based on the findings of these studies, an optimized description of mixed-event is proposed, for which the current status is presented.

*Supported by BMFTR and the Helmholtz Association.*

HK 27.8 Wed 16:15 Redoutensaal

**Conceptual Design of a Fragment Separator for Producing Positron-Emitting Light-Ion Beams in Hadron Therapy** — •SURAJ KUMAR SINGH<sup>1,2</sup>, BERNHARD FRANZAK<sup>1</sup>, CHRISTOPH SCHEIDENBERGER<sup>1,2,3</sup>, DARIA KOSTYLEVA<sup>1</sup>, EMMA HAETTNER<sup>1</sup>, and SIVAJI PURUSHOTHAMAN<sup>1</sup> for the Super-FRS Experiment-Collaboration — <sup>1</sup> GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — <sup>2</sup> II. Physikalisches Institut, JLU, Gießen — <sup>3</sup> Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Giessen

Recent advances in hadron therapy have stimulated growing interest in the use of light, positron-emitting ion beams as an alternative to conventional heavy ions such as <sup>12</sup>C. These radionuclides-produced efficiently through projectile fragmentation and in-flight separation-offer half-lives and production yields well suited for in-beam positron emission tomography (PET), enabling improved real-time verification of beam range during treatment. In this poster, a conceptual design for a fragment separator optimized to deliver such therapeutic positron-emitting light ions will be presented. The system integrates a production target with a sequence of dipole and quadrupole magnets, energy-loss degraders, and time-of-flight diagnostics to perform Bp-ΔE-ToF particle identification and achieve high beam purity and tunability. This design provides a flexible platform capable of supplying a range of clinically relevant positron-emitting isotopes, supporting enhanced imaging-guided dose delivery and paving the way for more precise and adaptive cancer treatment modalities.

HK 27.9 Wed 16:15 Redoutensaal

**New Rutherford Backscattering Spectrometry chamber for experimental nuclear astrophysics in Cologne** — •BENEDIKT MACHLINER, MARTIN MÜLLER, SVENJA WILDEN, and ANDREAS ZILGES — University of Cologne, Institute for Nuclear Physics, Germany

Understanding the formation of the elements in the universe is one of the ultimate objectives of nuclear astrophysics. In order to gain a more profound understanding of the complex processes involved in nucleosynthesis, it is crucial to consider the input from all constituents of this highly interdisciplinary field. Key observables, that experimental nuclear physics can contribute, include cross sections and reaction rates, which are indispensable for constraining model calculations.

In order to experimentally determine absolute reaction cross sections, it is necessary to know the number of target nuclei per unit area with sufficient precision. A method that is frequently utilized to determine the areal density - i.e. the target thickness - is Rutherford Backscattering Spectrometry (RBS). This work presents the new RBS chamber of the Institute for Nuclear Physics at the University of Cologne, which can be attached to both of the institute's accelerators, namely the 10 MV FN Tandem and 6 MV Tandetrion accelerator [1]. The recent experimental campaign demonstrates a substantial enhancement in efficiency, attributable to the advanced instrumentation, without any compromise in precision, as suggested by preliminary data.

Supported by the DFG (ZI 510/12-1).

[1] A. Dewald *et al.*, Nucl. Instrum. Methods B **294** (2013) 18-23

HK 27.10 Wed 16:15 Redoutensaal

**Improving the ALPACA particle-gamma spectrometer for telescope based particle identification** — •NICK MARX, MARKUS MÜLLENMEISTER, MICHAEL WEINERT, and ANDREAS ZILGES — University of Cologne, Institute for Nuclear Physics, Germany

Studying nuclear reactions requires precise particle identification (PID) [1], especially when multiple particles are generated in similar energy regions. The current work assesses the capabilities of Passivated Implanted Planar Silicon (PIPS) detectors operating in a telescope configuration, similar to the setup used in the SONIC@HORUS array [2]. The objective is to determine whether it is capable of accurately distinguishing between protons, deuterons, and tritons and whether the resolution is improved by new thin detectors. The detector performance was tested using deuteron beams at 10\*MeV and 18\*MeV at the FN Tandem accelerator of the University of Cologne. Measurements included both scattering and nuclear reactions on a <sup>197</sup>Au target in the ALPACA scattering chamber [3] to evaluate energy resolution and particle identification under realistic experimental conditions. First results demonstrate the achievable energy resolution and PID performance. These findings allow a direct comparison and evaluation of the improved detector setup for upcoming experiments.

[1] G. F. Knoll, *Radiation Detection and Measurement*, 4th ed., Wiley, Hoboken (2010).

[2] S. G. Pickstone *et al.*, Nucl. Instr. and Meth. A **875** (2017) 104.

[3] G. Huppelsberg, Master's thesis, University of Cologne (2024).

HK 27.11 Wed 16:15 Redoutensaal

**Investigation of the decay  $\chi_{c2} \rightarrow K^+ K^- \eta'$  and search for the exotic  $K_1^*$  at the BESIII Experiment** — •ANNA TSIAS, ACHIM DENIG, and NILS HUESKEN — Johannes Gutenberg-Universität Mainz

The BESIII experiment provides an opportunity to investigate  $\chi_{cJ}$  decays occurring in radiative  $\Psi(2S)$  transitions, thanks to its large data sample of  $(2259.3 \pm 11.1) \times 10^6$   $\psi(2S)$  events. Motivated by evidence for exotic mesons like the

$\pi_1(1600)$ , this analysis investigates  $\chi_{c2}$  decays to search for exotic resonances in the strange sector. In the  $K\eta'$  subsystem, there is the possibility to observe the hypothesized  $K_1^*$ , a strange member of the exotic hybrid nonet with quantum numbers  $J^{PC} = 1^{-+}$ . This is motivated by the observation of analogous states such as the  $\pi_1(1600)$  and  $\eta_1(1855)$  in similar charmonium decays. This decay channel is further of interest because it enables the study of higher-mass  $f_2$  and  $f_4$  mesons in the  $K^+ K^-$  subsystem, several of which were last reported in the 1990s and have not been revisited with modern datasets. Additionally, the  $f_2$  resonances observed in the  $K^+ K^-$  system are possible tensor glueball candidates, making this analysis a potential starting point for their identification.

HK 27.12 Wed 16:15 Redoutensaal

**Results from parabolic flight campaigns using a compact scintillation detector** — •ROMAN BERGERT, DZMITRY KAZLOU, HANS-GEORG ZAUNICK, and KAI-THOMAS BRINKMANN — 2<sup>nd</sup> Physics Institute, Justus Liebig University Giessen

A compact, low-power scintillation detector designed for environmental radiation monitoring and dosimetry applications will be presented. The detector utilizes an EJ-276D plastic scintillator, which possesses good pulse-shape discrimination (PSD) characteristics, thereby facilitating effective particle identification. The detector signal readout is performed using a Red Pitaya STEMLab 125-14 platform serving as a high-speed digitizer (125 MS/s, 14 bits resolution), combined with a bespoke high-voltage bias supply and a dual-channel silicon photomultiplier (SiPM) analog front-end readout. The two-channel analog front-end provides a high-gain path that is optimized for high resolution in the low-energy range, as well as a low-gain path that covers the high-energy range, thereby ensuring a higher dynamic range.

The fully integrated system is lightweight (<1 kg), compact (12 cm x 9 cm x 6 cm), and low-power (<8 W), rendering it highly suitable for portable, battery-powered, or autonomous operation. The detector assembly performance was evaluated during multiple parabolic flight campaigns, during which the detector operated autonomously in mixed radiation fields, acquiring complete signal waveforms for subsequent offline PSD analysis. The results are taken to discuss the feasibility of our compact, PSD-capable detector for future radiation monitoring and dosimetry missions.

HK 27.13 Wed 16:15 Redoutensaal

**Double-Sided Strip LGAD Detector Performance Study in Beam Operation** — •YEVHEN KOZYMYKA<sup>1</sup>, THOMAS BERGAUER<sup>2</sup>, TETIANA GALATYUK<sup>1,3,4</sup>, ALBERT HIRT<sup>5</sup>, MATTHIAS KAUSEL<sup>5,6</sup>, MLADEN KIS<sup>3</sup>, WILHELM KRÜGER<sup>1</sup>, SERGEY LINEV<sup>3</sup>, JAN MICHEL<sup>3</sup>, JERZY PIETRASZKO<sup>3</sup>, CHRISTIAN JOACHIM SCHMIDT<sup>3</sup>, MICHAEL TRÄGER<sup>3</sup>, MICHAEL TRAXLER<sup>3</sup>, FELIX ULRICH-PUR<sup>5</sup>, MATTEO CENTIS VIGNALI<sup>7</sup>, ASHISH BISHT<sup>7</sup>, ALFONS DEHE<sup>8</sup>, and YUANJI TIAN<sup>8</sup> — <sup>1</sup>Technische Universität Darmstadt — <sup>2</sup>Marietta Blau Institute for Particle Physics of the Austrian Academy of Sciences — <sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH — <sup>4</sup>Helmholtz Forschungsakademie Hessen für FAIR — <sup>5</sup>TU Wien, Atominstytut — <sup>6</sup>EBG MedAustron — <sup>7</sup>Fondazione Bruno Kessler, Centre of Materials and Microsystems — <sup>8</sup>Hahn-Schickard-Gesellschaft für angewandte Forschung e.V.

Strip low-gain avalanche diode (LGAD) detectors have demonstrated an excellent timing and spatial resolution, making them attractive for high energy physics applications, ion computed tomography and beam diagnostics. Double-sided readout is expected to increase the tracking accuracy in medical applications with no timing precision loss, while further reducing the material budget of the system.

We present our results from performing extensive diagnostics on a double-sided LGAD with parallel strip orientation, both with self-correlation as well as using single-sided LGADs as reference, performed with proton, helium and carbon beams of varying energies.

HK 27.14 Wed 16:15 Redoutensaal

**Development of a Scintillating Fiber Tracker as a Beam Monitor for Sub-Therapy Particle Rates at the Marburger Ion Beam Therapy Center** — THERESA HEINZ<sup>1,2</sup>, KAI-THOMAS BRINKMANN<sup>1</sup>, •LARA DIPPEL<sup>1</sup>, and HANS-GEORG ZAUNICK<sup>1</sup> — <sup>1</sup>2nd Physics Institute, Justus Liebig University Giessen, Germany — <sup>2</sup>D-PHYS, Institute for Particle Physics and Astrophysics (IPA)

This work presents the characterization and development of a scintillating fiber detector intended to be used as a beam monitoring system at the Marburg Ion Beam Therapy Center (MIT) for sub-therapy particle rates, where the in-house monitoring systems fail. The central focuses are the investigation of primary particle rate limitation and detector dead times, which were studied through dedicated measurements. These measurements provide performance benchmarks for future integration into various experimental setups which require lower particle rates.

Additionally, the development of the next detector version which contains more fibers and improves spatial resolution will be presented. Preparations for an FPGA-based readout system are carried out, enabling on-board logic for versatile detector operation. Geant4 simulations were carried out to validate the new detector design.



HK 27.15 Wed 16:15 Redoutensaal

**Bringing Particle Physics to Metal Festivals: Impressions from the Music Forge Festival** — •ANIKO TIM FENSKE<sup>1</sup>, KAI-THOMAS BRINKMANN<sup>1</sup>, HANS-GEORG ZAUNICK<sup>1</sup>, MARVIN PETER<sup>1</sup>, CHRISTIAN KLEIN-BOESING<sup>2</sup>, and DAVID BORGELT<sup>2</sup> for the Netzwerk Teilchenwelt-Collaboration — <sup>1</sup>2<sup>nd</sup> Physics Institute, Justus Liebig University, Giessen, Germany — <sup>2</sup>Institut für Kernphysik in Münster

The decreasing trust of modern society in science and scientists (becoming especially prominent during Covid pandemic) pushes scientists to find new ways of rebuilding that trust and making themselves visible and approachable. In our opinion, this task must be tackled via two main approaches. On the one hand, we as scientists should be using understandable language and motivating communication in conversations with non-scientists or those outside of our own field of expertise. On the other hand, we should visit places and events where science is rarely encountered and recognized.

This was the reason for us to start a cooperation with the Netzwerk Teilchenwelt group from Münster and the Music Forge Festival in the village of Lich, near Gießen, in 2024. In 2025, this cooperation was continued and we used the three days of the festival to communicate with a broad audience in and around a booth on the festival ground.

Additionally, some games and activities such as a "particle wall of death" and a soap volcano using dry ice were presented to attract the target group.

This contribution will show a selection of impressions from our outreach activities at the Music Forge Festival 2025.

HK 27.16 Wed 16:15 Redoutensaal

**Super-FRS Ion Catcher - Overview and Progress** — •JAMIE HARKIN for the Super-FRS Experiment-Collaboration — Justus-Liebig-Universität Gießen

At the Super-FRS-IC, the exotic nuclei produced at relativistic energies and separated in-flight will be thermalized in the Cryogenic Stopping Cell (CSC). The new CSC for the Super-FRS, currently under construction, features a High Areal Density Orthogonal (HADO) design, achieving an areal density of cryogenic helium (He) exceeding  $25 \text{ mg cm}^{-2}$  - a four-fold increase over existing systems. The stopping cell chamber (split into stopping and extraction regions), will be nested inside a larger insulating vacuum chamber. The beam will be delivered through air and two thin (100 micron) aluminium beam windows. Investigations into the deformation caused by the pressure differential between the regions; resulting energy deposition difference relative to beam position in the beam windows; optimizing thermal coupling between the cryo-coolers and the cryo-cell; ideal potentials of the DC push electrodes in the stopping region have been conducted. This poster presents these results, and the status of construction.

HK 27.17 Wed 16:15 Redoutensaal

**Particle Track classification using Object Condensation at MAGIX** — •NILS HESSE for the MAGIX-Collaboration — JGU Mainz

Machine Learning has been a part of modern physics for many years now, aiding with denoising, particle identification and even being used for generating particle events. However, a general limitation lies in the fact that neural networks have a fixed number of inputs and outputs, making classification of an unknown number of particle tracks not just more complex, but also inefficient.

Object Condensation is a loss function developed by Jan Kieseler in 2020, it solves this problem by transforming the input data into a learned condensation space and clustering in said space. This work explores the application of Object Condensation to the Prototype TPC of the Mainz Gas Injection target experiment (MAGIX) at the Mainz Energy-Recovering Superconducting Accelerator (MESA). Preliminary results are presented alongside an overview of the underlying principles of the Object Condensation approach.

HK 27.18 Wed 16:15 Redoutensaal

**A Comparative Study of Baryon Stopping Models: SMASH and ANGANTYR** — •MANOU P. ENGEL<sup>1</sup>, CARL B. ROSENKVIST<sup>1,3</sup>, and HANNAH ELFNER<sup>2,1,3,4</sup> —

<sup>1</sup>Institute for Theoretical Physics, Goethe University, Max-von-Laue-Strasse 1, 60438 Frankfurt am Main, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt, Germany — <sup>3</sup>Frankfurt Institute for Advanced Studies, Ruth-Moufang-Strasse 1, 60438 Frankfurt am Main, Germany — <sup>4</sup>Helmholtz Research Academy Hesse for FAIR (HFHF), GSI Helmholtz Center, Campus Frankfurt, Max-von-Laue-Strasse 12, 60438 Frankfurt am Main, Germany

In SMASH, a hadronic transport model, particle formation is modeled through hadronic resonances as well as *string* excitation and fragmentation, handled by PYTHIA8. Leading hadrons can interact earlier than newly produced, not yet fully formed hadrons. This mechanism reproduces baryon stopping in experimental data well at *low collision energies*, while it tends to overestimate stopping at *high energies*.

ANGANTYR, PYTHIA8's default Glauber-based heavy-ion model, models stopping through multiple nucleon interactions and provides a more realistic description of baryon stopping at LHC energies.

In this work, these two approaches will be compared to identify possible avenues to improve the description of baryon stopping in SMASH across colli-

sion energies. Specifically, we study their rapidity distributions and transverse-mass spectra as functions of centrality and collision energy. The results are compared to heavy-ion data from the LHC and from the STAR experiment at RHIC.

HK 27.19 Wed 16:15 Redoutensaal

**Status of the CBM Micro Vertex Detector Simulations\*** — •JULIO ANDARY for the CBM-MVD-Collaboration — Goethe-Universität Frankfurt am Main  
CBM's Micro Vertex Detector (MVD) will help identify rare particles emitted in violent heavy ion collisions at FAIR and supplements the main tracker (STS) with high-precision pointing capability close to the target. This places, besides outstanding radiation hardness, high demands on the material budget of the detector which in turn has an impact on the performance of the detector. Thus, the detector was optimized w.r.t. multiple scattering and adding unwanted background tracks originating from external conversion of photons.

The focus of this contribution is on the gain in tracking performance enabled by the MVD, also considering alternative detector geometries. Currently, there are two distinct variants of the MVD geometry - a vertexing geometry and a tracking geometry, adjusted to optimize either secondary vertexing of rare particles or particle tracking in a high multiplicity environment, together with the STS detector.

\*This work has been supported by BMFTR (05H24RF5), GSI and HFHF.

HK 27.20 Wed 16:15 Redoutensaal

**PID using unsupervised clustering methods and pulse shape discrimination in a Phoswich detector** — •SIMON GLENNEMEIER-MARKE<sup>1,2</sup>, KAI-THOMAS BRINKMANN<sup>1,2</sup> und LARA DIPPEL<sup>1,2</sup> — <sup>1</sup>2<sup>nd</sup> Physics Institute, Justus-Liebig-University, Gießen — <sup>2</sup>LOEWE Research Cluster for Advanced Medical Physics in Imaging and Therapy (ADMIT)

On this poster, we present a workflow for particle identification (PID) in a Phoswich detector, which consists of a fast plastic scintillator optically coupled to a thicker barium fluoride (BaF) scintillator. The dissimilarity in the scintillation characteristics of both materials enables pulse shape discrimination (PSD) between different particle species. We use a dataset obtained at Marburg Ion Beam Therapy Center (MIT) using 300 MeV/u carbon ions impinging on a water target. Feature engineering and unsupervised clustering methods are applied to categorize new observations, unseen during training, even in high rate environments where signal pile-ups occur. Classified detections can then be used to determine the relative abundances. This project is part of the ADMIT consortium under Project Part A, which focuses on estimating spectral neutron fluxes for flash therapy in tumor treatment applications. This project is financed with funds of LOEWE - Landes-Offensive zur Entwicklung Wissenschaftlich-ökonomischer Exzellenz, Förderlinie 2: LOEWE-Schwerpunkte.

HK 27.21 Wed 16:15 Redoutensaal

**Thermal triggering of superconducting nanowires for a potential electron tagger at KATRIN** — •CHRISTIAN GÖNNER<sup>1,2</sup>, JUAN NAVARRO ARENAS<sup>1</sup>, CARSTEN SCHUCK<sup>1</sup>, and CHRISTIAN WEINHEIMER<sup>2</sup> — <sup>1</sup>Department for Quantum Technology, University of Muenster, Germany — <sup>2</sup>Institute for Nuclear Physics, University of Muenster, Germany

The neutrino mass experiment KATRIN has effectively collected 1000 days of tritium beta decay data, allowing to achieve a sensitivity for an upper limit on the electron neutrino mass of  $m < 300 \text{ meV}$  at 90% C.L.. After searching for sterile keV neutrinos with the TRISTAN detector at KATRIN a potential next generation experiment labeled KATRIN++ aims to go beyond this limit and probe the inverted mass ordering range down to neutrino masses  $m < 50 \text{ meV}$ . Besides the necessary development of an atomic tritium source, achieving the required sensitivity requires a new differential method with sub-eV energy resolution. This may be possible through direct time-of-flight spectroscopy of beta-decay electrons. This approach requires detection of electrons when entering the KATRIN spectrometer with minimal change of its energy. The feasibility of a detector based on superconducting nanowires as is already used in single-photon detectors (SNSPDs) is investigated. It could offer the required sensitivity and timing resolution by exploiting the disruption of the superconducting state, while a 2D membrane interaction medium for beta electrons, yielding quasi-discrete excitations to detect via the superconducting nanowires. This work is supported by BMFTR under contract number 05A23PMA.

HK 27.22 Wed 16:15 Redoutensaal

**Feasibility studies for the measurement of collective phenomena with multi-particle azimuthal correlations and cumulants in CBM at FAIR** — •ANTE BILANDZIC for the CBM-Collaboration — Technical University of Munich, TUM School of Natural Sciences, Department of Physics, Garching, Germany

In non-central heavy-ion collisions, the initial volume containing the strongly interacting nuclear matter is anisotropic in the coordinate space, due to the leading-order ellipsoidal geometry of non-central collisions. Multiple interactions within this anisotropic volume cause the anisotropy to be transferred from the coordinate space into the momentum space via the thermalized medium, resulting in the anisotropic flow phenomenon. Anisotropic flow is a sensitive probe

of the equation of state and transport properties of produced matter, particularly of its shear viscosity.

In this contribution, the status of feasibility studies for measuring collective anisotropic flow with multiparticle azimuthal correlations and cumulants is presented for data-taking conditions in the CBM experiment at FAIR.

HK 27.23 Wed 16:15 Redoutensaal

**Lifetime determination of first excited 0+ state of 52Cr** — •STEFFEN MEYER<sup>1</sup>, THORSTEN KRÖLL<sup>1</sup>, ANNA-LENA HARTIG<sup>1</sup>, MARTIN VON TRESCKOW<sup>1</sup>, RUXANDRA BORCEA<sup>2</sup>, STEFANA CALINESCU<sup>2</sup>, ADINA COMAN<sup>2</sup>, CRISTIAN COSTACHE<sup>2</sup>, IRINA DINESCU<sup>2</sup>, RAZVAN LICA<sup>2</sup>, NICU MARGINEAN<sup>2</sup>, CONSTANTIN MIHAI<sup>2</sup>, SORIN PASCU<sup>2</sup>, SEBASTIAN TOMA<sup>2</sup>, ANDREI TURTURICA<sup>2</sup>, KALIN GLADNISHKI<sup>3</sup>, DIANA KOICHEVA<sup>3</sup>, GEORGI RAINOVSKI<sup>3</sup>, MARGARITA EFSTATHIOU<sup>4</sup>, and PAVLOS KOSEOGLOU<sup>4</sup> — <sup>1</sup>TU Darmstadt — <sup>2</sup>IFIN-HH, Magurele, Romania — <sup>3</sup>University of Sofia, Bulgaria — <sup>4</sup>University of Athens, Greece

For 52Cr a coexistence of a spherical ground and deformed excited 0+ state can be expected. A recent measurement for the first excited 0+ state determined the E0/E2 branching ratio to the 0+ ground and the first 2+ state. In order to determine the absolute value of the E0 strength the lifetime of the first excited 0+ state is required.

To determine this lifetime a DSAM experiment was performed in 2024 using the ROSPHERE detector array at the tandem accelerator at IFIN-HH in Magurele, Romania. It was noted that the lifetime is outside the sensitivity range of DSAM. To follow up on this experiment a plunger measurement was performed in 2025 with the IFIN-HH plunger device. Now the lifetime will be determined using the RDDS method, which is suitable to determine lifetimes in the suspected range.

The current state of the analysis with preliminary values is presented.

This work is supported by EURO-LABS grant No. 101057511.

HK 27.24 Wed 16:15 Redoutensaal

**Fast detector simulation with machine learning for ALICE 3** — •NILS MEURER — Goethe-Universität Frankfurt am Main  
High-energy physics experiments rely on simulations to correct measured collision data for detector effects. Performing these simulations causes high demands in computing resources. Machine learning (ML) models are considered a fast alternative for traditional simulation approaches.

In this poster, a conceptual study of ML-based detector response models using simulation data of the future ALICE 3 experiment is presented. The tracking performance and reconstruction efficiency for inclusive charged particles are compared to the full detector simulation and different ML approaches are explored. The current status of the project will be presented.

Supported by BMFTR and the Helmholtz Association.

HK 27.25 Wed 16:15 Redoutensaal

**$\phi$  Production at subthreshold energies at HADES** — •FELIX FRITZEMEIER — Max-von-Laue-Straße 1, 60438 Frankfurt am Main  
HADES explores the region of the phase diagram of strongly interacting matter with the highest net-baryon densities accessible in heavy-ion collisions. In this regime, sub-threshold strangeness production is a particularly sensitive probe of the energy sharing inside the fireball. The  $\phi$ -meson is especially interesting at deep subthreshold energies: the  $\phi/K^-$  ratio is observed to increase towards lower  $\sqrt{s_{NN}}$ , and a successful reconstruction of  $\phi$  mesons in Au+Au at  $\sqrt{s_{NN}} = 2.24$  GeV (well below the free production threshold of  $\sqrt{s_{NN}} = 2.90$  GeV) would provide the lowest-energy  $\phi$  data point measured so far.

The analysis is highly challenging, but as a first step we achieve good agreement between same-event and mixed-event invariant-mass distributions, demonstrating control over the combinatorial background. This establishes a solid basis for further studies with the next-generation calibrated data set and an improved signal-to-background ratio through enhanced charged-kaon identification.

HK 27.26 Wed 16:15 Redoutensaal

**Prospect of hypernuclei flow measurements with HADES in Ag+Ag collisions at  $\sqrt{s_{NN}} = 2.55$  GeV** — •CHRISTOPHER GRIMM for the HADES-Collaboration — Goethe-Universität, Frankfurt am Main

The hyperon-nucleon (Y-N) interaction plays an important role in the equation of state (EOS) of nuclear matter at high baryon densities, crucial for the understanding of neutron stars. To this end, the measurement of hypernuclei, in particular their collective behavior, offers unique insights. On earth we can produce hypernuclei in heavy-ion collisions and detect them with detectors like the High Acceptance Di-Electron Spectrometer (HADES) located at the GSI Helmholtz Centre for Heavy-Ion Research in Darmstadt, Germany. HADES combines a nearly complete azimuthal coverage with a high mass resolution and is therefore able to reconstruct hypernuclei in a significant number.

The HADES collaboration presented the first observation of  $^3_\Lambda H$  and  $^4_\Lambda H$  in Ag+Ag collisions at  $\sqrt{s_{NN}} = 2.55$  GeV, emitted around mid-rapidity, yielding approximately 1000  $^3_\Lambda H$  and 4000  $^4_\Lambda H$  signal candidates. In this work we estimate if this multiplicity is sufficient to measure, for the first time, the directed ( $v_1$ ) and elliptic ( $v_2$ ) flow components of hypernuclei. Additionally, we

present predictions for the elliptic flow of hypernuclei ( $v_2$ ) using a coalescence model.

HK 27.27 Wed 16:15 Redoutensaal

**Hydrodynamic attractors in periodically driven weakly and strongly coupled systems** — •MARTIN VRDOLJAK<sup>1</sup>, SÖREN SCHLICHTING<sup>2</sup>, ALEXAS MAZELIAUSKAS<sup>3</sup>, LOUIS ONWUKA<sup>4</sup>, SIMON SCHNEIDER<sup>5</sup>, and TOSHALI MITRA<sup>6</sup> — <sup>1</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>2</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>3</sup>Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg, Germany — <sup>4</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>5</sup>Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — <sup>6</sup>Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg, Germany

This research investigates equilibration processes and hydrodynamic reactions within systems subjected to periodic one-dimensional expansion. By employing a multi-faceted approach, incorporating strongly coupled holographic models, weakly coupled kinetic theory, and various hydrodynamic frameworks, we analyze the shear response to periodic driving across a range of amplitudes and frequencies. Unlike the standard monotonic Bjorken expansion, these systems do not converge toward thermal equilibrium or traditional Navier-Stokes behavior. In the regime of low drive frequencies and small amplitudes, we observe a universal late-time cyclic attractor that is consistent across different frameworks and accurately characterized by Müller-Israel-Stewart (MIS) theory. Conversely, high-amplitude driving triggers non-linear heating, which causes a continuous drift in both the fundamental system properties and the resulting attractor dynamics.

HK 27.28 Wed 16:15 Redoutensaal

**Radon concentration monitoring for future liquid xenon radon removal systems** — •SAKUNTHA NIRODANA PRATHAPAGE, LUTZ ALTHUESER, ROBERT BRAUN, DAVID KOKE, VOLKER HANNEN, CHRISTIAN HUHMANN, YING-TING LIN, PHILIPP SCHULTE, PATRICK UNKHOFF, DANIEL WENZ, and CHRISTIAN WEINHEIMER — University of Münster, Germany

In next generation dark matter experiments, such as XLZD, it is important to maintain a low radioactive background inside the detector as the dark matter events are extremely rare and mimicked by background signals. The intrinsic radioactive noble isotope Radon-222, which is continuously emanating from detector materials and its decay progenies contribute to an unshieldable background inside liquid xenon detectors. Continuous cryogenic distillation reduces the radon level by exploiting radon's lower volatility relative to xenon, thereby trapping it within the distillation column where it subsequently decays with a 3.8-day half-life. As a part of the LowRAD project an in-column radon detector is designed and constructed, that exploits the inherent enrichment of radon in the distillation column, which enhances the sensitivity for measuring low initial radon concentrations via scintillation light detection. This will allow the online monitoring of the radon concentration inside the distillation column and in turn the radon concentration of the whole experiment. This poster highlights the design of a 16-PMTs detector within the radon column to continuously monitor radon events in enriched xenon.

This work is supported by the EU through the ERC AdG 'LowRad' (101055063).

HK 27.29 Wed 16:15 Redoutensaal

**Tracking performance studies for the ALICE 3 detector using ACTS** — •MARIA GABRIELA GOMES and KLAUS REYERS for the ALICE Germany-Collaboration — Heidelberg University, Heidelberg, Germany

The ALICE 3 experiment is a proposed next-generation detector for heavy-ion collisions at the LHC, with a physics programme based on observables that require charged-particle tracking with high efficiency and a wide pseudorapidity coverage. In this presentation, simulation-based studies of the tracking performance of the ALICE 3 detector using the ACTS (A Common Tracking Software) framework are presented. The tracking geometry is based on silicon pixel sensors arranged in cylindrical layers and forward disks, allowing performance studies up to  $^* \eta^* = 4$ . The results focus on the reconstruction efficiency and transverse momentum resolution, with particular emphasis on the performance of the outer tracking system and its impact on the reconstruction of low-momentum particles. The results are obtained from Monte Carlo simulations of heavy-ion collision events and are compared for different reconstruction configurations. These studies illustrate the capabilities and limitations of ACTS in the ALICE 3 environment and provide essential input for the optimisation of the detector layout and reconstruction strategies.

HK 27.30 Wed 16:15 Redoutensaal

**Exploring the particle emission source in proton-proton collisions with collective expansion** — •SEBASTIAN WIND — Technical University of Munich

While the formation of Quark-Gluon Plasma (QGP) and associated collective behavior are well-established in heavy-ion collisions, their existence in proton-proton (pp) collisions remains unknown. Recent femtosopic measurements

have observed assumed signatures of collective behavior in pp collisions, challenging our understanding of small system collisions.

In this poster, we investigate the  $m_T$ -scaling behavior via collective expansion using the analytically solvable hydrodynamical Gubser solution. By comparing our predictions to ALICE collaboration data and contrasting them with free-streaming model calculations, we try to understand whether the observed  $m_T$ -scaling behavior can be related to the collective expansion. This work provides insights into potential QGP formation in small system collisions and the applicability of hydrodynamics in describing pp collisions.

HK 27.31 Wed 16:15 Redoutensaal

**Development of Low-Cost and Compact Radiation Monitoring, Long-Range Data Transmission and Tracking Systems for Stratospheric Balloon Missions** — •NICO KRUG, HANS-GEORG ZAUNICK, and KAI-THOMAS BRINKMANN — 2<sup>nd</sup> Physics Institute Justus Liebig University Giessen

A cost-effective readout and monitoring system based on a Raspberry Pi and designed for integration into ongoing stratospheric balloon missions will be presented.

The Strato project consists of a series of stratospheric balloon experiments relying on commercial-off-the-shelf (COTS) components. It features a custom low-power printed circuit board (PCB) built around a Raspberry Pi Zero, incorporating the in-house developed MuonPi detector as well as commercial environmental sensors connected via a generic I<sup>2</sup>C interface. The system uses the long-range LoRaWAN communication protocol to maintain contact throughout the entire flight for data transmission and tracking. It can be optionally extended with a telemetry beacon or a cellular communication module to ensure reliable message reception near ground level.

The poster will discuss the performance and robustness of the integrated system under the challenging conditions of near-space environments. Initial environmental and detector measurements as well as data transmission results obtained during past flights are presented and evaluated.

HK 27.32 Wed 16:15 Redoutensaal

**Gamma rays in r-process sites** — LUCAS DE BORBA FLESCHE, •ALMUDENA ARCONES, JAN KUSKE, and GIACOMO RICIGLIANO — Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 2, Darmstadt 64289, Germany

The rapid neutron capture process (r-process) synthesizes heavy elements, but its astrophysical sites remain partially unconfirmed. Identifying delayed gamma-ray emission from unstable r-process nuclei is crucial for site verification. This study models time-dependent gamma-ray spectra from r-process nucleosynthesis in varied conditions, including those found in supernovae and neutron star mergers, using the WinNet nuclear reaction network. Focusing on long timescales relevant to galactic remnants, we identify key long-lived isotopes dominating the flux across all three r-process peaks, as well as certain actinide decay chains. We assess the observability of these lines by calculating light curves and Doppler broadened spectra against current and future detector sensitivities (e.g., NuStar and GammaTPC). A prominent high-energy gamma line (661.66 keV) is the most promising signature, potentially visible up to 500 years. Furthermore, we predict that low-energy emission lines should be detectable in existing supernova remnants. These results provide critical guidance for upcoming gamma-ray telescopes seeking to localize the astrophysical origin of heavy elements.

## HK 28: Invited Talks

Time: Thursday 11:00–13:00

Location: MED 00.915

### Invited Talk

HK 28.1 Thu 11:00 MED 00.915

**Toward the Island of Stability** — •KHUYAGBAATAR JADAMBAA — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany  
Superheavy elements with extremely large atomic numbers remain one of the central and interdisciplinary research topics in modern science. In nuclear physics, one of the major goals is to explore the properties of superheavy nuclei (SHN) in the region of  $Z = 114$ – $126$  and  $N=184$ , where the next shell closures are predicted to occur. Superheavy nuclei in this region are expected to exhibit significantly longer spontaneous fission half-lives than their neighboring ones. Consequently, the fission landscape of SHN, in terms of half-life, has been envisioned as an Island of Stability surrounded by a sea of instability. Intensive research programs dedicated to probing the shell structure and fission stability of SHN are ongoing worldwide, including those conducted with the gas-filled recoil separator TASCA at GSI, Germany. I will present/discuss the current status of studies on the fission-landscape of SHN toward the Island of Stability.

### Invited Talk

HK 28.2 Thu 11:30 MED 00.915

**From stars to underground labs: Nuclear astrophysics measurements at Felsenkeller** — •ELIANA MASHA — Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Nuclear reactions in stars take place at very low energies and are characterized by extremely small cross sections. To reproduce these conditions in the laboratory, high-intensity ion beams and low background environments are required. Underground accelerator laboratories provide such conditions by suppressing cosmic-ray induced background, enabling direct measurements at relevant astrophysical energies. This approach was pioneered by the LUNA experiment at Gran Sasso and has since been extended to other underground facilities worldwide. Among them, the Felsenkeller laboratory in Dresden offers new opportunities for precision nuclear cross-section measurements for different astrophysical scenarios. This talk will introduce the connection between nuclear processes in stars and underground laboratory experiments, and present selected science cases from the Felsenkeller laboratory.

### Invited Talk

HK 28.3 Thu 12:00 MED 00.915

**Hunting exotic mesons in the light-quark sector at GlueX** — •FARAH AFZAL for the GlueX-Collaboration — Ruhr University Bochum, Bochum, Germany

The detailed understanding of the hadron spectrum is currently one of the biggest open issues in the field of hadron physics. Most of the observed states are classified as quark-antiquark mesons or three-quark baryons. However, quantum chromodynamics (QCD) allows for a much richer spectrum with more complex, non-conventional configurations, such as multi-quark states, hybrid mesons and glueballs. Hybrid mesons, which manifest gluonic degrees of freedom, serve as an ideal testing ground for the non-perturbative regime of QCD and understanding the role of gluons in hadron formation.

The main goal of the GlueX experiment is to search for exotic hybrid mesons and to map out their spectrum in the light-quark sector. The experiment is located in Hall D at Jefferson Lab, USA, and uses a linearly polarized photon beam with energies of up to 12 GeV incident on a liquid hydrogen target and consists of a high-acceptance spectrometer with excellent charged as well as neutral particle detection capabilities. This allows us to study the production mechanisms and decays of a wide range of hadronic resonances.

This talk gives an overview of the ongoing search for exotic mesons in the light-quark sector at GlueX.

### Invited Talk

HK 28.4 Thu 12:30 MED 00.915

**Dispersive analyses of Primakoff reactions with kaons** — •BASTIAN KUBIS — Helmholtz-Institut für Strahlen- und Kernphysik (Theorie), Universität Bonn, Nussallee 14-16, 53115 Bonn

The scattering of a charged-kaon beam off the Coulomb field of a heavy nucleus, as planned at the AMBER experiment at CERN, allows one to investigate photon-kaon reactions to various final states, so-called Primakoff processes. We investigate two important such reactions. First, we analyse  $\gamma K \rightarrow K\pi$  and show how dispersion theory provides access to both the chiral anomaly and radiative resonance couplings in a unified manner. Second, from Compton scattering on the kaon, electric and magnetic polarisabilities can be extracted, which provide fundamental structure information about the lightest strange hadrons. We discuss similarities and differences to the analogous COMPASS analysis with charged pions, and show how the effects of the  $K^*(892)$  resonance, seemingly impeding the polarisability determination, can be included model-independently.

## HK 29: Hadron Structure and Spectroscopy V

Time: Thursday 13:45–15:30

Location: PHIL C 301

## Group Report

HK 29.1 Thu 13:45 PHIL C 301

**Measurement of the cross section for  $\gamma p \rightarrow \phi \pi^+ \pi^- p$  and search for the  $Y(2175)$  in photoproduction with the GlueX experiment** — •KLAUS GÖTZEN<sup>1</sup> and FRANK NERLING<sup>1,2</sup> for the GlueX-Collaboration — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>2</sup>Goethe-Universität Frankfurt, Germany

The  $Y(2175)$ , recently renamed to  $\phi(2170)$ , is discussed to be a strange partner state of the famous charmonium-like exotic vector state  $Y(4260)$ . The former has originally been observed in initial-state radiation by the BaBar experiment in 2006. Meanwhile, it has been reported in different  $e^+e^-$  annihilation experiments. Based on the first measurement of the differential cross section for the exclusive reaction  $\gamma + p \rightarrow \phi(1020)\pi^+\pi^-p$ , we have performed a search for this strangeonium-like exotic candidate  $\phi(2170) \rightarrow \phi\pi^+\pi^-$  in the GlueX data [1]. It is addressed here for the first time in a photoproduction experiment. We do not find evidence for this state at the resonance parameters quoted by the Particle Data Group and provide upper limits on the photoproduction cross section. Instead, we find a structure at a mass of  $m(\phi\pi^+\pi^-) = 2.24 \text{ GeV}/c^2$  with a statistical significance of about  $5\sigma$ . The parameters of this structure differ from those quoted by the Particle Data Group for the  $\phi(2170)$  and are consistent with a previous observation in  $e^+e^-$  annihilation. In addition, there is evidence for a second structure at  $1.82 \text{ GeV}/c^2$ .

[1] GlueX Collab., subm. to PRL, Dec 2025; arXiv:2512.04136 [hep-ex]

HK 29.2 Thu 14:15 PHIL C 301

**Weak Decay of  $\Omega^-$ -Dibaryons** — •EMILI HILL, ISHFAQ AHMAD RATHER, and JÜRGEN SCHAFFNER-BIELICH — Goethe Universität, Frankfurt am Main, Germany

We study the weak decay of  $\Omega^-$  dibaryons within SU(3) flavor symmetry and chiral perturbation theory. These exotic states, carrying strange quarks, are relevant for understanding hyperon-hyperon interactions in dense neutron star matter. We examine mesonic and non-mesonic decay modes of the  $\Omega^-\Xi^-$  and  $\Omega^-\Xi^0$  systems using a pole-model framework. The decay pattern shows a strong sensitivity to the binding energy  $\epsilon$ . For small values of the binding energy, mesonic decays dominate and the behavior resembles the decay of a free hyperon. As  $\epsilon$  increases, non-mesonic channels overtake the mesonic ones. The crossover appears near  $\epsilon \approx 2.7 \text{ MeV}$  for  $\Omega^-\Xi^-$  and  $\epsilon \approx 3.8 \text{ MeV}$  for  $\Omega^-\Xi^0$ . These results identify the non-mesonic modes as promising channels for future searches. The study also points to the need for improved theoretical input, especially for the maximally strange  $\Omega^-\Xi^-$  system, to understand its possible impact on neutron stars and heavy-ion collisions.

HK 29.3 Thu 14:30 PHIL C 301

**Search for the spin-exotic  $\pi_1(1600)$  in a three-pion system with GlueX data** — •ILIA BELOV and FARAH AFZAL for the GlueX-Collaboration — Institut für Experimentalphysik I, Ruhr-Universität Bochum, 44801 Bochum, Germany

The GlueX experiment in Hall D at Jefferson Lab is designed for studies of the light meson spectrum with an emphasis on searches for hybrid mesons that have exotic quantum numbers and therefore cannot be classified as conventional hadrons. The experimental facility exploits a linearly polarized tagged photon beam in the energy range from 8.2 to 8.8 GeV. The photon beam is incident on a liquid hydrogen fixed target. The detector setup consists of a spectrometer with a nearly  $4\pi$  angular coverage, which has excellent capabilities for reconstruction of charged particle tracks, reconstruction of electromagnetic showers, and charged particle identification. Advanced searches for spin-exotic mesons are performed through the application of Partial Wave Analysis techniques.

The  $\pi_1(1600)$  hadron with  $1^{--}$  quantum numbers is predicted to have a considerable decay width to a three-pion system. In this talk, I present studies towards a Partial Wave Analysis of the  $\pi^+\pi^-\pi^-$  system produced in the  $\gamma p \rightarrow \pi^+\pi^-\pi^-\Delta^{++}(\rightarrow p\pi^+)$  reaction with a polarized beam.

HK 29.4 Thu 14:45 PHIL C 301

**Search for  $Y$  state in  $e^+e^- \rightarrow \gamma\eta_c$  at BESIII** — •YU GANG<sup>1,2</sup>, KLAUS GÖTZEN<sup>1</sup>, FRANK NERLING<sup>1,2</sup>, and KLAUS PETERS<sup>1,2</sup> — <sup>1</sup>GSI, Darmstadt — <sup>2</sup>Goethe Universität Frankfurt

The BESIII experiment is operating since 2008 and it is well suited for charmonium spectroscopy. Since 2003, dozens of charmonium-like states have been discovered in experiment, however, their properties do not match the prediction of the charmonium quark model and the nature of these so-called XYZ states is still unknown. The most famous vector charmonium-like state  $Y(4260)$  has been discussed to be a hybrid or a tetra-quark state. In a hybrid meson, the extra gluonic degree of freedom allows for an  $M1$  transition without spin-flip, the partial decay width  $\Gamma(Y_{hyb} \rightarrow \gamma\eta_c)$  is considerably larger than conventional vector-to-pseudoscalar transition. In phenomenology, the cross sections of exclusive  $\gamma\eta_c$  production up to NNLO in electron-positron collision with center-of-mass energy ( $\sqrt{s}$ ) from 4.0 to 5.5 GeV has been predicted. The NNLO result prefers the enhancement in  $e^+e^- \rightarrow \gamma\eta_c$  for center-of-mass energies between  $\sqrt{s} = 4.23 \text{ GeV}$  and  $4.36 \text{ GeV}$ , originating from decays of the exotic particle candidate  $Y(4260)$ .

Preliminary results of the energy dependent cross section measurement of  $e^+e^- \rightarrow \gamma\eta_c$  to search for  $Y \rightarrow \gamma\eta_c$  decays is presented.

HK 29.5 Thu 15:00 PHIL C 301

**Femtoscopic study of the proton-proton and proton-deuteron systems in heavy-ion collisions at the LHC** — •WIOLETA RZESA for the ALICE Germany-Collaboration — Technische Universität München, München, Germany

This work presents femtoscopic correlations of proton-proton (p-p) and proton-deuteron (p-d) pairs measured in Pb-Pb collisions at a center-of-mass energy of  $\sqrt{s_{NN}} = 5.02 \text{ TeV}$  by the ALICE Collaboration. The p-p correlation functions allow the extraction of a precise power-law dependence of the nucleon femtoscopic radius on the pair transverse mass ( $m_T$ ), as well as a linear dependence on the average charged-particle multiplicity. These dependencies are studied across three centrality intervals (0–10%, 10–30%, 30–50%) of Pb-Pb collisions. The measured p-d correlations are well described by both two-body and three-body calculations. This indicates that the femtoscopic observable in Pb-Pb collisions is not sensitive to short-distance features of the p-(p-n) interaction, owing to the relatively large inter-particle distances created in the heavy-ion environment at the LHC. Moreover, the proton  $m_T$ -scaling obtained for the p-p and p-d systems is compatible within one standard deviation of the experimental uncertainties. These findings provide new input for fundamental studies of the production and behavior of light (anti)nuclei under extreme conditions.

HK 29.6 Thu 15:15 PHIL C 301

**Selection and Resonant Structures in Semileptonic  $B \rightarrow D\pi\mu\nu$  Decays at LHCb** — •PIET NOGGA and SEBASTIAN NEUBERT — University of Bonn

Semileptonic  $B$  decays provide a powerful environment to study the strong interaction, as the hadronic system is produced in isolation from the leptonic system. This offers a clean setting for investigating hadronic resonances, free from interference with the leptonic part of the decay. However, the presence of an undetected neutrino makes the reconstruction of these decays experimentally challenging and introduces substantial background contamination.

The LHCb experiment records large and high-quality samples of  $B$  mesons, making it an excellent environment to study such semileptonic processes. This talk presents the analysis of the decay  $B \rightarrow D\pi\mu\nu$ , with a focus on the development and optimization of the selection processes required to reconstruct this challenging final state. A combination of simulation and data-driven processes is necessary to maximize signal purity, and the talk will cover the corresponding selection strategy. These optimizations allow us to investigate the hadronic system in detail, including possible intermediate resonances and their potential molecular nature.

## HK 30: Hadron Structure and Spectroscopy VI

Time: Thursday 13:45–15:45

Location: PHIL A 401

## Group Report

HK 30.1 Thu 13:45 PHIL A 401

**Inclusive measurement of  $R$**  — THOMAS LENZ, •WEIPING WANG, and ACHIM DENIG for the BESIII-Collaboration — Johannes Gutenberg-Universität Mainz, Germany

The inclusive measurement of  $R$ , which is the ratio of the leading-order cross sections between inclusive hadronic events and a pair of muon leptons, is of great importance in the precision test of the Standard Model. For example, the determination of quantum electrodynamics running coupling constant at the  $Z$  pole,

the evaluation of the anomalous magnetic moment of muon, and search and study of exotic hadron states. In this presentation, we will introduce the inclusive measurement of  $R$  at BESIII, including the published results and ongoing efforts based on the conventional energy-scan method. In addition, we will present a novel approach for  $R$  measurement that combines the advantages of the initial-state radiation technique with the inclusive method. This approach enables an inclusive determination of  $R$  over the energy range from 0.3 to 2.0 GeV, which is of significant interest to the community.

**Group Report**

HK 30.2 Thu 14:15 PHIL A 401

**Experimental input to HVP from the BESIII collaboration** — •RICCARDO ALIBERTI, ACHIM DENIG, CHRISTOPH REDMER, and WEIPING WANG for the BESIII-Collaboration — JGU Mainz

The time-like pion (vector) Form Factor (FF), i.e. the cross section for the process  $e^+e^- \rightarrow \pi^+\pi^-$ , is the most important input to the dispersive evaluation of the Hadronic Vacuum Polarization (HVP) contribution to the anomalous magnetic moment of the muon  $a_\mu$ . Decades of pion FF, and in general hadronic cross section, measurements have allowed the muon g-2 theory initiative to publish in 2020 a SM prediction for  $a_\mu$  with sub-percent accuracy on the HVP contribution. This value is in strong tension (more than  $5\sigma$ ) with the latest experimental results reported by the muon g-2 collaboration. Despite such a tension would be a clear sign of new Physics, recent ab-initio calculations of HVP from lattice QCD have reached an accuracy competitive with the dispersive approach and their results lead to a SM value for  $a_\mu$ , which is well in agreement with the direct measurements. At the same time, a new measurement of the pion FF by the CMD-3 collaboration shows a systematical deviation from previous results which would cover the discrepancy between the dispersive evaluation of HVP and the results from lattice QCD. In this talk, we will present the experimental efforts on going within the BESIII collaboration to provide new inputs to the dispersive evaluation of HVP with particular emphasis on a new high-precision measurement of the pion FF.

HK 30.3 Thu 14:45 PHIL A 401

**Amplitude Analysis of the decay  $\Lambda_b^0 \rightarrow \Lambda_c^+ \bar{D}^0 K^-$**  — •ELLINOR ECKSTEIN, KAI SEBASTIAN HABERMANN, and SEBASTIAN NEUBERT — Helmholtz-Institut für Strahlen- und Kernphysik, Bonn

Understanding the internal structure of exotic hadrons remains one of the central challenges in hadron physics over the past two decades. Many of these unconventional states have been observed in decays of  $b$ -flavored hadrons, which are produced in large quantities at the LHCb experiment located at the LHC. A precise description of such decay processes requires a detailed modelling of the various resonant contributions that arise in hadronic two-body subsystems. The full decay amplitude must account for all relevant decay topologies as well as the interference between overlapping resonances.

In this talk, I will present the first amplitude analysis of the decay  $\Lambda_b^0 \rightarrow \Lambda_c^+ \bar{D}^0 K^-$ , observed with the LHCb experiment. The decay channel is dominated by  $D_s$  resonances in the intermediate state decaying to  $\bar{D}^0 K^-$  and also receives contributions from  $\Xi_c$  resonances in the  $\Lambda_c^+ K^-$  subsystem. Particularly interesting is the  $\Lambda_c^+ \bar{D}^0$  subsystem, because it consists of the same valence quark content as the well established pentaquark states observed in the  $J/\psi p$  system of the decay  $\Lambda_b^0 \rightarrow J/\psi p K^-$ . Studying the possible coupling of these pentaquark states to the  $\Lambda_c^+ \bar{D}^0$  system offers a new avenue to probe their internal structure and gain deeper insight into the nature of exotic hadrons.

HK 30.4 Thu 15:00 PHIL A 401

**First measurement of the  $K^*-K_S^0$  correlation function in pp collisions at ALICE in Run 3** — •NILS KONERT for the ALICE Germany-Collaboration — James-Franck-Straße 1, 85748 Garching b. München

The recent discovery of the  $T_{cc}^+$  by LHCb, together with the growing number of unconventional hadronic states, has highlighted clear tensions with the traditional valence-quark picture. Several resonances do not fit naturally into the expected  $q\bar{q}$  spectrum. Among them, the  $f_1(1420)$  and  $f_1(1510)$  have been discussed as potential tetraquark candidates, although their internal structure remains unsettled.

Femtoscopy provides a powerful tool to probe such questions. By measuring correlations between two decay products, femtoscopy techniques are sensitive to

the underlying hadron-hadron interaction, and therefore to possible structural differences of the parent resonance. Both  $f_1(1420)$  and  $f_1(1510)$  decay into  $K^*$  and  $K_S^0$ , making this pair a promising system for investigating exotic configurations.

This contribution presents the first measurement of the  $K^*-K_S^0$  correlation function using data collected by the ALICE experiment in pp collisions at  $\sqrt{s} = 13.6$  TeV during LHC Run 3. The unprecedented statistics of Run 3 enable a significantly improved sensitivity to the interaction dynamics of this system, offering new insight into the possible exotic nature of the associated axial-vector states.

This project has been funded by the DFG under Germany's Excellence Strategy - EXC2094 - 390783311 and by BMFTTR Verbundforschung (05P24WO4 ALICE).

HK 30.5 Thu 15:15 PHIL A 401

**First measurement of the  $\Lambda$ - $\phi$  correlation function with data taken by ALICE in Run 3** — •CHRISTOPHER KLUMM for the ALICE Germany-Collaboration — James-Franck-Straße 1, 85748 Garching b. München

Neutron stars are among the densest objects in the observable universe and play a crucial role in advancing our understanding of dense hadronic matter. One of the central open questions is the so-called hyperon puzzle. In general, the relationship between the mass and radius of a neutron star is determined by its equation of state (EoS). Due to the extreme densities and pressures in the stellar core, the conversion of neutrons into hyperons is expected. However, this conversion leads to a softening of the EoS, preventing it from reproducing astrophysical observations. To counteract this effect, repulsive contributions to the hyperon-hyperon interaction are required. One proposed mechanism is the exchange of  $\phi$  mesons between  $\Lambda$  hyperons, which could produce such a repulsion. With the transition to Run 3 of the LHC, the ALICE detector now benefits from a substantial increase in luminosity and statistics, enabling new insight into the baryon-baryon interaction using the femtoscopy method. Leveraging these improved capabilities, this contribution presents the first measurements of the two-body correlation between  $\Lambda$  and  $\phi$  particles, using data collected by the ALICE experiment in pp collisions at  $\sqrt{s} = 13.6$  TeV during Run 3 of the LHC.

This project has been funded by the DFG under Germany's Excellence Strategy - EXC2094 - 390783311 and by BMFTTR Verbundforschung (05P24WO4 ALICE).

HK 30.6 Thu 15:30 PHIL A 401

**Track Reconstruction Performance Studies of Electrons at the BESIII Experiment** — •SILAS BENEDIKT DEBUS, ACHIM DENIG, and CHRISTOPH FLORIAN REDMER — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

The investigation of hadron production in two-photon collisions at  $e^+e^-$  colliders is essential to provide further input to the data-driven calculations of the hadronic Light-by-Light (HLbL) contribution to the anomalous magnetic moment of the muon  $a_\mu$ . In order to provide reliable information as a function of the momentum transfer, excellent knowledge of the tracking efficiency of the scattered electrons is mandatory.

The BESIII experiment, located at the Institute of High Energy Physics in Beijing, China, has collected more than  $20 \text{ fb}^{-1}$  of  $e^+e^-$  collision data at a center-of-mass energy of  $3.773 \text{ GeV}$ , which is perfectly suited to study two-photon reactions at momentum transfers of  $\mathcal{O}(1 \text{ GeV}^2)$ . Since these processes predominantly occur at small scattering angles, we report in this presentation a combined study of track reconstruction and particle identification efficiencies for electrons in the relevant angular region of the BESIII detector, using the process  $e^+e^- \rightarrow e^+e^-\gamma$  as reference reaction. — Supported by DFG FOR5327

## HK 31: Structure and Dynamics of Nuclei VII

Time: Thursday 13:45–15:45

Location: AM 00.011

**Group Report**

HK 31.1 Thu 13:45 AM 00.011

**Studying Exotic Nuclei with the FRS Ion Catcher: Recent Results and Developments** — •MEETIKA NARANG for the Super-FRS Experiment Collaboration-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany.

At the Fragment Separator (FRS) of GSI/FAIR, exotic nuclei are produced at relativistic energies via projectile fragmentation or fission and are separated in-flight. The fragments are subsequently thermalized in the Cryogenic Stopping Cell (CSC) and delivered to the multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS), which features a high resolving power of up to one million and mass accuracies down to  $10^{-8}$  in short cycle times of a few tens of milliseconds.

A wide range of nuclides has been studied at the FRS Ion Catcher. Direct mass measurements of neutron-deficient isotopes near the  $N = Z$  line below  $^{100}\text{Sn}$  and neutron-rich nuclei close to the  $N = 126$  shell closure below  $^{208}\text{Pb}$  have been per-

formed, providing new insights into the evolution of nuclear structure in these key regions. Mass measurements of fission products from a  $^{252}\text{Cf}$  spontaneous fission source have shown evidence for shape phase transitions around  $N \approx 90$  ( $Z = 56-63$ ) and enabled the direct determination of independent isotopic fission yields (IIFYs). Recent proof-of-principle experiments were performed focusing on multi-nucleon transfer reactions and the study of fundamental laws of nature by employing radioactive molecules.

This contribution presents an overview of the experimental setup, technical developments, recent experimental highlights, and prospects for upcoming experiments.

**Group Report**

HK 31.2 Thu 14:15 AM 00.011

**Multinucleon transfer experimental campaigns at GSI** — •ALI MOLLAE-BRAHIMI for the Super-FRS Experiment Collaboration-Collaboration — FAIR facility, Darmstadt, Germany — GSI facility, Darmstadt, Germany

Studying exotic nuclei exhibiting an extreme ratio of neutrons to protons is one of the primary means for better understanding of fundamental nuclear properties, which is crucial to comprehend the formation and existence of heavy elements in our universe. Nevertheless, it is well understood that nuclei from certain regions on the chart of nuclei, e.g., neutron-rich actinides, will not be efficiently produced in commonly used fission and fragmentation production methods. The MultiNucleon Transfer (MNT) reaction mechanism is considered the most promising and more efficient pathway to reach this region.

The Super-FRS experiment collaboration is performing MNT experiments at GSI using beams at near Coulomb barrier energies. This is performed with primary and secondary slowed-down relativistic beams at the FRS with the FRS Ion Catcher [1] and with primary beams at the UNILAC. The ultimate goal of the MNT program is to conduct future experiments at Super-FRS at FAIR. This contribution will present the plans and preliminary results obtained with  $^{238}\text{U}$  beam and the first test with  $^{236}\text{U}$  secondary beam on a Bi target and identification via mass measurements at the FRS Ion Catcher; plus general description of experiments with  $\alpha$ -spectroscopy and TOF- $\Delta E$ -E methods after the UNILAC.

[1] A. Mollaebrahimi et al., Nuclear Physics A 1057, 2025

HK 31.3 Thu 14:45 AM 00.011

**Measurements of the reaction cross sections of neutron-rich Sn isotopes at the R<sup>3</sup>B setup** — •ELEONORA KUDAIBERGENOVA<sup>1</sup>, THOMAS AUMANN<sup>1,2,3</sup>, IGOR GASPARIC<sup>4</sup>, ANDREA HORVAT<sup>4</sup>, IVANA LIHTAR<sup>5</sup>, LUKAS PONNATH<sup>1</sup>, and DOMINIC ROSSI<sup>1,2</sup> for the R3B-Collaboration — <sup>1</sup>Institut für Kernphysik, TUDA, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — <sup>3</sup>Helmholtz Forschungsakademie HFHF — <sup>4</sup>Rudjer Boskovic Institute, Zagreb, Croatia — <sup>5</sup>Facility for Rare Isotope Beams, MSU, USA

Constraining the parameters of the nuclear Equation of State (EoS) is one of the central issues in nuclear physics, especially since the slope parameter  $L$  is still poorly constrained experimentally. It has been identified that a precise determination of the neutron-removal cross section in neutron-rich nuclei, which correlates with the neutron-skin thickness, would provide constraints on  $L$ . To this end, an experiment was performed at the R<sup>3</sup>B setup at GSI as a part of the FAIR Phase-0 program. The reactions are studied in inverse kinematics with neutron-rich tin isotopes in the mass range  $A=124$ – $134$  on carbon targets of different thicknesses. In this communication the total reaction, charge-changing and charge-exchange analysis of  $^{124}\text{Sn} + ^{12}\text{C}$  at 900 MeV/u is presented.

The project was supported by the BMFT via Project No. 05P24RD1, the Helmholtz Research Academy Hessen for FAIR and the GSI-TU Darmstadt co-operation agreement.

HK 31.4 Thu 15:00 AM 00.011

**Simulation of nucleon knockout reactions in a semiclassical eikonal approach** — •STEFAN TYPTEL — TU Darmstadt, Fachbereich Physik, Institut für Kernphysik — GSI Helmholtzzentrum für Schwerionenforschung, Theorie

Nucleon knockout reactions are a valuable tool to study atomic nuclei, in particular their single-particle structure and neutron skin thickness. At beam energies of a few hundred MeV per nucleon, the reaction cross section can be calculated conveniently in the eikonal approach using the imaginary part of nucleus-nucleus or nucleus-nucleon optical potentials. These are obtained from recently

improved parameterizations of nucleon-nucleon scattering cross sections including their angular distribution and Pauli-blocking effects. Cross sections of various processes, e.g., one- and two-nucleon removal or charge-changing reactions are calculated using nuclear structure input from a relativistic energy density functional. The reaction process is described in a Monte-Carlo simulation to take higher-order effects into account. Results for various reactions will be presented.

Supported by the Helmholtz Forschungsakademie Hessen für FAIR (HFHF).

HK 31.5 Thu 15:15 AM 00.011

**Production cross-sections of  $N \approx 126$  fragments from 1 GeV/u  $^{208}\text{Pb}$  at FRAGMENT Separator FRS** — •SURAJ KUMAR SINGH for the Super-FRS Experiment-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — Justus-Liebig-Universität Gießen, Germany

Studies of nuclei far from the valley of stability are crucial for understanding nuclear reactions and nuclear structure, with implications ranging from fundamental physics to nuclear astrophysics and applications. In particular, neutron-rich nuclei near the  $N = 126$  shell closure play a key role as potential waiting-point nuclei in the rapid neutron-capture ( $r$ -) process, strongly influencing the formation of the heaviest elements in the universe. Accessing these isotopes requires reliable predictions of production rates, which in turn depend on accurate production cross-sections. Since theoretical calculations in this region remain challenging, experimental cross-section measurements provide essential input for planning future studies of these exotic nuclides and for improving reaction models.

In this contribution, cross-section measurements from 1 GeV/u  $^{208}\text{Pb}$  projectiles on a  $^9\text{Be}$  target, performed at the Fragment Separator (FRS) at GSI will be presented. The new data provide insights into the underlying production mechanisms and serve as important benchmarks for state-of-the-art theoretical models used to predict yields of yet-unmeasured isotopes.

HK 31.6 Thu 15:30 AM 00.011

**Production cross section measurements with a 170Er beam at the GSI FRS** — •JUSTUS EDER for the Super-FRS Experiment-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung — Justus-Liebig Universität Gießen

New production cross section results are presented from the FAIR Phase-0 experiment "Structure of neutron-rich, rare-earth nuclei far from stability" (G-22-00100), performed at the GSI Fragment Separator (FRS) using the newly developed 1080 MeV/u  $^{170}\text{Er}$  beam on a beryllium target. The measurements probe the exotic, highly deformed nuclear region near  $Z=68$ , employing both the  $B\rho - \Delta E - B\rho$  separation and  $B\rho - \Delta E^* - \text{TOF}$ -identification techniques. Particle identification has been significantly improved through refined delay-line corrections in the tracking detectors TPCs, which enhance position resolution, as well as position-dependent timing corrections in the scintillators, leading to more accurate time-of-flight measurements. Preliminary production cross sections obtained with these refinements are reported. Remaining corrections, systematic uncertainties, and prospects for further refinement are briefly discussed. These developments support future high-precision cross section studies, which are of relevance for reliable yield predictions for future NUSTAR experiments at FAIR.

## HK 32: Heavy-Ion Collisions and QCD Phases V

Time: Thursday 13:45–15:45

Location: PHIL C 601

### Group Report

HK 32.1 Thu 13:45 PHIL C 601

**Investigating the properties of (anti-)hypernuclei with the ALICE detector at the LHC** — •CAROLINA JAUCH for the ALICE Germany-Collaboration — Universität Heidelberg

Among the thousands of particles produced in high energy heavy-ion collisions at the LHC, light (anti-)hypernuclei are of particular interest. Studying their internal structure provides a unique opportunity to probe the strong interaction between hyperons and nucleons. The lightest known (anti-)hypernucleus, the (anti-)hypertriton, is a bound state of a proton, a neutron, and a  $\Lambda$  hyperon. Several groundbreaking results on its production and properties were reported by ALICE in recent years. The upgraded ALICE detector and the large data sample collected during the ongoing LHC Run 3 enable more precise measurements and the study of rare observables.

This contribution presents the latest ALICE results on (anti-)hypernuclei and outlines prospects for future investigations. In particular, the first measurement of the anti-hypertriton transverse momentum spectrum in pp collisions allows to test different assumptions on its wavefunction. Moreover, the first reconstruction of the (anti-)hypertriton three-body decay in ALICE pp collisions and the measurement of its relative branching ratio,  $R_3$ , offer insight into its internal structure. The precision of the recently published measurement of heavier (anti-)hypernuclei, the hyperhydrogen-4 and hyperhelium-4, including the very first

observation of the antihyperhelium-4, can be improved using the Run 3 heavy-ion data sample, and a more detailed study of their properties will be feasible.

HK 32.2 Thu 14:15 PHIL C 601

**Sexaquark Search in ALICE** — •ANDRÉS BÓRQUEZ for the ALICE Germany-Collaboration — Heidelberg University

In 2017, G. Farrar proposed the sexaquark, a hypothetical six-quark state with the quark content  $uuddss$ . This particle is characterized by being neutral, compactly bound, and cosmologically stable within certain mass limits. These unique properties make it a compelling dark matter candidate.

Despite its elusive nature, several experimental collaborations have searched for evidence of its existence. This contribution presents an update on the ongoing search for the sexaquark within the ALICE experiment at the LHC. The strategy focuses on identifying displaced strangeness production caused by the annihilation of anti-sexaquarks with detector material following their potential production in Pb-Pb collisions during LHC Run 2.

HK 32.3 Thu 14:30 PHIL C 601

**Measurement of higher-order net-proton fluctuations with ALICE** — •ILYA FOKIN for the ALICE Germany-Collaboration — Physikalisches Institut, Universität Heidelberg

Fluctuations of conserved charges, such as the baryon number, are a unique tool to study the phase diagram of strongly interacting matter. Cumulants of distributions of conserved charges in heavy-ion collisions can be related to the equation of state in lattice QCD (LQCD) and thus make the calculations from first principle accessible in the experiment. Starting from the fourth-order, these calculations predict a significant difference between the baryon number susceptibilities using the full QCD partition function on the lattice and a hadron resonance gas model.

For a quantitative comparison, correlations from local baryon number conservation must be considered in the theoretical baseline and additional contributions from volume fluctuations must be quantified.

In this contribution, measurements of the higher-order cumulants of the net-proton number up to fourth order in Pb–Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV with the ALICE detector at the LHC are presented as a function of the pseudorapidity acceptance and centrality.

HK 32.4 Thu 14:45 PHIL C 601

**Universal scaling of transport coefficients near the QCD critical point** — •JOHANNES ROTH<sup>1</sup>, YUNXIN YE<sup>2</sup>, SÖREN SCHLICHTING<sup>3</sup>, and LORENZ VON SMEKAL<sup>1,4</sup> — <sup>1</sup>Institut für Theoretische Physik, Justus-Liebig-Universität, 35392 Giessen, Germany — <sup>2</sup>Theoretisch-Physikalisches Institut, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany — <sup>3</sup>Fakultät für Physik, Universität Bielefeld, 33615 Bielefeld, Germany — <sup>4</sup>Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Giessen

Near a critical point, including the one conjectured in the QCD phase diagram at finite baryon chemical potential, the slow dynamics of long-wavelength modes is expected to become universal. I will review the argument for the associated dynamic universality class being that of Model H in the Halperin-Hohenberg classification, i.e., that of a liquid-gas critical point. Based on a novel real-time formulation of the functional renormalization group, I will present results for universal scaling functions of the thermal diffusivity and the shear viscosity, and discuss their relevance in the ongoing search for the QCD critical point.

HK 32.5 Thu 15:00 PHIL C 601

**Out-of-equilibrium scaling in driven first-order phase transitions** — •LEON SIEKE<sup>1</sup>, JESSICA FUCHS<sup>1</sup>, and LORENZ VON SMEKAL<sup>1,2</sup> — <sup>1</sup>Institut für Theoretische Physik, Justus-Liebig-Universität, 35392 Gießen, Germany — <sup>2</sup>Helmholtz Forschungssakademie Hessen für FAIR (HFHF), Campus Gießen, 35392 Gießen, Germany

First-order and critical phase transitions behave qualitatively different under nearly adiabatic conditions. The former proceed through nucleation and growth, and are accompanied by metastability and hysteresis, while the latter feature diverging correlations and universal scaling. When transitions occur in finite time, non-equilibrium effects gain relevance, and this sharp distinction becomes blurred.

We investigate the real-time dynamics of a  $Z_2$ -symmetric scalar field theory in the dynamic universality class of Model A in driven phase transitions across the first-order line using classical-statistical lattice simulations. We find that universal non-equilibrium scaling can emerge even in the first-order region, provided the driving is fast enough to avoid nucleation but slow enough for correlations to form. The resulting scaling behavior is analogous to the Kibble-Zurek mechanism

and we compute the associated universal scaling functions for the order parameter.

Our results clarify how universal behavior can arise in driven first-order phase transitions and delineate the conditions under which nucleation, scaling, or trivial mean-field behavior dominate.

HK 32.6 Thu 15:15 PHIL C 601

**Critical Behavior of  $O(N)$  Model G in the large- $N$  Limit** — •JONAS HIRSCH<sup>1</sup>, JOHANNES V. ROTH<sup>1</sup>, and LORENZ VON SMEKAL<sup>1,2</sup> — <sup>1</sup>Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — <sup>2</sup>Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Giessen, 35392 Giessen, Germany

The chiral phase transition of QCD in the limit of two massless quark flavors is widely believed to be of second order in the  $O(4)$  universality class. Since the work of Rajagopal and Wilczek, its dynamic universality class is then expected to be an  $O(4)$  extension of the original Model G by Halperin and Hohenberg. The characteristic feature of this dynamic model is the reversible mode coupling between the conserved iso-(axial-)vector charges and the chiral condensate as the order parameter field which all relax at equal rates due to *strong dynamic scaling* [1]. In this talk, we will consider Model G with a generalized  $N$ -component order parameter, for which we perform the limit  $N \rightarrow \infty$ . We show exact results for the universal spectral function in the symmetric phase by using large- $N$  counting rules for Dyson-Schwinger equations. Furthermore, we discuss an extension to the broken phase and a nonzero external source, which corresponds to a non-vanishing quark mass. Lastly, we investigate the loss of the strong-scaling fixed point, and how it could be recovered by NLO correction.

[1] J.V. Roth, Y. Ye, S. Schlichting, L. von Smekal, *Dynamic critical behavior of the chiral phase transition from the real-time functional renormalization group*, JHEP, vol. 01, 2025, p. 118

HK 32.7 Thu 15:30 PHIL C 601

**Critical dynamics with the analytically continued functional renormalization group** — •PATRICK NIEKAMP<sup>1</sup>, JOHANNES ROTH<sup>1</sup>, and LORENZ VON SMEKAL<sup>1,2</sup> — <sup>1</sup>Institut für Theoretische Physik, Justus-Liebig-Universität, 35392 Giessen, Germany — <sup>2</sup>Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Giessen, 35392 Giessen, Germany

Euclidean approaches such as the functional renormalization group (FRG) have been abundantly and successfully used to study the universal static critical behavior of various physical systems near continuous phase transitions. For the study of critical dynamics, on the other hand, one usually relies on real-time methods. Our research aims to connect and relate the two approaches by comparing analytically continued (aFRG) and real-time FRG on the closed time path. In particular, we investigate the dynamic critical behavior of a dissipative open quantum system near equilibrium in the spirit of the Caldeira-Leggett model with the aFRG and compare that with real-time results for the dynamic universality class of the corresponding Model A (according to the classification by Halperin and Hohenberg). The long-term goal of this project is to understand the merits and limitations of studying more complicated critical dynamics, including conservation laws and reversible mode couplings as relevant for QCD, with analytically continued Euclidean versus real-time approaches.

## HK 33: Nuclear Astrophysics IV

Time: Thursday 13:45–15:45

Location: PHIL A 602

HK 33.1 Thu 13:45 PHIL A 602

**Systematic Study of EOS Effects in BNS Mergers** — •MAXIMILIAN JACOBI — Friedrich-Schiller-Universität, Jena, Germany

Observations of binary neutron star (BNS) mergers are among the most promising opportunities to constrain the nuclear equation of state (EOS) at intermediate to high density with multi-messenger astronomy. Vice versa, it is crucial to understand how observables such as gravitational waves and the ejection of matter depend on the EOS. However, most BNS merger simulation studies employ a relatively small number of EOS models chosen in an arbitrary fashion due to the limited availability of EOS models. Therefore, derived relations between observables and EOS properties are usually given in terms of single parameters such as the tidal polarizability or the radius of a cold neutron star of a characteristic mass. In this talk I will present a set of BNS merger simulations employing a set of microphysical EOS with systematically varied properties. This approach allows us to study the impact of the EOS properties at high and intermediate densities independently and derive a more detailed understanding of the interplay between BNS mergers and nuclear physics.

HK 33.2 Thu 14:00 PHIL A 602

**Binary neutron stars: multi-messenger analyses to constrain equation of state** — •GIULIA HUEZ — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany

Binary neutron star mergers are exceptional laboratories for probing the properties of nuclear matter at supranuclear densities. To extract the physical parameters of these systems and gain insights into the underlying physics, Bayesian parameter estimation techniques have been extensively employed in multi-messenger observations of gravitational waves, kilonovae, and gamma-ray bursts. In this talk, I will present results from a joint and coherent multi-messenger analysis of GW170817, the first observed binary neutron star merger. This comprehensive approach enables tighter constraints on the extrinsic parameters of the system, such as distance and inclination, while also incorporating numerical-relativity-informed relations that connect observable quantities to the intrinsic binary properties. Through this kind of analysis, we achieve improved precision in the inference of neutron star equation of state. Furthermore, I will discuss how these results highlight key areas where future numerical-relativity simulations should focus to improve our phenomenological models, particularly for kilonovae, postmerger gravitational waves, and numerical-relativity-informed relations, thereby enhancing the accuracy and robustness of future analyses.



HK 33.3 Thu 14:15 PHIL A 602

**Quantifying uncertainties for the nuclear equation of state in  $\beta$ -equilibrium** — •HANNAH GÖTTLING<sup>1,2</sup>, LUIS HOFF<sup>1,2</sup>, KAI HEBELER<sup>1,2,3</sup>, and ACHIM SCHWENK<sup>1,2,3</sup> — <sup>1</sup>Technische Universität Darmstadt, Department of Physics — <sup>2</sup>ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — <sup>3</sup>Max-Planck-Institut für Kernphysik, Heidelberg

The nuclear equation of state (EOS) characterizes the properties of matter as a function of density, temperature, and proton fraction, and thus connects microscopic strong interaction calculations with descriptions of compact objects in astrophysics. Focusing on the low-density regime, chiral effective field theory (EFT) provides a systematically improvable description of nuclear systems. With Gaussian processes (GPs) we construct an emulator to realize non-parametric evaluations of the EOS considering correlations among independent variables and calculate derivatives to provide thermodynamic quantities. Moreover, we employ GPs for a statistical description of chiral expansion coefficients and apply Bayesian statistics to assess the EFT truncation errors. This leads to a range of the EOS for nuclear matter in  $\beta$ -equilibrium with propagated EFT truncation uncertainties.

Funded by the LOEWE Top Professorship LOEWE/4a/519/05.00.002(0014)98.

HK 33.4 Thu 14:30 PHIL A 602

**Probing Energetic Supernovae Through Nebular Phase Modeling** — •GIACOMO RICIGLIANO — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg 69117, Germany

Energetic supernovae are promising sites for heavy element nucleosynthesis and exhibit a wide range of explosion mechanisms, yet the observational signatures of these processes remain difficult to interpret. In particular, the presence of r-process material in non-merger transients is still uncertain, and the physical engines powering the most energetic stripped-envelope supernovae (such as central engine activity or ejecta-CSM interaction) are not yet well constrained. Nebular phase observations offer a direct way to address these questions, as they probe the inner ejecta where nucleosynthesis products and explosion physics are most clearly imprinted. We model optically thin nebular plasmas in full NLTE, including compositions extending up to the third r-process peak. We find that even modest amounts of heavy neutron-rich material generate distinct forbidden fine-structure emission in the near- to mid-IR, making this wavelength range highly sensitive to r-process signatures. In parallel, we examine how variations in ionization structure, line strengths, and line profiles can serve as diagnostics of central engine activity or ejecta-CSM interaction. Together, these results highlight the diagnostic potential of late-time IR and optical spectroscopy for uncovering both heavy element production and the physical mechanisms driving extreme stellar explosions.

HK 33.5 Thu 14:45 PHIL A 602

**Role of composition and neutrino spectra in the collapse of massive stars** — •JUSTIN SCHÄFER<sup>1,2</sup>, GABRIEL MARTÍNEZ-PINEDO<sup>1,2</sup>, and OLIVER JUST<sup>2</sup> — <sup>1</sup>Institut für Kernphysik (Theoriezentrum), TU Darmstadt — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt

The collapse of massive stars after iron core formation is determined by electron captures on a broad range of nuclei. To understand this, a description of electron captures and accurate determination of the composition is crucial. In this work we aim to explore the impact of compositional changes on the deleptonization rate, most important nuclei, and neutrino luminosities. We show that different treatments of partition functions, which govern the distribution of nuclear states at given temperatures and densities, influence the individual composition, and thus most important nuclei, substantially. However, the deleptonization rate and therefore the evolution of the collapsing star is rather unaffected by the detailed composition of matter, leading to similar neutrino luminosities. It turns out that the neutrino spectra, rather than precise rates, determine the final conditions in the core. This work is supported by the Deutsche Forschungsgemeinschaft

(DFG, German Research Foundation) - Project-ID 279384907 - SFB 1245, and MA 4248/3-1 and the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC Advanced Grant KILONOVA No.885281).

HK 33.6 Thu 15:00 PHIL A 602

**Super-FRS Ion Catcher - Overview and Progress** — •JAMIE HARKIN for the Super-FRS Experiment-Collaboration — Justus-Liebig-Universität Gießen

The Super-FRS Ion Catcher (Super-FRS-IC) setup will enable the measurements of beta-delayed (multiple-)neutron emission probabilities ( $P_{xn}$ ) i.e., data for r-process nucleosynthesis models that is lacking the most. Moreover, the setup will study multi-nucleon transfer (MNT) reactions driven by secondary beams as a promising method for accessing the unexplored heavy neutron-rich nuclei. These topics will be in focus in the Early- and First-Science programs at the Super-FRS at FAIR. The Super-FRS-IC will also provide thermalized, low emission beams to the LaSpec and MATS experiments. With the Super-FRS-IC, the exotic nuclei produced at relativistic energies and separated in-flight will be thermalized in the Cryogenic Stopping Cell (CSC), transported over a radio frequency quadrupole (RFQ) beamline and analyzed in the Multiple-Reflection Time-Of-Flight Mass-Spectrometer (MR-TOF-MS). This contribution presents the status of the construction of the Super-FRS-IC and an outlook to the experiments to be performed.

HK 33.7 Thu 15:15 PHIL A 602

**The DT neutron generator in Dresden: Fusion reactor studies, neutron activation analyses and nuclear astrophysics** — •STEFFEN TURKAT<sup>1</sup>, TORALF DÖRING<sup>2</sup>, AXEL KLIX<sup>3</sup>, BJÖRN LEHNERT<sup>1</sup>, MAX OSSWALD<sup>1</sup>, FREDERIK UHLEMANN<sup>1</sup>, and KAI ZUBER<sup>1</sup> — <sup>1</sup>Institut für Kern- und Teilchenphysik, TU Dresden — <sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf — <sup>3</sup>Institut für Neutronenphysik und Reaktortechnik, Karlsruher Institut für Technologie

The Deuterium-Tritium neutron generator of TU Dresden delivers proton and deuteron beams of several milliamperes with energies of up to 350 keV. So far, its primary application was focused on the generation of 14 MeV neutrons via the  $^3\text{H}(d,n)^4\text{He}$  reaction, achieving rates of up to  $10^{12}$  neutrons per second. It is therefore Europe's most intense facility of its kind, dedicated mainly to fusion reactor research and neutron activation analyses.

In addition, the laboratory's scope extends to an even broader range of activities, including cross-section measurements, implantation studies, nuclear astrophysics, neutrino physics and others. This contribution will focus on the facility's relevance for fusion reactor studies, but also trace its past, present, and future, as it transitions into a multi-purpose laboratory.

HK 33.8 Thu 15:30 PHIL A 602

**Background radiation measurements and muon simulations for nuclear astrophysics in the new low seismic lab of the DZA** — •SIMON VINCENT<sup>1,2</sup>, DANIEL BEMMERER<sup>3</sup>, GÜNTHER HASINGER<sup>1,2</sup>, MICHÈLE HEURS<sup>4,2,5</sup>, MIKE LINDNER<sup>2</sup>, and KONRAD SCHMIDT<sup>3</sup> — <sup>1</sup>TU Dresden — <sup>2</sup>Deutsches Zentrum für Astrophysik (DZA) — <sup>3</sup>Helmholtz-Zentrum Dresden-Rossendorf (HZDR) — <sup>4</sup>Leibniz-Universität Hannover — <sup>5</sup>DESY Zeuthen

The German center for astrophysics (DZA, Deutsches Zentrum für Astrophysik) plans to build, among other projects, a 200 m deep underground facility. The facility is called the Low Seismic Lab (LSL) and will be placed in Lusatia, at a precise location still to be determined. Here we report on studies relevant to future nuclear and astroparticle experiments in LSL, in order to estimate the remaining cosmic-ray induced radiation background. The specific natural radioactivity of samples of several ~250 m deep drill holes called DZA02, DZA03, and DZA05, respectively, has been determined using  $\gamma$ -ray spectroscopy at the Felsenkeller underground lab (Dresden), with a non-destructive technique including sample geometry modelling. In addition, GEANT4-based simulation studies of cosmic muon propagation have been performed to calculate the muon and neutron flux in LSL.

## HK 34: Fundamental Symmetries I

Time: Thursday 13:45–15:00

Location: AM 00.021

### Group Report

HK 34.1 Thu 13:45 AM 00.021

**The P2 experiment at MESA** — SEBASTIAN BAUNACK<sup>1</sup>, MAARTEN BOONEKAMP<sup>4</sup>, BORIS GLÄSER<sup>1</sup>, SHRUTI GUDLA<sup>1</sup>, JAYANTA NAIK<sup>1</sup>, RAHIMA KRINI<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, MORAN NEHER<sup>1</sup>, TOBIAS RIMKE<sup>1</sup>, PAUL SCHÖNER<sup>2</sup>, SIDDHARTH THAKKER<sup>1</sup>, and •MALTE WILFERT<sup>1</sup> — <sup>1</sup>Institut für Kernphysik, Johannes Gutenberg-Universität Mainz — <sup>2</sup>Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — <sup>3</sup>PRISMA+ Cluster of Excellence, Johannes Gutenberg-Universität Mainz — <sup>4</sup>IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

The weak mixing angle  $\sin^2 \theta_W$  can be measured in parity violating elastic electron-proton scattering. The aim of the P2 experiment is a very precise mea-

surement of the weak mixing angle with an accuracy of 0.15% at a low four-momentum transfer of  $Q^2 = 4.5 \cdot 10^{-3} \text{ GeV}^2$ . In combination with existing measurements at the Z pole with comparable accuracy, this comprises a test of the standard model with a sensitivity towards new physics up to a mass scale of 50 TeV. The experiment is being set up at the MESA accelerator in Mainz. In this talk, the motivation and challenges for this measurement will be discussed together with the current status of the construction of the P2 experiment.

**Group Report**

HK 34.2 Thu 14:15 AM 00.021

**The Mu2e experiment at Fermilab: a status report in view of the first data taking phase** — •ANNA FERRARI, STEFAN E. MUELLER, OLIVER KNODEL, and REUVEN RACHAMIN for the Mu2e-Collaboration — Helmholtz- Zentrum Dresden-Rossendorf, Dresden, Germany

The Mu2e experiment, which is currently entering the final installation phase at the Fermi National Accelerator Laboratory in USA, will search for the charged-lepton flavor violating neutrino-less conversion of negative muons into electrons in the field of an aluminum nucleus. A conversion signal would require physics beyond the Standard Model, and the aim of Mu2e is to reach a single-event sensitivity four order of magnitude better than previous experiments. This can be achieved through an efficient production and transport of the muon beam, a rigorous control of all backgrounds that could mimic the monoenergetic conversion electrons, and an accurate normalization of the signal events. The present status of the Mu2e experiment will be presented, while the main detector subsystems has been installed at their final locations inside the Mu2e hall, and the strategies of the first data taking period have been defined.

HK 34.3 Thu 14:45 AM 00.021

**High-precision Q-value measurements for neutrino physics using the JYFLTRAP Penning trap** — •JOUNI RUOTSALAINEN<sup>1</sup>, ELINA KAUPPINEN<sup>1</sup>, ANU KANKAINEN<sup>1</sup>, TOMMI ERONEN<sup>1</sup>, MAXIME MOUGEOT<sup>1</sup>, VIKAS KUMAR<sup>1</sup>,

JOUNI SUHONEN<sup>1,2</sup>, JENNI KOTILA<sup>2,3</sup>, ZHUANG GE<sup>1</sup>, and MAREK STRYJCZYK<sup>1</sup> — <sup>1</sup>University of Jyväskylä, Department of Physics, Accelerator Laboratory, P.O. Box 35(YFL) FI-40014 University of Jyväskylä, Jyväskylä, Finland — <sup>2</sup>International Centre for Advanced Training and Research in Physics (CIFRA), P.O. Box MG12, 077125 Bucharest-Măgurele, Romania — <sup>3</sup>Finnish Institute for Educational Research, University of Jyväskylä, P.O. Box 35, Jyväskylä FI-40014, Finland

In this contribution, I will present the results and conclusions of the precise Q-value measurements of the <sup>110</sup>Ag<sup>m</sup> beta decay, and <sup>104</sup>Ru and <sup>122</sup>Sn double-beta decays, and the utilized JYFLTRAP double Penning trap system at the University of Jyväskylä, Finland. These nuclides are possible candidates for future experiments studying the mass of the neutrino and whether the neutrino is its own antiparticle. In collaboration with the nuclear theory group at the University of Jyväskylä, the half-lives of the decays were calculated to determine the feasibility of observing these decays. While the <sup>110</sup>Ag<sup>m</sup> was determined to be a suitable candidate for neutrino mass measurements, the half-lives of <sup>104</sup>Ru and <sup>122</sup>Sn neutrinoless double-beta decay were estimated to be too long for the decays to be observed with current experimental sensitivity.

**HK 35: Instrumentation VI**

Time: Thursday 13:45–15:45

Location: PHIL A 301

**Group Report**

HK 35.1 Thu 13:45 PHIL A 301

**First-level Event Selector of CBM** — JAN DE CUEVELAND<sup>1,2</sup>, DIRK HUTTER<sup>1,2</sup>, and •ANDREAS REDELBACH<sup>1,2</sup> for the CBM-Collaboration — <sup>1</sup>Frankfurt Institute for Advanced Studies — <sup>2</sup>Goethe University Frankfurt, Germany

In the upcoming CBM experiment at GSI/FAIR very high interaction rates with multiple free-streaming triggerless detectors create huge amounts of data which must be processed in real-time. The First-level Event Selector (FLES) serves as the central event selection system of CBM. It functions as a high-performance computer cluster performing the online analysis of physics data, including full event reconstruction, at the incoming design data rate. Combining data from approximately 5000 input links to self-contained, overlapping processing intervals and distributing them to compute nodes form the basis for subsequent steps of online reconstruction and event selection. Timeslice intervals can be built efficiently over a high-throughput InfiniBand network and distributed to online computing resources for full online event reconstruction and analysis in a heterogeneous HPC cluster system. This also includes specialized algorithms for efficient processing of timeslice intervals in 4-D, and finally selecting the events relevant for storage. This presentation summarizes the status of the CBM FLES project. A particular focus will be on the underlying design combining maximum performance and flexibility with minimum memory consumption. Also recent developments will be shown that have been successfully tested at the CBM predecessor experiment mCBM.

This work is supported by BMBF (05P21RFFC1).

HK 35.2 Thu 14:15 PHIL A 301

**Implementation of the DOGMA DAQ for the P371 Experiment at CERN** — •HUAGEN XU and MICHAEL TRAXLER for the P371 and the DOGMA-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH

The P371 experiment at CERN investigates whether antiprotons are initially polarized during production in high-energy proton collisions with an unpolarized target. To test this hypothesis, a dedicated measurement was prepared at the T11 beamline in the East Area of the CERN PS. Assuming an analyzing power of approximately 4.5% in the CNI (Coulomb-Nuclear-Interference) region of antiproton-proton elastic scattering, the polarization can be detected by measuring the left-right asymmetry of elastic events at scattering angles around 10 mrad using a 3.5 GeV/c antiproton beam. The measurement concept is to use a liquid hydrogen target as an analyzer, with incident and scattered particle tracks reconstructed using tracking detectors, including straw tubes and microfibers, upstream and downstream of the target. Scattered antiprotons are identified and distinguished from background using a DIRC system for offline particle identification.

To fulfill this measurement, a new data acquisition system, DOGMA, was implemented for the first time, handling roughly 1800 readout channels. DOGMA is a modular DAQ board offering 32 input channels with an integrated amplifier (maximum gain of 30), discriminator, and TDC. The performance of the DOGMA system for the beam time will be presented.

HK 35.3 Thu 14:30 PHIL A 301

**High throughput cluster finding on the readout FPGA for the CBM-TRD** — •DAVID SCHLEDT for the CBM-Collaboration — Goethe University Frankfurt am Main, Germany

The CBM experiment at FAIR/GSI in Darmstadt, will measure rare diagnostic probes of the QCD phase diagram at interaction rates of up to 10 MHz with high sensitivity and statistics. The CBM DAQ is based on self-triggered readout electronics resulting in large amount of data, which has to be processed in real time. The SPADIC readout ASIC transmits the full pulse shape information and features forced neighbor readout. Therefore, the initially produced data volume is relatively high, which lends itself for processing on the readout FPGA. The first processing step to reduce the data volume is to extract the information encoded in the pulse shape, i.e. the energy and time. The next step to further reduce the data volume before the online processing is to combine adjacent channel hits into clusters. As CBM runs without a trigger system the hits need to be grouped in time and space in real time. Therefore, a fast high throughput cluster finding algorithm is necessary to process the data without data losses. This work will present how such an algorithm can be implemented on the readout FPGA, with a particular focus on the implementation with high-level-synthesis (HLS).

Supported by: German BMFTR-grants 05P24PM1 and 05P24RF2

HK 35.4 Thu 14:45 PHIL A 301

**Investigations of the integrating readout system of the P2 experiment at MESA** — SEBASTIAN BAUNACK<sup>1</sup>, MICHAEL GERICHKE<sup>3</sup>, BORIS GLÄSER<sup>1</sup>, SHRUTI GUDLA<sup>1</sup>, RAHIMA KRINI<sup>1</sup>, FRANK MAAS<sup>1,2,4</sup>, JAYANTA NAIK<sup>1</sup>, •MORAN NEHER<sup>1</sup>, TOBIAS RIMKE<sup>1</sup>, SIDDHARTH THAKKER<sup>1</sup>, and MALTE WILFERT<sup>1</sup> — <sup>1</sup>Institut für Kernphysik, Johannes Gutenberg-Universität Mainz — <sup>2</sup>Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — <sup>3</sup>Department of Physics and Astronomy, University of Manitoba, Winnipeg, Canada — <sup>4</sup>PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz

The P2 experiment aims for a high precision measurement of the weak mixing angle, a fundamental parameter of the Standard Model. The weak mixing angle will be extracted from the parity-violating asymmetry in elastic electron-proton scattering at low momentum transfer, with an expected raw asymmetry of  $A_{\text{raw}} = 0.2403 \times 10^{-7}$ . The central component of the detector system is an integrating Cherenkov ring detector, which measures the flux of scattered electrons. The flux depends on the helicity of the electron beam and gives rise to the production of Cherenkov light.

The detector modules consist of a photomultiplier tube, the P2 voltage divider and pre-amplifier and the P2 sampling ADC. In this presentation, the P2 experiment is introduced and the current status of the readout system is presented.

HK 35.5 Thu 15:00 PHIL A 301

**Trigger system based on time-spatial correlations for SiPM-RICH detectors** — •JESÚS PEÑA-RODRÍGUEZ for the CBM-Collaboration — Bergische Universität Wuppertal, Wuppertal, Germany

Future experiments in high-energy physics work on new detection technologies with higher time and spatial resolution. This will enhance data quality to search for specific decay channels or interaction products. Detectors employed for particle identification use different technologies, geometries, and algorithms. Ring

Imaging Cherenkov (RICH) detectors are one of them; they record Cherenkov rings from charged particles traversing a radiator medium and discriminate between particles depending on the angle of the Cherenkov emission. New RICH techs explores Silicon Photomultipliers (SiPMs) as photon detectors. SiPMs provide high time resolution, spatial granularity, magnetic field immunity, mechanical robustness, and low material budget. Nevertheless, high dark count rates and low radiation tolerance challenge the implementation of SiPMs in RICH detectors. We explore a trigger system that exploits Cherenkov ring features: spatial correlation (circular/ellipsoidal shape) and time coincidence (picosecond arrival time) of Cherenkov photons. This approach rejects most of the fake events caused by DCR, saving buffer and bandwidth. We performed MC simulations to generate realistic SiPM noise and Cherenkov rings. These signals were injected into the digital implementation (FPGA Lattice ECP5) of the trigger system to evaluate its signal-to-noise ratio and detection efficiency.

HK 35.6 Thu 15:15 PHIL A 301

**An Automated Test Setup for Pipeline ADC Characterization** — ÖS-CAR ANDÚJAR SABÁN<sup>1</sup>, NING CAO<sup>1</sup>, LUIGI CAPOZZA<sup>1</sup>, HARALD DEPPE<sup>2</sup>, HOLGER FLEMMING<sup>2</sup>, RAVI GOWDRU MANJUNATA<sup>1</sup>, •ALEXANDER LEHNEN<sup>1</sup>, FRANK MAAS<sup>1,2</sup>, OLIVER NOLL<sup>1</sup>, PAUL SCHÖNER<sup>1</sup>, CHRISTOPH ROSNER<sup>1</sup>, PETER WIECZOREK<sup>2</sup>, and SAHRA WOLFF<sup>1</sup> for the PANDA-Collaboration — <sup>1</sup>Helmholtz-Institut Mainz, Mainz, Deutschland — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Deutschland

An analog-to-digital converter (ADC) chip is being developed at the GSI Darmstadt for the readout of the electromagnetic calorimeter of the PANDA detector. To enable characterization of this chip, a test setup was designed and implemented at the Helmholtz Institute Mainz. The setup allows fully automated measurements over a wide range of clock frequencies and input signal frequen-

cies. This enables systematic investigation of both calibration behavior and dynamic performance. Its modular design provides flexibility, allowing extensions and improvements as needed. An implemented server allows multiple users to connect simultaneously and control measurements remotely. This architecture, combined with full automation, allows for reproducible testing of current and future ADC chips.

HK 35.7 Thu 15:30 PHIL A 301

**Further Development of the Calibration Routine for the High-Voltage Regulation PCB for the PANDA Barrel Electromagnetic Calorimeter (EMC)** —

•KARL SIMON HABERMEHL, KAI-THOMAS BRINKMANN, HANS-GEORG ZAUNICK, and ANIKO TIM FENSKE for the PANDA-Collaboration — 2<sup>nd</sup> Physics Institute, Justus Liebig University, Giessen, Germany

The barrel section of the electromagnetic calorimeter (EMC) of the PANDA experiment at the future FAIR accelerator is designed to achieve excellent photon energy resolution over a wide dynamic range. To reach this level of precision, the various calorimeter subsystems (in particular the readout and front-end electronics) require careful optimization.

One of the most important components is the high-voltage distribution electronics (HVD), which supplies the avalanche photodiodes (APDs) with the bias voltages and therefore defines their gain. Since the performance of the HVD is temperature dependent and the operating temperature cannot be predicted accurately, it must be calibrated over a wide temperature range. For this purpose, a routine for series calibration of the HVD-PCBs has been developed. This contribution will give an impression of the currently running calibration procedure and foreseen improvements as well as some of the calibration results.

*Supported by BMFTR, GSI and HFHE.*

## HK 36: Instrumentation VII

Time: Thursday 13:45–15:45

Location: PHIL B 302

### Group Report

HK 36.1 Thu 13:45 PHIL B 302

**The Silicon Tracking System for the CBM Experiment: Series Production and Detector Performance Evaluation** — •LADY MARYANN COLLAZO SANCHEZ for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

The Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) investigates strongly interacting matter at high baryon densities. Its core tracking subsystem, the Silicon Tracking System (STS), provides charged-particle tracking and momentum reconstruction at interaction rates up to 10 MHz within a free-streaming data acquisition scheme, reconstructing around 10<sup>3</sup> charged tracks per nucleus–nucleus collision. The STS consists of eight tracking stations equipped with 876 double-sided silicon microstrip modules mounted on low-mass carbon–fiber ladders to minimize material budget. Prototype STS components were tested in beam experiments within the mini-CBM (mCBM) setup at SIS18 and in the E16 experiment, validating detector performance, free-streaming readout, and online reconstruction.

This report summarizes the current status of the STS project. Series production of modules and ladders is ongoing, and detector construction is in progress. It describes the full sequence of electrical, mechanical, and performance qualification procedures for modules, ladders, and half-unit assemblies. It presents results from comprehensive beam–based performance studies, detector controls, and the final readout chain.

HK 36.2 Thu 14:15 PHIL B 302

**Aluminum strip-lines on pCVD diamond carriers\*** — •EVA-DHIDHO TAKA<sup>1</sup>, FRANZ A. MATEJCEK<sup>1</sup>, CHRISTIAN MÜNTZ<sup>1</sup>, and JOACHIM STROTH<sup>1,2,3</sup> — <sup>1</sup>Goethe-Universität Frankfurt — <sup>2</sup>GSI Darmstadt — <sup>3</sup>Helmholtz Forschungskademie Hessen für FAIR

The present work focuses on the aluminum metallization of pCVD (polycrystalline Chemical Vapor Deposition) diamond substrates and patterning of strip-lines. This is a generic research project with the goal of producing lightweight, vacuum compatible modules to minimize multiple scattering, highly appealing for micro-vertexing applications. Conductive traces, to perform the readout and control of silicon sensors, are introduced directly on the carrier thus obtaining pCVD diamond carriers with expanded functionalities: adding electrical connectivity along with mechanical stability and efficient heat management.

This application requires trace thicknesses up to the order of micrometers. Since combining trace sharpness, thickness homogeneity, and a process with dependable reproducibility poses a challenge, a method consisting of consecutive deposition steps is proposed. A thin Aluminum seed layer is initially sputtered into a prepped pCVD diamond surface. The layer is then precisely patterned utilizing mask-less photolithography, and the so produced lines are subsequently thickened in an electrodeposition process. This contribution introduces the method and presents first results.

\*This work is affiliated with the ERuM-Pro Si-D Consortium, supported by BMFTR (05H24RF1).

HK 36.3 Thu 14:30 PHIL B 302

**Update on the Developments in Optimization and Characterization for the ToAst-based Silicon-Strip-Detectors of the PANDA MVD** — •RAPHAEL RATZ<sup>1</sup>, KAI-THOMAS BRINKMANN<sup>1</sup>, MARVIN PETER<sup>1</sup>, HANS-GEORG ZAUNICK<sup>1</sup>, GIOVANNI MAZZA<sup>2</sup>, MICHELE CASELLE<sup>3</sup>, and DANIELA CALVO<sup>2</sup> for the PANDA-Collaboration — <sup>1</sup>2<sup>nd</sup> Physics Institute, Justus Liebig University, Giessen — <sup>2</sup>Istituto Nazionale di Fisica Nucleare - Sezione di Torino, Turin — <sup>3</sup>Karlsruhe Institute of Technology, Karlsruhe

The Micro Vertex Detector (MVD) of the PANDA experiment consists of silicon strip detectors, read out by the Torino Amplifier for silicon Strip detectors (ToAst) ASIC. Each ToAst employs a multitude of parameters, some of which affect the Signal-to-Noise Ratio (SNR) of the Time-over-Threshold (ToT) measurement. Thus, an optimization and an energy calibration for the measured ToTs is favorable.

After establishing the parameters that most affect SNR, they were optimized pairwise using a grid search method with the integrated testpulsar of the ToAst. As the analysis of the correlation matrix suggests multiparameter effects on the SNR, a Bayesian optimization algorithm was investigated. While covering more than two parameters simultaneously, this approach also decreases the time needed compared to a grid search, allowing each sensor channel to be optimized individually.

In addition, a calibration between the measured ToT and the deposited charge, and subsequently the deposited energy, was achieved. Lastly, a web-based user interface for configuring sensors and online analysis of measurements was developed. *Supported by BMFTR.*

HK 36.4 Thu 14:45 PHIL B 302

**The Assembly and Integration of a Half-unit of the Silicon Tracking System (STS) Detector** — •GNANA SINDHU SUBRAMANYA for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

The Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) investigates strongly interacting matter at high net-baryon densities. Its Silicon Tracking System (STS) provides precise tracking of charged particles in heavy-ion collisions, where tracking efficiency and vertex resolution are crucial for rare probes such as open charm and di-leptons, directly linking detector performance to CBM's physics goals.

This presentation describes the STS half-unit and the development and verification of a reliable assembly and integration protocol. Prototype components were used to simulate mechanical assembly and ensure safe handling before working with sensor modules and electronics. The protocol defines the place-

ment of mechanical and electronic components, including ladders with Front-End Board (FEB) boxes housing front-end electronics (FEEs). Cable routing and power connections between FEBs and the readout chain were verified. Mechanical constraints were checked to prevent interference during module assembly and integration into the full STS.

HK 36.5 Thu 15:00 PHIL B 302

**Amplification Based Radiation Damage Compensation in Diamond Detectors** — •YEVHEN KOZYMK<sup>1</sup>, THOMAS BERGAUER<sup>2</sup>, TETYANA GALATYUK<sup>1,3,4</sup>, ALBERT HIRTL<sup>5</sup>, MATTHIAS KAUSEL<sup>5,6</sup>, MLADEN KIS<sup>3</sup>, WILHELM KRÜGER<sup>1</sup>, SERGEY LINEV<sup>3</sup>, JAN MICHEL<sup>3</sup>, JERZY PIETRASZKO<sup>3</sup>, CHRISTIAN JOACHIM SCHMIDT<sup>3</sup>, MICHAEL TRÄGER<sup>3</sup>, MICHAEL TRAXLER<sup>3</sup>, FELIX ULRICH-PUR<sup>5</sup>, MATTEO CENTIS VIGNALI<sup>7</sup>, and ASHISH BISHT<sup>7</sup> — <sup>1</sup>Technische Universität Darmstadt — <sup>2</sup>Marietta Blau Institute for Particle Physics of the Austrian Academy of Sciences — <sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH — <sup>4</sup>Helmholtz Forschungsakademie Hessen für FAIR — <sup>5</sup>TU Wien, Atominstitut — <sup>6</sup>EBG MedAustron — <sup>7</sup>Fondazione Bruno Kessler, Centre of Materials and Microsystems

Diamond detectors are widely used for beam monitoring and time zero applications due to their high timing precision, detection efficiency and radiation hardness. However, the accumulated radiation damage from heavy-ion beams eventually drops the charge collection efficiency below the detectable threshold, resulting in loss of efficiency.

Diagnostics are performed on a pCVD diamond sensor that saw heavy use in the mCBM experiment and has an efficiency hole in the center, utilizing LGADs as reference detectors. We demonstrate the use of a two-stage amplification circuit and conversion from strip to pad readout for restoring the efficiency of a highly damaged diamond sensor with a 73 AMeV helium beam.

HK 36.6 Thu 15:15 PHIL B 302

**The Super-FRS beam intensity monitor** — •CHIARA NOCIFORO<sup>1</sup>, MATTEO ALFONSI<sup>1</sup>, TOBIAS BLATZ<sup>1</sup>, JOSHUA ALVARO GALVIS TARQUINO<sup>1</sup>, RAINER HASEITL<sup>1</sup>, RAINER HETTRICH<sup>1</sup>, CHRISTOS KARAGIANNIS<sup>1</sup>, MLADEN KIS<sup>1</sup>, MARTIN KUMM<sup>2</sup>, ROLF LONSING<sup>2</sup>, RAHUL SINGH<sup>1</sup>, and MICHAEL TRÄGER<sup>1</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>2</sup>Fulda University of Applied Sciences, Fulda, Germany

The beam diagnostics at the entrance of the Super-FRS, under installation at FAIR for the production of in-flight radioactive ion beams, is used to tune the separator and provide the necessary measures for machine protection and online

monitoring. In addition, the high intensity of the primary SIS ion beams delivered up to the target must be stored to normalise the measured rates and extract the production cross sections of the new secondary ion beams. The main design challenge is to cope with the high intensities and the expected background radiation, since the detecting system should survive for extended periods of operation without hands-on maintenance. Two complementary CVD diamond detectors with excellent radiation resistance were built as reference counting detectors up to few MHz particle rate, overlapping with the standard intensity monitors at FAIR. Customised electronics with large dynamic range developed for the readout of the diamond analogue signals was coupled to the detector and tested at the pre-assembled target vacuum chamber. The design of the Super-FRS intensity monitor and its peculiarity will be presented and the latest achievements of the performed tests will be reported.

HK 36.7 Thu 15:30 PHIL B 302

**Development and performance of the readout board of the STS detector for the CBM experiment** — •PATRYK SEMENIUK for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — Goethe University Frankfurt, Max-von-Laue-Straße 1, 60438 Frankfurt am Main, Germany — AGH University of Krakow, Mickiewicza 30, 30-059 Kraków, Poland

The Silicon Tracking System (STS) of the CBM experiment requires a high-bandwidth readout chain operating under strict spatial and performance constraints. A new generation of STS Readout Boards (STS-ROB), developed as the successor to the CROB, forms the concentrator stage between the front-end electronics and the CRI-based backend. Each STS-ROB integrates three GBTx ASICs, a Versatile Link optical interface, and connectivity optimized for AC-coupled 320-Mb/s LVDS E-Links from front-end ASICs at different sensor bias potentials.

Recent work focused on commissioning and integration of the STS-ROB into the readout chain using the CBM Common Readout Interface (CRI) and the self-developed Readout-Powering Board (RPOB). Stable GBTx initialization, reliable optical and electrical communication, and robust power delivery were demonstrated, confirming that the STS-ROB meets the system's operational requirements.

In the final detector, the STS will comprise several hundred STS-ROB units with dedicated add-on and powering boards; the concept, integration results, and current status of the STS-ROB will be presented.

## HK 37: Hadron Structure and Spectroscopy VII

Time: Thursday 16:15–18:00

Location: PHIL C 301

### Group Report

HK 37.1 Thu 16:15 PHIL C 301

**Measurements of two-photon scattering reactions at the BESIII experiment as inputs to the Hadronic Light-by-Light contribution to  $(g - 2)_\mu$**  — ACHIM DENIG, MAX LELLMANN, JAN MUSKALLA, and •CHRISTOPH FLORIAN REDMER for the BESIII-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

While recently agreement between the direct measurements and the Standard Model prediction of the anomalous magnetic moment of the muon was reported, further improvement of the prediction is required to match the precision of the measurement. The prediction is limited by the knowledge of the hadronic contributions, which can be calculated from data-driven approaches. One of these contributions is the hadronic Light-by-Light scattering. It depends on the knowledge of transition form factors of light pseudoscalar, scalar, axial, and tensor mesons as well as the coupling of multi-meson systems to two photons, which are accessible in  $e^+e^-$  collisions.

The BESIII experiment, operated at the BEPCII accelerator in Beijing, China, has collected the world's largest data sets of  $e^+e^-$  collisions in the  $\tau$ -charm region between 2 GeV and 5 GeV. The recently completed  $20\text{ fb}^{-1}$  data set at 3.773 GeV is ideally suited to study the momentum-transfer dependence of transition form factors at space-like momentum transfers of  $Q^2 \approx 1\text{ GeV}^2$ , which is of special relevance in the context of  $a_\mu$ . In this presentation we discuss recent results, ongoing projects, and future prospects of the measurements at the BESIII experiment. — Supported by DFG FOR5327

HK 37.2 Thu 16:45 PHIL C 301

**Probing hyperon-hyperon interactions with CBM at FAIR** — •GANDHARVA APPAGERE for the CBM-Collaboration — Stockholm University, Stockholm, Sweden

Hyperons play a central role in the composition of dense baryonic matter and are expected to emerge in the cores of neutron stars at supra-nuclear densities, influencing the equation of state. A quantitative understanding of hyperon-hyperon interactions, governed by non-perturbative QCD, is therefore essential for constraining the properties of dense matter. In this contribution, recent studies of multi-strange baryon interactions are presented with the framework of the Com-

pressed Baryonic Matter (CBM) experiment at FAIR as a part of "QCD at FAIR" initiative. Using realistic CBM simulation data for high-rate proton-proton collisions, we investigate  $\Lambda\Lambda$  and  $\Sigma^+\Sigma^+$  systems. We emphasize on interaction signatures such as cusp effects and near-threshold structures, explored using dispersion-relation-based approaches based up on Monte Carlo simulations of exclusive reaction channels. The presented results establish a solid methodological foundation for future measurements with CBM and illustrate its potential to provide crucial experimental constraints on hyperonic interactions relevant for neutron-star matter.

HK 37.3 Thu 17:00 PHIL C 301

**Measurement of the chiral anomaly at COMPASS** — •JAN FRIEDRICH for the COMPASS-Collaboration — Physik-Department, Technische Universität München, Garching

Using the Primakoff technique for 190 GeV pions on nuclear targets, we have determined the chiral anomaly in the process  $\pi\gamma \rightarrow \pi\pi^0$  with unprecedented precision. We report on the challenges of background subtraction, radiative corrections and the luminosity determination.

HK 37.4 Thu 17:15 PHIL C 301

**The GSI pion beam program: QCD-driven studies of hadron structure and dynamics** — •MARVIN KOHLS — GSI Helmholtzzentrum für Schwerionenforschung GmbH

We present plans for the upcoming pion beam program at GSI from 2027 on. This program leverages secondary pion beams ( $< 2\text{ GeV}/c$ ) in combination with the HADES spectrometer to address fundamental questions in strong QCD physics with a focus on precision studies in the fields of baryon spectroscopy and structure. We will determine baryon-meson coupling constants and electromagnetic transition form factors in the time-like region. With the planned beam intensities we expect to collect enough statistics to enable detailed partial wave analyses and the study of rare decay channels. These measurements are crucial for understanding hadron structure and for modeling dilepton emission in heavy-ion collisions. As a complementary focus, we study vector meson properties in cold nuclear matter through dielectron spectroscopy. The program

will investigate in-medium modifications of vector mesons and their relation to chiral symmetry restoration. This program represents a principal component of the broader QCD-driven roadmap at GSI/FAIR (QCD at FAIR), bridging nuclear, hadron, and heavy-ion physics communities while complementing photon beam facilities worldwide.

HK 37.5 Thu 17:30 PHIL C 301

**Physics performance studies of the CBM Neutron Calorimeter (NCAL)** — •DACHI OKROPIRIZZE<sup>1,2</sup>, DIETER GRZONKA<sup>2,3</sup>, and JAMES RITMAN<sup>2,1,3</sup> for the CBM-Collaboration — <sup>1</sup>Ruhr-Universität Bochum (RUB), Bochum, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>3</sup>Forschungszentrum Jülich (FZJ), IKP-1, Jülich, Germany

The Compressed Baryonic Matter (CBM) experiment at FAIR aims to explore the QCD phase diagram at high net-baryon densities. Event characterization and centrality determination are currently provided by the Forward Spectator Detector (FSD), which measures charged projectile spectators. To include neutral spectators, a forward neutron calorimeter (NCAL) based on segmented plastic scintillators is proposed. This upgrade is expected to improve impact-parameter reconstruction and constrain collective flow observables.

In addition to heavy-ion reactions, NCAL enables a vibrant program in elementary reactions using the same experimental setup. We present Monte Carlo studies of channels with final-state neutrons to explore the detector's physics reach. Standalone Monte Carlo simulations characterize the NCAL response, focusing on detection efficiency and energy deposition over the relevant energy range. By propagating simulated events through the model, we obtain detector-

level observables. Taken together, these studies provide first estimates of NCAL's performance for spectator measurements in heavy-ion collisions and neutron-sensitive spectroscopy in elementary channels.

HK 37.6 Thu 17:45 PHIL C 301

**Performance studies of the CBM Forward Spectator Detector for (pp and) dp-reactions** — •RUIJIA YANG<sup>1</sup>, FRANK GOLDENBAUM<sup>1,2</sup>, and PETR CHALOUPEK<sup>3</sup> for the CBM-Collaboration — <sup>1</sup>Bergische Universität Wuppertal — <sup>2</sup>GSI — <sup>3</sup>Czech Technical University

The Forward Spectator Detector (FSD) of the CBM (Compressed Baryonic Matter) experiment plays a crucial role in both heavy-ion and proton-proton (pp) collisions. In pp interactions, the FSD is designed to identify events with small momentum transfer, typically dominated by elastic or quasi-elastic scattering, where the outgoing protons retain most of their energy and are deflected at very small angles. This contribution presents recent simulation studies performed to optimize the granularity and geometry of the FSD. With the full CBM geometry, the impact of the FSD module size, beam-pipe shape and material budget on the spatial resolution and detection efficiency has been systematically investigated. In addition, two event generators – a Fritiof (FTF) event generator and a PLUTO-based generator – have been implemented to simulate deuteron-proton (dp) reactions in CBM, in order to investigate the capability of CBM to study quasi-free pp and proton-neutron (pn) reactions. Integration of these generators into the CBM simulation is ongoing, and first results – together with updated FSD performance studies – will be presented at the conference.

## HK 38: Hadron Structure and Spectroscopy VIII

Time: Thursday 16:15–18:00

Location: PHIL A 401

### Group Report

HK 38.1 Thu 16:15 PHIL A 401

**Studies of  $\Lambda(1405)$  photoproduction at BGOOD** — •ANTONIO JOAO CLARA FIGUEIREDO for the BGOOD-Collaboration — Physikalisches Institut, Universität Bonn

The  $\Lambda(1405)$  has long been considered a prime candidate for an unconventional hadronic state, with strong evidence supporting a dynamically generated meson-baryon molecular structure. To clarify the nature of the  $\Lambda(1405)$ , precise measurements of its line shape and differential production cross sections are essential.

The BGOOD experiment at the ELSA facility provides an ideal environment for the investigation of  $\Lambda(1405)$  photoproduction at low momentum transfer. BGOOD combines a central electromagnetic calorimeter for neutral meson reconstruction with a forward magnetic spectrometer for charged particle identification, enabling access to very low momentum transfer kinematics which may be sensitive to molecular production mechanisms.

I will report on the current status of the  $\Lambda(1405)$  investigation at BGOOD in the photoproduction reaction  $\gamma p \rightarrow K^+ \Lambda(1405)$ . Measurements of line shapes and differential cross sections will be presented, with particular emphasis on the  $\Sigma^0 \pi^0$  decay channel and ongoing studies of the predicted two-pole structure of the  $\Lambda(1405)$ .

HK 38.2 Thu 16:45 PHIL A 401

**$\eta'$  beam asymmetry at threshold using the BGOOD experiment** — •LEONI LUTTER for the BGOOD-Collaboration — Physikalisches Institut

The unexpected nodal structure of the beam asymmetry reported by the GRAAL collaboration in  $\eta'$  photoproduction very close to threshold could be explained by a previously unobserved very narrow resonance. BGOOD is one of the few experiments worldwide which is able to verify this result. The experiment is composed of a central calorimeter for neutral meson decays and a forward spectrometer for charged particle identification. Close to threshold the  $\gamma p \rightarrow \eta' p$  reaction can be reconstructed over all centre-of-mass angles from proton identification at forward angles. A linearly polarised photon beam produced via coherent bremsstrahlung off a diamond radiator makes it possible to measure the  $\eta'$  beam asymmetry. Preliminary results of the  $\gamma p \rightarrow \eta' p$  beam asymmetry will be presented.

HK 38.3 Thu 17:00 PHIL A 401

**Investigation of the reaction  $pp \rightarrow ppK^+K^-$  at 4.5 GeV with HADES detector** — •VALENTIN KLADOV<sup>1,2</sup>, JOHAN MESSCHENDORP<sup>2</sup>, and JAMES RITMAN<sup>1,2,3</sup> for the HADES-Collaboration — <sup>1</sup>Ruhr-Universität Bochum, Bochum, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>3</sup>Forschungszentrum Jülich GmbH, Jülich, Germany

This study presents an exclusive analysis of the  $pp \rightarrow ppK^+K^-$  reaction using data collected with the HADES detector with a 4.5 GeV proton beam. The event selection is based on a neural-network particle identification employing a domain-adversarial approach. Together with a kinematic refit imposing four-momentum conservation, the purity of the final sample reaches  $S/B \approx 30$ . Clear

contributions from  $\phi(1020) \rightarrow K^+K^-$  and  $\Lambda(1520) \rightarrow pK^-$  are observed, with masses and widths consistent with the PDG data. S-wave final-state interactions are investigated by extracting the  $pK^-$  and  $K^+K^-$  scattering-length parameters. This talk focuses on the particle identification performance studies, systematic uncertainties, and several new results, including improved angular analysis for the spin alignment of the  $\phi(1020)$  resonance and a coupled-channel analysis of  $\Lambda(1405) \rightarrow \Sigma^0 \pi^0 / pK^-$  decays.

HK 38.4 Thu 17:15 PHIL A 401

**Feasibility Studies for hidden-charm Pentaquark searches with CBM** — •RALF KLIENT for the CBM-Collaboration — Ruhr-Universität Bochum, Bochum, Germany — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

We investigate the feasibility to measure the direct production of pentaquark-like states at the CBM experiment at FAIR in proton-proton collisions. For these, we performed feasibility studies by evaluating the performance assuming the three LHCb-discovered pentaquark states. Using GEANT4-based simulations we analyzed the reaction to  $ppJ/\psi$  in the  $e^+e^-$  decay channel of the  $J/\psi$  at a beam energy of 29 GeV. The study demonstrates CBM's excellent capabilities with an invariant mass resolution for the  $pJ/\psi$  system below 7 MeV/ $c^2$  and signal acceptance  $\times$  efficiency exceeding 10% whilst reducing background by  $\mathcal{O}(10^{-9})$ . Our results confirm CBM can provide high-precision measurements of pentaquark-like state properties through an independent production mechanism, offering crucial complementary data to the inclusive measurements and significantly advancing understanding of exotic hadronic states.

HK 38.5 Thu 17:30 PHIL A 401

**Study of exclusive  $\eta$  meson production in proton-proton collisions with the HADES spectrometer** — •SZYMON TRELIŃSKI<sup>1,2</sup>, JAMES RITMAN<sup>2,3,4</sup>, and IZABELA CIEPAŁ<sup>1</sup> for the HADES-Collaboration — <sup>1</sup>IFJ PAN Krakow — <sup>2</sup>Ruhr-Universität Bochum — <sup>3</sup>GSI Helmholtzzentrum — <sup>4</sup>Forschungszentrum Jülich Proton-proton collisions at a center-of-mass energy of 3.46 GeV, measured in February 2022 with the HADES detector at GSI, provide great opportunity to study exclusive  $\eta$  meson production. This energy lies in the transition region between near-threshold energies, described by effective Lagrangian models, and the soft regime, where Regge phenomenology is applied. Measurements in this range help to bridge these descriptions and contribute to a more coherent understanding of nonperturbative QCD dynamics.

The analysis focuses on the exclusive reaction  $pp \rightarrow pp\eta \rightarrow pp\pi^+\pi^-\pi^0$ , with the  $\eta$  reconstructed in its  $\pi^+\pi^-\pi^0$  decay channel. This channel provides high statistics due to its large branching ratio combined with good reconstruction efficiency. The study considers different event topologies to extend the accessible phase space.

The talk will present the event selection strategy, the application of the kinematic fit, the background subtraction procedure, and the multidimensional unfolding technique, together with early-stage results on the total and differential cross sections for exclusive  $\eta$  production.

HK 38.6 Thu 17:45 PHIL A 401

**Recent Measurements of the  $\Lambda(1670)$  Differential Cross Section At the BGOOD Experiment** — •DAVID KOWALK and THOMAS JUDE for the BGOOD-Collaboration — Physikalisches Institut, Universität Bonn

The lighter  $\Lambda(1405)$  resonance is commonly interpreted as a  $\bar{K}N$  bound state. It is therefore to be investigated if the heavier  $\Lambda(1670)$  may also exhibit this molecular

structure. Forward angle  $K^+$  identification is therefore essential. The BGOOD photoproduction experiment is ideal for these studies. It consists of a central calorimeter, ideal for the identification of hyperon decays, and a forward spectrometer for  $K^+$  identification. I will present preliminary measurements of the  $K^+\Lambda(1670)$  photoproduction differential cross section, identified via different  $\Lambda(1670)$  decay modes.

## HK 39: Structure and Dynamics of Nuclei VIII

Time: Thursday 16:15–18:00

Location: AM 00.011

HK 39.1 Thu 16:15 AM 00.011

**Electron-Induced Fission at the S-DALINAC - Status and Objectives** — •DIANDRA RICHTER, G. STEINHILBER, N. PIETRALLA, J. BIRKHAN, B. HESBACHER, T. RAMAKER, O. MÖLLER, M. ARNOLD, and J. ISAAK — IKP, Darmstadt, Germany

The origin of heavy chemical elements in the Universe remains a major open question. One of the main production mechanisms is the rapid neutron capture process. It takes place in neutron star mergers and terminates in the r-process fission cycle along very neutron-rich nuclei [1]. In the actinide region, neutron captures compete with nuclear fission, producing fragments that serve as neutron-rich r-process seeds. Accurate r-process models therefore require detailed fission data, but experimental information on fission from different excitation energies of transuranium actinides is scarce. At TU Darmstadt, a new setup for electron-induced fission is currently being developed, using electron beams from the superconducting linear accelerator S-DALINAC [2]. Silicon strip detectors will measure energies and timing of both fission fragments, while scattered electrons will be detected in coincidence using the QCLAM spectrometer. This arrangement will allow measurements of fission fragment masses as a function of excitation energy and momentum transfer. An overview of the current status will be presented in this contribution. This work is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under project-ID Nos. INST 163/754-1 FUGG and 499256822 GRK 2891 "Nuclear Photonics". [1] J. J. Cowan et al., Rev. Mod. Phys. 93, 015002 (2021); [2] N. Pietralla, Nucl. Phys. News 28, 4 (2018)

HK 39.2 Thu 16:30 AM 00.011

**Relative  $^{232}\text{Th}(\gamma, f)$  and  $^{234}\text{U}(\gamma, f)$  Cross-Sections using Quasi-Monoenergetic  $\gamma$ -ray Beams** — •THORHEN WITZEL<sup>1</sup>, DIMITRI BALABANSKI<sup>4</sup>, MIHAI CUCIUC<sup>4</sup>, JOACHIM ENDERS<sup>1</sup>, SEAN W. FINCH<sup>2</sup>, ALF GÖÖK<sup>3</sup>, CALVIN R. HOWELL<sup>2</sup>, ANNABEL IBEL<sup>1</sup>, RONALD C. MALONE<sup>7</sup>, MAXIMILIAN MEIER<sup>1</sup>, FORREST Q.L. FRIESEN<sup>2</sup>, ANDREAS OBERSTEDT<sup>4</sup>, STEPHAN OBERSTEDT<sup>5</sup>, MARIUS PECK<sup>1</sup>, NORBERT PIETRALLA<sup>1</sup>, ANTHONY P.D. RAMIREZ<sup>6</sup>, JACK A. SILANO<sup>6</sup>, ALEXANDRU STATE<sup>4</sup>, GERHART STEINHILBER<sup>1</sup>, ANTON P. TONCHEV<sup>6</sup>, WERNER TORNOW<sup>2</sup>, and VINCENT WENDE<sup>1</sup> — <sup>1</sup>Institut für Kernphysik, Fachbereich Physik, TU Darmstadt, Darmstadt, Germany — <sup>2</sup>Triangle Universities Nuclear Laboratory, Duke University, Durham, NC, USA — <sup>3</sup>Uppsala Universitet, Uppsala, Sweden — <sup>4</sup>ELI-NP, IFIN-HH, Magurele, Romania — <sup>5</sup>EC-JRC Geel, Belgium — <sup>6</sup>Lawrence Livermore National Laboratory, Livermore, CA, USA — <sup>7</sup>U.S. Naval Academy, Annapolis, MD, USA

Precise and reliable data on photofission cross-sections are essential for modeling of the r-process as well as technical applications of nuclear fission. Although fission cross-sections have been studied for over 80 years, there are still some discrepancies in the nuclear data libraries for some actinides. We analyzed count rates from ionisation chamber experiments using quasi-monochromatic  $\gamma$ -ray beams ranging from 6 to 12.8 MeV, investigating the shape of the cross-sections of  $^{232}\text{Th}(\gamma, f)$  and  $^{234}\text{U}(\gamma, f)$  using  $^{238}\text{U}(\gamma, f)$  as a well known reference.

\*This work is supported by the Deutsche Forschungsgemeinschaft (DFG) Project-ID 499256822 GRK 2891 Nuclear Photonics.

HK 39.3 Thu 16:45 AM 00.011

**In-gas-jet laser ionization spectroscopy of the  $K = 8^-$  isomer in  $^{254}\text{No}$**  — •PREMADITYA CHHETRI for the JetRIS-Collaboration — Johannes Gutenberg Universität, Mainz, Germany

Decay and in-beam spectroscopy have provided extensive information on the level structure of heavy nuclei, but often cannot unambiguously determine the underlying single-particle structure of the nucleus. This limitation is particularly evident for the long-lived  $K^\pi = 8^-$  isomer in  $^{254}\text{No}$ , whose quasiparticle structure has remained disputed for almost two decades. In fusion-evaporation experiments, the rotational band built of this isomer is only weakly populated preventing a reliable measurement of key observables such as M1/E2 branching ratios and  $g$ -factors. Consequently, previous configuration assignments mainly relied on indirect decay patterns and comparisons with nuclear models.

Here, we report on in-gas-jet laser ionization spectroscopy measurements of the  $K = 8^-$  isomer in  $^{254}\text{No}$  performed with the JetRIS setup at the SHIP velocity filter at GSI. After stopping and neutralization in argon gas, the atoms are

re-ionized in a supersonic gas jet using a two-step laser ionization scheme. The resulting hyperfine structure provides direct, nuclear-model-independent access to the magnetic dipole moment, electric quadrupole moment, and isomer shift of the  $K = 8^-$  state. The deduced intrinsic  $g$ -factor allowed an unambiguous assignment of configuration of the isomer, resolving a long-standing ambiguity in the nuclear structure of  $^{254}\text{No}$ .

HK 39.4 Thu 17:00 AM 00.011

**Evolution of changes in mean-square charge radii in californium isotopes** — •KENNETH VAN BEEK for the RADRIS-Collaboration — Technische Universität Darmstadt, Deutschland — GSI Helmholtzzentrum für Schwerionenforschung, Deutschland

The experimental determination of atomic and nuclear properties such as atomic energy levels, ionization potentials, electromagnetic moments, trends in mean-square charge radii, and isotope shifts for nuclei in the region of heavy elements ( $Z \geq 100$ ) remains difficult. The main challenges are low production rates at accelerator facilities and unfavorable half-lives of the fusion products. This necessitates the use of highly efficient and selective laser spectroscopy techniques. At GSI-FAIR in Darmstadt, Germany, the Radiation Detected Resonance Ionization Spectroscopy (RADRIS) apparatus has been successfully used to study aforementioned properties in  $^{245,246,248-250,254}\text{Fm}$  and  $^{252-255}\text{No}$ . The employed detection of laser ions via their  $\alpha$ -decay became impractical for nuclei with half-lives on the order of several tens of hours using a single detector. Thus, a more versatile detector design was developed to increase the method's reach towards longer-lived nuclei. In a recent measurement campaign, the new setup was used to investigate isotope shifts in a long isotopic chain in the element californium, including  $^{246}\text{Cf}$  with a half-life of  $t_{1/2} = 35.7\text{ h}$ . This talk will present laser spectroscopic results in  $^{240,241,242,244,246}\text{Cf}$  and the extracted information for trends in changes of mean-square charge radii, complementing former investigations of  $^{249-253}\text{Cf}$  at the RISIKO mass separator of the Johannes Gutenberg-University Mainz, Germany.

HK 39.5 Thu 17:15 AM 00.011

**First Limits on Double Alpha Decay of Ra-224** — •MAKAR SIMONOV<sup>1</sup> and HEINRICH WILSENACH<sup>2</sup> for the Double Alpha at FRS Ion Catcher-Collaboration — <sup>1</sup>Justus-Liebig-Universität Gießen, Gießen, Germany — <sup>2</sup>The Hebrew University of Jerusalem, Jerusalem, Israel

The simultaneous emission of two alpha particles was proposed as an exotic way for heavy nuclei to decay about 45 years ago, and the initial conservative estimate for the branching ratio was less than  $10^{-20}$ . Recent microscopic calculations have yielded an experimentally accessible estimate of  $10^{-8}$  for radium isotopes with mass numbers  $A = 220, 222, 224$ , and an experiment to search for double alpha decay of Ra-224 was conducted at the FRS Ion Catcher, GSI, Germany.

Over four months of data taking, a 34 kBq radioactive source of Th-228 was used to produce Ra-224 ions. These ions, filtered from other Th-228 descendants by a radio-frequency quadrupole and electrostatically focused, were delivered to a thin carbon implantation foil. Two double-sided silicon strip detectors were used to record alpha and beta particles. The number of registered alpha decays of Ra-224 was approximately  $10^9$ , which should be sufficient to verify the theoretical estimate.

This report will provide final assessments of the time and energy resolution of the detector system. The main focus is the evaluation of the random-coincidence background to set a limit on the branching ratio of the double alpha decay of Ra-224.

HK 39.6 Thu 17:30 AM 00.011

**Evidence for M1 scissors mode states in  $^{242}\text{Pu}$  from nuclear resonance fluorescence** — •M. BEUSCHLEIN<sup>1</sup>, J. BIRKHAN<sup>1</sup>, J. KLEEMANN<sup>1</sup>, O. PAPST<sup>1</sup>, N. PIETRALLA<sup>1</sup>, R. SCHWENGER<sup>2</sup>, S. WEISS<sup>2</sup>, V. WERNER<sup>1</sup>, U. AHMED<sup>1</sup>, T. BECK<sup>1,3</sup>, I. BRANDHERM<sup>1</sup>, A. GUPTA<sup>1</sup>, J. HAUF<sup>1</sup>, K. E. IDE<sup>1</sup>, P. KOSEOGLOU<sup>1</sup>, H. MAYR<sup>1</sup>, C. M. NICKEL<sup>1</sup>, K. PRIFTI<sup>1</sup>, D. SAVRAN<sup>4</sup>, T. STETZ<sup>1</sup>, and R. ZIDAROVA<sup>1</sup> — <sup>1</sup>IKP, Darmstadt, Germany — <sup>2</sup>HZDR, Dresden, Germany — <sup>3</sup>FRIB, East Lansing, MI, USA — <sup>4</sup>GSI, Darmstadt, Germany

The availability of nuclear structure information on transuranium actinides supports stellar nucleosynthesis modeling and isotope-selective material inspection via photonuclear reactions. However, experimental data in this region remain

scarce. The first nuclear resonance fluorescence (NRF) experiment on  $^{242}\text{Pu}$  was conducted at the S-DALINAC at TU Darmstadt to probe its low-energy dipole response. A 1 g sample of  $^{242}\text{PuO}_2$  was irradiated with bremsstrahlung up to an endpoint energy of 3.7 MeV. By comparing NRF spectra with the sample activity and natural background, photo-excited  $J = 1$  states of  $^{242}\text{Pu}$  were identified. From the assignment of the intrinsic projection quantum number  $K$  based on measured decay branching ratios, evidence was found for five fragments of the  $M1$  scissors mode as well as for low-lying  $E1$  excitations. Experimental details,  $\gamma$ -ray spectra, and measured transition strengths of newly observed  $^{242}\text{Pu}$  states will be presented.

This work is supported by the DFG through the research grant GRK 2891 "Nuclear Photonics," Project-ID No. 499256822.

HK 39.7 Thu 17:45 AM 00.011

**Excitation-Energy Dependence of Fission Fragment Observables in the  $^{234}\text{U}(\gamma, f)$  Reaction** — •VINCENT WENDE<sup>1</sup>, DIMITR BALABANSKI<sup>4</sup>, MIHAI CUCIUC<sup>4</sup>, JOACHIM ENDERS<sup>1</sup>, SEAN W. FINCH<sup>2</sup>, ALF GÖÖK<sup>3</sup>, CALVIN R. HOWELL<sup>2</sup>, ANNABEL IBEL<sup>1</sup>, RONALD C. MALONE<sup>7</sup>, MAXIMILIAN MEIER<sup>1</sup>, FOR-

REST Q.L. FRIESEN<sup>2</sup>, ANDREAS OBERSTEDT<sup>4</sup>, STEPHAN OBERSTEDT<sup>5</sup>, MARIUS PECK<sup>1</sup>, NORBERT PIETRALLA<sup>1</sup>, ANTHONY P.D. RAMIREZ<sup>6</sup>, JACK A. SILANO<sup>6</sup>, ALEXANDRU STATE<sup>4</sup>, GERHART STEINHILBER<sup>1</sup>, ANTON P. TONCHEV<sup>6</sup>, and WERNER TORNOW<sup>2</sup> — <sup>1</sup>Institut für Kernphysik, Fachbereich Physik, TU Darmstadt, Darmstadt, Germany — <sup>2</sup>Triangle Universities Nuclear Laboratory, Duke University, Durham, NC, USA — <sup>3</sup>Uppsala Universitet, Uppsala, Sweden — <sup>4</sup>ELI-NP, IFIN-HH, Magurele, Romania — <sup>5</sup>EC-JRC Geel, Belgium — <sup>6</sup>Lawrence Livermore National Laboratory, Livermore, CA, USA — <sup>7</sup>U.S. Naval Academy, Annapolis, MD, USA

Advancing the microscopic understanding of the nuclear fission process relies on high-precision experimental data. This contribution shows results of an experimental campaign at HIγS, using linearly-polarized quasi-monochromatic photon beams between 6.2 and 13 MeV in the entrance channel. Mass, total kinetic energy, and angular distributions of fission fragments have been measured simultaneously using a position-sensitive twin Frisch-grid ionization chamber, exploring the dependence of fragment observables on the excitation energy.

\*This work is supported by the Deutsche Forschungsgemeinschaft (DFG) - Project-ID 499256822 - GRK 2891 'Nuclear Photonics'.

## HK 40: Heavy-Ion Collisions and QCD Phases VI

Time: Thursday 16:15–18:00

Location: PHIL C 601

HK 40.1 Thu 16:15 PHIL C 601

**Machine-learning-based modeling of particle production in pp collisions measured by ALICE** — •MARIA CALMON BEHLING, MARIO KRÜGER, JEROME JUNG, and HENNER BÜSCHING — Institut für Kernphysik, Goethe Universität Frankfurt

During the data-taking campaigns Run 1 and Run 2 at the LHC, the ALICE collaboration recorded a large amount of proton-proton (pp) collisions across a variety of center-of-mass energies ( $\sqrt{s}$ ). This dataset is well suited to study the energy dependence of particle production. Deep neural networks (DNNs) provide a data-driven approach to capture the multidimensional dependence of particle production on fundamental observables like the charged-particle multiplicity ( $N_{\text{ch}}$ ), the transverse momentum ( $p_T$ ) and  $\sqrt{s}$ .

In this talk, ALICE measurements of  $N_{\text{ch}}$  and  $p_T$ -dependent inclusive charged-particle spectra at various center-of-mass energies are parametrized with DNNs. Together with a DNN-based particle composition, this is used to provide particle-differential predictions for a wide range of energies. The DNN predictions are compared to existing measurements as well as to commonly used event generators. The results allow estimating the transverse energy of the final-state particles, which is directly related to the initial energy density of the collisions.

Supported by BMFTR and the Helmholtz Association.

HK 40.2 Thu 16:30 PHIL C 601

**Measurement of  $\eta$  mesons in pp collisions at  $\sqrt{s} = 13.6$  TeV with ALICE at a magnetic field of  $B = 0.2$  T** — •LAURA GANS-BARTL for the ALICE Germany-Collaboration — Institut für Kernphysik, Goethe Universität Frankfurt am Main

The ALICE experiment at CERN investigates the properties of the Quark Gluon Plasma (QGP). One key probe to study the QGP, dileptons, offers direct access to the medium's temperature. At low transverse momentum ( $p_T$ ), the dilepton spectrum is dominated by  $\eta$  meson Dalitz decays, making an accurate description of the low- $p_T$   $\eta$  yield essential for precise dilepton measurements.

The low- $p_T$  region is experimentally challenging for  $\eta$  reconstruction due to large combinatorial background and low reconstruction efficiency. In ALICE, the accessible  $p_T$  range can be extended by reducing the magnetic field strength from  $B = 0.5$  T to  $B = 0.2$  T, which significantly improves the reconstruction of very low- $p_T$  tracks.

This talk addresses the ALICE Run 3 analysis of  $\eta$  meson production in pp collisions at  $B = 0.2$  T, measured via the Dalitz decay channel. Photons are reconstructed using the Photon Conversion Method (PCM), while the electrons are reconstructed as primary tracks. The current status of the analysis will be presented.

Supported by BMFTR and the Helmholtz Association.

HK 40.3 Thu 16:45 PHIL C 601

**Measurement of  $\pi^0$  and  $\eta$  mesons in Pb-Pb collisions at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV using ML-based photon identification** — •ISABEL KANTAK for the ALICE Germany-Collaboration — Physikalisches Institut, Heidelberg, Germany

Neutral pions and  $\eta$  mesons serve as sensitive probes of the quark-gluon plasma (QGP) formed in heavy-ion collisions. In the low  $p_T$  region, light mesons provide insight into hadronisation processes and the evolution of the QGP. High  $p_T$  measurements, on the other hand, are essential for studying the mechanism of parton energy loss mechanism and the resulting suppression of light mesons in the QGP medium. Furthermore, precise measurements of  $\pi^0$  and  $\eta$  mesons are indispensable for direct-photon analyses, as they constitute the dominant

sources of decay photons.

Photons are reconstructed via the Photon Conversion Method (PCM). A machine learning-based photon identification method has been implemented. The BDT method enhances photon purity without compromising efficiency, thereby improving statistical significance of the reconstructed meson spectra. In this contribution, I will discuss the performance of ML-based photon identification and the current status of  $\pi^0$  and  $\eta$  mesons in Pb-Pb collisions at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV. I will present invariant yield measurements as a function of centrality and compare the results to those obtained with standard cut-based techniques.

HK 40.4 Thu 17:00 PHIL C 601

**ML-based direct photon and neutral meson measurement in Pb-Pb collisions at  $\sqrt{s_{\text{NN}}} = 5.02$  TeV in the ALICE experiment at LHC** — •ABHISHEK NATH for the ALICE Germany-Collaboration — Ruprecht Karl University of Heidelberg, Heidelberg, Germany

The ALICE experiment at LHC-CERN aims to analyze the properties of the quark-gluon plasma (QGP) formed during heavy-ion collisions. Neutral meson yields determine  $R_{\text{AA}}$  and constrain parton energy loss, whereas direct photons from thermal and hard-scattering sources probe the QGP temperature. However, large photon backgrounds from neutral meson decays hinder direct-photon extraction, causing significant loss of precision at low  $p_T$  in Run 2 heavy-ion Pb-Pb data. To overcome this limitation, we introduce a machine learning-based approach for photon candidate selection within the Photon Conversion Method (PCM). An XGBoost classifier trained on Monte Carlo simulations anchored to the Run 2 Pb-Pb  $\sqrt{s_{\text{NN}}} = 5.02$  TeV dataset replaces traditional cut-based selections to provide data samples with simultaneously optimized photon efficiency and purity.

In this talk, I will present the application of this ML-enhanced PCM analysis, showing updated transverse momentum spectra for  $\pi^0$ ,  $\eta$ , and direct photons. The resulting  $R_{\text{AA}}$ ,  $\eta/\pi^0$  ratio, and direct photon excess ratio ( $R_{\gamma}$ ) are then compared with the traditional cut-based measurements as well as with state-of-the-art theoretical model predictions.

HK 40.5 Thu 17:15 PHIL C 601

**Study of neutral meson production in Pb-Pb collisions at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV as a function of centrality** — •ANNA PISHCHAEVA for the ALICE Germany-Collaboration — Physikalisches Institut, Universität Heidelberg

Photons that are produced throughout the spacetime evolution of quark-gluon plasma (QGP) are an ideal probe to study its characteristics, since they do not interact with the medium. To access the information carried by the photons that come directly from QGP, one must subtract the background of photons from neutral mesons decays (mainly  $\pi^0$ ,  $\eta$ ). Furthermore, the energy loss of partons traversing the QGP medium in the high  $p_T$  region can be studied with a nuclear modification factor of  $\pi^0$  and  $\eta$ .

In this cut based analysis, photons are reconstructed using the photon conversion method (PCM). Neutral pions and  $\eta$  mesons are identified as peaks in the two-photon invariant mass at their corresponding rest mass. This talk presents results for Run 3 on the neutral pions and  $\eta$  meson production in Pb-Pb collisions at  $\sqrt{s_{\text{NN}}} = 5.36$  TeV. The obtained invariant differential yields of  $\pi^0$  and  $\eta$  in the current analysis are presented and compared to charged pions at  $\sqrt{s_{\text{NN}}} = 5.02$  TeV.



HK 40.6 Thu 17:30 PHIL C 601

**Hadron-photon correlations in pp collisions in ALICE** — •JULIUS KINNER for the ALICE Germany-Collaboration — Universität Münster

Ultrarelativistic proton and heavy-ion collisions are measured with ALICE at the LHC, allowing the study of quantum chromodynamics and the quark-gluon plasma. Two interesting observables are jets, collimated hadrons created by a hard scattering, and direct photons, created directly in the collision and not stemming from particle decays.

The production of direct photons and inclusive photons in jets, and their relations, can be studied via angular two-particle correlations using the  $\Delta\phi$  and  $\Delta\eta$  of trigger and associated particles. High- $p_T$  charged particles are used as triggers and proxies for jets, and electromagnetic probes as associated particles.

Correlation functions of associated  $\gamma$  and  $\pi^0$  are calculated with the photon conversion method and an invariant mass analysis of  $\pi^0 \rightarrow \gamma\gamma$ , using ALICE data from pp collisions at  $\sqrt{s} = 13.6$  TeV, which is a work in progress. This is done as the continuation of a phenomenological study with PYTHIA simulations, which was carried out in the context of a possible measurement of angular jet-direct-photon correlations with the subtraction method (subtracting the decay-photon contribution from inclusive photons) to study the electromagnetic structure of jets.

Supported by BMFTTR

HK 40.7 Thu 17:45 PHIL C 601

**Measurement of radius dependent jet suppression in Pb-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV with a novel mixed-event approach** — •NADINE ALICE GRÜN-WALD for the ALICE Germany-Collaboration — Physikalisches Institut, Universität Heidelberg

The Quark-Gluon Plasma (QGP) is produced in heavy-ion collisions where quarks and gluons are deconfined and new physics phenomena emerge. The ALICE experiment is dedicated to measure heavy-ion collisions at the LHC where the QGP can be studied using jets from partons, which are produced in the early stage of the collisions.

In this talk mixed events as a new approach to describe the uncorrelated background in jet measurements in heavy-ion collisions in ALICE are presented.

The resulting charged-particle jet  $R_{AA}$  measurements have high precision over a broad kinematic range, reaching significantly lower jet  $p_T$  values as compared to the traditional analyses. Various jet resolution parameters are studied to measure the radius dependence of the jet energy loss and thereby the redistribution of the lost energy to the surrounding QGP medium. Comparison of these measurements to theoretical calculations including the medium response will provide new insight into jet quenching phenomenology and its underlying mechanism.

## HK 41: Heavy-Ion Collisions and QCD Phases VII

Time: Thursday 16:15–18:00

Location: PHIL A 602

### Group Report

HK 41.1 Thu 16:15 PHIL A 602

**Dielectron production in pp and Pb-Pb collisions with ALICE in LHC Run 3** — •EMMA EGE for the ALICE Germany-Collaboration — Goethe Universität, Frankfurt, Germany

Dielectrons are ideal probes to study the properties of strongly-interacting matter, produced in relativistic heavy-ion collisions, as they are created in all stages of the collision and do not interact strongly with the medium. However, at LHC energies, the thermal dielectrons emitted in the early stages from the quark-gluon plasma (QGP) are overshadowed by correlated  $e^+e^-$ -pairs from semi-leptonic decays of heavy-flavor (HF) hadrons. Since the decay length of HF hadrons is much larger than that of prompt contributions, such as from the thermal radiation, dielectrons can be topologically separated based on their distance-of-closest approach (DCA) to the primary vertex of the collision. DCA measurements in pp collisions enable the search for prompt sources in small systems and can be used as a baseline for heavy-ion studies to identify the thermal radiation of the QGP. The improved pointing resolution of the upgraded ALICE detector for Run 3 leads to a better topological separation of prompt thermal radiation and non-prompt  $e^+e^-$ -pairs from HF hadron decays.

In this talk, an overview of the latest results regarding the dielectron production in pp collisions at  $\sqrt{s} = 13.6$  TeV and Pb-Pb collisions at  $\sqrt{s_{NN}} = 5.36$  TeV in Run 3, recorded with the ALICE detector, is given. A special focus is set on the topological separation with DCA, and the impact of the detector upgrades on the dielectron analysis.

HK 41.2 Thu 16:45 PHIL A 602

**Performance of soft dielectron measurement in pp collisions at  $\sqrt{s} = 13.6$  TeV with ALICE in Run 3** — •BELANA LUBINSKI for the ALICE Germany-Collaboration — Goethe University Frankfurt

Low-mass dielectrons are an exceptional tool to deepen our understanding of strongly interacting matter produced in hadronic and nuclear collisions. As they are produced during all stages of the collision and are unaffected by the strong interaction, they keep the information of their original production mechanism. This allows dielectrons to probe even the soft regime of QCD which is often unaccessible otherwise.

At the Intersecting Storage Rings (ISR) at CERN, an enhancement of  $e^+e^-$  pairs over the expectation from known dielectron sources had been measured at low invariant mass and small pair momenta in pp collisions at  $\sqrt{s} = 63$  GeV. A similar kinematic regime can be accessed with ALICE by reducing the magnetic field of the central barrel solenoid. First results from Run 2 indicate an excess also at LHC energies, albeit with a significance of  $1.6\sigma$ . With the upgrade of the ALICE detector for Run 3 much higher data-acquisition rates can be achieved increasing the event statistics by a factor of 400 compared to Run 2.

In this talk, a first look at pp collisions at  $\sqrt{s} = 13.6$  TeV recorded with a reduced ALICE magnetic solenoid field will be presented and their potential to address the excess observed in Run 2 will be discussed.

HK 41.3 Thu 17:00 PHIL A 602

**Dielectron performance of the CBM experiment** — •ADRIAN MEYER-AHRENS for the CBM-Collaboration — Institut für Kernphysik Münster, Münster, Deutschland

The Compressed Baryonic Matter (CBM) experiment is a fixed-target experiment currently under construction at FAIR in Darmstadt which will explore the QCD phase diagram at high net-baryon densities using heavy-ion beams in the kinetic energy range of 2-11 AGeV provided by the SIS100 accelerator complex. Dielectrons serve as versatile probes for properties of the hot and dense medium created in the collisions, since they do not interact strongly and escape the fireball undisturbed. Dielectron analysis depends on a reliable estimation of the combinatorial background, dominated by  $\pi^0$  decays, misidentified hadrons as well as electrons from photon conversions in the target or detector material. In this talk, simulation results concerning the dielectron performance of CBM in Au-Au collisions will be presented, with a discussion of background estimation techniques and the extraction of the thermal signal.

This project has received funding from NRW Netzwerke (NW21-024-E).

HK 41.4 Thu 17:15 PHIL A 602

**Preliminary study for dilepton flow analysis with CBM** — •SIMON NEUHAUS for the CBM-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

Dileptons enable the study of the early phases of the quark-gluon-plasma formed in heavy-ion collisions, as they escape the medium without QCD interactions. Their particle flow characterized by flow coefficients  $v_n$  ( $n = 1, 2, \dots$ ) allows us to probe azimuthal anisotropies of these early phases. While dilepton flow has already been investigated in experiments including HADES, no corresponding studies exist yet for the upcoming CBM experiment.

This talk will present the preliminary study of the reconstruction of the dilepton flow at the upcoming CBM experiment. CBM is a fixed-target heavy-ion experiment currently under construction at FAIR/GSI. Additionally, we evaluate the impact of electron identification purity on the physics case of flow reconstruction. This study is based on simulations of Au-Au collisions generated with SMASH at 8 AGeV collision energy.

\*Work supported by "Netzwerke 2021", an initiative of the Ministry of Culture and Science of the State of Northrhine Westphalia, and BMBF 05P24PX1.

HK 41.5 Thu 17:30 PHIL A 602

**Combined description of thermal and vacuum contributions to the dilepton spectrum** — •JESSICA VOGEL<sup>1</sup>, TETYANA GALATYUK<sup>1,2</sup>, FLORIAN SECK<sup>1</sup>, and JOACHIM STROTH<sup>2,3</sup> — <sup>1</sup>Technische Universität Darmstadt — <sup>2</sup>GSI, Darmstadt — <sup>3</sup>Goethe-Universität Frankfurt

Dileptons give access to the hot and dense matter created in heavy-ion collisions, as they escape the reaction zone largely unaffected by strong interactions. Measurements of such penetrating probes provide insight into the properties of the created fireball. High baryon densities are reached at beam energies of a few GeV which lead to significant in-medium modifications on the spectral functions of vector mesons.

Because the short-lived  $\rho$  meson mainly decays inside the fireball, it primarily produces thermal dileptons. However, the longer-lived  $\omega$  meson decays partly outside the fireball and thus contributes with a mix of thermal and vacuum rates to the dilepton spectrum.

This work introduces a framework that models the dilepton spectrum by describing the vacuum decays via the shining method and determines the ther-

mal contribution using a coarse-graining microscopic transport approach. This joined approach gives accurate predictions of the invariant mass spectrum in collisions within the few GeV regime. We examine how the relative contribution of thermal and vacuum rates varies with transverse momentum and how the collision centrality influences the results.

This work has been supported by the DFG through grant CRC-TR 211.

HK 41.6 Thu 17:45 PHIL A 602

**Dielectron reconstruction in the HADES Au+Au Beam Energy Scan** — •HENRIK FLÖRSHEIMER for the HADES-Collaboration — Technische Universität Darmstadt

Heavy-ion collisions at relativistic energies create a hot and dense medium whose microscopic properties can be studied using electromagnetic probes. Dileptons are especially valuable for this purpose, as they do not interact strongly with the surrounding matter, allowing them to carry undisturbed information about the QCD matter produced throughout the reaction.

The beam energy scan features Au+Au collisions at four energies, 200, 400, 600, and 800 AMeV, which allows for the investigation of energy-dependent properties of created QCD matter.

In this contribution, the key steps of the dielectron analysis will be outlined and the first results will be presented.

This work is supported by: BMFTR- 05P24RD6 and HGS-HIRE

## HK 42: Fundamental Symmetries II

Time: Thursday 16:15–17:30

Location: AM 00.021

### Group Report

HK 42.1 Thu 16:15 AM 00.021

**The Search for Electric Dipole Moments of Charged Particles in Storage Rings** — •ACHIM ANDRES — GSI, Darmstadt, Germany

Electric dipole moments (EDMs) are probes of physics beyond the Standard Model and are closely related to the search for new sources of CP violation required to explain the matter-antimatter asymmetry of the universe. Permanent EDMs violate time-reversal and parity symmetries and, assuming the CPT theorem, imply CP violation. In addition, axions and axion-like particles (ALPs), proposed to solve the strong CP problem and as candidates for dark matter, are predicted to induce oscillating EDMs.

The COoler SYnchrotron (COSY) at Forschungszentrum Jülich provided polarized deuteron beams and was an ideal starting point for the JEDI Collaboration to develop storage-ring-based EDM searches. Over recent years, several milestones were achieved at COSY, including high-precision spin-tune measurements, spin-coherence times exceeding 1000 s, and operation of radio-frequency (rf) devices for spin manipulation. These achievements enabled the first direct measurement of the deuteron's permanent EDM in a storage ring and the first search for oscillating EDMs, both observed through the build-up of vertical polarization. This presentation summarizes the experimental results obtained and discusses upcoming steps toward high-precision storage-ring EDM measurements.

### Group Report

HK 42.2 Thu 16:45 AM 00.021

**Status report of the free neutron lifetime experiment  $\tau$ SPECT** — •MARTIN FERTL for the tauSPECT-Collaboration — Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The accurate determination of the free neutron lifetime  $\tau_n$  is of particular interest in low-energy precision particle physics. The Standard Model relates the neutron lifetime  $\tau_n$  to the CKM matrix element  $V_{ud}$  and the ratio  $\lambda = g_V/g_A$  through precisely calculated radiative corrections. A neutron-based determination of  $V_{ud}$  provides a nuclear-structure free input to the test of the CKM matrix

unitarity. The  $\tau$ SPECT experiment pursues the approach of suspending ultracold neutrons in a three-dimensional fully-magnetic trap with the goal to determine  $\tau_n$  with an uncertainty of  $< 0.3$  s. Magnetic storage minimizes experimental systematic uncertainties related to neutron losses on material walls. We present the status of  $\tau$ SPECT currently operated at the Paul Scherrer Institute (PSI) in Switzerland. We address the optimization of UCN loading, systematic studies, and comparisons with simulations. Ideas for experimental developments for future improvements below will  $< 0.3$  s be presented.

HK 42.3 Thu 17:15 AM 00.021

**Status of the neutron decay experiment PERC** — •LILLI LÖBEL — School of Natural Sciences, Technische Universität München, Germany

The decay of free neutrons is a powerful tool for precision tests of the Standard Model of particle physics. Correlation coefficients - such as the beta asymmetry  $A$  and the Fierz interference term  $b$  - serve as input for the determination of the CKM matrix element  $V_{ud}$  and for searches for (effective) scalar and tensor as well as right-handed couplings.

The neutron decay spectrometer PERC (Proton Electron Radiation Channel), which is set up at the research reactor FRM II in Garching, Germany, aims to improve the accuracy of several correlation coefficients by up to one order of magnitude. PERC consists of a 12 m long superconducting magnet system, in which the neutron beam is contained by a non-depolarizing neutron guide. The magnetic field guides electrons and protons produced in the neutron decay towards the main detector, which will initially be a scintillation detector with photomultiplier tube readout and later be upgraded to a silicon detector. A second detector system, which consists of a scintillator read out by silicon photomultipliers, is installed in the upstream area of PERC and allows to identify backscatter events. First measurements are planned for the end of 2026 after the restart of the FRM II.

The talk gives an overview of PERC and presents the current status.

PERC was supported by the Priority Program SPP 1491 of the DFG and the cluster of excellence "Origin and Structure of the Universe".

## HK 43: Computing and Outreach

Time: Thursday 16:15–17:00

Location: PHIL B 604

HK 43.1 Thu 16:15 PHIL B 604

**Application of the Millepede II algorithm to the NeuLAND time-position calibration** — •YANZHAO WANG<sup>1</sup>, LUCA FLANDOLI<sup>1</sup>, IGOR GASPARIC<sup>2</sup>, and ANDREAS ZILGES<sup>1</sup> — <sup>1</sup>University of Cologne, Institute for Nuclear Physics, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung, Germany

The New Large-Area Neutron Detector NeuLAND, as part of the R<sup>3</sup>B experiment at FAIR, aims to provide a high detection efficiency and spatial-temporal resolution of neutrons generated from high-intensity radioactive beams[1]. In this talk, we introduce a new calibration method for the NeuLAND detector, based on an adaptation of the Millepede II algorithm. This new method simplifies analysis procedures and, unlike the current method, does not require the reconstruction of cosmic tracks. Major obstacles during the adaptation, such as the rank deficit, limitations on the linear calibration relation and distortion due to noises will also be addressed in the talk.

Supported by BMBF (project 05P24PK1).

[1] K. Boretzky *et al.*, Nucl. Instrum. Methods Phys. Res. A1014 (2021) 165701

HK 43.2 Thu 16:30 PHIL B 604

**From Stars to Life: Astrophysics as a Science Communication Vehicle for Nuclear Physics** — •JONA DREIER and CHRISTIAN KLEIN-BÖSING for the Netzwerk Teilchenwelt-Collaboration — Institut für Kernphysik, Universität Münster

Physics and nuclear/particle physics in particular face the challenge of presenting their complex research methods and abstract findings to a broad audience. It is not only a responsibility to report activities and results to the public, but also essential to build trust in sustained investment in science and to engage the next generation, opening pathways into physics.

While there is a multitude of highly informative formats, which are mostly accessible to already interested individuals, more easily approachable formats are relatively scarce. Astrophysics and astrobiology offer a promising opportunity to combine a topic that resonates with a broad audience with sophisticated physics research. We present and discuss a concept of workshops and interventions for different age groups that connect stellar evolution with conditions for the emergence of intelligent life. Convection experiments illustrate underlying physical principles, while numerical simulations are used to determine stellar lifetimes.

Supported by NRW-FAIR.

HK 43.3 Thu 16:45 PHIL B 604

**Discover the  $Z_c(3900)$  - a BESIII Masterclass** — •NILS HÜSKEN, ACHIM DENIG, THOMAS LENZ, SASKIA PLURA, and HEIKE VORMSTEIN — Johannes Gutenberg-Universität Mainz

An electron-positron collider like BEPCII provides clean collisions with a small number of particles in the final state. These can be measured and identified with a detector like BESIII applying just a few general principles that are common to

many modern particle physics experiments. At the same time, one of the high-profile results of more than 15 years of running BESIII - the discovery of the exotic hadron  $Z_c(3900)$  - really only requires to separate leptons from pions and use energy-momentum conservation to obtain a sizable signal. In combination,

our experiment is thus ideally suited for outreach activities. In this talk, we will discuss a new Masterclass using data from the BESIII experiment to (re-)discover the  $Z_c(3900)$ , highlighting a modern breakthrough in hadron spectroscopy from one of the leading experiments in the field.

## HK 44: Instrumentation VIII

Time: Thursday 16:15–18:00

Location: PHIL A 301

HK 44.1 Thu 16:15 PHIL A 301

**Integrated Control Systems for the Silicon Tracking System of the CBM experiment** — •DAVID GUTIERREZ MENENDEZ for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — Goethe-Universität Frankfurt, Frankfurt, Germany

The Silicon Tracking System (STS) is the central detector for charged-particle tracking in the Compressed Baryonic Matter (CBM) experiment at FAIR. Its performance relies not only on the precise operation of 1.8 million readout channels but also on robust Detector Control Systems (DCS) and Experiment Control Systems (ECS) to ensure safe, stable, and automated detector operation. The team previously carried out initial validation of control functionality in the mini-CBM setup. It exercised key components of the STS slow controls, readout supervision, and interlock logic under realistic beam conditions.

Building on these results, dedicated developments and extensive testing have been conducted in a large-scale lab setup to deploy a complete control infrastructure for the assembly and integration of the STS half-units, including monitoring, configuration, and finite-state-machine control for front-end electronics, power systems, and environmental sensors. This lab campaign also serves as a testbed for integrating DCS and ECS workflows ahead of installation at FAIR.

The current status of the STS control systems, together with recent progress and upcoming integration steps, will be presented.

HK 44.2 Thu 16:30 PHIL A 301

**Systematic studies of the CBM MVD cooling system with CFD simulations** — •CHRISTOPHER BRAUN for the CBM-MVD-Collaboration — Goethe-Universität The Micro Vertex Detector (MVD) is the first downstream detector of the Compressed Baryonic Matter Experiment (CBM) at the future Facility for Antiproton and Ion Research (FAIR). It consists of four planar stations, placed equidistantly at distances between 8 and 20 cm downstream of the target, and is equipped with dedicated CMOS Monolithic Active Pixel Sensors (MAPS). Its stations operate in a harsh radiation environment and within the moderate vacuum of the target chamber. Each detector plane will feature a material budget  $x/X_0$  ranging between 0.3 and 0.5 %. These strict material budget constraints and vacuum operation call for a two-stage cooling system, based on passive, conductive inside, and an active, convective cooling outside of the acceptance.

This contribution will present the cooling concept of the CBM MVD, with focus on CFD simulations of the full system, which are compared with experimental results obtained with a prototype setup operating in vacuum, and a performance comparison of different coolants (Water, Glycol-Water, and Novec-649) for the detector's coolant temperature range between  $-10^\circ\text{C}$  and  $+15^\circ\text{C}$ .

HK 44.3 Thu 16:45 PHIL A 301

**Precision Assembly for the P2 Inner Tracker** — •EMRE ELIBOLLAR for the P2-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität, Johann-Joachim-Becher-Weg 45, Mainz, Germany

The P2 experiment at the new electron accelerator MESA in Mainz aims to measure the weak mixing angle in elastic electron-proton scattering at low momentum transfer  $Q^2$  with unprecedented precision. Precise assembly of silicon tracker modules is essential for reliable track reconstruction and for controlling systematic uncertainties in the determination of the momentum transfer. The tracker system measures the scattering angle of outgoing low-energy electrons. To meet these requirements, an automated assembly workflow based on a four-axis robotic system (Gluebot) has been developed and validated.

The system was adapted to detector constraints with emphasis on alignment accuracy, repeatability, and operational stability. The detector design requires a sensor placement precision better than  $50\text{ }\mu\text{m}$ . Targeted hardware modifications and software improvements were implemented in the Gluebot, enabling stable automated gluing and pick-and-place operations with  $\mu\text{m}$ -level positioning performance.

The feasibility of automated tracker-module assembly was demonstrated using representative components. Beyond its original scope, the system is used for additional detector projects, demonstrating its robustness. The talk will present the system design, achieved performance, and its role in ongoing tracker-module production.

HK 44.4 Thu 17:00 PHIL A 301

**Investigations of gas flow through nozzles to optimise the deflection of filament target beams** — •EVA-MARIA HAUSCH, JOST FRONING, SIMON OBSZERNINKS, and ALFONS KHOUKAZ — Institut für Kernphysik, Universität Münster, 48149 Münster, Germany

To deflect a cryogenic hydrogen target beam, a recently developed method called cryobending is used, whereby gaseous helium is directed towards the filament target beam through deflection nozzles. Experiments have indicated that this allows the target beam to be deflected in a targeted manner to overcome a distance of more than 4 metres. Two types of deflection nozzles have been tested so far. In addition to experimental approaches such as interferometry, gas flow simulations are intended to determine the most effective type and size of nozzle, i.e. with which nozzle the least amount of helium gas can be used for the largest possible deflection to minimise the impact on the vacuum.

In this talk, the first approaches to determining the optimal operating parameters regarding cryobending will be discussed.

Funding was received from GSI F&E (MSKHOU2527), BMBF (05P21PMFP1) and NRW Netzwerke (NW21-024-E).

HK 44.5 Thu 17:15 PHIL A 301

**Design of the liquid hydrogen target for the P2 parity violating experiment at MESA** — SEBASTIAN BAUNACK<sup>1</sup>, MAARTEN BONNEKAMP<sup>2,4</sup>, BORIS GLÄSER<sup>1</sup>, SHRUTI GUPTA<sup>1</sup>, RAHIMA KRINI<sup>1</sup>, FRANK MAAS<sup>1,2,3</sup>, •JAYANTA NAIK<sup>1</sup>, MORAN NEHER<sup>1</sup>, TOBIAS RIMKE<sup>1</sup>, PAUL SCHÖNER<sup>2</sup>, SIDDHARTH THAKKER<sup>1</sup>, and MALTE WILFERT<sup>1</sup> for the P2-Collaboration — <sup>1</sup>Institut für Kernphysik, Johannes Gutenberg-Universität Mainz — <sup>2</sup>Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz — <sup>3</sup>PRISMA Cluster of Excellence, Johannes Gutenberg-Universität Mainz — <sup>4</sup>IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

The P2 experiment aims to precisely measure the weak mixing angle  $\sin^2\theta_W$  through parity-violating electron-proton scattering at low momentum transfer. This is projected to achieve a relative precision of 0.16% for  $\sin^2\theta_W$ . To achieve this precision, there is a need for a target design that will have small false asymmetry due to aluminum windows and the conical diverter. The liquid hydrogen target is 60 cm long, along with a potential helium cell positioned upstream of the primary hydrogen cell.

In this talk, the design of the target cell is explained, which includes the simulation results for the aluminum upstream and downstream windows, helium cell, and the conical flow diverter.

HK 44.6 Thu 17:30 PHIL A 301

**Long-distance filament target beams** — •JOST FRONING, EVA-MARIA HAUSCH, SIMON OBSZERNINKS, and ALFONS KHOUKAZ — Institut für Kernphysik, Universität Münster, 48149 Münster, Germany

When using cryogenic filament target beams in accelerator experiments in nuclear and particle physics, it may be necessary to overcome greater distances between the beam production nozzle and the interaction point. To demonstrate the suitability of such a filament target beam, a new setup with a distance of more than 4 m between the nozzle and the beam dump was recently commissioned in Münster. This talk shows how a continuous frozen hydrogen filament target beam with a diameter of  $10\text{ }\mu\text{m}$  can be deflected and guided to the interaction point using a newly developed technique called cryobending, which uses helium gas to steer the target beam.

Funding was received from GSI F&E (MSKHOU2527), BMBF (05P21PMFP1) and NRW Netzwerke (NW21-024-E).

HK 44.7 Thu 17:45 PHIL A 301

**Electromagnetic Characterization and Performance Analysis of Button Beam Position Monitors - cSTART** — •ANJANA MADHUSOODHANAN NAIR PK<sup>1,2</sup>, ARNULF QUADT<sup>1</sup>, CHRISTOPH QUITMANN<sup>2</sup>, DIMA EL KHECHEN<sup>3</sup>, JAKOB KRÄMER<sup>2</sup>, and NIGEL JOHN SMALE<sup>3</sup> — <sup>1</sup>II. Physikalisches Institut Georg-August-Universität Göttingen — <sup>2</sup>RI Research Instruments GmbH, Bergisch Gladbach — <sup>3</sup>Karlsruhe Institute of Technology

Button-type Beam Position Monitors (BPMs) are a key element of the beam diagnostics system for the cSTART (compact STorage ring for Accelerator Research and Technology) project, where precise beam position measurements are essential for stable operation. This study presents the electromagnetic characterization and performance evaluation of the cSTART button BPM design through

a combination of numerical simulations and experimental validation, including *CST Particle Studio* simulations of signal formation, button capacitance, frequency response, and wakefield effects, as well as Time Domain Reflectometry measurements and beam-based tests at the FLUTE facility with controlled beam

offsets. The results demonstrate the accuracy, limitations, and suitability of the BPM system for cSTART operation and contribute to the optimization of beam diagnostics in compact storage ring accelerators.

## HK 45: Instrumentation IX

Time: Thursday 16:15–17:45

Location: PHIL B 302

HK 45.1 Thu 16:15 PHIL B 302

**Development and Characterization of the CBM Neutron Calorimeter (NCAL)** — •DACHI OKROPIRIDGE<sup>1,2</sup>, DIETER GRZONKA<sup>2,3</sup>, and JAMES RITMAN<sup>2,1,3</sup> for the CBM-Collaboration — <sup>1</sup>Ruhr-Universität Bochum (RUB), Bochum, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>3</sup>Forschungszentrum Jülich (FZJ), IKP-1, Jülich, Germany

The Neutron Calorimeter (NCAL) is proposed as a neutral spectator detector for the Compressed Baryonic Matter (CBM) experiment at FAIR. Located downstream of the Forward Spectator Detector (FSD), the NCAL detects spectator neutrons at small polar angles, thereby improving centrality determination and reaction-plane reconstruction. Furthermore, it enables a complementary physics program for elementary reactions with final-state neutrons.

The detector design features thick plastic scintillator modules with photomultiplier readout. Two prototypes have been constructed and characterized using minimum-ionizing particles and radioactive sources. A scintillator-based veto detector was developed for charged-particle rejection. We report on response measurements performed with quasi-monoenergetic neutron beams at the UJV Rez cyclotron, evaluating neutron detection efficiency and energy resolution.

Additionally, NCAL prototypes were tested in the mCBM experiment at GSI. Integrated into a DiRICH-based data acquisition system, the detector's rate capability and stability were investigated under realistic beam conditions.

HK 45.2 Thu 16:30 PHIL B 302

**Thermal Neutron Detection with Lithium-Silica Glass in Proton Therapy** — •KIM TABEA GIEBHAIN<sup>1</sup>, ANNA BECKER<sup>2,3</sup>, LARA DIPPEL<sup>1,3</sup>, MARKEL FIX-MARTINEZ<sup>2,3</sup>, HANS-GEORG ZAUNICK<sup>1,3</sup>, DZMITRY KAZLOU<sup>1</sup>, KILIAN-SIMON BAUMANN<sup>2,3</sup>, ULRICH WEBER<sup>2,3</sup>, KLEMENS ZINK<sup>2,3</sup>, and KAI-THOMAS BRINKMANN<sup>1,3</sup> — <sup>1</sup>2<sup>nd</sup> Physics Institute, Justus Liebig University, Giessen, Germany — <sup>2</sup>TH Mittelhessen University of Applied Sciences, Giessen, Germany — <sup>3</sup>LOEWE Research Cluster for Advanced Medical Physics in Imaging and Therapy (ADMIT)

Neutron detection is an important topic in IonBeam Therapy, specifically when irradiating patients with ultra high dose rates (also known as FLASH). At cyclotron-based facilities, these dose rates can only be reached at the highest energies without a degrader, which necessitates range modulators and thick absorbers to ensure conformal tumor coverage in clinical ranges. These absorbers can increase the amount of produced neutrons significantly. To reliably assess the neutron amount, efficient neutron detectors are needed to benchmark Monte-Carlo simulations which are used for dosimetric assessment. This work presents the findings of a scintillation-based thermal neutron detector, consisting of Lithium-silica glass and a photomultiplier tube. The detector has been tested at an Americium-Beryllium neutron source and for different absorbers at the Marburg IonBeam Therapy center.

This project is financed with funds of LOEWE-Landes-Offensive zur Entwicklung Wissenschaftlich-ökonomischer Exzellenz, Förderlinie 2: LOEWE-Schwerpunkte

HK 45.3 Thu 16:45 PHIL B 302

**Normalization detectors for the neutron lifetime experiment tauSPECT** — •VIKTORIA ERMUTH<sup>1</sup>, MARTIN FERTL<sup>1</sup>, and DIETER RIES<sup>2</sup> for the tauSPECT-Collaboration — <sup>1</sup>Institute of Physics, Johannes Gutenberg-Universität Mainz, Mainz, Germany — <sup>2</sup>Paul Scherrer Institute, Villigen PSI, Switzerland

The  $\tau$ SPECT experiment measures the free neutron lifetime by confining ultracold neutrons (UCN) with magnetic field gradients and counting the remaining neutrons after varying storage times. There are statistical and systematic changes over time in the yield and energy of the neutrons produced by the pulsed UCN source that can lead to systematic uncertainties. Therefore, the amount of UCNs filled into the trap during each filling cycle has to be monitored. A neutron detector has been built and installed in the experiment beamline to monitor the flux of UCNs during the filling process. The charged particles resulting from the neutron capture reaction  $^{10}\text{B}(n,\alpha)^7\text{Li}$  cause scintillation in a  $^{10}\text{B}$ -coated ZnS:Ag layer. This light is detected by silicon photomultipliers coupled in coincidence to the scintillator. A second version suited for a larger beamline diameter and with some design improvements is currently under development. Since the two detectors will be at different heights on the UCN path, this will also give an insight into the UCN energy spectrum.

This talk will show the detector's design, results of measurements, as well as the progress for the improved version.

HK 45.4 Thu 17:00 PHIL B 302

**Development of a BaF - Plastic Phoswich Detector for Particle Identification in Mixed Fields** — •LARA DIPPEL<sup>1,2</sup>, ANNA BECKER<sup>2,3</sup>, KILIAN-SIMON BAUMANN<sup>2,3</sup>, KAI-THOMAS BRINKMANN<sup>1,2</sup>, KIM TABEA GIEBHAIN<sup>1</sup>, DZMITRY KAZLOU<sup>1</sup>, MARKEL FIX MARTINEZ<sup>2,3</sup>, ULI WEBER<sup>2,3</sup>, HANS-GEORG ZAUNICK<sup>1,2</sup>, and KLEMENS ZINK<sup>2,3</sup> — <sup>1</sup>2nd Physics Institute, Justus Liebig University Giessen, Germany — <sup>2</sup>LOEWE Research Cluster for Advanced Medical Physics in Imaging and Therapy (ADMIT) — <sup>3</sup>TH Mittelhessen University of Applied Sciences, Giessen, Germany

This work presents the development of a Phoswich detector for fast neutron detection and particle discrimination in mixed radiation fields. The detector consists of a Barium Fluoride (BaF) crystal optically coupled to a thin plastic scintillator. Measurements were performed at the Marburg Ion Beam Therapy Center, where a water phantom was irradiated with 300 MeV/u carbon ions. Particle discrimination and identification were achieved using pulse shape discrimination (PSD) techniques, allowing the relative abundances of particles produced in the irradiation to be extracted. The measurement setup was replicated in a Geant4 simulation to validate the particle identification and to compare the relative particle yields. This work is part of the ADMIT consortium under Project Part A, which focuses on estimating spectral neutron fluxes for flash therapy in tumor treatment applications.

This project is financed with funds of LOEWE - Landes-Offensive zur Entwicklung Wissenschaftlich-ökonomischer Exzellenz, Förderlinie 2: LOEWE-Schwerpunkte.

HK 45.5 Thu 17:15 PHIL B 302

**Portable standalone n/y detector based on RedPitaya board** — •DZMITRY KAZLOU, ROMAN BERGERT, HANS-GEORG ZAUNICK, and KAI-THOMAS BRINKMANN — <sup>2nd</sup> Institute of Experimental Physics, Justus-Liebig-University, Giessen, Germany

A portable neutron/ $\gamma$  detector was developed leveraging the open-source RedPitaya platform (Xilinx Zynq-7010/7020 SoC) as a compact data acquisition system based on a 125 MS/s 14-bit ADC, combining low-cost and easily accessible components. A custom open source SiPM bias board was used to eliminate the need for an external high-voltage supply. Dedicated fast broad-band preamplifiers have been developed for the Hamamatsu S14160-6050 and S14160-3010 silicon photomultipliers, providing a dual-channel readout with an extended dynamic range. The commercially available EJ-276D plastic scintillator was chosen as the detector material due to its well-performing pulse shape discrimination (PSD) capability, enabling efficient separation of fast neutrons from  $\gamma$ -rays.

The detector was calibrated with standard  $\gamma$ -sources ( $^{137}\text{Cs}$ ,  $^{22}\text{Na}$ ,  $^{207}\text{Bi}$ ) and characterized in mixed neutron/ $\gamma$  fields from known AmBe,  $^{252}\text{Cf}$ , and RaBe sources, after which it was tested in a high-energy neutron field with  $\gamma$  background. The proton beam measurements were performed to obtain the proton light-yield quenching factor, which is necessary for the subsequent unfolding of the neutron spectrum. The resulting portable device is highly suited for radiation monitoring, dosimetry, and applications requiring simultaneous identification of neutrons and  $\gamma$ -quanta.

HK 45.6 Thu 17:30 PHIL B 302

**A spatially resolving detector for ultracold neutrons** — •KONRAD FRANZ<sup>1</sup>, MARTIN FERTL<sup>1</sup>, and DIETER RIES<sup>2</sup> for the tauSPECT-Collaboration — <sup>1</sup>Institute of Physics, Johannes Gutenberg University Mainz, Mainz, Germany — <sup>2</sup>Paul Scherrer Institute, Villigen PSI, Switzerland

Ultracold neutrons (UCNs) are neutrons with a kinetic energy of around 100 neV. Their defining property is that they can be confined by material vessels and magnetic field gradients. This allows for long observation times and thereby precision measurements of fundamental neutron properties. Spatial resolution is often desirable in UCN experiments, as it provides information about the energy and phase space distribution of the probed ensemble. The presented detector design consists of a sandwich structure. In a  $^{10}\text{B}$  conversion layer neutrons generate energetic ions through the  $^{10}\text{B}(n,\alpha)$  reaction. In the subsequent scintillation layer light is released which is then guided onto an array of silicon photomultipliers by a 3D printed light guide. This setup is well suited for in-situ detection of UCNs in strong magnetic fields and compatible with vacuum environments. In a first test beam time, a detector prototype was compared to a commercial UCN detector and its spatial resolution was evaluated. This talk will

present the detector setup as well as the test beam time results. Furthermore, its use case for tackling systematic effects in the latest generation of precision

neutron lifetime experiments will be highlighted at the example of the  $\tau$ SPECT experiment.

## HK 46: Members' Assembly

### Agenda

- Approval of the minutes and the agenda
- Report from HK division chair
- Report from KHuK
- Aob

Time: Thursday 18:00–19:30

Location: AM 00.017

All members of the Hadronic and Nuclear Physics Division are invited to participate.

## HK 47: Invited Talks

Time: Friday 9:00–10:30

Location: MED 00.915

**Invited Talk** HK 47.1 Fri 9:00 MED 00.915  
**Supernova signatures on Earth and beyond** — •JENNY FEIGE — Museum für Naturkunde, Berlin, Germany

The detection of cosmic signatures in deep-sea, ice, and lunar samples has made an important contribution to nuclear astrophysics in recent years. In particular,  $^{60}\text{Fe}$  from near-Earth supernovae has been imprinted during the time periods 2-3 and 7-8 Myr ago, together with  $^{244}\text{Pu}$ , which is produced exclusively by the rapid neutron capture process. These data, which establish a link between supernovae and the r-process, add another piece to the puzzle of the possible r-process sites.

This data also corroborates theoretical studies that suggest that more than 10 SNe exploded at a distance of 50-150 pc over the last 10-15 Myr. Their overriding shock fronts created a volume of hot gas that is seen in observational data and referred to as the Local Bubble, which currently engulfs our Solar System.

Here, I review the advancements made during the recent years in (1) the detection of different interstellar radioisotopes in deep-ocean and terrestrial records, and (2) what these detections reveal on the nature of the interstellar matter our Solar System encountered in the past.

**Invited Talk** HK 47.2 Fri 9:30 MED 00.915  
**ALICE 3 - The next-generation heavy-ion experiment at the LHC** — •LARS DÖPPER for the ALICE Germany-Collaboration — Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn — Forschungs- und Technologiezentrum Detektorphysik, Universität Bonn

ALICE 3 is a completely new heavy-ion setup at the LHC, proposed as the successor and next generation of the current ALICE detector. To utilize the LHC to its full potential as a heavy-ion collider during Run 5, a completely new detector is required and envisioned to start operation after the Long Shutdown 4 in 2036.

Building on the physics achievements of Runs 3 and 4, ALICE 3 is designed to address key open questions in heavy-ion physics, with a particular focus on the heavy-flavour sector at low transverse momentum. These measurements will provide unique sensitivity to the time evolution of the quark-gluon plasma and its approach to thermal equilibrium. To facilitate these precision measurements,

ALICE 3 will consist of a full silicon-pixel tracking system, covering the pseudo-rapidity range of at least  $|\eta| < 2.5$ . This tracking system at the heart of ALICE 3 is further complemented by systems for particle identification. All of this will be encased within a new superconducting solenoid magnet with a field strength of 2 T.

In this talk I will give an overview about the motivation behind this new detector, the different detector subsystems and some of the challenges we have yet to overcome on our journey towards ALICE 3.

This work is supported by BMFTR.

**Invited Talk** HK 47.3 Fri 10:00 MED 00.915  
**Towards Physics Operation of the CBM Experiment at FAIR** — •ADRIAN RODRÍGUEZ RODRÍGUEZ for the CBM-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH

The Compressed Baryonic Matter (CBM) experiment at FAIR is designed to explore strongly interacting matter at high net-baryon densities, created in nucleus–nucleus collisions at  $\sqrt{s_{NN}} = 2.5\text{--}4.9$  GeV. Addressing this physics program requires a novel experimental approach capable of sustaining interaction rates of up to 10 MHz. CBM therefore implements a triggerless, free-streaming readout scheme, combined with a fully integrated detector, data transport, and online computing architecture. The experiment is now transitioning from prototyping to large-scale realization. A central detector subsystem is the Silicon Tracking System (STS), which provides charged-particle momentum reconstruction with a resolution better than 2%. Embedded in a 1 Tm magnetic field, the STS is a low-mass, large-acceptance, radiation-hard silicon tracker composed of 876 double-sided microstrip modules arranged in eight stations. Module production and qualification are well advanced, and integration activities have progressed to the assembly of the first functional detector sub-units. In parallel, the FAIR Phase-0 program enables performance measurements of CBM detector components and validates their operation under realistic heavy-ion conditions. This contribution reviews the CBM physics goals and experimental concept, with emphasis on the STS, summarizing the status of detector construction and recent results from integration and commissioning towards the upcoming physics phase.

## HK 48: Invited Talks

Time: Friday 11:00–12:30

Location: MED 00.915

**Invited Talk** HK 48.1 Fri 11:00 MED 00.915  
**Probing confinement and string-breaking with quantum simulations** — •TORSTEN ZACHE — Universität Innsbruck, Institut für Theoretische Physik — Institut für Quantenoptik und Quanteninformation (IQOQI Innsbruck) der Österreichischen Akademie der Wissenschaften

The simulation of QCD at finite baryon density or in non-equilibrium scenarios remains an outstanding challenge for traditional computing methods. Quantum simulation offers a promising alternative. In this talk, I briefly review the current status of quantum simulations of lattice gauge theories and present recent progress toward simulating QCD-like physics, including the observation of confinement and string-breaking in lower dimensional gauge theories on existing quantum devices.

**Invited Talk** HK 48.2 Fri 11:30 MED 00.915  
**Exploring stochastic aspects of nuclear gamma decays with photonuclear reactions** — •JOHANN ISAAK — TU Darmstadt, Institut für Kernphysik, Darmstadt, Germany

Understanding electromagnetic decays of atomic nuclei is essential both for advancing our knowledge of fundamental nuclear structure phenomena and for numerous applications, such as modeling nucleosynthesis processes. Photonuclear reactions provide a powerful tool to probe the photoresponse of nuclei and to explore the competition between statistical and non-statistical gamma decays. In this talk, I will present recent results obtained with quasimonochromatic photon beams, exploring the gamma decay behavior of both spherical and deformed nuclei across a wide range of excitation energies, from the dominant giant dipole resonance down to energies below the neutron separation threshold. I will high-

light the interplay between statistical and non-statistical decays and discuss their consequences on our understanding of nuclear structure and broader implications. The talk will conclude with a perspective on open questions and future directions in this field.

Invited Talk

HK 48.3   Fri 12:00   MED 00.915

Precision QCD with ePIC at the Electron-Ion Collider — •TYLER KUTZ — Johannes Gutenberg-Universität Mainz

The majority of visible matter in the Universe is hadronic, composed of quarks and gluons whose interactions are modeled by quantum chromodynamics (QCD). Describing the properties of protons, neutrons, and nuclei in terms of

their fundamental QCD constituents remains a major experimental and theoretical effort. The electron-ion collider (EIC), being developed at Brookhaven National Lab, is a next-generation facility designed for high-precision studies of QCD. By facilitating collisions of polarized electrons with polarized protons and nuclei, the EIC will enable multi-dimensional probes of nucleon and nuclear structure. These measurements are essential to understanding the origin of nucleon mass and spin, the nucleon's 3D structure, QCD in the nuclear medium, and other emergent QCD phenomena. This talk will give an overview of ePIC, the first EIC detector collaboration, including the collaboration organization, detector capabilities, physics program, and future outlook.

# Theoretical and Mathematical Physics Division

## Fachverband Theoretische und Mathematische Grundlagen der Physik (MP)

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### Overview of Invited Talks and Sessions

(Lecture halls KH 02.013 and KH 00.015)

#### Invited Talks

|        |     |             |           |                                                                                                                                          |
|--------|-----|-------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------|
| MP 1.1 | Mon | 14:45–15:15 | KH 02.013 | <b>The Wehrl entropy problem: mathematical physics meets complex analysis and representation theory</b> — •RUPERT FRANK                  |
| MP 1.2 | Mon | 15:15–15:45 | KH 02.013 | <b>News on relative entropy</b> — RICARDO CORREA DA SILVA, •MARKUS B. FRÖB, GANDALF LECHNER, LEONARDO SANGALETTI                         |
| MP 2.1 | Tue | 11:00–11:30 | KH 02.013 | <b>Frustration free Hamiltonians for Finitely Correlated States – ground space structure and spectral gap</b> — •NORBERT SCHUCH          |
| MP 3.1 | Tue | 16:15–16:45 | KH 02.013 | <b>Osterwalder-Schrader axioms for a class of unitary 2D Conformal Field Theories</b> — •MARIA STELLA ADAMO, YUTO MORIWAKI, YOH TANIMOTO |
| MP 3.2 | Tue | 16:45–17:15 | KH 02.013 | <b>Schwarzian Field Theory for Probabilists</b> — •PETER WILDEMAN                                                                        |
| MP 3.3 | Tue | 17:15–17:45 | KH 02.013 | <b>Local topological order and boundary algebras</b> — COREY JONES, •PIETER NAAIKENS, DAVID PENNEYS, DANIEL WALLICK                      |
| MP 4.1 | Wed | 11:00–11:30 | KH 02.013 | <b>Exact Schwinger functions for a class of bounded interactions in <math>d \geq 2</math></b> — •WOJCIECH DYBALSKI                       |
| MP 4.2 | Wed | 11:30–12:00 | KH 02.013 | <b>L4 bound for the energy density in thermal field theory</b> — •DANIELA CADAMURO                                                       |
| MP 5.1 | Wed | 13:45–14:15 | KH 02.013 | <b>Nontrivial Riemann Zeros as Spectrum</b> — •ENDERALP YAKABOYLU                                                                        |
| MP 9.1 | Thu | 11:00–11:30 | KH 02.013 | <b>Light Cone Structure of Quantum Spacetime Geometry</b> — •WOLFGANG WIELAND                                                            |

#### Sessions

|              |     |             |              |                                                                               |
|--------------|-----|-------------|--------------|-------------------------------------------------------------------------------|
| MP 1.1–1.2   | Mon | 14:45–15:45 | KH 02.013    | <b>Quantum Information: Entropy</b>                                           |
| MP 2.1–2.4   | Tue | 11:00–12:15 | KH 02.013    | <b>Correlated States</b>                                                      |
| MP 3.1–3.5   | Tue | 16:15–18:15 | KH 02.013    | <b>Quantum Field Theory I: Axiomatic, Probabilistic, Algebraic, Conformal</b> |
| MP 4.1–4.3   | Wed | 11:00–12:15 | KH 02.013    | <b>Quantum Field Theory II</b>                                                |
| MP 5.1–5.6   | Wed | 13:45–15:30 | KH 02.013    | <b>Quantum Mechanics: Spectral Theory and Many-Body Systems</b>               |
| MP 6.1–6.4   | Wed | 16:15–17:15 | KH 02.013    | <b>Holography: AdS/CFT</b>                                                    |
| MP 7         | Wed | 17:30–18:00 | KH 02.013    | <b>Members' Assembly</b>                                                      |
| MP 8.1–8.8   | Wed | 18:00–18:45 | Redoutensaal | <b>Poster Session</b>                                                         |
| MP 9.1–9.5   | Thu | 11:00–12:30 | KH 02.013    | <b>Geometry, Black Holes, Universality</b>                                    |
| MP 10.1–10.7 | Thu | 13:45–15:30 | KH 02.013    | <b>Strong Fields</b>                                                          |
| MP 11.1–11.7 | Thu | 16:15–18:00 | KH 00.015    | <b>Various Topics in Relativity</b>                                           |

#### Members' Assembly of the Theoretical and Mathematical Physics Division

Wednesday 17:30–18:00 KH 02.013

- Bericht und Planung
- Aussprache
- Verschiedenes



## Sessions

– Invited Talks, Contributed Talks, and Posters –

### MP 1: Quantum Information: Entropy

Time: Monday 14:45–15:45

Location: KH 02.013

#### Invited Talk

MP 1.1 Mon 14:45 KH 02.013

**The Wehrl entropy problem: mathematical physics meets complex analysis and representation theory** — •RUPERT FRANK — LMU Munich

The coherent state transform, under various names, appears in many fields of mathematics and physics. It is associated with representations of a group. In this talk we give a gentle introduction to the (generalized) Wehrl entropy problem, which consists in minimizing the entropy of the coherent state transform of a quantum state.

#### Invited Talk

MP 1.2 Mon 15:15 KH 02.013

**News on relative entropy** — RICARDO CORREA DA SILVA<sup>1</sup>, •MARKUS B. FRÖB<sup>1</sup>, GANDALF LECHNER<sup>1</sup>, and LEONARDO SANGALETTI<sup>2</sup> — <sup>1</sup>Department Mathe-

matik, FAU Erlangen-Nürnberg, Germany — <sup>2</sup>Dipartimento di Fisica, Università di Genova, Italy

I present recent work on a new integral representation for the relative entropy (or Kullback-Leibler divergence) for general von Neumann algebras, generalizing results for matrix algebras. This representation allows easy proofs of its properties such as joint convexity and an extended version of the data processing inequality, namely monotonicity under positive unit-preserving maps. Moreover, it can be used to define Csiszár's  $f$ -divergences for von Neumann algebras, which depend on an arbitrary convex function  $f$ , and which give the relative entropy in the special case  $f(x) = x \ln x$ .

### MP 2: Correlated States

Time: Tuesday 11:00–12:15

Location: KH 02.013

#### Invited Talk

MP 2.1 Tue 11:00 KH 02.013

**Frustration free Hamiltonians for Finitely Correlated States – ground space structure and spectral gap** — •NORBERT SCHUCH — Universität Wien, Wien, Austria

Finitely Correlated States (FCS), or Matrix Product States, form an efficiently representable class of states on infinite spin chains, with the AKLT model as a prominent example. I will present some new findings on FCS and their *parent Hamiltonians* – frustration free Hamiltonians constructed to have the FCS as an exact ground state. First, I will discuss how such Hamiltonians can have a remarkably rich ground space structure, ranging from unique ground states and critical systems all the way to systems with undecidable ground space structure. Second, I will explain how to use hierarchies of semidefinite relaxations to systematically obtain rigorous and precise lower bounds on the spectral gaps of such models, which provably improve on all known methods to bound such gaps.

MP 2.2 Tue 11:30 KH 02.013

**Fractional quantum Hall states as infinite matrix product states** — •SEVERIN SCHRAVEN<sup>1</sup> and SIMONE WARZEL<sup>1,2,3</sup> — <sup>1</sup>Department of Mathematics, TU Munich, Germany — <sup>2</sup>Munich Center for Quantum Science and Technology, Munich, Germany — <sup>3</sup>Department of Physics, TU Munich, Germany

In this work we present a novel matrix product representation of the Laughlin wave function on the plane. This representation enables the quantitative control of the coefficients of the Laughlin wave function when expanded in a Slater/permanent basis. It renders the properties such as factorization inherent in the Laughlin state transparent. We use the representation to show the exponential decay of connected correlations and a gap in the entanglement spectrum for the Laughlin state on a thin cylinder. All of the above also applies to the Laughlin state times a monomial symmetric polynomial.

MP 2.3 Tue 11:45 KH 02.013

**Hyperinvariant Spin Network States – An AdS/CFT Model from First Principles** — FYNN OTTO<sup>1</sup>, •REFIK MANSUROGLU<sup>2</sup>, NORBERT SCHUCH<sup>2,3</sup>, OTFRIED GÜHNE<sup>1</sup>, and HANNO SAHLMANN<sup>4</sup> — <sup>1</sup>Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany — <sup>2</sup>University of Vienna, Faculty of Physics, Boltzmanngasse 5, 1090 Vienna, Austria — <sup>3</sup>University of Vienna, Faculty of Mathematics, Oskar-Morgenstern-

Platz 1, 1090 Vienna, Austria — <sup>4</sup>Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 7, 91058 Erlangen, Germany

As discrete implementations of the anti de-Sitter/conformal field theory (AdS/CFT) correspondence, hyperinvariant tensor networks have created bridges between the fields of quantum information theory and quantum gravity. Adding SU(2) symmetry to the tensor network allows a direct connection to spin network states, a basis of the kinematic Hilbert space of loop quantum gravity (LQG). We discuss existence and limitations for hyperinvariant tensor networks incorporating a local SU(2) symmetry and provide examples of hyperinvariant tensor networks, but also prove constraints on their existence in the form of no-go theorems that exclude absolutely maximally entangled states as well as general holographic codes from local SU(2)-invariance. We finally discuss applications of this new connection and existing examples in the form of calculations of surface areas and geodesic lengths as expectation values of the LQG area and length operators.

MP 2.4 Tue 12:00 KH 02.013

**Holography from Tensor Networks: An RT-like Formula from Homological codes** — •JORGE ORTIZ — Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany — Universität Hamburg, Mittelweg 177, 20148 Hamburg, Germany

We present a microscopic approach to holographic duality based on tensor networks built from simple quantum error-correcting codes, specifically toric codes. We construct a layered network by gluing toric codes step by step to encode bulk degrees of freedom into boundary ones, in close analogy to holographic tensor-network models such as the HaPPY code. In this setup, bulk effective field theory operators are embedded into quantum-gravity degrees of freedom while remaining agnostic about the emergent spacetime curvature.

In the first non-trivial example, we compute entanglement entropies and obtain an RT-like formula. This realises entanglement-wedge reconstruction in a fully discrete, controllable model, dictated by the error-correcting properties of the code.

When adding further layers, the explicit computation of entropies quickly becomes intractable, which motivates a more abstract, topological-algebraic description of the network.

### MP 3: Quantum Field Theory I: Axiomatic, Probabilistic, Algebraic, Conformal

Time: Tuesday 16:15–18:15

Location: KH 02.013

#### Invited Talk

MP 3.1 Tue 16:15 KH 02.013

**Osterwalder-Schrader axioms for a class of unitary 2D Conformal Field Theories** — •MARIA STELLA ADAMO<sup>1</sup>, YUTO MORIWAKI<sup>2</sup>, and YOH TANIMOTO<sup>3</sup> — <sup>1</sup>Department Mathematik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Cauerstrasse 11, 91058 Erlangen, Germany — <sup>2</sup>Interdisciplinary Theoretical and Mathematical Science Program (iTHEMS) Wako, Saitama 351-

0198, Japan — <sup>3</sup>Dipartimento di Matematica, Università di Roma "Tor Vergata", Via della Ricerca Scientifica 1, I-00133 Roma, Italy

We provide a brief overview of axiomatic frameworks for quantum field theory in the case where the spacetime is 2-dimensional and the theory is invariant under conformal transformations, with a particular focus on the Wightman formalism of quantum fields.

For a general quantum field theory, the reconstruction theorem by Osterwalder-Schrader provides conditions to be verified by correlation functions in the Euclidean space to produce a quantum field theory in the Wightman formalism. In our work, for a reasonable class of unitary full Vertex Operator Algebras describing a class of unitary 2D conformal field theories, we construct Euclidean correlation functions that verify a conformal version of the Osterwalder-Schrader axioms.

**Invited Talk** MP 3.2 Tue 16:45 KH 02.013  
**Schwarzian Field Theory for Probabilists** — •PETER WILDEMAN — University of Geneva

What does Liouville field theory, the SYK random matrix model and JT quantum gravity have in common? If you'd ask a physicist in recent years, they would be quick to point out that the low-energy behaviour of all these models should be described by the Schwarzian field theory. In itself, the latter can be understood as a probability measure on a quotient of the group of circle-diffeomorphisms  $\text{Diff}(\mathbb{T})/\text{PSL}(2, \mathbb{R})$ . We discuss a rigorous approach constructing the measure in terms of a non-linear transformation of Brownian bridges, following ideas by Belokurov-Shavgulidze. Furthermore, we present new results that uniquely characterise the measure in terms of an appropriate change-of-variables formula, which can be seen as an analogue of the Cameron-Martin theorem on the space of circle diffeomorphisms. As a byproduct, we also obtain a short proof for the calculation of the measure's partition function (i.e. total mass), confirming a prediction by Stanford-Witten. This talk is based on joint work with Roland Bauerschmidt and Ilya Losev.

**Invited Talk** MP 3.3 Tue 17:15 KH 02.013  
**Local topological order and boundary algebras** — COREY JONES<sup>1</sup>, •PIETER NAAIJKENS<sup>2</sup>, DAVID PENNEYS<sup>3</sup>, and DANIEL WALLICK<sup>3</sup> — <sup>1</sup>North Carolina State University, Raleigh, NC, USA — <sup>2</sup>Cardiff University, Cardiff, UK — <sup>3</sup>The Ohio State University, Columbus, OH, USA

Topologically ordered phases of matter have interesting features, such as the existence of quasi-particles with braid statistics. These quasi-particles can be studied using an AQFT-inspired approach along the lines of the celebrated Doplicher-Haag-Roberts programme on superselection sectors. In this talk I will introduce an axiomatisation, called *local topological order*, of such quantum models. These axioms are defined in terms of nets of (ground state) projections satisfying certain conditions. They allow us to define a physical boundary algebra, and I will outline how in concrete models (such as Kitaev's toric code or Levin-Wen mod-

els) the bulk superselection sector ("DHR") category can be recovered from the boundary algebra, giving a mathematical framework for *topological holography*. If time permits, I will explain how these axioms can be extended to included models with *topological* boundaries, and outline how this can be used to study, for example, Walker-Wang bulk-boundary systems.

MP 3.4 Tue 17:45 KH 02.013  
**Applications of the Lax-Phillips Theorem in Algebraic Quantum Field Theory** — •JONAS SCHÖBER — Brigham Young University, Provo, Utah, USA

Algebraic quantum field theory is one of the main attempts to provide a formal mathematical framework for quantum field theory. Its core idea is to assign to every space-time region a von Neumann algebra of local observables, subject to the Haag-Kastler axioms, which encode locality, covariance, and causality. Translating the Haag-Kastler axioms from von Neumann algebras to the simpler setting of so-called standard subspaces leads to the investigation of one-parameter semigroups of unitary endomorphisms of standard subspaces. In this talk, we show how a real version of the classical Lax-Phillips Theorem, originally developed in the context of scattering theory, can be used to represent these endomorphism semigroups in an  $L^2$ -space over the real line. We also outline how this concrete realization allows one to obtain structural results about the semigroups.

MP 3.5 Tue 18:00 KH 02.013  
**Operator statistics from a simple approximate CFT** — ALEXANDER ALTLAND<sup>1</sup>, JULIAN SONNER<sup>2</sup>, and •KONSTANTIN WEISENBERGER<sup>1</sup> — <sup>1</sup>Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany — <sup>2</sup>Département de Physique Théorique, Université de Genève, CH-1211 Genève 4, Switzerland  
 Recently, in the context of the AdS3/CFT2 correspondence, the notion of ensembles of  $2d$  quantum field theories specified by distributions of OPE-coefficients and conformal dimensions  $\{C_{ijk}, h_i, \bar{h}_i\}$  has been introduced (Belin et al, *JHEP09(2024)163*). These ensembles, dubbed 'approximate CFTs' (aCFTs), are expected to be conformally invariant on average while also exhibiting signatures of quantum chaos. We give the first explicit construction of such an ensemble:  $N_c$  colors of Dirac fermions in the presence of quenched gauge-field disorder. For  $N_c = 1$ , we present prescriptions for the calculation of moments of OPE coefficients and conformal dimensions, and use them to reconstruct all associated probability distributions of the theory. For  $N_c > 1$ , we apply the same methods to find the variance of OPE coefficients of bilinear fields. Finally, we also demonstrate the emergence of random matrix statistics upon perturbing the system by a mass operator.

## MP 4: Quantum Field Theory II

Time: Wednesday 11:00–12:15

Location: KH 02.013

**Invited Talk** MP 4.1 Wed 11:00 KH 02.013  
**Exact Schwinger functions for a class of bounded interactions in  $d \geq 2$**  — •WOJCIECH DYBAŁSKI — AMU Poznan, Poland

We study scalar Euclidean quantum field theories with interactions defined by bounded, measurable functions. We assume that these functions have well-defined limits at both positive and negative infinity. In the spirit of the Buchholz-Verch approach we start from a large class of field renormalization functions and look for choices admitting interesting UV behaviour. We exhibit choices for which all connected Schwinger functions, except perhaps for the two-point function, exist non-perturbatively in the UV limit. Moreover, we obtain closed form formulas for these Schwinger functions demonstrating non-Gaussianity of the field. The remaining challenge of rigorously controlling the two-point function is also discussed. (Based on CMP(2025)406:211).

**Invited Talk** MP 4.2 Wed 11:30 KH 02.013  
**L4 bound for the energy density in thermal field theory** — •DANIELA CADAMURO — Institute for Theoretical Physics, University of Leipzig

Lower bounds to the energy density are of fundamental importance for physics (laws of thermodynamics, stability of spacetimes, etc) and for mathematics (self-adjointness of quantum fields, etc). In the case of thermal field theory, where particles and holes are both present and contribute to the energy density of the system, it is not expected that the energy density, or rather the Liouvillian density, fulfills energy inequalities in the usual sense. However, when the estimate

is weighted with the modular Hamiltonian of the theory, a certain positivity is retained. We call this a quantum L4 inequality. We will show that in the thermal representation of the free massive scalar field, such an inequality is fulfilled by the quantum generator of the time evolution of the theory in this sector.

MP 4.3 Wed 12:00 KH 02.013  
**Inertial Repulsion from Quantum Geometry** — •MAIKE FAHRENHOFN and MATTHIAS GEILHUF — Condensed Matter and Materials Theory Division, Department of Physics, Chalmers University of Technology, 41258 Göteborg, Sweden

We derive a repulsive, charge-dipole-like interaction for a Dirac particle in a rotating frame, arising from a geometric  $U(1)$  gauge symmetry associated with the Berry phase [1]. The Lagrangian of this system includes a non-inertial correction due to centrifugal field coupling. By imposing gauge symmetry and treating it as a full gauge theory, the Lagrangian is extended to include Berry connection and curvature terms. Upon integrating out the geometric gauge field, the effective action is obtained. This leads to the emergence of a repulsive, long-range effective interaction in the Lagrangian. Explicitly, in the non-inertial frame of the observer, the geometric gauge invariance effectively leads to a repulsive Coulomb-interaction in momentum space. In real space, the inertial repulsion manifests in a  $1/|r|^2$  potential, which is symmetric about the origin of rotation and mirrors charge-dipole interaction.

[1] Maike Fahrensohn and R. Matthias Geilhufe. Inertial Repulsion from Quantum Geometry. 2025. arXiv: 2511.03510.

## MP 5: Quantum Mechanics: Spectral Theory and Many-Body Systems

Time: Wednesday 13:45–15:30

Location: KH 02.013

### Invited Talk

MP 5.1 Wed 13:45 KH 02.013

**Nontrivial Riemann Zeros as Spectrum** — •ENDERALP YAKABOYLU — Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg

Define  $Y(s) := \Gamma(s+1)(1-2^{1-s})\zeta(s)$ , and denote by  $\mathcal{Z} := \{\gamma \in \mathbb{C} \mid Y(\gamma) = 0\}$  its set of zeros, which includes both the periodic eta zeros, determined by  $(1-2^{1-s}) = 0$  with  $s \neq 1$ , and the nontrivial zeta zeros  $\rho$ . We introduce a non-symmetric operator

$$\hat{\mathcal{R}}: \mathcal{D}(\hat{\mathcal{R}}) \subset L^2([0, \infty)) \rightarrow L^2([0, \infty)),$$

with spectrum

$$\sigma(\hat{\mathcal{R}}) = \{i(1/2 - \gamma) \mid \gamma \in \mathcal{Z}\}.$$

Assuming that all nontrivial zeros of the zeta function are *simple*, we construct a positive semidefinite operator  $\hat{W}$  intertwining  $\hat{\mathcal{R}}$  and its adjoint on the spectral subspace associated with the nontrivial zeros,

$$\hat{\mathcal{R}}^\dagger \hat{W} = \hat{W} \hat{\mathcal{R}}.$$

The positivity of  $\hat{W}$ , which represents an operator-theoretic form of (*Bombieri's refinement of*) *Weil's positivity criterion*, enforces  $\Re(\rho) = 1/2$  for all  $\rho$ , in accordance with the Riemann Hypothesis. Furthermore, from the similarity between  $\hat{\mathcal{R}}$  and  $\hat{\mathcal{R}}^\dagger$ , we obtain a *self-adjoint Hilbert-Pólya operator*, whose spectrum coincides with the imaginary parts of the nontrivial zeta zeros.

The presented framework can be generalized to higher-order zeta zeros, if such exist, and to any other Mellin-transformable  $L$ -function satisfying a functional equation.

MP 5.2 Wed 14:15 KH 02.013

**Wegner model in high dimension: Singular continuous spectrum from AAT self-consistency and  $U(1)$  symmetry-breaking** — •JULIAN ARENZ — Institut für Theoretische Physik, Universität zu Köln

Adopting the self-consistent theory of localization due to Abou-Chacra, Anderson, Thouless (AAT), we analyze the  $N = 1$  Wegner model in high lattice dimension. By examining in detail the non-compact symmetry-breaking mechanism underlying the field theory, we uncover a new class of solutions of the AAT self-consistency equation. Their pattern of symmetry-breaking differs from the metallic and insulating solutions and naturally leads to a singular continuous spectrum of the Wegner Hamiltonian.

MP 5.3 Wed 14:30 KH 02.013

**Properties of higher-order squeezing** — •FELIX FISCHER — FAU Erlangen

Squeezed light is a corner stone of modern quantum optics, with applications ranging from increasing measurement precision at LIGO to bosonic quantum computing. Higher-order generalizations are a promising candidate for error correction schemes in continuous variable quantum computing. However their well-definedness has been the subject of longstanding debate. In this talk, we show that higher-order squeezing operators become well-defined when imposing suitable boundary conditions at infinity. We observe that different boundary conditions correspond to different dynamics and ultimately different physical systems. Furthermore, we investigate the spectra, dynamics and symmetries of higher-order squeezing operators. In particular, higher-order squeezing dynamics show, opposed to usual second order squeezing, oscillatory behaviour in time.

MP 5.4 Wed 14:45 KH 02.013

**Beyond the rotating-wave approximation: error bounds for higher order approximations** — •LEONHARD RICHTER<sup>1</sup>, ROBIN HILLIER<sup>2</sup>, DAVIDE LONIGRO<sup>1</sup>, and DANIEL BURGARTH<sup>1</sup> — <sup>1</sup>Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany — <sup>2</sup>Department of Mathematics and Statistics, Lancaster University, UK

The rotating-wave approximation (RWA) is a widely used method for simplifying differential equations such as the Schrödinger equation in light-matter systems.

However, its limitations have become more apparent with recent technological advancements highlighting the need for more sophisticated approximation schemes. Our aim is to address one particular drawback of the RWA: the error it introduces accumulates over time eventually rendering its application unjustified. In the case of bounded time-periodic Hamiltonians, the RWA is known to be the first order in the Floquet-Magnus expansion. Recently, a novel perspective on this expansion allowed to provide explicit error bounds that capture the time-dependence of each order reasonably well.

We extend this perspective to the unbounded case where the Floquet-Magnus expansion is generally not known to converge. Our approach iteratively constructs effective Hamiltonians that are time-independent in the interaction picture and scale with a specified order in frequency. Crucially, we are also able to provide explicit error bounds for the difference between the effective and original dynamics.

This work is in collaboration with Robin Hillier, Davide Lonigro, and Daniel Burgarth.

MP 5.5 Wed 15:00 KH 02.013

**Renormalization of generalized spin-boson models with critical ultraviolet divergences** — BENJAMIN ALVAREZ<sup>1</sup>, SASCHA LILL<sup>2</sup>, •DAVIDE LONIGRO<sup>3</sup>, and JAVIER VALENTÍN MARTÍN<sup>4</sup> — <sup>1</sup>Aix Marseille Univ, Univ Toulon, CNRS, CPT, Marseille, France — <sup>2</sup>Department of Mathematical Sciences, Universitetsparken 5, DK-2100 Copenhagen, Denmark — <sup>3</sup>Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany — <sup>4</sup>Universität Paderborn, Institut für Mathematik, Institut für Photonische Quantensysteme, Warburger Str. 100, 33098 Paderborn, Germany

We provide a rigorous construction of generalized spin-boson models with commuting transition matrices and form factors exhibiting critical ultraviolet (UV) divergences. That is, we cover all divergences where a self-energy renormalization, but no non-Fock representation, is required. Our method is based on a direct definition of the renormalized Hamiltonian on a sufficiently large test domain, followed by a Friedrichs extension. We then prove that this Hamiltonian coincides with the one obtained by cut-off renormalization. Furthermore, we show that for specific supercritical cases, i.e., when a non-Fock representation is required, the renormalized Hamiltonian is trivial.

MP 5.6 Wed 15:15 KH 02.013

**Complexity transitions in Krylov basis for random and time-periodic unitary circuits** — HIMANSHU SAHU<sup>1,2,3</sup>, •ARANYA BHATTACHARYA<sup>4,5</sup>, and PIN-GAL PRATYUSH NATH<sup>6</sup> — <sup>1</sup>Perimeter Institute for Theoretical Physics, Waterloo, ON, N2L 2Y5, Canada. — <sup>2</sup>Department of Physics and Astronomy and Institute for Quantum Computing, University of Waterloo, ON N2L 3G1, Canada. — <sup>3</sup>Department of Physics and Department of Instrumentation & Applied Physics, Indian Institute of Sciences, C.V. Raman Avenue, Bangalore 560012, India. — <sup>4</sup>Institute of Physics, Jagiellonian University, Łojasiewicza 11, 30-348 Krakow, Poland. — <sup>5</sup>School of Mathematics, University of Bristol, Fry Building Woodland Road, Bristol BS8 1UG, UK — <sup>6</sup>Centre for High Energy Physics, Indian Institute of Science, C.V. Raman Avenue, Bangalore 560012, India.

We study the growth and saturation of complexity in Krylov basis in random quantum circuits. In Haar-random unitary evolution, we show that, for large system sizes, this notion of complexity grows linearly before saturating at a late-time value of  $d/2$ , where  $d$  is the Hilbert space dimension, at times proportional to  $d$ . In brick-wall case, complexity in Krylov basis exhibits dynamics consistent with Haar-random unitary evolution, while the inclusion of measurements significantly slows its growth down. For Floquet random circuits, we show that localized phases lead to reduced late-time saturation values of the complexity, which we utilise to probe the transition between thermal and many-body localized phases.

## MP 6: Holography: AdS/CFT

Time: Wednesday 16:15–17:15

Location: KH 02.013

MP 6.1 Wed 16:15 KH 02.013

**Deriving Area Metric Dynamics from Entanglement** — •LAVISH CHAWLA<sup>1,2</sup>, ARANYA BHATTACHARYA<sup>1,3</sup>, MARIO FLORY<sup>1</sup>, and MATEUSZ KULIG<sup>1</sup> — <sup>1</sup>Jagiellonian University in Krakow, Poland — <sup>2</sup>Friedrich-Schiller-Universität Jena, Germany — <sup>3</sup>University of Bristol, United Kingdom

In this talk, we will present recent progress on deriving the equations of motion for a generalised geometric structure-area metrics-linearised around empty Anti-de Sitter (AdS) spacetime within the framework of the AdS/CFT correspondence. The discussion is organized into three parts. First, we will introduce the

defining properties of area metric tensor and briefly discuss their emergence in various approaches of quantum gravity, as well as why they are relevant in holography. In the second part, we focus on spherical entangling regions in three-dimensional CFTs, and, by combining the first law of entanglement with the Ryu-Takayanagi formula, we determine how leading order area metric fluctuations in the asymptotic AdS expansion contribute to the holographic stress tensor. This provides a new entry in the holographic dictionary linking area metric perturbations to boundary energy momentum data. Finally, using this dictionary, we show that for finite spherical subregions, the combined requirements

of the first law of entanglement and holographic entanglement entropy impose nontrivial constraints on the dynamics of area metric perturbations.

MP 6.2 Wed 16:30 KH 02.013

**Bulk actions and equations for Area Metrics in AdS/CFT** — ARANYA BHATTACHARYA<sup>1,2</sup>, LAVISH CHAWLA<sup>1,3</sup>, •MARIO FLORY<sup>1</sup>, and MATEUSZ KULIG<sup>1</sup> — <sup>1</sup>Jagiellonian University, Cracow, Poland — <sup>2</sup>University of Bristol, Bristol, UK — <sup>3</sup>Friedrich-Schiller-Universität, Jena, Germany

Continuing the talk by L. Chawla, we investigate possible bulk Lagrangians for linearised area metric perturbations around AdS space. Beyond the Ryu-Takayanagi formula and the first law of entanglement, we expect these Lagrangians to be severely constrained by the requirement of consistency with holographic renormalisation. To make progress in this direction, we analyse the asymptotic behaviour allowed for the area metric fluctuations by generic model Lagrangians and their equations of motion. Finally, we show that expressing these fluctuations in terms of Lanczos-like potentials leads to a particularly elegant formulation of the linearised theory.

MP 6.3 Wed 16:45 KH 02.013

**Deformations of the Chiral SYK Model and its Gravity Dual** — DMITRY BAGRETS<sup>2</sup>, KONSTANTIN WEISENBERGER<sup>1</sup>, and •SARINA MICHAEL<sup>1</sup> — <sup>1</sup>Universität zu Köln, Zùlpicher Straße 77, 50937 Köln — <sup>2</sup>Forschungszentrum Jùlich, Wilhelm-Johnen-StraÙe, 52428 Jùlich

Based on previous work [Altland2025], we construct an extension of the (1+1)-dimensional chiral SYK model, which provides a microscopic realization of a

maximally chaotic yet exactly solvable system, and also it turned out to be the holographic dual of a BTZ black hole. In the deep infrared, both are governed by a generalization of the Schwarzian theory, the Alekseev-Shatashvili (AS) action, which captures the dynamics of soft-mode fluctuations. On the gravity side, we include rotating BTZ geometries, giving a split into left- and right-moving temperatures in the dual CFT, and we add fermions on this background to find the boundary correlators. We rederive these also from pure AdS<sub>3</sub> via diffeomorphisms and extend this construction to genuinely off-shell boundary reparametrizations. On the CFT side, we study a bilocal deformation of the IR description using renormalization-group methods and show that it induces a crossover in the power law of the propagator, leading to a phase diagram with a critical line separating the two regimes.

MP 6.4 Wed 17:00 KH 02.013

**Determining masses of hadronic bound states using a holographic ansatz** — •KONRAD BECKER — Julius Maximilians Universität Würzburg

Holography has been found to be an exceptional tool in particle physics. In this talk I will introduce a holographic bottom-up model based on AdS/CFT which we use to describe a QCD-like theory. In this model one can calculate masses of scalar and vector mesons as well as baryons. I also introduce a way of including an additional global symmetry on the field theory side. This can be used to include flavor symmetry in such a model. Breaking this symmetry by giving different masses to the quarks gives predictions for the lightest QCD baryons which match the measured results surprisingly well.

## MP 7: Members' Assembly

Time: Wednesday 17:30–18:00

Location: KH 02.013

All members of the Theoretical and Mathematical Physics Division are invited to participate.

## MP 8: Poster Session

Time: Wednesday 18:00–18:45

Location: Redoutensaal

MP 8.1 Wed 18:00 Redoutensaal

**Newton Revisited: Modifications and Practical Insights into Classical Mechanics** — •AMRITPAL SINGH NAFRIA — IEC University

This paper challenges the foundational principle of applied force in classical mechanics by systematically addressing the limitations of Newton's second law in real-world scenarios. It demonstrates that the standard formulation is insufficient for accurate prediction when non-conservative forces are present.

Through a series of innovative experiments and detailed theoretical analyses, the work quantitatively reveals significant discrepancies between ideal theoretical predictions and empirical observations. The investigation meticulously accounts for the effects of friction and air resistance, and extends the analysis to consider celestial variations across different planetary environments.

The study employs advanced methodologies, including the use of weighing scales for the direct measurement of resistance forces. It integrates calculations across a wide spectrum of contexts, from terrestrial conditions to the low-gravity environment of Pluto, thereby providing a comprehensive and nuanced view of force dynamics.

The findings underscore the critical necessity for refined mechanical models that explicitly incorporate resistance effects. This work establishes a framework for more accurately predicting and managing force interactions in practical engineering and physics applications, paving the way for more effective force measurement and application techniques in both terrestrial and extraterrestrial environments.

MP 8.2 Wed 18:00 Redoutensaal

**Addition of relativistic velocities with arbitrary directions in four-dimensional space** — •ROLAND ALFRED SPRENGER — Herford, Germany

A vectorial construction method for adding relativistic velocities with arbitrary directions is presented and justified. Without using oblique Minkowski diagrams with scale changes, but using an additional auxiliary dimension, vector addition is performed purely geometrically in a four-dimensional Euclidean space and projected back into three-dimensional real space. This forces all velocities to be limited to the speed of light purely geometrically. The auxiliary dimension represents the time component of the motion geometrically and has no independent physical dynamics. The approach is completely equivalent to special relativity and offers an alternative geometric perspective on the role of time in relativistic motions.

MP 8.3 Wed 18:00 Redoutensaal

**Testing Non-Commutative Spacetime and Dark Matter Coupling via X-Ray Binary QPO Observations** — •BATUHAN ÇIL<sup>1,2</sup> and ERTAN GÜDEKLİ<sup>3</sup> —

<sup>1</sup>Faculty of Sciences and Literature, Department of Mathematics, Haliç University, Istanbul 34060, Turkey — <sup>2</sup>Graduate School of Engineering and Science, Istanbul University, Istanbul 34134, Turkey — <sup>3</sup>Department of Physics, Istanbul University, Istanbul 34134, Turkey

This study investigates the orbital dynamics and quasi-periodic oscillations (QPOs) of test particles around a charged non-commutative Schwarzschild black hole immersed in perfect-fluid dark matter (PFDM). Using the effective-potential formalism, we derive the specific energy, angular momentum and ISCO radii as functions of  $\alpha$ ,  $\beta$  and  $Q$ . PFDM introduces logarithmic corrections to the metric, while non-commutativity smooths the near-horizon geometry and shifts the epicyclic frequency profiles inward. We also compare the model with QPO data from four X-ray binaries via MCMC, obtaining bounds on  $\alpha$ ,  $\beta$  and  $Q$  and showing that PFDM and non-commutative effects leave observable signatures in strong-field QPO behaviour.

MP 8.4 Wed 18:00 Redoutensaal

**Symmetry-breaking constraints from higher-group structure in axion electrodynamics** — •TIMO SCHULZE — II. Institut für Theoretische Physik, Universität Hamburg

Over the past decade, generalised symmetries have opened a new perspective on global symmetries by describing them in terms of higher categorical structures. In a  $d$ -dimensional QFT, a  $q$ -form symmetry is generated by topological defects supported on closed  $(d - q - 1)$ -manifolds, acting on  $q$ -dimensional charged operators. In axion electrodynamics, electric and magnetic 1-form symmetries as well as axionic 0- and 2-form symmetries can combine into a higher-group structure. Building on previous work by Brennan and Cordova, we study and attempt to formalise how higher-group data constrain the order of emergence of these symmetries along RG flows. We suggest further constraints on explicit breaking terms for both electric and magnetic 1-form symmetries below the breaking scale of the axionic 0-form shift symmetry. In particular, this implies that magnetically charged probe particles below that scale must also be electrically charged.

MP 8.5 Wed 18:00 Redoutensaal

**An Algorithm with Positive Geometry and Polynomials  $P(2\pi)$  for Elementary Particle Physics** — •HELMUT SCHMIDT — Grasbrunn, Germany

The new field of positive geometry draws on algebraic geometry, which describes shapes and spaces by solving systems of polynomial equations. The neu-

tron mass  $m_{\text{Neutron}}/m_e = (2\pi)^4 + (2\pi)^3 + (2\pi)^2 - (2\pi)^1 - (2\pi)^0 - (2\pi)^{-1} + 2(2\pi)^{-2} + 2(2\pi)^{-4} - 2(2\pi)^{-6} + 6(2\pi)^{-8} = 1838.6836611$  is accurate to 10 decimal places. The formula can be divided into 3 objects, each with 3 spatial coordinates and a common time. The first term corresponds to 3 gluons. The second term contains two electrons and a superposition of the quarks u and d. The third term contains the detection in the measuring device in the form of a cascade with streams of electrons. The proton mass  $m_p/m_e$  differs from that of the neutron  $E_{C+} = -\pi^1 + 2\pi^{-1} - \pi^{-3} + 2\pi^{-5} - \pi^{-7} + \pi^{-9} - \pi^{-12} - 2\pi^{-14}$  and contains the binding energy, or charge. The electron is weightless with  $(2\pi) = 1$  and is the center for a circular inversion of all other particles. For each of the three spatial dimensions, the torque and angular momentum are conserved with  $2\pi c$ . From this, an algorithm is developed that describes the rest masses and standard deviations of all elementary particles, with the symmetries for matter/antimatter, attraction/repulsion, and creation and annihilation. The Earth's diameter, sidereal time, and synodic time are the required parameters.  $2\pi c \text{ m day} = D_{\text{equatorial Earth diameter}}$

MP 8.6 Wed 18:00 Redoutensaal

**Modeling and simulation of diffraction efficiency growth during holographic grating recording** — •ALEXEI MESHALKIN, ELENA ACHIMOVA, VLADIMIR ABASKIN, VERONICA CAZAC, CONSTANTIN LOSMANSCHI, and VLADISLAV BOTNARI — Institute of Applied Physics, Moldova State University, Chisinau, Moldova

This work presents theoretical and numerical studies on the modeling of wave propagation and light matter interaction during the recording of holographic diffraction gratings. The simulations focus on the evolution of diffraction efficiency as a function of the grating profile, spatial period, and phase-relief depth. Numerical modeling was implemented in MATLAB using the Angular Spectrum Method for light propagation, where all grating parameters were defined based on corresponding experimental data. The obtained simulation results were compared with experimental measurements for holographic gratings recorded in thin films of azopolymers and chalcogenide amorphous materials. A good correlation between the simulated and measured diffraction efficiencies confirms

the applicability of the proposed numerical model for describing holographic recording processes. Moreover, the developed approach enables solving the inverse problem: determining grating parameters from measured diffraction efficiency.

MP 8.7 Wed 18:00 Redoutensaal

**Speed Limits from Symmetries in Quantum Control** — •MARCO WEIDMANN<sup>1</sup>, SANTANA LUJAN<sup>1,2</sup>, and DANIEL BURGARTH<sup>1</sup> — <sup>1</sup>Friedrich-Alexander Universität Erlangen-Nürnberg — <sup>2</sup>German Aerospace Center (DLR)

We present lower bounds on the time needed to implement any given unitary operation in a given control system. The bound crucially depends on the size of the minimal perturbation to the control system that renders the target operation unreachable. This reachability analysis is carried out using the tools of geometric control theory, which are deeply rooted in the theory of Lie Algebras and their commutants. Using Semidefinite programming (SDP) and gradient optimization techniques, we calculate the smallest perturbation that increases the dimension of the commutant of the tensor-square representation.

MP 8.8 Wed 18:00 Redoutensaal

**Self-adjoint extensions of the higher order Rabi model** — •FELIX KNAPP and DAVIDE LONGRO — Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany

The quantum Rabi model is a paradigmatic system for studying light-matter interactions, describing the linear coupling between a two-level system and a single bosonic mode. In this work, we investigate higher-order quantum Rabi models of the form

$$\omega a^\dagger a + g((a^\dagger)^k + a^k)\sigma_x + \Delta\sigma_z,$$

where the interaction term is nonlinear in the bosonic creation and annihilation operators. The operator is defined on a natural dense domain given by finite photon-number states tensored with the two-level system. By analyzing the deficiency indices, we show that for  $k \geq 3$  the operator is not essentially self-adjoint on this domain and explicitly characterize its self-adjoint extensions. Moreover, we prove that the spectrum of this operator is purely discrete.

## MP 9: Geometry, Black Holes, Universality

Time: Thursday 11:00–12:30

Location: KH 02.013

### Invited Talk

MP 9.1 Thu 11:00 KH 02.013

**Light Cone Structure of Quantum Spacetime Geometry** — •WOLFGANG WIELAND — Lehrstuhl für Theoretische Physik III, Friedrich-Alexander-Universität Erlangen-Nürnberg

In Einstein's theory of general relativity, the causal structure of spacetime is itself dynamical. Causality is encoded into the geometry of light cones that bend under the influence of gravity. Quantum theory, on the other hand, tells us that nature is intrinsically probabilistic. A sharply defined causal structure, as it appears in classical general relativity, contradicts quantum theory. A more general framework is needed. This talk outlines a research programme in quantum gravity to develop a mathematical understanding of the causal structure at the quantum level. This is, in fact, a problem common to different approaches from local quantum field theory, to the perturbative S-matrix approach and loop quantum gravity. After a brief introduction into the conceptual aspects of the problem, we will report on several new results on this frontier. First, we explain how to construct physical observables using the light cone geometry. Then, building upon earlier results in loop quantum gravity, we take the description to the quantum level. Finally, we explain how a fundamental quantum discreteness of geometry can alter the spectrum of highly luminous gravitational wave events. The talk is based on arXiv:2504.10802, 2402.12578, 2401.17491, 2104.05803.

MP 9.2 Thu 11:30 KH 02.013

**Finite Projective Physics: the world as a process of events** — •KLAUS MECKE — Universität Erlangen-Nürnberg, Germany

Modern physics is based on the assumption that natural phenomena are the result of force fields and elementary particles moving in a continuous space-time, whereby the dynamics can be described mathematically using differential equations. An alternative to this substance ontology is the assumption that phenomena are processes of elementary events that are causally linked to each other, so that space, time, and matter properties emerge from fundamental process relations. This process ontology - proposed by Alfred North Whitehead - can be formulated mathematically as a finite projective geometry of event points, whereby the dynamics is simply given by local quadratic forms, i.e., by a finite metric field. The task remains to derive from this geometric structure the dynamical laws that are known to be empirically adequate. To this end, finite projective analogues of classical mechanics (time dependence), electrodynamics (spatial gauge fields), and quantum mechanics (random particle events) are formulated and their equivalence to standard analytical theories is demonstrated in the continuum limit. The origin of important concepts such as Legendre transformation,

gauge symmetry, and commutator relations can be explained by fundamental features of finite projective geometry, which characterizes any event process. Finally, the possibility of a unified theory of general relativity and quantum field theory of elementary particles is outlined, in which finite projective geometry is the basic structure instead of a differentiable Riemannian manifold.

MP 9.3 Thu 11:45 KH 02.013

**Rényi second laws for Charged AdS Black Hole** — ALICE BERNAMONTI<sup>1</sup>, FEDERICO GALLI<sup>1</sup>, and •EMILIANO RIZZA<sup>2</sup> — <sup>1</sup>Università degli Studi di Firenze, Florence, Italy — <sup>2</sup>Jagiellonian University, Krakow, Poland

Hawking's black hole area theorem offers a geometric interpretation of the second law of thermodynamics, imposing fundamental constraints on gravitational dynamics. By examining entropic inequalities following from the monotonicity of Rényi entropies, it is shown that these constraints often set stricter bounds than those imposed by the area theorem in asymptotically AdS space.

This work aims to explore in detail the case of charged AdS black holes, which exhibit rich thermodynamic phase structures in the canonical ensemble. In particular, we study the coalescence of charged black holes in AdS, establishing a lower bound on the mass of the final state and an efficiency bound on the amount of gravitational radiation.

MP 9.4 Thu 12:00 KH 02.013

**A New Universality Emerging in the Generic Approach to Stochastic Quantum Scattering** — •SIMON KÖHNES and THOMAS GUHR — Universität Duisburg-Essen, Duisburg, Deutschland

Scattering theory is indispensable to understand a variety of systems ranging from nuclei and atoms to systems in mesoscopic and condensed matter physics, but also to wireless communication. These systems often exhibit chaotic dynamics in a broad sense which prompted generic stochastic approaches. Recently we succeeded in deriving the distributions for off-diagonal scattering matrix elements and cross sections by using Random Matrix Theory and Supersymmetry. We arrive at integrals over Goldstone modes, more precisely over a coset supermanifold. These results now facilitate to prove a 60 year old conjecture: Ericson argued that the mentioned distributions become Gaussian or exponential, respectively, in the regime of strongly overlapping resonances. Our proof is based on an asymptotic expansion which we carry out after a proper reparameterization of the multidimensional integration manifold.

MP 9.5 Thu 12:15 KH 02.013

**Work versus force: Simultaneous processes for describing interactions** — •GRIT KALIES<sup>1</sup>, DUONG D. DO<sup>2</sup>, and CORNELIA BREITKOPF<sup>3</sup> — <sup>1</sup>HTW University of Applied Sciences, Dresden, Germany — <sup>2</sup>The University of Queensland, Brisbane, Australia — <sup>3</sup>Technical University of Dresden, Dresden, Germany

A consistent description of nature is an essential goal that has not been achieved by current theoretical physics, which uses four different fundamental forces to describe interactions. This could change when interactions are described by processes (work is actio) rather than by forces, not only at the macroscopic level but also at the quantum level. We discuss and contrast the two distinct concepts of

interaction and interpret the idea of an acting force (force is actio) as a helpful geometric substitute, obscuring the simultaneous processes that actually take place. Using examples such as the lifting, acceleration or displacement of a body as well as of quantum objects, we demonstrate the advantages of applying process equations, including those that describe a change in the momentum of a particle or body. The results indicate that simultaneous processes allow for a more detailed energetic analysis of quantum objects and pave a path for reconciling classical thermodynamics and quantum physics towards a deterministic description of quantum objects.

## MP 10: Strong Fields

Time: Thursday 13:45–15:30

Location: KH 02.013

MP 10.1 Thu 13:45 KH 02.013

**Dynamically assisted nuclear fusion** — DANIIL RYNDYK<sup>1,3</sup>, CHRISTIAN KOHLFÜRST<sup>1</sup>, FRIEDEMANN QUEISSER<sup>1</sup>, and •RALF SCHÜTZHOLD<sup>1,2</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — <sup>2</sup>Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — <sup>3</sup>Forschungszentrum Jülich GmbH, Wilhelm-Johnen-Straße, 52428 Jülich, Germany

We study the enhancement of tunneling through a potential barrier, such as the Coulomb potential in nuclear fusion, by an additional electromagnetic field, such as an x-ray free electron laser (XFEL). In addition to the known effects of pre-acceleration and potential deformation already present in the adiabatic regime, as well as energy mixing in analogy to the Franz-Keldysh effect in the non-adiabatic regime, the field can enhance tunneling by pushing part of the wave function out of the rear end of the barrier. We find that the XFEL field strengths required for these dynamical assistance mechanisms are challenging, but still well below the Schwinger critical field.

[1] F. Queisser and R. Schützhold, *Dynamically assisted nuclear fusion*, Phys. Rev. C **100**, 041601(R) (2019)

[2] C. Kohlfürst, F. Queisser and R. Schützhold, *Dynamically assisted tunneling in the impulse regime*, Phys. Rev. Research **3**, 033153 (2021)

[3] D. Ryndyk, C. Kohlfürst, F. Queisser, and R. Schützhold, *Dynamically assisted tunneling in the Floquet picture*, Phys. Rev. Research **6**, 023056 (2024)

MP 10.2 Thu 14:00 KH 02.013

**Towards a vacuum birefringence experiment at the Helmholtz International Beamline for Extreme Fields** — •FELIX KARBSTEIN — Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Quantum field theory predicts a nonlinear response of the vacuum to strong electromagnetic fields of macroscopic extent. This fundamental tenet has remained experimentally challenging and is yet to be tested in the laboratory. A particularly distinct signature of the resulting optical activity of the quantum vacuum is vacuum birefringence manifesting itself in a polarization-flipped signal component. This offers an excellent opportunity for a precision test of nonlinear quantum electrodynamics (QED) in an uncharted parameter regime. In this talk I will provide an update on the status of the dark-field approach devised to measure the leading (both polarization-flipped and unflipped) quantum vacuum signals in a dedicated experiment at the European X-ray Free Electron Laser (EuXFEL) within the Helmholtz International Beamline for Extreme Fields (HIBEF) User Consortium.

MP 10.3 Thu 14:15 KH 02.013

**Detection schemes for quantum vacuum birefringence** — •NASER AHMADINIAZ<sup>1</sup>, THOMAS COWAN<sup>1,2</sup>, CHRISTIAN KOHLFÜRST<sup>1</sup>, ROLAND SAUERBREY<sup>1</sup>, MICHAL SMID<sup>1</sup>, TOMA TONCIAN<sup>1</sup>, and RALF SCHÜTZHOLD<sup>1,3</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — <sup>2</sup>Institut für Kern und Teilchenphysik, Technische Universität Dresden, 01062 Dresden, Germany — <sup>3</sup>Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Strong electromagnetic fields can not only create matter but also turn the quantum vacuum into an anisotropic medium. This effect is called vacuum birefringence. Motivated by recent experimental initiatives of the BIREF@HIBEF collaboration at the Helmholtz International Beamline for Extreme Fields (HIBEF) of the HED instrument at the European XFEL, we study birefringent scattering of x-rays in the strong field of high-intensity optical lasers and compare several beam geometries. Special emphasis is placed on scenarios where signal and background photons differ in polarization, propagation direction, and possibly energy, in order to enhance detectability.

[1] N. Ahmadianiaz, C. Bähz et al. (BIREF@HIBEF Collaboration), High Power Laser Science and Engineering **13** (2025).

[2] N. Ahmadianiaz, T.E. Cowan et al. Phys. Rev. D **108**, 076005 (2023).

MP 10.4 Thu 14:30 KH 02.013

**Matter from light: The Sauter-Schwinger effect** — •CHRISTIAN KOHLFÜRST<sup>1</sup>, NASER AHMADINIAZ<sup>1</sup>, SEBASTIAN M. SCHMIDT<sup>1,2</sup>, and RALF SCHÜTZHOLD<sup>1,2</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — <sup>2</sup>Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Strong electromagnetic fields can push even the quantum vacuum itself to its limits, forcing it out of equilibrium and triggering the creation of pairs of electrons and positrons. In this talk, we focus on the most extreme form of matter creation through light: the non-perturbative Sauter-Schwinger effect. In particular, we consider characteristic signatures in the particle distributions of the created electron-positron pairs and provide further context in terms of Relativistic Quantum Transport Theory.

[1] J. P. Edwards et al., Phys. Rev. D **112**, L031901 (2025).

[2] C. Kohlfürst, Phys. Rev. D **110**, L111903 (2024).

[3] C. Kohlfürst et al., Phys. Rev. Lett. **129**, 241801 (2022).

MP 10.5 Thu 14:45 KH 02.013

**Essential Nonlocality of Spin and Polarization Distributions in Strong-Field Quantum Electrodynamics** — SAMUELE MONTEFIORI<sup>1</sup>, ANTONINO DI PIAZZA<sup>2,3,1</sup>, TOBIAS PODSZUS<sup>1</sup>, CHRISTOPH H. KEITEL<sup>1</sup>, and •MATTEO TAMBURINI<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Kernphysik, Heidelberg, Germany — <sup>2</sup>University of Rochester, Rochester, USA — <sup>3</sup>Laboratory for Laser Energetics, Rochester, USA

Lepton spin and photon polarization are fundamental quantum degrees of freedom that govern scattering amplitudes and observable asymmetries. Advances in high-power lasers have opened the strong-field quantum electrodynamics (QED) regime, where modeling of nonlinear Compton scattering (NCS) typically relies on the collinear, locally constant field approximation (LCFA). We show that constructing angle- and polarization-resolved NCS distributions from local, instantaneous lepton states in a uniform constant crossed field can yield unphysical spin and polarization vectors with magnitudes exceeding unity, while accounting for the full photon formation length eliminates these pathologies. We introduce a new LCFA method that integrates over the entire formation region and, when applied to electron-laser interactions and to emission in strong magnetic fields, predicts qualitative and quantitative polarization differences relative to the commonly used local, collinear-emission model.

MP 10.6 Thu 15:00 KH 02.013

**Comparative analysis of laser chirping schemes for compensation of ponderomotive broadening in high-intensity Compton sources** — •NIKITA LARIN<sup>1,2</sup> and DANIEL SEIPT<sup>1,2</sup> — <sup>1</sup>Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Inverse Compton scattering (ICS) is a well-established source of X-ray and  $\gamma$ -ray radiation with broad applications in medicine, biology, nuclear, and material sciences. A key advantage of ICS sources is their ability to generate photon beams with high spectral brightness.

However, achieving the necessary large photon yield requires operation at relativistic laser intensities, which introduces ponderomotive broadening. This effect directly limits the desired spectral brightness. To mitigate this constraint and enhance the performance of ICS sources, the use of chirped laser pulses has been proposed as a compensation strategy [1–4].

We present a comparative study of various chirping prescriptions by applying a novel time-frequency analysis method to the nonlinear Compton emission process. This approach provides deeper insights into the effectiveness of the different chirping prescriptions and guides further refinements toward creating narrowband X-ray and  $\gamma$ -ray sources based on ICS.

[1] I. Ghebregziabher et al., PRSTAB **16**, 030705 (2013). [2] B. Terzić et al., PRL **112**, 074801 (2014). [3] V. Kharin et al., PRL **120**, 044802 (2018). [4] D. Seipt et al., PRL **122**, 204802 (2019).

MP 10.7 Thu 15:15 KH 02.013

**Status report of the photon photon scattering experiment at CALA** — •TIMO POHLE<sup>1</sup>, LEONARD DOYLE<sup>1</sup>, FABIAN SCHÜTZE<sup>2,3</sup>, POOYAN KHADEMI<sup>2,3</sup>, FELIX KARBSTEIN<sup>2,3</sup>, MATT ZEPF<sup>2,3</sup>, and JÖRG SCHREIBER<sup>1</sup> — <sup>1</sup>CALA/LMU, Am Coulombwall 1, 85748 Garching — <sup>2</sup>Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena — <sup>3</sup>Faculty of Physics and Astronomy, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

In the Centre for Advanced Laser Applications (CALA) near Munich, an experiment is being set up with the aim of measuring photon-photon scattering in the all-optical regime. We expect tens of photon scattering when colliding two petawatt pulses from the ATLAS-3000 Laser head on. Measuring this weak sig-

nal in the environment of ultra-intense laser pulses consisting of  $\mathcal{O}(10^{20})$  photons each is one of the main challenges of the experiment, which we want to overcome using the darkfield approach and a time-gated detection scheme. The quantification of this signal will help to verify the predictions made by the current theory about the quantum vacuum in a strong field environment. In my talk, I will give an overview of our planned experimental setup in combination with the expected signal yield predicted by analytical and numerical work [1] as well as report on the current progress of the implementation. Furthermore, I will show our approach to the detection of the weak signal and highlight other challenges in the realization of the experiment.

[1] Schütze et al. *Phys. Rev. D* **2024**, 109 (9), 096009.

## MP 11: Various Topics in Relativity

Time: Thursday 16:15–18:00

Location: KH 00.015

MP 11.1 Thu 16:15 KH 00.015

**A witness of superluminal signalling in quantum theory and its modifications.** — •ARITRO MUKHERJEE — University of Duisburg-Essen

Linearity of the master equations in quantum theory and in many of its proposed modifications is often taken to guarantee the absence of superluminal signalling, thereby preserving causality. However, in many scenarios master equations are not always available in closed analytic form, limiting the applicability of this argument. To address this, we first introduce a general operational witness for detecting superluminal signalling that does not rely on explicit knowledge of a master equation and may be easily assessed when analytical methods are not available. Furthermore, applying this witness reveals a surprising result: even linear master equations can permit superluminal signalling unless a specific locality condition is satisfied. Hence we show that linearity of the corresponding master equations is not a sufficient criteria for causality. In contrast, the witness we propose provides a necessary and sufficient criterion for ruling out superluminal signalling in full generality.

MP 11.2 Thu 16:30 KH 00.015

**Velocity dependent potential** — •LARS CALLENBACH — Frankfurt am Main, Germany

The four-dimensional wave equation can be transformed to Laplace's equation applying a change of coordinates. In these four-dimensional Laplace coordinates a velocity dependent potential is derived from first principles for relative coordinates and velocities and its properties are analyzed. Especially this potential is the classical three-dimensional potential when the particles are at rest with respect to each other and in general this potential represents a central force interaction. Applying the Lagrange and Hamilton formalism the solutions of the dynamics are derived - with a simple structure: a bounded periodic motion on a circle in four dimensions. The explicit formulas for gravitational (and electrodynamical) equations underlying the motion are presented and the theoretical results are applied to data of our solar system showing that the bounded motion on a circle in four dimensions has many scalar constants of motion.

MP 11.3 Thu 16:45 KH 00.015

**Euclidean Relativity Describes A Mathematical Reality** — •MARKOLF H. NIEMZ — Heidelberg University

Special/general relativity (SR/GR) work for all observers, but they do not provide diagrams of nature that work for all observers. This is because they do not describe nature as an absolute manifold, where all action is due to an absolute parameter. We show: Euclidean relativity (ER) achieves precisely that. It describes a mathematical Master Reality, which is *absolute* 4D Euclidean space (ES). All objects move through ES at the dimensionless speed  $C$ . There is no time in ES. All action in ES is due to an *absolute*, external evolution parameter  $\theta$ . Every object experiences two projections from ES as space and time: The axis of its current 4D motion is its proper time  $\tau$ . Three orthogonal axes are its 3D space  $x_1, x_2, x_3$ . An observer's physical reality is the Minkowskian reassembly of his axes  $x_1, x_2, x_3, \tau$ . In this " $\tau$ -based Minkowskian spacetime" ( $\tau$ -MS),  $\tau$  is the new time coordinate and  $\theta$  converts to parameter time  $\vartheta$ . ER reproduces the Lorentz factor and gravitational time dilation, but gravity is Newtonian. Action at a distance is not a problem: Information is instantaneous in timeless ES. Only in  $\tau$ -MS does the time coordinate cause a delay. Presumably, gravity is carried by gravitons and manifests itself in  $\tau$ -MS as waves. ER rejects curved spacetime, cosmic inflation, expanding space, dark energy, and non-locality. Nevertheless, ER predicts time's arrow, the Hubble tension, and entanglement. There are two options: Physics either sticks to SR/GR and highly speculative concepts, or it breaks new ground with ER.

[www.preprints.org/manuscript/202207.0399](http://www.preprints.org/manuscript/202207.0399)

MP 11.4 Thu 17:00 KH 00.015

**Negative square roots: Wishful thinking in spacetime physics** — •RENÉ FRIEDRICH — Strasbourg

The current approaches to quantum gravity are all based on the fundamental assumption of a Lorentzian spacetime manifold as it was understood by Minkowski in his famous lecture "Space and Time" in 1908. However, this assumption is far from being free of inconsistencies:

a) The squared metric "F" used by Minkowski does not apply to spacelike spacetime intervals (problem of negative squares), revealing that spacetime is not continuous in spacelike direction.

b) To remedy this, Minkowski introduced a sort of twofold patchwork metric ("F" and "-F").

c) This handling of the problem was not acceptable for many physicists and led to the proliferation of a multitude of different "conventions" for the spacetime interval which have become a veritable "elephant in the room" of spacetime physics.

d) Misner-Thorne-Wheeler took the problem to extremes, by setting two opposite metrics equal, a positive square with a negative square, implying a real number equal to an imaginary number. Real equals imaginary: That is just the definition of wishful thinking (!).

e) The current approaches to quantum gravity should check the basic assumptions they are relying on, because every theory is only as good as its underlying assumptions.

MP 11.5 Thu 17:15 KH 00.015

**The tiny theory: a single fundamental principle yielding general relativity and the standard model** — •CHRISTOPH SCHILLER — Motion Mountain Research, Munich

The Lagrangians of general relativity and of the standard model of particle physics with massive neutrinos, including elementary particle masses and the other fundamental constants, can be deduced from a single fundamental principle based on fluctuating strands of Planck radius. In particular, the fundamental principle explains the principle of least action, the equality of inertial and gravitational mass, and allows estimating the mass values of the elementary particles.

[1] The tiny theory: a single fundamental principle yielding general relativity, particle physics, and gauge anomaly cancellation, <https://www.researchgate.net/publication/397264142>

[2] <https://tiny.motionmountain.net>

[3] Testing a model for emergent spinor wave functions explaining elementary particles, gauge interactions and fundamental constants, <https://www.researchgate.net/publication/361866270>

[4] Testing the uniqueness of a unified theory based on topology and geometry, <https://www.researchgate.net/publication/389673692>

MP 11.6 Thu 17:30 KH 00.015

**From Relativistic Conversation Law of Charged Particles to Creating of Photons** — •BIN SU — Institut für theoretische Physik, TU Berlin

An application of relativistic dynamics of charged particles in Minkowski force [1] on strengthened accelerated electrons till almost to speed of light is suitable in terms of their relativistic kinematic energy and momentum to discuss. The accelerated charged particles would under the certain settings of electromagnetic apartment for example [2], create synchrotron rays, say photons, which carry the interaction between the accelerated electrons and their located electromagnetic fields and mediate their obtained Minkowski force. The both - particles and fields constitute a conservation system. The possible area of produced radiated frequency could be asserted from the parameters both of particles and their circumstance such as orbital and fields according to relativistic dynamics[1]. This frequency area and the rays direction could be roughly estimated from assumed values of velocities of accelerated electrons in a defined percentage of light velocity. For example the synchrotron ray from electron with two digit light velocity under the certain strength of the magnetic field attains nearly Hundert petahertz, are expected to be experimentally verified.

[1] B. Su \*relativistic dynamics of electrical matter in Minkowski force\*, Scientific Programme 2025 [2] elektronen-Stretcher: <https://www.pi.uni-bonn.de/elsa/de>



MP 11.7 Thu 17:45 KH 00.015

**Rest length and dilated time in five-dimensional spacetime** — •ROLAND ALFRED SPRENGER — Herford, Germany

This talk presents a geometric method for determining time dilation and proper length of relativistically moving bodies without the use of an affine coordinate system or scale transformations. Based on special relativity, a five-dimensional spacetime is introduced in which the constructions can be formulated consistently. The additional dimension is timelike and serves to accommodate time

components that lead to formal mixing of spatial and temporal quantities in four-dimensional representations. Time dilation and proper length follow from simple geometric relations, with simultaneity defined by light spheres rather than spatial hyperplanes. The rest frame of the moving body appears as a reference system rotated about the time axis. Superluminal velocities may occur, but they affect only components associated with the additional timelike dimension and not the observable spatial direction.

## Plasma Physics Division Fachverband Plasmaphysik (P)

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### Overview of Invited Talks and Sessions

(Lecture halls KH 02.016, KH 01.020, KH 01.012, KH 01.013, and KS H C; Poster Redoutensaal)

#### Plenary Talk of the Plasma Physics Division

|       |     |            |         |                                                                                                   |
|-------|-----|------------|---------|---------------------------------------------------------------------------------------------------|
| PV IV | Tue | 9:00– 9:45 | AudiMax | <b>Basics of plasma technologies: examples for applications and diagnostics — •HOLGER KERSTEN</b> |
|-------|-----|------------|---------|---------------------------------------------------------------------------------------------------|

#### Invited Talks

|        |     |             |           |                                                                                                                                                                                                                                                                           |
|--------|-----|-------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P 3.1  | Mon | 16:15–16:45 | KH 02.016 | <b>EMC3-Eirene simulation of neutral source effects on density build-up in the W7-X island divertor — •VICTORIA WINTERS, FELIX REIMOLD, YUHE FENG, VICTORIA HAAK, VALERIA PERSEO, GEORG SCHLISIO, THE W7-X TEAM</b>                                                       |
| P 3.2  | Mon | 16:45–17:15 | KH 02.016 | <b>Optimizing divertor heat loads on Wendelstein 7-X using multi-objective optimization — •ALEXANDER KNEIPS, MICHAEL ENDLER, JOACHIM GEIGER, JIANKUN HUA, YUNFENG LIANG, DIRK NAUJOKS, MATTHIAS OTTE, VINCENZO SANFRATELLO, YUTONG YANG</b>                               |
| P 4.1  | Mon | 16:15–16:45 | KH 01.020 | <b>Data-integrated simulations and machine learning analysis of plasma processing of SiO<sub>x</sub>/Cu memristive devices — TOBIAS GERGS, ROUVEN LAMPRECHT, OLE GRONENBERG, SAHITYA YARRAGOLLA, HERMANN KOHLSTEDT, •JAN TRIESCHMANN</b>                                  |
| P 4.2  | Mon | 16:45–17:15 | KH 01.020 | <b>A multi-ratio method for determination of the electric field from 2p states in transient argon discharges at atmospheric pressure — •ZDENEK BONAVENTURA, ZDENEK NAVRATIL, DETLEF LOFFHAGEN, MARKUS BECKER, TOMAS HODER</b>                                             |
| P 5.1  | Tue | 11:00–11:30 | KH 02.016 | <b>Nanoparticles prepared by sputter-driven gas aggregation — •ANDREY SHUKUROV</b>                                                                                                                                                                                        |
| P 6.1  | Tue | 11:00–11:30 | KH 01.020 | <b>Controlled Exposure of High-Temperature Ceramics in the Scrape-Off Layer of WEST — •B. DE MARTINO, J. P. GUNN, B. GUILLERMIN, D. MAZON, A. CASNER, L. CIUPIŃSKI, G. KOMOROWSKA</b>                                                                                     |
| P 7.1  | Tue | 16:15–16:45 | KH 02.016 | <b>Post-puff SOL broadening on MAST-U: evidence for cross-field transport changes — •YACOPO DAMIZIA, SASKIA MORDJICK, NICK WALKDEN, JACK LOVELL, STEVEN THOMAS, EKIN OZTURK</b>                                                                                           |
| P 8.1  | Tue | 16:15–16:45 | KH 01.020 | <b>Near-plasma Chemical Surface Engineering — •PAULA NAVASCUÉS, DIRK HEGEMANN</b>                                                                                                                                                                                         |
| P 9.1  | Wed | 11:00–11:30 | KH 01.020 | <b>Controlling spokes in magnetron sputtering discharges — •MARTIN RUDOLPH</b>                                                                                                                                                                                            |
| P 10.1 | Wed | 11:00–11:30 | KH 02.016 | <b>Laser fusion activities in Germany - applications in planetary and stellar astrophysics and experiments at high-power laser facilities — •DOMINIK KRAUS</b>                                                                                                            |
| P 11.1 | Wed | 13:45–14:15 | KH 02.016 | <b>Proxima Fusion - Building stellarators to power the future — •JONATHAN SCHILLING</b>                                                                                                                                                                                   |
| P 11.2 | Wed | 14:15–14:45 | KH 02.016 | <b>Equilibrium and stability in Wendelstein 7-X high beta plasmas — •HENNING THOMSEN, CHRISTIAN BRANDT, CHARLOTTE BÜSCHEL, EDITH V. HAUSTEN, MARTIN C. KELLY, KIAN RAHBARNIA, PEDRO PONS VILLALONGA, SARA VAZ MENDES, KSENIA ALEYNKOVA, GOLO FUCHERT, NIKLAS S. POLEI</b> |
| P 12.1 | Wed | 13:45–14:15 | KH 01.020 | <b>Modelling and analysis of DBDs for thin-film deposition at atmospheric pressure — •MARJAN STANKOV, LARS BRÖCKER, CLAUS-PETER KLAGES, MARKUS M. BECKER, DETLEF LOFFHAGEN</b>                                                                                            |
| P 13.1 | Wed | 16:15–16:45 | KH 01.020 | <b>Thin film deposition with dielectric-barrier discharges at atmospheric pressure: open questions and some answers — •LARS BROECKER, CLAUS-PETER KLAGES</b>                                                                                                              |
| P 15.1 | Thu | 11:00–11:30 | KH 01.020 | <b>Demonstration of X-ray Diagnostics for Heavy-Ion-Heated Matter — •JULIAN LÜTGERT</b>                                                                                                                                                                                   |

|        |     |             |           |                                                                                                                                                                                                                                                                            |
|--------|-----|-------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P 17.1 | Thu | 16:15–16:45 | KH 02.016 | <b>Energetic proton damage for simulating fusion relevant neutron damage on reactor materials</b> — •RAHUL RAYAPROLU                                                                                                                                                       |
| P 18.1 | Thu | 16:15–16:45 | KH 01.020 | <b>High-energy-density and high-pressure states investigated with x-ray imaging at HED-HiBEF</b> — •ALEJANDRO LASO GARCIA                                                                                                                                                  |
| P 21.1 | Fri | 9:00– 9:30  | KH 01.013 | <b>Performance Pitfalls and Design Principles of Retarding Potential Analyzers</b> — •THOMAS TROTTENBERG                                                                                                                                                                   |
| P 21.2 | Fri | 9:30–10:00  | KH 01.013 | <b>Microwave cavity resonance spectroscopy: a novel approach for spatially resolved electron density measurements</b> — •JENS OBERRATH                                                                                                                                     |
| P 22.1 | Fri | 9:00– 9:30  | KH 01.012 | <b>ERO/ERO2.0 modelling for tokamaks, stellarators and linear plasma devices</b> — •JURI ROMAZANOV, HENRI KUMPULAINEN, CHRISTOPH BAUMANN, SEBASTIAN RODE, ANDRIY TARASENKO, ANDREAS KIRSCHNER, GEORGI TIMKOVSKII, DMITRY MATVEEV, SEBASTIAN BREZINSEK, JET TEAM, W7-X TEAM |

## Sessions

|               |     |             |              |                                         |
|---------------|-----|-------------|--------------|-----------------------------------------|
| P 1.1–1.2     | Mon | 14:45–15:35 | KH 02.016    | <b>Magnetic Confinement I</b>           |
| P 2.1–2.3     | Mon | 14:45–15:50 | KH 01.020    | <b>Astrophysical Plasmas</b>            |
| P 3.1–3.5     | Mon | 16:15–18:20 | KH 02.016    | <b>Magnetic Confinement II</b>          |
| P 4.1–4.5     | Mon | 16:15–18:00 | KH 01.020    | <b>Codes and Modeling I</b>             |
| P 5.1–5.5     | Tue | 11:00–12:30 | KH 02.016    | <b>Low Pressure Plasmas I</b>           |
| P 6.1–6.5     | Tue | 11:00–12:30 | KH 01.020    | <b>Plasma Wall Interaction I</b>        |
| P 7.1–7.6     | Tue | 16:15–18:55 | KH 02.016    | <b>Magnetic Confinement III</b>         |
| P 8.1–8.8     | Tue | 16:15–18:45 | KH 01.020    | <b>Low Pressure Plasmas II</b>          |
| P 9.1–9.5     | Wed | 11:00–12:30 | KH 01.020    | <b>Low Pressure Plasmas III</b>         |
| P 10.1–10.5   | Wed | 11:00–12:30 | KH 02.016    | <b>High Energy Density Physics I</b>    |
| P 11.1–11.5   | Wed | 13:45–15:50 | KH 02.016    | <b>Magnetic Confinement IV</b>          |
| P 12.1–12.7   | Wed | 13:45–15:45 | KH 01.020    | <b>Atmospheric Pressure Plasmas I</b>   |
| P 13.1–13.7   | Wed | 16:15–18:15 | KH 01.020    | <b>Atmospheric Pressure Plasmas II</b>  |
| P 14.1–14.4   | Thu | 11:00–12:30 | KH 02.016    | <b>Magnetic Confinement V</b>           |
| P 15.1–15.5   | Thu | 11:00–12:30 | KH 01.020    | <b>High Energy Density Physics II</b>   |
| P 16.1–16.117 | Thu | 13:45–15:45 | Redoutensaal | <b>Poster Session Plasma Physics</b>    |
| P 17.1–17.5   | Thu | 16:15–18:15 | KH 02.016    | <b>Plasma Wall Interaction II</b>       |
| P 18.1–18.4   | Thu | 16:15–17:30 | KH 01.020    | <b>High Energy Density Physics III</b>  |
| P 19.1–19.3   | Thu | 17:30–18:15 | KH 01.020    | <b>Atmospheric Pressure Plasmas III</b> |
| P 20          | Thu | 18:30–19:30 | KS H C       | <b>Members' Assembly</b>                |
| P 21.1–21.4   | Fri | 9:00–10:30  | KH 01.013    | <b>Codes and Modeling II</b>            |
| P 22.1–22.5   | Fri | 9:00–10:30  | KH 01.012    | <b>Plasma Wall Interaction III</b>      |
| P 23.1–23.2   | Fri | 11:00–11:30 | KH 01.012    | <b>Low Pressure Plasmas IV</b>          |
| P 24.1–24.4   | Fri | 11:00–12:00 | KH 01.013    | <b>Laser Plasmas</b>                    |
| P 25.1–25.2   | Fri | 11:30–12:00 | KH 01.012    | <b>Plasma Wall Interaction IV</b>       |

## Members' Assembly of the Plasma Physics Division

Thursday 18:30–19:30 KS H C  
snacks included

- Reports
- Elections
- Miscellaneous

## Sessions

– Invited Talks, Contributed Talks, and Posters –

### P 1: Magnetic Confinement I

Time: Monday 14:45–15:35

Location: KH 02.016

P 1.1 Mon 14:45 KH 02.016

**Application of TALIF for the characterization of negative hydrogen ion production in ion sources for NBI** — •JULIAN HÖRSCH, CHRISTIAN WIMMER, and URSEL FANTZ — Max-Planck-Institut für Plasmaphysik

The understanding of the surface conversion process of hydrogen/deuterium atoms or positive ions to negative  $H^-/D^-$  ions at a low work-function surface is of special interest for the physics understanding of negative ion sources. The negative ion yield from surface conversion is determined by the work function of the converter surface, the flux of the precursor particles ( $H/D$  or  $H_x^+/D_x^+$ ) on the surface and their energy distribution function (EDF). To investigate the flux, respectively the density of neutral hydrogen atoms and their EDF, a two-photon absorption laser induced fluorescence (TALIF) diagnostic is implemented at the negative ion source BATMAN Upgrade (BUG). TALIF measurements at BUG were previously limited by the low signal-to-noise ratio, which made an accurate EDF resolution that is required to resolve potential two-temperature EDFs impossible. Recent improvements of the TALIF diagnostic allowed for the first time the resolution and confirmation of a two-temperature EDF at BUG. This contribution discusses the results of investigations with the improved setup that enables now more in-depth investigations together with additional diagnostics as for  $H^-$  density or plasma potentials.

P 1.2 Mon 15:10 KH 02.016

**Modeling of the BATMAN Upgrade ion-source using the CsFlow3D code** — •DANIELE MUSSINI, CHRISTIAN WIMMER, DIRK WÜNDERLICH, and URSEL FANTZ — Max-Planck-Institut für Plasmaphysik (IPP), Boltzmannstr. 2, 85748 Garching

The ion sources for the neutral beam injectors (NBI) of ITER rely on the production of negative hydrogen ions on a surface featuring a low work function (plasma grid, PG). Cs is continuously evaporated into the source forming a layer on the PG in order to reduce the work function to low values ( $<2\text{eV}$ ). However, the redistribution of Cs inside the source and the interaction of the plasma with the source surfaces lead to a temporally unstable and inhomogeneous Cs layer. The knowledge of Cs fluxes onto and out of the PG becomes thus necessary in order to be able to carry out stable long pulses at ITER's requirements (several hundred s in H, 3600s in D). Yet, the neutral Cs density can be measured, Cs fluxes are experimentally not accessible. The Monte-Carlo Test-Particle code CsFlow3D is used to model the Cs dynamics inside the BATMAN Upgrade ion-source exploiting several inputs such as plasma parameters, electromagnetic field as well as sticking coefficients. For the first time, 3D plasma parameters from a fluid code are implemented in CsFlow3D. Three different synthetic lines of sight for the quantification of neutral Cs are implemented into the code to validate the code with the experiment. This contribution presents preliminary results after the implementation of the new plasma parameters.

### P 2: Astrophysical Plasmas

Time: Monday 14:45–15:50

Location: KH 01.020

P 2.1 Mon 14:45 KH 01.020

**Astrophysical perpendicular shocks for intermediate Mach numbers** — •VALENTINE DEVOS, ARTEM BOHDAN, and FRANK JENKO — Max Planck Institute for Plasma Physics, Garching bei München

This project investigates the microphysics and structure of collisionless shocks from planetary to astrophysical scales, focusing on the intermediate Mach-number regime. Using fully kinetic Particle-In-Cell simulations, we study the transition from low-Mach instabilities (whistler precursors, modified two-stream modes) to high-Mach regimes dominated by Weibel and Buneman instabilities.

A key objective is to characterise electron kinetics and the conditions enabling efficient acceleration through Diffusive Shock Acceleration (DSA), Shock Surfing (SSA), and Shock Drifting (SDA).

To identify and track instabilities, we compute theoretical whistler anisotropy thresholds from particle distributions, evaluate linear growth rates for whistler and Weibel modes, and compare them with simulation results. We also derive dispersion relations to link the observed wave activity to the underlying kinetic processes.

Overall, this work clarifies how micro-instabilities regulate electron heating and acceleration across Mach numbers, connecting low- and high-Mach collisionless shocks in space and astrophysical plasmas.

P 2.2 Mon 15:10 KH 01.020

**Turbulence in Molecular Clouds** — •CHRISTIAN HEPPE<sup>1</sup>, ALEXEI IVLEV<sup>2</sup>, FRANK JENKO<sup>1</sup>, and DANIELE VILLA<sup>1</sup> — <sup>1</sup>Max-Planck-Institute for Plasma-physics, Garching — <sup>2</sup>Max-Planck-Institute for Extraterrestrial Physics, Garching

The bulk mass of gas in the interstellar medium (ISM) is located in so called Molecular Clouds (MCs), which are dense and cold environments also known as nurseries of stars. Due to highly energetic Cosmic Rays (CRs) these dense gases

are still weakly ionized even deep into their centers. We investigate the effect of this partial ionization by means of 3D two-fluid MHD turbulence simulations in which we model the neutral and ionized gas coupled by a collisional drag term explicitly. As the coupling is collisional we expect, on scales smaller than their collision frequencies, the gases to increasingly decouple while on larger scales the gases to move in unison. This has direct impacts on linear MHD waves and consequently on the turbulent cascade in these systems. We investigate the impact of the decoupling on the energy transfer over scales in the turbulent cascade, attempt to generalize the characteristics of turbulence in these weakly ionized environments and present the implications for star formation and CR transport.

P 2.3 Mon 15:35 KH 01.020

**Particle acceleration at oblique high-Mach-Number shocks propagating in a turbulent medium** — •ELOISE MOORE<sup>1</sup>, KAROL FULAT<sup>2</sup>, MAHMOUD AL-AWASHRA<sup>3</sup>, MICHELLE TSIROU<sup>3</sup>, and MARTIN POHL<sup>1,3</sup> — <sup>1</sup>Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — <sup>2</sup>Department of Astronomy, University of Wisconsin-Madison, Madison, WI 53706, USA — <sup>3</sup>Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany

Astrophysical collisionless shocks are efficient particle accelerators that require some pre-acceleration mechanism in order for electrons to participate in diffusive shock acceleration. The particle-in-cell (PIC) method provides a kinetic description of a system from first principles of collisionless plasma. Using the PIC code, THATMPI, we perform novel simulations of oblique non-relativistic high-Mach-number shocks propagating into an upstream containing pre-existing decaying turbulence. Such turbulence consists of perturbations in the magnetic field varying in amplitude, and a self-consistent current driven by the ions to limit the phase speed to low levels. We investigate the role of turbulence in modifying the shock structure, plasma instabilities and ultimately particle acceleration, by comparing our results to simulations with a homogeneous upstream.

## P 3: Magnetic Confinement II

Time: Monday 16:15–18:20

Location: KH 02.016

## Invited Talk

P 3.1 Mon 16:15 KH 02.016

**EMC3-Eirene simulation of neutral source effects on density build-up in the W7-X island divertor** — •VICTORIA WINTERS<sup>1,2</sup>, FELIX REIMOLD<sup>2</sup>, YUHE FENG<sup>2</sup>, VICTORIA HAAK<sup>2</sup>, VALERIA PERSEO<sup>2</sup>, GEORG SCHLISIO<sup>2</sup>, and THE W7-X TEAM<sup>2</sup> — <sup>1</sup>Universität Greifswald, Institut für Physik, Greifswald D-17489 Germany — <sup>2</sup>Max-Planck-Institut für Plasmaphysik, Greifswald D-17491 Germany

Achieving high plasma density near the divertor target in magnetically confined fusion devices is crucial for efficient heat and particle exhaust. The W7-X stellarator is qualifying the island divertor as a potential exhaust solution for a future stellarator reactor. Simplified models of the island divertor predict that increasing the internal island field line pitch ( $\Theta$ ) should have a beneficial effect on density build-up at the divertor. This hypothesis was tested numerically using the EMC3-Eirene code for three different W7-X magnetic configurations with increasing  $\Theta$  (low iota, standard, and high iota). While the low iota configuration showed the poorest density build-up, as expected, no improvement in density build-up was observed between standard and high iota, even with the factor of 2 increase in  $\Theta$ . This deviation from predicted behavior was attributed to the proximity of the X-point to a vertical divertor plate, introducing a limiter-like component. Removing the vertical target from the simulation recovered the expected scaling from the simplified models. This work underscores the importance of the island's neutral screening efficiency on density build-up. Potential consequences, such as inducing X-point radiators, will be discussed.

## Invited Talk

P 3.2 Mon 16:45 KH 02.016

**Optimizing divertor heat loads on Wendelstein 7-X using multi-objective optimization** — •ALEXANDER KNEIPS<sup>1</sup>, MICHAEL ENDLER<sup>2</sup>, JOACHIM GEIGER<sup>2</sup>, JIANKUN HUA<sup>3</sup>, YUNFENG LIANG<sup>1,3</sup>, DIRK NAUJOKS<sup>2</sup>, MATTHIAS OTTE<sup>2</sup>, VINCENZO SANFRATELLO<sup>1</sup>, and YUTONG YANG<sup>1</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management 1 - Plasmaphysik, Jülich, 52425, Germany — <sup>2</sup>Max-Planck-Institut für Plasmaphysik, Greifswald, 17491, Germany — <sup>3</sup>Huazhong University of Science and Technology, Wuhan, 430074, People's Republic of China

Modular stellarators such as Wendelstein 7-X offer considerable flexibility in their magnetic configuration space. Due to the many possible choices in configuration, it becomes possible to not optimize just for one target metric, but to combine multiple metrics into one study. Specialized methods exist for such multi-objective studies which can autonomously explore the Pareto front of different possible tradeoffs between objectives. In this talk, we show how to leverage multi-objective methods to explore configurations with reduced heat loads on plasma-facing components. Particularly, we explore how much heat loads can overall be reduced through tuning of the main coil currents, and then explore how much further reduction is possible by tolerating increased heat loads in other areas.

P 3.3 Mon 17:15 KH 02.016

**Fast divertor plasma dynamics at Wendelstein 7-X** — •SEBASTIAN HÖRMANN<sup>1,2</sup>, M. GRIENER<sup>1</sup>, G. BIRKENMEIER<sup>1,2</sup>, F. REIMOLD<sup>3</sup>, M. KRYCHOWIAK<sup>3</sup>, D. GRADIC<sup>3</sup>, F.B.T. SIDDIKI<sup>3</sup>, C. KILLER<sup>3</sup>, A. VON STECHOW<sup>3</sup>, U. STROTH<sup>1,2</sup>, THE ASDEX UPGRADE TEAM<sup>1</sup>, and THE W7-X TEAM<sup>3</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — <sup>2</sup>TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — <sup>3</sup>Max-Planck-Institut für Plasmaphysik, Greifswald 17491, Germany

Understanding and quantifying particle and energy transport at the plasma boundary, as well as detachment and its stability in the divertor region, is crucial for magnetic confinement fusion, as this determines both plasma performance and target loads. For this reason, several thermal helium beam systems, have been installed in the divertors of Wendelstein 7-X. These diagnostics allow the investigation of edge transport processes, such as modes and filaments, with high

spatiotemporal resolution of 10 kHz in both  $n_e$  and  $T_e$  and up to 1 MHz in line intensity. The contribution will present the diagnostic implementation, validation and its possibilities. Furthermore, the talk will focus on the influence of large plasma events on divertor plasma and detachment in the island divertor regions, causing density and temperature changes in the island of up to 50% in a time range in the order of 0.1 ms to 10 ms. In combination with other diagnostics, as well as for different magnetic configurations and machine parameters, the nature of these events will be discussed, and the influence on the wall will be determined.

P 3.4 Mon 17:40 KH 02.016

**Resilience of stellarator plasmas against thermal quenches induced by tungsten TESPEL injection** — •HJÖRDIS BOUVAIN<sup>1</sup>, ANDREAS DINKLAGE<sup>1</sup>, NAOKI TAMURA<sup>1</sup>, ISABEL GARCIA-CORTES<sup>2</sup>, TOMAS GONDA<sup>3</sup>, KATSUMI IDA<sup>4</sup>, HIROE IGAMI<sup>4</sup>, ANDREAS LANGENBERG<sup>1</sup>, HIROSHI KASAHARA<sup>4</sup>, KIERAN MCCARTHY<sup>3</sup>, DANIEL MEDINA-ROQUE<sup>3</sup>, KEISUKE MUKAI<sup>4</sup>, YOSHIRO NARUSHIMA<sup>4</sup>, KIAN RAHBARNIA<sup>1</sup>, CHIHIRO SUZUKI<sup>4</sup>, YUKI TAKEMURA<sup>4</sup>, TOKIHIKO TOKUZAWA<sup>4</sup>, THOMAS WEGNER<sup>1</sup>, MIKIYO YOSHINUMA<sup>4</sup>, THE W7-X TEAM<sup>1</sup>, and THE LHD EXPERIMENT TEAM<sup>4</sup> — <sup>1</sup>Max-Planck-Institute for Plasma Physics, Greifswald, Germany — <sup>2</sup>Laboratorio Nacional de Fusión, CIEMAT, Madrid, Spain — <sup>3</sup>Auburn University, Auburn, USA — <sup>4</sup>National Institute for Fusion Science, Toki, Japan

Plasma-terminating events, e.g. induced by the sudden influx of high-Z impurities due to mechanical failures, threaten the safe operation of large-scale fusion devices. Unlike tokamaks, in stellarators such an event cannot lead to a current disruption, but thermal quenches can still occur. To quantify the potential damage to plasma-facing components caused by the sudden energy loss, large amounts of tungsten were injected via TESPEL in W7-X and LHD plasmas. It was found that beyond a threshold of tungsten atoms and plasma parameters, impurity induced radiative losses along propagating cold fronts may induce termination. Close to this threshold, an intrinsic resilience to the perturbations was observed: despite energy losses up to ~90%, the plasmas recovered without external intervention. This underscores the improved robustness of stellarator plasmas to strong perturbations.

P 3.5 Mon 18:05 KH 02.016

**Demonstrating the capabilities of the Electron Cyclotron Absorption (ECA) Diagnostic at W7-X in a case study.** — •JONAS ZIMMERMANN, TORSTEN STANGE, SERGIY PONOMARENKO, HEINRICH LAQUA, and W7-X TEAM — Institut für Plasmaphysik, Greifswald, Deutschland

Electron cyclotron resonance heating (ECRH) is the primary heating system of the Wendelstein 7-X (W7-X) device and a major component of the heating mix of most next-generation magnetically confined plasma experiments. Ensuring high heating efficiency is important for machine safety, experimental success, and cost-effectiveness. The propagation and absorption of a heating beam depend on plasma parameters as well as the coupling of the beam to the X- or O-mode at the plasma edge. The electron cyclotron absorption (ECA) diagnostic at W7-X measures ECRH beam shine-through, providing a first-pass heating efficiency measure. During X-mode operation, where full absorption is expected, shine-through power of a few percent was detected. A detector channel was upgraded to include a motorized polarization rotator. With this, the unabsorbed power could be attributed to partial O-mode coupling. Full absorption was finally achieved using a systematic optimization procedure for the coupled polarization. It was possible to measure the magnetic shear induced polarization rotation of the ECRH beam. Comparison of this measurement with the expected change in rotational transform (iota) along the beam path suggests the effective ECRH coupling point lies radially outward of the previously assumed last closed flux surface.

## P 4: Codes and Modeling I

Time: Monday 16:15–18:00

Location: KH 01.020

## Invited Talk

P 4.1 Mon 16:15 KH 01.020

**Data-integrated simulations and machine learning analysis of plasma processing of SiO<sub>x</sub>/Cu memristive devices** — TOBIAS GERGS, ROUVEN LAMPRECHT, OLE GRONENBERG, SAHITYA YARRAGOLLA, HERMANN KOHLSTEDT, and •JAN TRIESCHMANN — Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

The characteristics of SiO<sub>x</sub>/Cu memristive devices [1] deposited by reactive magnetron sputtering are highly sensitive to the obtained material properties, requiring fine control over local physical conditions during plasma deposition. The latter are investigated through machine learning (ML) surrogate modeling,

data-integrated physical simulations, and a data-driven analysis of corresponding wafer-level measurements. An ML surrogate model of the reactive plasma-surface interaction during Ar and O<sub>2</sub> ion impingement on SiO<sub>x</sub> is integrated in an axially symmetric 2D particle-in-cell/Monte Carlo collision simulation with dynamic surface conditions. It provides a comprehensive prediction of discharge and surface conditions, e.g., fluxes, energy. Insights from this simulation are correlated with a data-driven classification of measured device-level electrical characteristics. A statistical analysis over a wafer is applied to over 50,000 devices to identify how processing conditions influence device behavior. The analysis

reveals distinct device types linked to the local physical conditions during processing, highlighting the importance of plasma process control in determining functional outcomes in nanoscale electronic devices.

[1] Lamprecht et al., Adv. Eng. Mater. 27, 2401824 (2025)

German Research Foundation – Project-ID 434434223 (SFB 1461)

#### Invited Talk

P 4.2 Mon 16:45 KH 01.020

**A multi-ratio method for determination of the electric field from 2p states in transient argon discharges at atmospheric pressure** — •ZDENEK BONAVENTURA<sup>1</sup>, ZDENEK NAVRATIL<sup>1</sup>, DETLEF LOFFHAGEN<sup>2</sup>, MARKUS BECKER<sup>2</sup>, and TOMAS HODER<sup>1,2</sup> — <sup>1</sup>Department of Plasma Physics And Technology, Masaryk University, Brno, Czech Republic — <sup>2</sup>Leibniz Institute for Plasma Science and Technology, Greifswald, Germany

We present a theoretical analysis demonstrating that a multi-ratio optical emission spectroscopy (OES) approach can, in principle, be applied to determine the instantaneous mean electron energy and reduced electric field (E/N) in transient low-temperature argon discharges at atmospheric pressure, while also allowing recovery of the relative densities of the Ar<sub>1s5..2</sub> states. The method is derived from an advanced reaction kinetic model for argon accounting for 23 species and 409 processes by means of a dominant-balance analysis used to identify negligible terms and define explicit validity conditions in terms of reduced electric field, pressure, and relative excited-state densities for simplified formulation. By combining simplified balance equations for pairs of Ar<sub>2p10..2</sub> states, the dependence on the unknown electron density is eliminated, and densities of the Ar<sub>2p10..2</sub> states appear only in mutual ratios. The influence of metastable and resonant states is incorporated through specific terms, whose impact on the method sensitivity is quantified.

P 4.3 Mon 17:15 KH 01.020

**Modeling the Influence of Dielectric Materials on Plasma Characteristics in Capacitively Coupled Plasma Systems** — •MINE FAKILI, NESLIHAN SAHIN, and MURAT TANISLI — Department of Physics, Division of High Energy and Plasma Physics, Eskisehir Technical University, Eskişehir, Türkiye

In this study, the spatial distributions of plasma parameters in a 13.56 MHz single-frequency capacitively coupled plasma system were investigated with a focus on the effects of a dielectric material. The Poisson equation, together with the electron and ion continuity equations and the electron energy equation, were solved simultaneously. The system of equations was discretized using the finite difference method and iteratively solved employing the Newton-Raphson technique. The model considers the effect of the dielectric material placed between the electrodes on the electric field, charge density, plasma potential and electron temperature. Numerical results demonstrate that the dielectric material causes to significant variations in plasma density, potential profiles, and electron energy distribution. The model provides highly accurate results in the design and op-

timization of industrial plasma processes, making a significant contribution to fields such as semiconductor manufacturing and thin film deposition.

P 4.4 Mon 17:30 KH 01.020

**Comprehensive comparison of relativistic particle pushers for Particle-in-Cell codes** — •HOLGER SCHMITZ — Central Laser Facility, STFC Rutherford-Appleton Laboratory, Didcot OX11 0QX, United Kingdom

Computational investigations of kinetic processes in plasma physics routinely make use of the Particle-in-Cell (PIC) simulation technique. One of the core components in PIC codes is the particle pusher, which integrates the trajectories of the simulation particles in the electromagnetic fields. Traditionally, the Boris scheme has been chosen as the default integration scheme due to its simplicity and long-term stability. Over the last couple of decades, a number of new integration schemes have been proposed that attempt to address some shortcomings of the Boris pusher in the relativistic regime. However, these schemes are typically evaluated only in the scenarios for which they were originally designed, and no comprehensive, systematic comparison exists to date. In this work we present a comparison between several relativistic particle-integration schemes across a wide variety of test cases that probe different physical regimes and numerical challenges. An important class of these pushers can be generalised to provide higher order schemes. Some tests for the fourth order generalisations are also presented. The goal is to provide guidance for developers and users of PIC codes for the choice of particle pusher in relativistic simulations.

P 4.5 Mon 17:45 KH 01.020

**CFD Simulation of Porous Wick Two-Phase Flow in Liquid Metal Heat Pipe for a Divertor Plasma-Facing Component** — •MENNO BAKKER<sup>1</sup>, MAX VONCKEN<sup>2</sup>, ALEXIS TERRA<sup>1</sup>, SEYEDMOHAMMAD VAFAEI<sup>1</sup>, YIRAN MAO<sup>1</sup>, JAN WILLEM COENEN<sup>1</sup>, and CHRISTIAN LINSMEIER<sup>1</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma-physics (IFN-1), Jülich 52425, Germany — <sup>2</sup>Eindhoven University of Technology, Power&Flow group, Department of Mechanical Engineering, Groene Loper 3, 5612 AE Eindhoven, Netherlands

The divertor plasma-facing components (PFCs) in fusion applications must withstand high heat loads that can reach up to 20 MW/m<sup>2</sup> in steady state loading conditions. These extreme heat loads must be efficiently exhausted by suitable heat sink systems. In this work, a PFC based on liquid metal heat pipes (LMHP) is proposed (PFC-LMHP). Analytical and numerical models are developed to provide an initial assessment of the heat transfer rate of such PFC-LMHPs. Furthermore, CFD simulations are used to study the two-phase flow within the porous wick. The impact of porosity and the volume fraction of fluid on the liquid mass flow from the condenser to the evaporator of the LMHP is investigated. Preliminary analysis is initiated on commercially available LMHP to validate the models.

## P 5: Low Pressure Plasmas I

Time: Tuesday 11:00–12:30

Location: KH 02.016

#### Invited Talk

P 5.1 Tue 11:00 KH 02.016

**Nanoparticles prepared by sputter-driven gas aggregation** — •ANDREY SHUKUROV — Charles University, Faculty of Mathematics and Physics, Department of Macromolecular Physics, Prague, Czech Republic

Sputter-driven gas aggregation, first pioneered by the Freiburg group in the 1990s, has become a well-established and versatile method for synthesizing metal nanoparticles (NPs) through the condensation of atomic metal vapors in a cold inert gas. While planar magnetrons have traditionally been used for this process, the gradual evolution of their erosion tracks imposes limitations on process stability and controllability. Cylindrical magnetrons offer an effective way to overcome these constraints and significantly extend target lifetime. However, despite their widespread use in thin-film deposition, cylindrical magnetrons have not yet been adapted for gas-phase nanoparticle synthesis. In this contribution, we demonstrate the use of dc planar and cylindrical magnetrons for the gas-phase production of metal NPs, including hybrid bimetal nanoparticles with complex morphologies such as core@shell and Janus structures. We further present reactive sputtering in Ar/N<sub>2</sub> mixtures, which enables the synthesis of metal nitride (MeN) nanoparticles, where Me = Ti, Zr, Hf, Cu, or Fe. By systematically varying gas composition, pressure, and discharge current, we obtain nanoparticles with tunable size distributions and chemical compositions. The resulting materials show strong potential for applications in refractory plasmonics, solar-light harvesting, and electrochemical CO<sub>2</sub> reduction. Representative results will be presented and discussed.

P 5.2 Tue 11:30 KH 02.016

**Influence of discharge parameters on the synthesis and properties of nanoparticles in reactive plasmas** — •ALEXANDER SCHMITZ, ANDREAS PETERSEN, and FRANKO GREINER — Institute of Experimental and Applied Physics, Kiel University, Germany

Reactive plasma can be an attractive source for sub-micron particles of several 100 nm size. Such particles are a candidate for pharmaceutical carriers, catalytic or functional material. The influence of the discharge parameters on the accretion growth process and the nanoparticle properties especially still pose open questions. Their precise determination is not only of importance for fundamental research on particle dynamics and electron depletion processes, but also for potential technical applications.

Modern *in-situ* diagnostics based on light scattering like full-Stokes imaging polarimetry offer valuable insight into the particle characteristics. It is a door opener for accessible computer vision and precise scattering modeling to access particle properties. We present a first study on the tunability of nanoparticle properties with regard to the particle size distributions, complex refractive index and their spatial dynamics.

P 5.3 Tue 11:45 KH 02.016

**Calorimetric and electrostatic probe diagnostics of a gas aggregation source plasma** — •CAROLINE ADAM<sup>1</sup>, VIKTOR SCHNEIDER<sup>1</sup>, JESSICA NIEMANN<sup>1</sup>, DANIIL NIKITIN<sup>2</sup>, JAN HANUŠ<sup>2</sup>, RONALDO KATUTA<sup>2</sup>, IQRA WAHID<sup>2</sup>, VERONIKA ČERVENKOVÁ<sup>2</sup>, ANDREY SHUKUROV<sup>2</sup>, HYNEK BIEDERMAN<sup>2</sup>, and HOLGER KERSTEN<sup>1,3</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — <sup>2</sup>Faculty of Mathematics and Physics, Department of Macromolecular Physics, Charles University, Prague, Czech Republic — <sup>3</sup>Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

Gas aggregation cluster sources (GAS) have been emerging as a key technology for the production of clusters and nanoparticles (NPs) of precise size and composition. The resulting NP properties are significantly affected by the thermal balance during their growth in the aggregation zone. In this study, the characteristics of a novel controllable GAS setup are investigated, using a post (cylindrical) magnetron with a rotating magnetic circuit [1] equipped with a copper target in Ar and/or N<sub>2</sub> atmosphere, respectively. Energy fluxes are quantified by calorimetric measurements using passive thermal probes (PTP), while the plasma parameters are assessed by Langmuir probes. These quantities are critical to develop a comprehensive understanding of the correlation between (external) process parameters (e.g., current, voltage, continuous or pulsing, gas pressure) and (internal) plasma parameters and their correlation with NP growth, transport and microstructure. [1] D. Nikitin et al., Plasma Processes Polym. 18 (2021).

P 5.4 Tue 12:00 KH 02.016

**Non-adiabatic electron energization mechanism in plasmas with a magnetron configuration** — •LUKAS VOGELHUBER<sup>1</sup>, KEVIN KÖHN<sup>1</sup>, DENNIS KRÜGER<sup>1</sup>, JENS KALLÄHN<sup>1</sup>, YULIA SHAROVA<sup>1</sup>, LIANG XU<sup>2</sup>, RALF PETER BRINKMANN<sup>1</sup>, and DENIS EREMIN<sup>1</sup> — <sup>1</sup>Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — <sup>2</sup>School of Physical Science and Technology, Soochow University, Suzhou 215006, China

Partially magnetized plasma discharges in  $E \times B$  configurations are versatile tools, with applications ranging from Hall-effect thrusters for space propulsion to high-power impulse magnetron sputtering (HiPIMS) for thin-film deposition. In these configurations, structures known as spokes can form as potential humps moving in the  $\pm E \times B$  direction, and influence electron dynamics. Electrons confined in the racetrack region are typically considered to be magnetized, with their magnetic moment serving as an indicator of the degree of confinement; if

the magnetic moment is conserved along the trajectory, the energization is adiabatic. However, various processes can disrupt this conservation, including collisions, field interactions, and resonant particle motion, leading to non-adiabatic energy gain by electrons. In this work, this phenomenon is studied to gain a deeper understanding of the collisionless energization of electrons at potential humps in magnetized plasmas.

P 5.5 Tue 12:15 KH 02.016

**Interaction of fast particle agglomerates with a dusty plasma** — •DANIEL MAIER, CHRISTINA KNAPEK, ANDRÉ MELZER, DANIEL MOHR, and STEFAN SCHÜTT — Institute of Physics, University of Greifswald, Germany

Fast objects moving through a dispersive medium can interact in various ways and create a variety of phenomena (e.g. Mach cones or shocks). The investigation of this interaction has been a topic of research for long times.

Interactions of a dusty plasma under microgravity disturbed by fast particle agglomerates were observed in experiments using the "Zyflex" chamber. A cloud of micron sized particles in a low temperature plasma was disturbed by fast particle agglomerates that were unintentionally accelerated to high velocities during the experiments. This disturbance can lead to dust-free cavities in the region of the agglomerates with varying shape and size dependent on the velocity of the agglomerate and its moving direction in relation to the plane of the illuminating laser. Using a stereoscopic camera set-up consisting of four high-speed cameras with a resolution of 2.1 MP at a frame rate of 200 fps it is possible to calculate the spatial position of the dust particles and their motion during the interaction with the fast agglomerates in three dimensions.

In this contribution observations of such interactions will be shown focusing on the velocities and density of the surrounding dust particles as well as the spatiotemporal characteristics of the dust-free cavity.

This project has been funded under the DLR grant 50WM2161.

## P 6: Plasma Wall Interaction I

Time: Tuesday 11:00–12:30

Location: KH 01.020

### Invited Talk

P 6.1 Tue 11:00 KH 01.020

**Controlled Exposure of High-Temperature Ceramics in the Scrape-Off Layer of WEST** — •B. DE MARTINO<sup>1</sup>, J. P. GUNN<sup>1</sup>, B. GUILLERMIN<sup>1</sup>, D. MAZON<sup>1</sup>, A. CASNER<sup>2</sup>, L. CIUPIŃSKI<sup>3</sup>, and G. KOMOROWSKA<sup>3</sup> — <sup>1</sup>CEA, IRFM, F-13108 St-Paul-Lez-Durance, France — <sup>2</sup>Université de Bordeaux, CNRS, CEA, CELIA (Centre Lasers Intenses et Applications), UMR 5107, F-33405 Talence, France — <sup>3</sup>Warsaw University of Technology, Faculty of Materials Science and Engineering, Woloska 141, 02-507 Warsaw, POLAND

The WEST tokamak Scrape-Off Layer (SOL) is equipped with mobile Langmuir probes that can be fitted with sample holders, enabling controlled exposure of materials to extreme heat ( $10^6 - 10^8$  W/m<sup>2</sup>) and ion fluxes ( $10^{22} - 10^{24}$  m<sup>-2</sup> s<sup>-1</sup>). Two dedicated experiments were carried out to investigate the thermal response and ablation dynamics of High-Temperature Ceramics, using hydraulically and magnetically driven devices that target respectively the lower and upper ends of the accessible flux range. With the magnetically driven device, installed in the lower divertor, ablation of a SiC sample was achieved under strike-point fluxes. Strong Si emission lines are detected in VUV and visible spectroscopy immediately after exposure, indicating high sublimation rates. Divertor upper-view IR imaging shows saturation of the sample temperature, consistent with a phase change. The average parallel heat flux is estimated at 45 MW/m<sup>2</sup>, with plasma conditions fully characterised by in-situ diagnostics. Post-mortem analyses enable the characterisation of the damage undergone by the exposed samples.

The full authors list will be presented in the talk.

P 6.2 Tue 11:30 KH 01.020

**Experimental Investigations Of Hydrogen Isotope Interaction In Laboratory Boron Coatings** — •EDUARD WARKENTIN<sup>1,2</sup>, ANNE HOUBEN<sup>1</sup>, MARCIN RASINSKI<sup>1</sup>, SÖREN MÖLLER<sup>3</sup>, HANS RUDOLF KOSLOWSKI<sup>1</sup>, TIMO DITTMAR<sup>1</sup>, MARC SACKERS<sup>1</sup>, ARKADI KRETER<sup>1</sup>, TOM WAUTERS<sup>4</sup>, BERNHARD UMBERG<sup>1,2</sup>, and CHRISTIAN LINSMEIER<sup>1,2</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institut of Fusion Energy and Nuclear Waste Management - Plasma-physics (IFN-1), Jülich 52425, Germany — <sup>2</sup>Ruhr-Universität Bochum, Faculty of Physics and Astronomy, Bochum 44801, Germany — <sup>3</sup>Forschungszentrum Jülich GmbH, Institute of Energy Materials and Devices, Materials Synthesis and Processing (IMD-2), 52425 Jülich, Germany — <sup>4</sup>ITER Organization, Route de Vinon-sur-Verdon, CS 90 046 13067, St. Paul Lez Durance Cedex, France

Due to the change of the ITER first wall material from Be to W, oxygen and other impurities in the vessel are not sufficiently getterd by a W wall. A thin amorphous boron layer, which is applied via glow discharge boronization during the regular wall conditioning phase, can reintroduce impurity gettering and a more efficient plasma operation can be obtained. In order to investigate hydrogen retention and permeation of mixed boron coatings, B:D layers were fabricated by

magnetron sputter deposition on W and steel substrates. After characterization, the gas driven deuterium permeation flux was measured and the layer permeability was obtained. B:D coated samples were exposed to different deuterium plasma in order to investigate retention via nuclear reaction analysis and thermal desorption spectroscopy.

P 6.3 Tue 11:45 KH 01.020

**Characterization of the strike lines in the Wendelstein 7-X stellarator** — •SEBASTIAN DRÄGER<sup>1,2</sup>, THIERRY KREMEYER<sup>1</sup>, YU GAO<sup>1</sup>, FELIX REIMOLD<sup>1</sup>, and ROBERT WOLF<sup>1,2</sup> — <sup>1</sup>Max Planck Inst. for Plasma Physics, 17491 Greifswald, Germany — <sup>2</sup>Technical University of Berlin, Strasse des 17. Juni 135, 10623 Berlin, Germany

Magnetic confinement fusion power plants need for sustaining operation an efficient plasma exhaust. After heating the plasma, removal of fusion products is necessary or a steady-state can't be maintained. Even for today's experiments, density control via particle removal is valuable. Inside a device like Wendelstein 7-X (W7-X), the ionized particles of the plasma are confined by the magnetic field. An exhaust can only be accomplished after their neutralization. Therefore, in a divertor system, diverted field lines carry plasma away from the confining toroid onto target plates. Such a diversion can be achieved through X-points, -lines, or -loops. At W7-X, X-loops are created through a resonance on rational rotational transform surfaces, resulting in magnetic islands. The field lines of these islands, especially their separatrix, are intersected by the divertor target plates. At the intersection the ionized particles neutralize. Strike lines, high-intensity regions, emerge on the target surface. Here the divertor needs to sustain the incoming plasma heat flux. Unexpected changes in the flux topology may lead to a reduction in the exhaust efficiency or a risk of the divertor's integrity. To better understand and predict the strike lines behavior a set of experiment programs were evaluated. A full characterization of the strike lines dimensions and magnitudes was accomplished.

P 6.4 Tue 12:00 KH 01.020

**Vision transformer based model regression for plasma exposed surface structures** — •TORBEN SCHMITZ<sup>1,2</sup>, DIRK REISER<sup>1</sup>, JOSE IGNACIO ROBLEDÓ<sup>3</sup>, and SEBASTIJAN BREZINSEK<sup>1,2</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management Plasma Physics, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — <sup>2</sup>Faculty of Mathematics and Natural Sciences, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany — <sup>3</sup>Forschungszentrum Jülich GmbH, Jülich Supercomputing Centre, 52425 Jülich, Germany

Exposing a surface to an ion beam or plasma leads to erosion and the development of surface structures on the nanoscale. Such nanostructures have been ob-



served on tungsten samples exposed to plasma in magnetic confinement devices. A convenient description of the evolution of these structures is possible using a Kuramoto-Sivashinsky (KS) type model whose parameters we aim to infer for given experimental data. There exist previous approaches to this problem, one training a regression model on the Fourier transform of the surfaces, another using pretrained convolutional neural networks, finetuned on the regression task. We propose a different approach using the vision-transformer architecture and including additional input features to the training process. We show that training the model on our KS dataset leads to good predictive performance. We present details of the method and results on our synthetic (simulated) dataset. The results show the capability of our architecture to understand and extract information from fusion relevant surface structures.

P 6.5 Tue 12:15 KH 01.020

**Investigation on the Limitations of Liquid Metal Heat Pipes for Fusion Applications by Thermal Resistance Modeling** — •MAX VONCKEN<sup>1,2</sup>, MENNO BAKKER<sup>2</sup>, SEYEDMOHAMMAD VAFAEI<sup>2</sup>, YIRAN MAO<sup>2</sup>, ALEXIS TERRA<sup>2</sup>, JAN

WILLEM COENEN<sup>2</sup>, and CHRISTIAN LINSMEIER<sup>2</sup> — <sup>1</sup>Eindhoven University of Technology, Power&Flow Group, Department of Mechanical Engineering, Groene Loper 3, 5612 AE Eindhoven, Netherlands. — <sup>2</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics (IFN-1), Jülich 52425, Germany

Liquid metal heat pipes (LMHPs) can manage extreme heat fluxes with exceptionally high thermal conductivity. This capability makes them a promising alternative to conventional monoblocks for cooling plasma-facing components (PFCs) in the divertor region of magnetic confinement fusion devices. In this study, the thermal limitations of sodium and lithium as candidate working fluids and viable design parameter ranges for the envelope, such as diameter, length, and wall thickness, are identified. This has been achieved by a relatively simplified model of thermal resistance, employed as a fast pre-design tool prior to detailed CFD simulations. The developed model is also used to evaluate the thermal performance of a commercially available LMHP, and it is validated against the experiments.

## P 7: Magnetic Confinement III

Time: Tuesday 16:15–18:55

Location: KH 02.016

### Invited Talk

P 7.1 Tue 16:15 KH 02.016

**Post-puff SOL broadening on MAST-U: evidence for cross-field transport changes** — •YACOPO DAMIZIA<sup>1</sup>, SASKIA MORDJICK<sup>1</sup>, NICK WALKDEN<sup>2</sup>, JACK LOVELL<sup>3</sup>, STEVEN THOMAS<sup>4</sup>, and EKIN OZTURK<sup>1</sup> — <sup>1</sup>William & Mary, Williamsburg, VA, USA — <sup>2</sup>UKAEA, Culham Campus, Abingdon, Oxfordshire, OX14 3DB, UK — <sup>3</sup>Oak Ridge National Laboratory, Oak Ridge, TN, USA — <sup>4</sup>MIT Plasma Science and Fusion Center, Cambridge, MA, USA

We test whether density shoulder formation and evolution in the MAST-U scrape-off layer are governed by parallel draining or cross-field transport. Two L-mode discharges with similar parameters each receive a 50 ms deuterium puff and are measured with Thomson scattering,  $D\alpha$  and Langmuir probes. In both cases the divertor stays attached/high recycling while an upstream shoulder forms, but its post-puff decay is much slower in the lower upstream collisionality shot, indicating that shoulder persistence is set by modified cross-field transport rather than parallel draining.

P 7.2 Tue 16:45 KH 02.016

**Gyrokinetic studies in pedestal plasmas** — •FACUNDO SHEFFIELD<sup>1</sup>, TOBIAS GOERLER<sup>1</sup>, GABRIELE MERLO<sup>1</sup>, LIDIJA RADOVANOVIC<sup>2</sup>, FELIX WILMS<sup>1</sup>, ELISABETH WOLFRUM<sup>1</sup>, CLEMENTE ANGINI<sup>1</sup>, FRANK JENKO<sup>1</sup>, and THE ASDEX UPGRADE TEAM<sup>3</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstraße 2, Garching, Germany — <sup>2</sup>Institute of Applied Physics, TU Wien, Fusion@ÖAW, Wiedner Hauptstr. 8-10, Vienna, Austria — <sup>3</sup>See author list of H. Zohm et al, <https://doi.org/10.1088/1741-4326/ad249d>

The pedestal region in tokamak plasmas plays a critical role in determining overall confinement and performance. However, given the steep pressure gradients, high shaping and the interplay between several transport channels, the rich physics of the pedestal remains to be fully understood.

We therefore aim to shed light into key aspects of pedestal physics with high fidelity gyrokinetic simulations using the GENE and GENE-X codes. First we showcase the implementation and importance of parallel magnetic fluctuations in global pedestal simulations. Then, we study electron-scale pedestal instabilities propagating in the ion diamagnetic direction and show how they are still electron temperature gradient modes despite their unusual drift direction. Finally, we focus on the effects of shaping on the pedestal via changes in turbulent transport at multiple scales. Overall, our work advances the understanding of pedestal microinstabilities, clarifies the role of pedestal shape in turbulent transport, and showcases the relevance of parallel magnetic fluctuations in these systems.

P 7.3 Tue 17:10 KH 02.016

**Reduced Models for Turbulent Transport in W7-X** — •DON LAWRENCE CARL AGAPITO FERNANDO<sup>1</sup>, IONUT-GABRIEL FARCAȘ<sup>2</sup>, GABRIELE MERLO<sup>1</sup>, ALEJANDRO BAÑÓN NAVARRO<sup>1</sup>, and FRANK JENKO<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Garching, Germany — <sup>2</sup>Virginia Tech, Blacksburg, Virginia, USA

High-fidelity, first-principles simulations have become indispensable for understanding the complex turbulence dynamics in fusion plasmas. However, their high computational cost limits their use for rapid profile prediction, parameter scans, and optimization studies. This motivates the development of reduced models with robust predictive accuracy.

Here, we present reduced models for turbulent heat and particle fluxes in W7-X. These models are constructed from a database of adiabatic-ion electron-scale and kinetic-electron ion-scale simulations generated with the GENE-KNOSOS-Tango framework, supplemented by a number of simulations driven by a structure-exploiting sparse grid approach. An active-learning algorithm

was used to identify the most informative data points for model construction and regression.

The resulting models depend on key plasma parameters such as normalized temperature gradients, the ratio of temperature to density gradients, and the  $E \times B$  shear. Model predictions show good agreement with reference gyrokinetic fluxes within the training domain and at additional test positions. We also investigate strategies to generalize the models across arbitrary radial positions. These turbulent transport models for W7-X paves the way for faster profile prediction and reduces the computational effort of simulation-heavy workflows.

### 5 min break

P 7.4 Tue 17:40 KH 02.016

**GENE-X edge/SOL gyrokinetic turbulence simulations with fluid neutrals** — •SABINE OGIER-COLLIN, PHILIPP ULBL, WLADIMIR ZHOLOBENKO, and FRANK JENKO — Max-Planck Institute for Plasma Physics, Garching bei München, Germany.

In magnetic confinement fusion devices, the plasma edge and scrape-off layer (SOL) is not fully ionised. Neutral particles, by interacting with the plasma, affect radial profiles, gradient-driven instabilities, particle transport across the separatrix, and blob dynamics in the SOL. Understanding these processes is critical for optimising reactor core performance while ensuring efficient heat and particle exhaust.

We present the neutrals extension of GENE-X, a first-principles gyrokinetic turbulence code for edge and SOL transport in realistic magnetic geometries. This extension couples GENE-X's continuum full-f electromagnetic, collisional plasma model to a neutrals density evolution equation, as a first step towards a comprehensive neutrals fluid description. Charge-exchange reactions are modelled using a diffusion equation, and specially tailored conservative Krook operators have been derived for ionisation, recombination, and associated radiation.

Relaxation studies of electrons, deuterium ions, and deuterium atoms enable isolation of the effect of each coupling term on equilibration dynamics and plasma velocity-space structure. We also present first turbulence simulations in diverted geometry, targeting validation against the TCV-X21 dataset. This development enables gyrokinetic-level studies of how neutrals influence plasma turbulence in reactor-relevant regimes.

P 7.5 Tue 18:05 KH 02.016

**Microtearing mode turbulence and its role in high-density-gradient plasmas in Wendelstein 7-X** — •HUGO ISAAC CU-CASTILLO<sup>1</sup>, ALEJANDRO BAÑÓN NAVARRO<sup>1</sup>, GABRIELE MERLO<sup>1</sup>, FELIX REIMOLD<sup>2</sup>, THILO ROMBA<sup>2</sup>, OLIVER FORD<sup>2</sup>, SEBASTIAN BANNMANN<sup>2</sup>, MARKUS WAPPL<sup>2</sup>, JOACHIM GEIGER<sup>2</sup>, LILA VANO<sup>2</sup>, ALESSANDRO ZOCCO<sup>2</sup>, and FRANK JENKO<sup>1</sup> for the w7-x team-Collaboration — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — <sup>2</sup>Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Following the successful optimization of the stellarator Wendelstein 7-X (W7-X) to reduce neoclassical transport, microturbulence prevails as the primary transport mechanism limiting its plasma confinement.

Using the gyrokinetic code GENE, we demonstrate that Microtearing Modes (MTMs) dominate turbulent transport in a W7-X experimental scenario with high  $a/L_{n_i}$ , corresponding to a plasma heated purely by only Neutral Beam Injection. The appearance of MTMs is attributed to the absence of competing instabilities under these plasma conditions and the stabilizing influence of the nearly max- $J$  configuration of W7-X. Additionally, moderate collisionality and low magnetic shear further enable the appearance of MTM. Our simulations

show that, when MTM turbulence dominates, they reproduce additional experimental signatures observed in W7-X plasmas with  $a/L_{ne} > 1$ : (i) the turbulent heat flux is unaffected by the density gradient, and (ii) the electron heat channel by far exceeds the ion channel.

P 7.6 Tue 18:30 KH 02.016

**Geometry-dependent energetic bounds on gyrokinetic instabilities** — •PAUL COSTELLO and GABRIEL PLUNK — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

Outward turbulent transport of heat and particles largely dictates the necessary size of a viable tokamak or stellarator power plant. This turbulence is initiated by micro-scale plasma instabilities that are driven by the radial gradients of temperature and density in the plasma. Gyrokinetic theory forms the basis of our understanding of these instabilities, and gyrokinetic simulations are a relied-upon,

albeit expensive, tool for computing their growth rates. Here, we present a complementary approach to understanding linear instabilities: constructing energetic upper bounds on instability growth. These upper bounds are computed via a variational principle by seeking perturbations that maximize the extraction of free energy from the plasma gradients. In many cases, these upper bounds are governed by a low-dimensional system of equations, while still capturing the dependence of the linear growth rate on key parameters. We demonstrate methods to include magnetic geometry into the upper bound analysis through two main pieces of work. Firstly, we consider the effect of including trapped electrons in the analysis, finding a new stabilising mechanism possessed by quasi-isodynamic stellarators. Secondly, we present a method by which the upper bound can systematically be made tighter to the linear growth rate. We highlight the potential applicability of this approach to the optimisation of stellarators to reduce turbulent transport.

## P 8: Low Pressure Plasmas II

Time: Tuesday 16:15–18:45

Location: KH 01.020

### Invited Talk

P 8.1 Tue 16:15 KH 01.020

**Near-plasma Chemical Surface Engineering** — •PAULA NAVASCUÉS and DIRK HEGEMANN — Empa, St. Gallen, Switzerland

The possibility of avoiding ion bombardment during plasma surface engineering, while simultaneously benefiting from the contribution of reactive plasma species, is a targeted objective for materials processing. In this context, we have recently developed a new experimental strategy called near-plasma chemical (NPC) surface engineering. By introducing a polymeric mesh between the substrate and the plasma, close to the plasma-sheath boundary, charged particles are attracted to the mesh. As a result, unlike direct plasma exposure, high-energy deposition at the sample surface can be mitigated without modifying the plasma properties. The beneficial impacts of NPC have been demonstrated for plasma activation of polymers to enhance wettability and durability, as well as for the deposition of thin films via plasma polymerization. Furthermore, NPC can prevent dust deposition onto the samples, even in highly dusty plasmas, resulting in smooth surfaces at the nanoscale. In this talk, the main aspects explored by our group and our collaborators for Near-plasma Chemical Surface Engineering will be presented, as well as different applications of surface modification and thin film deposition using this approach.

P 8.2 Tue 16:45 KH 01.020

**Systematic investigations of static and dynamic effects determining the performance of the ELISE negative ion source in H and D** — •JOEY RUBIN, DIRK WÜNDERLICH, and URSEL FANTZ — Max Planck Institute for Plasma Physics - Boltzmannstrasse 2, 85748 Garching-bei-Munchen

The ELISE negative ion source is designed to meet the requirements of ITER's NBI system: deliver high negative ion currents  $I_{ext}$  in hydrogen (H)/deuterium (D) for up to 1h, keeping an acceptable co-extracted electron current  $I_e$ , high beam uniformity and low divergence.

A major challenge is the rapid rise of  $I_e$  during pulses, more pronounced in D (isotope effect). Previous campaigns showed that static (set directly by source parameters) and dynamic (time- and location-dependent plasma and surface processes, arising from the presence of Cs and its own behavior) effects contribute to the evolution of  $I_e$ . A mechanism explaining the observed increase of  $I_e$  was proposed, based on datasets collected over multiple campaigns with varying source configurations. A dedicated campaign was carried out in which ELISE was operated with full diagnostic coverage, stable caesium conditioning and closely matched driver plasma densities in H and D. Systematic scans of the operational parameters were performed for short (10 s) and long (300 s) pulses, enabling to separate static and dynamic contributions.

The results show that: the isotope effect is prominent in caesium density, extracted currents and beam divergence; the proposed mechanism for the dynamic rise of  $I_e$  is overall valid; beam divergence and uniformity do not simply correlate with plasma parameters.

P 8.3 Tue 17:10 KH 01.020

**Plasma Sheath Tailoring for Advanced 3d Plasma Etching: Emission, Excitation and Etching Properties of a CCP Discharge** — •NIKLAS EICHSTAEDT, ELIA JÜNGLING, MERET NÜRNBERG, MARC BÖKE, and ACHIM VON KEUDELL — Ruhr University Bochum, Germany

Three-dimensional plasma etching plays a crucial role in the fabrication of microstructures for advanced technological applications. The control and targeted manipulation of the ion density and flux are necessities to create three-dimensional structures. Previously, it has been demonstrated for an  $Ar/CF_4$  plasma that the inclusion of a localized magnetic field leads to asymmetric etching profiles with dependencies on various factors, including the applied bias voltage. This has been attributed to ExB-drift.

However, the exact mechanisms, especially regarding the plasma dynamics, are still unclear. To address this issue, the temporal development and the steady-state shape of an asymmetrical plasma sheath of a capacitively coupled plasma were examined using time-resolved as well as time-integrated optical emission spectroscopy. These sheath geometries, as well as the resulting etching rates and profiles, are compared between different experimental parameters such as the bias voltage, the mask geometries and the material of the surface ( $Si$  or  $SiO_2$ ). Based on those observations, we proposed a model explaining the influence of the observed plasma dynamics on the etching profiles.

P 8.4 Tue 17:25 KH 01.020

**Holographic optical tweezers for dusty plasmas** — PASCAL KÖNIG, NATASCHA BŁOCZYK, and •DIETMAR BLOCK — IEAP der CAU, 24098 Kiel, Germany

Dusty plasmas are well suited to study strongly coupled systems, because they allow to study their structure and dynamics at an individual particle level. To manipulate their dynamics, lasers are a very versatile tool. Laser heating as well optical tweezers have been realized in the past. This contribution will show first results of a new approach, which promises a new level of particle manipulation. We replaced the conventional optics of our tweezers with Fourier optics. A spatial light modulator allows to map arbitrary holograms to a dust cloud. We present such a holographic setup and show that it allows to tweeze particles. Based on examples, the potential of this new manipulation tool is shown and compared to conventional laser tweezers.

### 5 min break

P 8.5 Tue 17:45 KH 01.020

**Nanosecond discharges at high reduced electric fields as a tool for measuring energy efficiency (G-values)** — •INNA OREL<sup>1,2</sup>, YOUSSEF HAOUCHAT<sup>1,3</sup>, TAT LOON CHNG<sup>1,4</sup>, and SVETLANA STARIKOVSKAIA<sup>1</sup> — <sup>1</sup>Laboratory of Plasma Physics (CNRS, Ecole Polytechnique, University Paris-Sud, Observatoire de Paris, Sorbonne Université, Université Paris-Saclay, IPP), Palaiseau, France — <sup>2</sup>Ruhr University Bochum, Institute for Plasma and Atomic Physics, Bochum, Germany — <sup>3</sup>Biomedical Imaging Group, Ecole polytechnique federale de Lausanne, Lausanne, Switzerland — <sup>4</sup>Department of Mechanical Engineering, College of Design and Engineering, National University of Singapore, Singapore

We examine N-atom production in a pure  $N_2$  cylindrically symmetric, nanosecond, repetitively pulsed discharge at moderate pressure and high reduced electric field (E/N). Two specific energy deposition (SED) cases - 1 eV/molecule and  $10^{-2}$  eV/molecule - are investigated. On-axis N-atom densities are obtained using two-photon absorption laser-induced fluorescence (TALIF), and SED values are derived from voltage waveforms measured with back-current shunts. Radial species distributions are included in the analysis. The experimental G-values are compared with kinetic modelling. The results highlight the suitability of nanosecond discharges for studying dissociation efficiency at high reduced E/N.

P 8.6 Tue 18:00 KH 01.020

**The influence of the electrode material on rf plasma sheaths observed by force measurements on optically trapped microparticles** — •PHILIPP NAUDIET, JESSICA NIEMANN, VIKTOR SCHNEIDER, and HOLGER KERSTEN — Institute of Experimental and Applied Physics (IEAP), Kiel University

Using optically trapped microparticles, the sheath of a plasma can be probed in a non-invasive way. To investigate the effects of secondary electron emission from the surface of the electrode on the sheath of a capacitively coupled radio frequency plasma, the force upon single optically trapped microparticles was tracked along a path from the bulk of the plasma through the sheath towards the electrode. These measurements were carried out for electrodes made of stainless

steel, aluminium, titanium and glass-ceramic, under a range of different argon gas pressures and rf voltages.

We observe significant changes in the electric field force onto the microparticle depending on the electrode material. We attribute the changes in the location of the sheath edge and the forces onto the particle to the emission of secondary electrons from the surface of the electrode, and resulting changes of the particle's charge.

P 8.7 Tue 18:15 KH 01.020

**Characterizing pure electron plasmas with an electron beam diagnostic in a levitating dipole trap** — •VERONIKA BAYER<sup>1</sup>, ADAM DELLER<sup>1,2</sup>, ALEX CARD<sup>1</sup>, PATRIK STEINBRUNNER<sup>1</sup>, MATTHEW STONEKING<sup>3</sup>, and EVE STENSON<sup>1</sup> — <sup>1</sup>Max Planck Institut für Plasmaphysik, Garching b München — <sup>2</sup>University of California San Diego, San Diego, CA, USA — <sup>3</sup>Lawrence University, Appleton, WI, USA

Electric fields play a dominant role in the dynamics of pure electron non-neutral plasmas (NNPs), such as those studied in the APEX levitating dipole trap (APEX-LD). Multiple different, ideally non-invasive, diagnostics verify the presence of a plasma and determine the confinement time. Existing diagnostics are able to confirm the presence of plasma, as long as the plasma density changes. A new electron beam diagnostic, which can detect plasma regardless of density perturbation is implemented on a levitating dipole; and first results from this diagnostic are presented. Electrons are emitted by this diagnostic onto a field line passing through the center of the floating coil and are collected on

the opposite side. As plasmas become trapped within the magnetic field lines of APEX-LD, the resulting space charge potential can reflect the electron beam; the collected current therefore provides a way to determine the potential of the trapped plasma.

P 8.8 Tue 18:30 KH 01.020

**Characterization of three-dimensionally extended dust clouds containing active particles under microgravity** — •STEFAN SCHÜTT, CHRISTINA KNAPEK, DANIEL MAIER, DANIEL MOHR, and ANDRÉ MELZER — University of Greifswald, Greifswald, Germany

It was found that metal-coated melamine formaldehyde particles suspended in an rf plasma can exhibit active behavior when they are illuminated by lasers. Inhomogeneities and defects of the coating lead to the emergence of photophoretic forces, resulting in a behavior similar to Janus particles. In laboratory experiments, a fraction of 10 to 20 % of the particles showed such active behavior.

Here, silver and gold-coated particles were used in the Zyflex chamber on parabolic flights. The setup allowed to study void-free extended dust clouds with minimal external stress. A section of the dust cloud was observed with a stereoscopic four-camera setup, allowing to reconstruct particle trajectories in three dimensions. A characterization of the active dust clouds using the three-dimensional data will be presented in this contribution, including velocity distributions as well as other statistical measures.

This work was funded by DLR (German Aerospace Center) grants 50WM2161 and 50WM2561.

## P 9: Low Pressure Plasmas III

Time: Wednesday 11:00–12:30

Location: KH 01.020

### Invited Talk

P 9.1 Wed 11:00 KH 01.020

**Controlling spokes in magnetron sputtering discharges** — •MARTIN RUDOLPH — Leibniz Institute of Surface Engineering (IOM), Leipzig, Germany  
Spokes in magnetron sputtering discharges are zones of enhanced excitation and ionization that rotate along the racetrack. Their visible properties like intensity and velocity are known to depend sensitively on discharge conditions. Very intense spokes appear under conditions of strong magnetic field and low working gas pressure. In this case, spokes stand out strongly with their high emission intensity against a relatively dim background along the racetrack. This suggests that the properties of film-forming species depositing onto a substrate is dominated by the presence of spokes. The control of spoke properties may thus be an additional means to tailor the particle flux and fine-tune thin film properties. In this contribution, we discuss how such a control can be achieved using typical process parameters. We show that spoke intensity can be tuned by adjusting the working gas pressure. Moreover, we demonstrate the deliberate excitation of spokes at a defined location by introducing a step in the magnetic field strength along the racetrack. Finally, we show that spoke velocities can be adjusted using the working gas pressure and discharge current with lower velocities observed at higher gas pressures and lower discharge currents. The controlled manipulation of spokes may in the future enable spokes engineering allowing thin film properties to be tailored through deliberate tuning of spoke characteristics.

P 9.2 Wed 11:30 KH 01.020

**Metal-coated plastic spheres in dusty plasmas as active particles** — •ANDRÉ MELZER, TOBIAS MARDER, STEFAN SCHÜTT, HORST-HOLGER BOLTZ, THOMAS IHLE, CHRISTINA KNAPEK, DANIEL MAIER, and DANIEL MOHR — Institute of Physics, University of Greifswald, Greifswald, Germany

The dynamical properties of metal-coated dust microspheres confined in a gaseous plasma environment have been studied. It has been observed that such particles feature properties of active particles and that the particle activity changes over time and increases with the intensity of laser illumination. The dynamics of single particles as well as of small particle clusters have been analyzed quantitatively with various statistical methods to characterize their activity. Furthermore, clusters of metal-coated microspheres are observed to undergo a phase transition from an ordered to an unordered structure under increased laser illumination intensity due to the increased active motion of the particles.

P 9.3 Wed 11:45 KH 01.020

**Global Clebsch coordinates for rectangular magnetron fields** — •RALF PETER BRINKMANN, DENNIS KRÜGER, JENS KALLÄHN, KEVIN KÖHN, LUKAS VOGELHUBER, YULIA SHAROVA, LIANG XU, and DENIS EREMIN — Ruhr-University Bochum

Large-scale rectangular magnetrons are the workhorses of modern high-throughput coating and other plasma-processing applications. This work introduces a tool to assist in the theoretical modeling and numerical simulation of such devices: global Clebsch coordinates [1]. Focusing on the region above the cathode, the magnetic field  $\mathbf{B}(\mathbf{r})$  is shown to admit a divergence-free Clebsch formulation  $\mathbf{B} = \nabla\psi \times \nabla\vartheta$ , where  $\psi(\mathbf{r})$  is a magnetic flux func-

tion whose constant values define nested flux surfaces, and  $\vartheta(\mathbf{r})$  is a generalized azimuth labeling individual magnetic field lines. A third coordinate  $S(\mathbf{r})$  measures the arc length along field lines and provides a natural parameterization. The triplet  $(\psi, \vartheta, S)$  defines a system of field-aligned flux coordinates suited for describing plasma behavior in large rectangular magnetrons. The topological and geometrical principles of this construction are discussed and illustrated with a realistic rectangular magnetron field. The resulting mathematical framework provides a rigorous foundation for self-consistent modeling and simulation of plasma dynamics in field-aligned flux coordinates, with direct relevance to industrial-scale plasma processing.

P 9.4 Wed 12:00 KH 01.020

**Characterization of millimeter-sized low-pressure argon plasmas in aeroglass** — KARIN HANSEN<sup>1</sup>, JONAS LUMMA<sup>2</sup>, RAINER ADELUNG<sup>2</sup>, and •FRANKO GREINER<sup>1</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — <sup>2</sup>Department of Materials Science, Kiel University, Kiel, Germany

Electrodes and other solid boundaries are invariably separated from the plasma by a layer known as the plasma sheath. Depending on the discharge pressure, this sheath has a minimum thickness on the order of the electron Debye length. The intrinsic properties of the material and its surface structure may affect the plasma. Macroscopic gaps in the surface are only filled with plasma if their size is comparable to the sheath thickness. To study how plasma-facing walls made from aeroglass[1] influence the characteristics of a low-pressure argon discharge, we generated a plasma inside a millimeter bore in an aeroglass cylinder with a height of 8 mm and a diameter of 8 mm. Since the ratio of interface area to plasma volume increases as the bore radius decreases, any influence of the aeroglass should become observable for these small systems. Plasma diagnostics were carried out using electrostatic double probes. At discharge pressures of about 1000 Pa, we observed a high-density plasma mode that does not occur with conventional wall materials.

[1] Lena M. Saure et al., ACS Nano 2023, 17, 22, 22444\*22455, DOI: 10.1021/acsnano.3c05329

P 9.5 Wed 12:15 KH 01.020

**Ion energy dependence of plasma TMDC modifications** — •LUKA HANSEN<sup>1,2</sup>, MARKUS BORCHARDT<sup>1</sup>, ULRICH SCHÜRMANN<sup>2,3</sup>, CHITHRA H. SHARMA<sup>1</sup>, KAI ROSSNAGEL<sup>1,2</sup>, LORENZ KIENLE<sup>2,3</sup>, and JAN BENEDIKT<sup>1,2</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — <sup>2</sup>Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany — <sup>3</sup>Department of Materials Science, Kiel University, Kiel, Germany

Transition metal dichalcogenides (TMDCs) are two-dimensional quantum materials that could enable future technologies such as qubits or next-generation semiconductors [1]. While their intriguing electronic and structural properties have been studied extensively, questions remain about how to effectively tune these properties.

Plasma is a powerful TMDC tuning tool; e.g., it can etch multilayer systems to monolayer sheets [2]. However, the underlying plasma-TMDC interaction is

not well understood. To gain more insight into these processes, we use a low-pressure reactor with inverted geometry [3], which enables us to control the ion fluxes and energies individually. Ion mass spectrometry allows us to characterize these fluxes and detect ions originating from the TMDC *in operando* as a signature of crystal decomposition. This approach will help identify plasma con-

ditions under which TMDCs can be modified while preserving their structural integrity.

- [1] K. S. Novoselov *et al.*, 2016 *Science* **353** aac9439
- [2] A. Varghese *et al.*, 2017 *Nanoscale* **9** 3818
- [3] C. Schulze *et al.*, 2022 *Plasma* **5** 295-305

## P 10: High Energy Density Physics I

Time: Wednesday 11:00–12:30

Location: KH 02.016

### Invited Talk

P 10.1 Wed 11:00 KH 02.016

**Laser fusion activities in Germany - applications in planetary and stellar astrophysics and experiments at high-power laser facilities** — •DOMINIK KRAUS — University of Rostock, Rostock, Germany — Helmholtz-Zentrum Dresden-Rossendorf

Research in the field of laser-driven inertial fusion ("laser fusion") has gained significant momentum following the achievement of the Lawson criterion for fusion ignition at the National Ignition Facility, triggering substantial public and private investment worldwide, including in Germany.

Despite this progress, a detailed understanding of the complex physical processes along the compression pathway toward inertial fusion plasmas remains essential for the realization of laser fusion as a practical energy source. The most widely pursued laser fusion schemes begin with the compression of the ablator and deuterium-tritium fuel to megabar pressures, corresponding to conditions similar to those found in planetary interiors. This stage is followed by a quasi-isentropic compression to gigabar pressures, reaching regimes comparable to stellar interiors. Both phases fall within the regime of so-called warm dense matter, which remains only partially understood.

This talk will review current developments and key challenges in laser fusion research and outline potential contributions from experimental facilities in Germany. In addition, selected examples will demonstrate how these facilities can be used to advance our understanding of dense astrophysical plasmas.

P 10.2 Wed 11:30 KH 02.016

**Recent advances in the operation of nano-accelerators towards IFE applications** — •FABIAN BATSCHE<sup>1</sup>, DANIEL RIVAS<sup>1</sup>, MARIUS S. SCHOLLMEIER<sup>1</sup>, GEORG KORN<sup>1</sup>, HARTMUT RUHL<sup>1</sup>, and OUR COLLABORATORS<sup>2</sup> — <sup>1</sup>Marvel Fusion GmbH, Munich, Germany — <sup>2</sup>LMU Munich, Germany; ELI-NP, Romania; Thales LAS, France

We propose an alternative path towards inertial fusion energy (IFE) involving ultra-short pulse, petawatt-class lasers and nano-fabricated targets. These highly ordered nanowire arrays, or nano-accelerator (NA), can absorb laser pulses with intensities above  $10^{20}$  W/cm<sup>2</sup>, leading to a controlled and efficient energy transfer into radiation and kinetic particle energy. Optimal laser-solid interaction without pre-plasma formation is required for best performance of the NA, which requires ultra-high temporal laser contrast ( $< 10^{-12}$  on ps timescales) that can be achieved through the strongly non-linear processes of either plasma mirrors or second-harmonic generation (SHG).

In this presentation we report on recent progress in the validation of the NA concept through experiments at two PW-class laser facilities: the influence of double plasma-mirrors and changes in nanowire parameters on the laser contrast, laser absorption and emitted particle spectra is studied at the Extreme Light Infrastructure for Nuclear Physics (ELI-NP, 800 nm, 10 PW). The scaling with laser wavelength will be evaluated through the second-harmonic of the ATLAS-3000 laser pulses at the Centre for Advanced Laser Applications (CALA, 400 nm, >25 J, 30 fs). First results on SHG conversion efficiency, focus quality and contrast improvements will be presented.

P 10.3 Wed 11:45 KH 02.016

**Fusion energy research at the European XFEL: Current capabilities and future perspectives** — •ULF ZASTRAU — European XFEL, Holzkoppel 4, 22869 Schenefeld, Germany

The European XFEL in Schenefeld near Hamburg provides unprecedented opportunities to study matter under extreme conditions relevant to inertial fusion energy (IFE). Recent workshops and studies have outlined a coordinated strategy to exploit XFEL capabilities for diagnosing high-energy-density (HED) plas-

mas, characterizing fusion-relevant targets, and benchmarking hydrodynamic and radiation-transport models. In my talk, I will present the current capabilities of the HED-HIBEF instrument together with a roadmap for fusion-energy research at the facility. The program emphasizes precision X-ray probing of laser-driven plasmas, the development of dedicated diagnostics and target platforms, and the integration of a multi-kJ high-power laser at a new XFEL beamline for next-generation fusion experiments. These efforts aim to establish the European XFEL as a central hub for cross-disciplinary fusion-energy research, bridging basic plasma physics and applied energy science.

P 10.4 Wed 12:00 KH 02.016

**Toward predictive modeling of Inertial Confinement Fusion plasmas** — •MICHAEL BONITZ, DANIELS KRIMANS, HANNO KÄHLERT, and CHRISTOPHER MAKAIT — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

In Inertial confinement fusion (ICF) hydrogen rapidly undergoes compression, heating and ionization. Simulations have to take into account simultaneously laser-matter interaction, shock propagation, and nuclear reactions. Moreover, the initial phase of the compression is strongly influenced by nonequilibrium carriers, electronic quantum effects, and Coulomb correlations. Despite the rapid recent progress in theory and simulation of dense plasmas and warm dense matter [1], presently, no method exists that reliably captures all these processes, and commonly used radiation-hydrodynamics simulations do not have predictive capability. In Ref. 2 a solution of this dilemma has been proposed: a smart combination of a variety of different simulations, together with a first-principles based downfolding approach. The starting point are quantum Monte Carlo simulations, in equilibrium [3], and quantum kinetic theory [4], in nonequilibrium. This should allow for predictive ICF simulations in the near future.

[1] M. Bonitz *et al.*, Phys. Plasmas **27**, 042710 (2020); [2] M. Bonitz *et al.*, Phys. Plasmas **31**, 110501 (2024); [3] A. Filinov and M. Bonitz, Phys. Rev. E **108**, 055212 (2023); [4] M. Bonitz, "Quantum Kinetic Theory", 2nd ed. Springer 2016

P 10.5 Wed 12:15 KH 02.016

**Equation of State and Electronic Transport Properties of Dense Liquid Hydrogen** — ARMIN BERGERMANN<sup>1</sup>, •UWE KLEINSCHMIDT<sup>2</sup>, SIEGFRIED H. GLENZER<sup>1</sup>, and RONALD REDMER<sup>2,3</sup> — <sup>1</sup>SLAC National Accelerator Laboratory, Menlo Park CA 94309, USA — <sup>2</sup>Institute of Physics, University of Rostock, D-18051 Rostock, Germany — <sup>3</sup>Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, D-01328 Dresden, Germany

We present extensive first-principles calculations of the equation of state and electronic transport properties of hydrogen across a wide density ( $0.2 < \rho < 70$  g/cm<sup>3</sup>) and temperature ( $10^3 < T < 10^6$  K) regime, encompassing conditions relevant to giant planet interiors, stellar envelopes, and inertial confinement fusion plasmas. The equation of state data recover the ideal-gas and fully ionized plasma limits. Electronic transport coefficients were obtained via the Kubo-Greenwood formalism. The electrical conductivity exhibits an inversion region near  $\rho \sim 1$ -10 g/cm<sup>3</sup>, where degeneracy and coupling parameters are of order unity, marking the transition from molecular to metallic hydrogen. The thermal conductivity rises monotonically with increasing density and temperature, bridging between the Wiedemann-Franz behavior in the degenerate regime and the Spitzer scaling in the classical limit. Comparisons with analytical models show good agreement within their respective validity regimes. Our data set provides a high-accuracy benchmark for warm dense hydrogen and a reliable reference for applications such as planetary modeling, stellar structure calculations, and ICF design.

## P 11: Magnetic Confinement IV

Time: Wednesday 13:45–15:50

Location: KH 02.016

## Invited Talk

P 11.1 Wed 13:45 KH 02.016

**Proxima Fusion - Building stellarators to power the future** — •JONATHAN SCHILLING — Proxima Fusion, Munich, Germany

Proxima Fusion is Europe's fastest-growing fusion company, building the first generation of fusion power plants using quasi-isodynamic (QI) stellarators - the clearest, most robust path to putting fusion on the grid. Proxima Fusion is the first spin-out from the Max-Planck-Institute for Plasma Physics and builds on the record-breaking successes of the Wendelstein 7-X stellarator. Its roadmap towards the peer-reviewed Stellaris commercial power plant concept progresses through demonstration milestones including the Stellarator Model Coil and the Alpha demonstration stellarator slated to achieve net energy gain in the early 2030s, culminating in a first-of-a-kind grid-connected fusion power plant within the 2030s. Assembling a world-class team from institutions such as Max Planck IPP, MIT, Google[X], SpaceX, and leading universities, and backed by significant public and private investment, Proxima Fusion accelerates fusion from scientific achievement to industrial-scale reality. Proxima Fusion collaborates across the European fusion ecosystem to solve physics, engineering, and systems-integration challenges, advancing stellarator design, high-performance magnets, and rapid prototyping toward fusion's transformative impact on global energy. This talk will give an overview of Proxima Fusion's roadmap and high-light recent achievements.

## Invited Talk

P 11.2 Wed 14:15 KH 02.016

**Equilibrium and stability in Wendelstein 7-X high beta plasmas** — •HENNING THOMSEN, CHRISTIAN BRANDT, CHARLOTTE BÜSCHEL, EDITH V. HAUSTEN, MARTIN C. KELLY, KIAN RAHBARNIA, PEDRO PONS VILLALONGA, SARA VAZ MENDES, KSENIA ALEYNIKOVA, GOLO FUCHT, and NIKLAS S. POLEI — MPI f. Plasmaphysik, Wendesteinstr 1, 17491 Greifswald

High plasma pressures, characterized by the plasma beta, are necessary for future stellarator fusion reactors. The Wendelstein 7-X stellarator (W7-X) has been optimized to achieve stable plasma conditions with a volume-averaged beta (the ratio of plasma pressure and external magnetic pressure) of up to  $\langle\beta\rangle \approx 5\%$ . In the recent campaigns, measurements of magnetic diagnostics and equilibrium reconstructions [1], as well as tomographic inversions of the plasma radiation in soft-X ray range in high beta plasmas ( $\langle\beta\rangle \lesssim 3\%$ ) have been used to experimentally validate this optimization goal. The measured outward shift of the flux surfaces (Shafranov-shift) is consistent with the predictions. Coherent mode activity has been observed [2] during high beta plasma phases. Pressure driven, non-ideal ballooning modes are possible candidates, since those instabilities were not included in the original optimization of the magnetic configuration of W7-X. A summary of the current status of high beta plasma investigations in the Wendelstein 7-X stellarator will be presented.

[1] E.V. Hausten et. al, this conference

[2] C. Büschel et. al, this conference

P 11.3 Wed 14:45 KH 02.016

**Mode activity during high plasma beta at the Wendelstein 7-X stellarator** — •CHARLOTTE BÜSCHEL, CHRISTIAN BRANDT, HENNING THOMSEN, KSENIA ALEYNIKOVA, KIAN RAHBARNIA, EDITH VICTORIA HAUSTEN, MARTIN CLIFTON KELLY, SARA VAZ MENDES, PEDRO PONS VILLALONGA, KAI-JAKOB BRUNNER, GOLO FUCHT, JENS KNAUER, EKKEHARDT PASCH, ANDREAS LANGENBERG, and W7-X TEAM — IPP Greifswald, Greifswald, Germany

During the last two campaigns of Wendelstein 7-X, starting in October 2024 and lasting until May 2025, high plasma  $\beta$  was achieved in three different plasma scenarios: injection of frozen hydrogen pellets, a combined heating scenario of NBI and ECRH, and operation at reduced magnetic field around 1.8 T. Averaged plasma  $\beta$  values up to  $\langle\beta\rangle = 3\%$  and core beta values of  $\beta_0 = 8.5\%$  were

reached. This contribution categorizes the different types of mode activity observed at high plasma  $\beta$  and focuses on the characterization of quasi-coherent modes in a frequency range of  $f = 20 - 60$  kHz. The mode analysis is based on the line-integrated photodiode signals from the soft X-ray multi-camera system installed in Wendelstein 7-X utilizing the high spatial and temporal resolution of 360 photodiodes arranged in one poloidal plane of the plasma. The analysis includes the determination of the poloidal mode number, the ballooning character, the radial location and the propagation direction of the mode. The mode characteristics are analyzed with respect to their correlations to general plasma parameters such as temperature, density and confinement time.

P 11.4 Wed 15:10 KH 02.016

**Fully global simulations of electromagnetic turbulence and pressure-driven instabilities in tokamaks and stellarators** — •YANN NARBUTT<sup>1</sup>, M. BORCHARDT<sup>1</sup>, T. HAYWARD-SCHNEIDER<sup>1</sup>, R. KLEIBER<sup>1</sup>, A. KÖNIES<sup>1</sup>, A. MISHCHENKO<sup>1</sup>, C. NÜHRENBURG<sup>1</sup>, J. RIEMANN<sup>1</sup>, E. SÁNCHEZ<sup>2</sup>, K. ALEYNIKOVA<sup>1</sup>, and A. ZOCCO<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany — <sup>2</sup>Laboratorio Nacional de Fusión, CIEMAT, Avda. Complutense 40, Madrid 28040, Spain

Magnetic confinement fusion experiments require high  $\beta = \langle p \rangle / (B^2 / 2\mu_0)$ , the ratio of plasma pressure to magnetic pressure, to access high performance. Moderate  $\beta$  can be beneficial reducing for ion-temperature-gradient (ITG) driven turbulence. Typically, however, as  $\beta$  is increased above certain thresholds, pressure-driven instabilities appear which can potentially drive strong outward directed heat fluxes. To investigate these regimes we use the global gyrokinetic code EUTERPE to simulate plasmas in stellarators and tokamaks. Linear and nonlinear simulations, in the stellarator Wendelstein 7-X, show an unexpected absence of such instabilities as well as a reduction of heat fluxes as  $\beta$  rises. Given these results, additional simulations are performed in a tokamak for further understand pressure-driven instabilities from the perspective of global codes. Here, agreement between global gyrokinetics and ideal magnetohydrodynamics confirms that with large values of  $\beta$  pressure driven instabilities can indeed arise. However, in some parameter regimes these appear to be mitigated by kinetic and MHD effects.

P 11.5 Wed 15:35 KH 02.016

**Transport investigations in pellet-fuelled plasmas of ASDEX Upgrade** — •FLORIAN GSCHOESSER, CLEMENTE ANGIONI, MICHAEL BERGMANN, EMILIANO FABLE, RAINER FISCHER, PETER LANG, BERNHARD PLOECKL, FEDERICO STEFANELLI, DIRK STIEGLITZ, GIOVANNI TARDINI, HARTMUT ZOHN, and ASDEX UPGRADE TEAM — Max Planck Institute for Plasma Physics, Garching, Germany Pellets are, for all practical purposes, the only way to fuel plasmas in a future fusion reactor. The injection of such a pellet, formed from cryogenic solid hydrogen, introduces large modifications to the plasma parameters, especially in density and temperature. The resulting momentary transition of the plasma into a non-stationary state leads to transport processes that will be investigated. This talk will focus mainly on two aspects: on one hand, it will address the experimental efforts to achieve reliable and robust profile measurements during a pellet injection; on the other hand, it will present an approach to derive information regarding the transport processes by comparing experimental observations (Thomson scattering, DCN interferometer, IDA) and simulation results (ASTRA). Progressing from lower to higher complexity, the following cases will be discussed: First, "single" repetitive pellet perturbations are analyzed. The second case deals with a high-density quasi-stationary phase, where strong fueling is applied. Finally, the transition from low to high density via a sudden injection of pellets at high frequency is discussed. Some first simulation results and conclusions will be presented.

## P 12: Atmospheric Pressure Plasmas I

Time: Wednesday 13:45–15:45

Location: KH 01.020

## Invited Talk

P 12.1 Wed 13:45 KH 01.020

**Modelling and analysis of DBDs for thin-film deposition at atmospheric pressure** — •MARJAN STANKOV<sup>1</sup>, LARS BRÖCKER<sup>2</sup>, CLAUS-PETER KLAGES<sup>2</sup>, MARKUS M. BECKER<sup>1</sup>, and DETLEF LOFFHAGEN<sup>1</sup> — <sup>1</sup>Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — <sup>2</sup>Institute for Surface Technology, Technische Universität Braunschweig, Braunschweig, Germany Dielectric barrier discharges (DBDs) at atmospheric pressure are widely used as plasma sources for thin film deposition. The quest for non-invasive diagnostic methods able to reveal the underlying physics in such applications of DBDs has led to modelling studies emerging as a powerful solution. This contribution provides an overview on how time-dependent, spatially one-dimensional

(1D-t) and two-dimensional (2D-t) fluid-Poisson models enable the investigation of the influence of Si-containing precursors like HMDS, HMDSO and TMS on the behaviour of argon DBDs in different configurations. The presentation focuses on 1D-t modelling findings on the importance of Penning ionisation of precursor molecules by excited Ar states for electron production. It highlights the outcomes of the analysis of particle surface fluxes, identifying ions as the primary contributors to deposition in discharges with a short gas residence time. It also shows how the 2D-t modelling can explain a unique discharge mode experimentally observed in the presence of small amounts of precursors. The work is funded by the Deutsche Forschungsgemeinschaft – project no. 504701852.

P 12.2 Wed 14:15 KH 01.020

**The Influence of Floating Materials on Streamer Propagation in sDBD Systems** — •DOMINIK FILLA, NILS SCHOENEWEIHS, GERRIT HÜBNER, IHOR KOROLOV, THOMAS MUSSENBRÖCK, and MATE VASS — Department of Electrical Engineering and Information Science, Ruhr University Bochum, D-44780, Bochum, Germany

The efficient conversion of greenhouse gases and volatile organic compounds (VOCs) remains a significant challenge for environmental sustainability and advanced chemical processes. Surface dielectric barrier discharges (sDBDs) driven by nanosecond pulses offer a promising approach to address these challenges by exploiting the complex interplay between streamer discharges and nearby floating metal materials. This study investigates how floating surfaces affect the behavior of positive and negative streamers in He/N<sub>2</sub> sDBD systems. Using 2D plasma-fluid simulations, we analyze the impact of floating metal surfaces on streamer propagation, velocity, and the resulting electric field configuration. Numerical results reveal that streamers deposit charge on the floating material, thereby modifying the local electric field and subsequently affecting the propagation behavior of both positive and negative streamers. The simulations show good agreement with experimental observations via phase resolved optical emission spectroscopy. Supported by the DFG via SFB 1316.

P 12.3 Wed 14:30 KH 01.020

**Spatio-temporal development of pulsed-driven dielectric barrier discharges in a single-filament arrangement in Ar** — •HANS HÖFT<sup>1</sup>, ALICA TAKÁČOVÁ<sup>2</sup>, TOMÁŠ HODER<sup>1,2</sup>, and MARKUS M. BECKER<sup>1</sup> — <sup>1</sup>Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — <sup>2</sup>Department of Plasma Physics and Technology, Masaryk University, Brno, Czech Republic

Dielectric barrier discharges (DBDs) in argon were investigated using a double-sided, symmetric single-filament configuration with 0.5 mm alumina barriers and a 1 mm gas gap, which was housed in a Plexiglas cell and was flushed with a 100 sccm Ar flow at atmospheric pressure. The DBDs were driven by unipolar positive high-voltage pulses (50 ns rise/fall time, 10 kHz repetition frequency, 1 μs pulse width) with a varying amplitude (2.1–3.0 kV). Imaging by synchronised ICCD and streak camera measurements combined with fast electrical probes revealed a reproducible, thin constricted channel and surface discharges on both dielectrics. The discharge inception at the rising slope features as a cathode-directed streamer followed by a transient glow phase with complex characteristics; the streamer velocity was an order of magnitude lower than in air-like gas mixtures. Increasing the amplitude to 3.0 kV significantly altered the discharge inception and development compared to 2.1 kV, thus providing valuable data for modelling DBDs in Ar.

This work is funded by the Deutsche Forschungsgemeinschaft (DFG) – project number 504701852, and project LM2023039 funded by the Ministry of Education, Youth and Sports of the Czech Republic.

P 12.4 Wed 14:45 KH 01.020

**Pressure-dependent streamer dynamics of a nanosecond-pulsed surface dielectric barrier discharge in He/N<sub>2</sub>** — •NILS SCHOENEWEIHS, DOMINIK FILLA, GERRIT HÜBNER, THOMAS MUSSENBRÖCK, MATE VASS, and IHOR KOROLOV — Ruhr University Bochum, Bochum, Germany

Surface dielectric barrier discharges (sDBDs) have been extensively studied for applications ranging from plasma-assisted gas conversion to surface treatment. In this work, sDBDs driven by nanosecond voltage pulses are investigated in He/N<sub>2</sub> gas mixtures and at various pressures. 2D plasma\*fluid simulations (non-PDPSIM) and experiments are conducted to investigate streamer formation, propagation length and velocity and their implications for plasma-assisted conversion. Insights into the discharge dynamics are obtained by measuring emission from the He-I (3s)<sup>3</sup>S<sub>1</sub> state (with an excitation energy of 22.7 eV) and by calculating the corresponding spatio-temporal excitation rate using phase-resolved optical emission spectroscopy (PROES). Good qualitative agreement is found between PROES measurements and simulations. The results suggest strong coupling between the positive streamer at the powered electrode and the negative streamer at the grounded electrode in a twin-sDBD configuration. Varying the pressure strongly influences the velocity and propagation length of the streamer. Supported by the DFG via SFB 1316 (Projects A5 and A7).

P 12.5 Wed 15:00 KH 01.020

**Determination of the argon 3p<sup>5</sup>4s population distribution in a single-filament dielectric barrier discharge at atmospheric pressure** — •LEVIN KRÖS<sup>1,2</sup>, HANS HÖFT<sup>1</sup>, MARJAN STANKOV<sup>1</sup>, DETLEF LOFFHAGEN<sup>1</sup>, JEAN-PIERRE

H. VAN HELDEN<sup>3</sup>, and RONNY BRANDENBURG<sup>1,2</sup> — <sup>1</sup>Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — <sup>2</sup>Institute of Physics, University of Rostock, Rostock, Germany — <sup>3</sup>Faculty of Physics and Astronomy, Ruhr University Bochum, Bochum, Germany

Atoms and molecules in excited states impact the discharge and chemical reaction kinetics by their contribution to the production of charge carriers, via, e.g., step-wise ionisation or chemi-ionisation processes. In argon discharges, these processes are mainly driven by the energetically lowest excited states in the 3p<sup>5</sup>4s group, namely in Paschen notation, the two resonance states 1s<sub>2</sub> and 1s<sub>4</sub> and the two metastable states 1s<sub>3</sub> and 1s<sub>5</sub>. Measurements of number densities of all four 3p<sup>5</sup>4s states allow to determine the population distribution, which is valuable for benchmarking the kinetics of numerical models. We report spatio-temporally resolved number densities of those states measured in a single-filament dielectric barrier discharge operated with a sinusoidal high-voltage waveform at atmospheric pressure using tunable diode laser absorption spectroscopy. The population distribution will be compared with results of a time-dependent, spatially one-dimensional fluid model.

This work is funded by the DFG (project number: 504701852).

P 12.6 Wed 15:15 KH 01.020

**Peculiarities of the current transfer on a copper cathode microarcs in air in presence of metal vapour** — •MARGARITA BAEVA<sup>1</sup>, JONAS K. C. BALLENTIN<sup>2</sup>, and DIRK UHRLANDT<sup>1,2</sup> — <sup>1</sup>Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — <sup>2</sup>Institute of Electrical Power Engineering, University of Rostock, Rostock, Germany

Analysis of the current transfer on the copper cathode is performed for a switching arc arrangement operated at DC of 2 A at atmospheric pressure in a mixture air/Cu. The analysis is based on a unified non-equilibrium model that provides in a self-consistent manner the spatial distribution of the plasma properties needed for this analysis accounts for the increase of the gap length during the contact opening.

The presence of metal vapour in the plasma even in the considered mole fraction of 0.002 leads to the dominance of the singly charged copper ion. Ionization process occurs both in the space-charge region of the cathode and beyond the edge to the quasineutral plasma bulk. The computed spatial distribution of the electric potential indicates a maximum in the vicinity of the cathode, which causes an ion flux toward the plasma bulk. The predicted ratio of the ion to total current density amounts to 0.41-0.76 as a result of the interplay of increasing cathode voltage drop and in turn increasing ion mobility and drift velocity that overrules the decrease of the ion number density.

The work is funded by the German Research Foundation (DFG) Project number 524731006.

P 12.7 Wed 15:30 KH 01.020

**Silicon Nitride Membrane for Vacuum Ultraviolet (VUV) Spectroscopy of Commonly Used Plasma Jets** — •GÖRKEM BILGIN<sup>1</sup>, JAN BENEDIKT<sup>1,2</sup>, and LUKA HANSEN<sup>1,2</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — <sup>2</sup>Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Kiel, Germany

The diagnostic of VUV photons generated by non-thermal atmospheric pressure plasmas is complicated by the strong absorption in air and common window materials (e.g., LiF, MgF<sub>2</sub>) as these materials have cutoff wavelengths of around 110 nm [1, 2]. Various windowless techniques have been developed in the past to transfer the VUV photons into a vacuum, but each method has its drawbacks [2].

For this contribution, an evacuated monochromator, equipped with an ultrathin (20 nm) silicon nitride (Si<sub>3</sub>N<sub>4</sub>) membrane as an entrance window for the VUV radiation, was upgraded compared to [2] using narrower entrance/exit slits and a new detector, in order to improve the spectral resolution and achieve higher intensities.

VUV spectra of the COST Jet [3], Capillary Jet [4], and kINPen [5] will be presented, and the VUV emission correlated with UV/VIS spectra and electrical measurements.

[1] J. Golda *et al.* 2020 *Plasma Process. Polym.* **17** 1900216

[2] L. Hansen *et al.* 2025 *Plasma Sources Sci. Technol.* **34** 12LT01

[3] J. Golda *et al.* 2016 *J. Phys. D: Appl. Phys.* **49** 084003

[4] T. Winzer *et al.* 2022 *J. Appl. Phys.* **18** 183301

[5] S. Reuter *et al.* 2018 *J. Phys. D: Appl. Phys.* **51** 233001

## P 13: Atmospheric Pressure Plasmas II

Time: Wednesday 16:15–18:15

Location: KH 01.020

## Invited Talk

P 13.1 Wed 16:15 KH 01.020

**Thin film deposition with dielectric-barrier discharges at atmospheric pressure: open questions and some answers** — •LARS BROECKER and CLAUS-PETER KLAGES — Institute for Surface Technology (IOT), Technische Universität Braunschweig, 38108 Braunschweig, Germany

Plasma-enhanced chemical vapour deposition (PECVD) with dielectric-barrier discharges (DBDs) at atmospheric pressure is still only partially understood, which makes choosing the most suitable discharge configuration and plasma parameters quite difficult. In particular, the relevance of possible film-forming species, e.g. radicals, charged particles or the monomer itself, and their influence on the mechanical properties and film chemistry is often speculated upon but not fully understood. The determination of characteristic times involved in the deposition process, namely the gas residence time, the times for the transport of neutral particles and ions to the surface by diffusion and drift, respectively, and the time scales of ionic or radical gas phase reactions, can provide important information about the significance of the species for the film deposition process. Interestingly, cations formed from neutral species by electron impact or chemionization are often neglected, even though they drift to the substrate within a few microseconds. Recent experiments show that film deposition from ions dominates when the gas residence time is much shorter than the diffusion time of neutral particles. For certain monomers, cationic surface reactions appear to play a role, similar to initiated chemical vapour deposition (ICVD) processes.

P 13.2 Wed 16:45 KH 01.020

**Impact of simultaneous laser irradiation and plasma treatment to a Cu catalyst for CO<sub>2</sub> reduction** — •ALEXANDER SCHICKE<sup>1,2</sup>, JANNIS KAUFMANN<sup>1</sup>, SASCHA CHUR<sup>1</sup>, MARC BÖKE<sup>2</sup>, and JUDITH GOLDA<sup>1</sup> — <sup>1</sup>Plasma Interface Physics, Ruhr University Bochum, Germany — <sup>2</sup>Experimental Physics II, Ruhr University Bochum, Germany

Catalysts are able to optimise selectivity, efficiency, and reaction rates in chemical reactions. Therefore, they are critical in industrial applications for enabling more environmentally friendly processes. The efficiency of a catalyst is influenced by surface characteristics such as surface morphology and chemical composition. The morphology can be changed by nanostructures produced by laser irradiation, and the chemical composition can be altered by reactive species produced by atmospheric pressure plasmas. The combined treatment increases the efficiency by oxidising the surface. However, this simultaneous interaction between laser, plasma, and surface is highly complex.

We investigated this complex interaction in regards to optimise the efficiency of a Cu catalyst for the CO<sub>2</sub>-Reduction Reaction (CO<sub>2</sub>-RR). The electric fields and energy of pulsed laser irradiation produce Laser Induced Periodic Surface Structures (LIPSS) and Pulsed Laser Induced Dewetting Structures (PLIDS) which increase the effective area of the catalyst. Different reactive oxygen species (ROS), such as O<sub>2</sub>(a), O<sub>2</sub>(b) and ozone, produced by a helium-oxygen plasma, are measured. Up to 30% Cu<sub>2</sub>O and further up to 50 % CuO could be produced. The combined treatment increases the overall selectivity to C<sub>2+</sub> products.

P 13.3 Wed 17:00 KH 01.020

**characteristics of plasma catalytic conversion of n-Butane in micro cavity plasma array** — •YUE CHENG<sup>1</sup>, HENRIK VAN IMPEL<sup>1</sup>, DAVID STEUER<sup>1</sup>, VOLKER SCHULZ-VON DER GATHEN<sup>2</sup>, MARC BÖKE<sup>2</sup>, and JUDITH GOLDA<sup>1</sup> — <sup>1</sup>Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — <sup>2</sup>Experimental Physics II: Physics of Reactive Plasmas, Ruhr-University Bochum, D-44801 Bochum, Germany

n-Butane is a common volatile organic compound in automotive exhaust and exhibits acute toxicity, so its efficient and harmless removal is important for environmental and public health. This study investigates DBD plasma conversion of n-Butane by FTIR in MCPA, focusing on the effects of gas composition, catalyst and temperature on conversion and product selectivity. Introducing MnO<sub>2</sub>, BiTiO<sub>3</sub> or BiVO<sub>4</sub> as catalyst substantially reduces the number of ignited cavities and lowers the maximum conversion to 20%, indicating an anti-synergistic interaction between these catalysts and the present discharge configuration. For BiVO<sub>3</sub> and BiTiO<sub>4</sub> raising the catalyst surface temperature accelerates carbon deposition on the dielectric, which further suppresses reaction efficiency. However, BiVO<sub>4</sub> shows the lowest carbon loss and BiTiO<sub>3</sub> gives the smallest unassigned fraction in the product selectivity, meanwhile MnO<sub>2</sub> delivers the highest conversion at elevated temperatures up to 34%. Overall, developing plasma catalytic systems with enhanced anti-coking properties is key to improving conversion rates and steering selectivity toward target products. This work is supported by DFG within SFB1316 (A6).

P 13.4 Wed 17:15 KH 01.020

**The Influence of Catalyst Structure on Plasma Properties in Plasma Catalysis** — •ALEXANDER QUACK<sup>1</sup>, LENNARD BUCK<sup>1</sup>, KERSTIN SGONINA<sup>1</sup>, and JAN BENEDIKT<sup>1,2</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University — <sup>2</sup>Kiel Nano, Surface and Interface Science (KINSIS), Kiel University

In plasma catalysis, porous materials are often used to increase the catalyst surface area and number of active sites. However, the plasma often cannot reach these sites directly, limiting the transport of excited species from the plasma to the catalyst surface. Therefore, we investigate the influence of dielectric materials and porous structures of many sizes inside the plasma region and study the resulting modification on the formation, intensity and coverage of the plasma.

For the presented work, we use a custom-build reactor, which can be heated up to 600°C and has a transparent driven electrode for optical analysis with a camera. Additionally, the plasma gap can be modified from 0.5 to 8 mm changing the special dimension of the discharge and altering the plasma properties. The plasma is created at about 20 kHz and 8–20 kV<sub>pp</sub> and analyzed with current-voltage measurements deriving the plasma power, capacitances and coverage. A gas mixture of H<sub>2</sub>:CO<sub>2</sub> (3:1) is chosen to study the catalytic properties of the plasma with CH<sub>4</sub> and CO as chemical products that are detected by mass spectrometry as residual gas analysis. As dielectric materials, we use ceramic (ZrO<sub>2</sub>) spheres of different sizes (0.7–2.5 mm) as model material and Co<sub>3</sub>O<sub>4</sub> and CuZnO in forms of porous beads and powder as catalytic materials.

P 13.5 Wed 17:30 KH 01.020

**Investigating the influence of pulsed plasmas in water on copper surface** — •PIA-VICTORIA POTTKÄMPER, OLIVER KRETTEK, NILS HUBER, SVEN WELLER, and ACHIM VON KEUDELL — Ruhr University Bochum, Germany

In-liquid plasmas enable a variety of applications. For instance, they can be used to induce nanoparticle formation both in the treated liquid and on a surface in contact with the liquid. Plasmas in liquids, when ignited by voltage pulses with fast rise times and nanosecond pulse lengths applied to a small electrode wire, yield a high degree of dissociation of the molecules in the liquid, a high mass transport and efficient reaction rates. The in-liquid plasma causes the formation of reactive oxygen species from the water molecules. The reactive species can propagate through the liquid. When a surface is in direct contact with the liquid, the species can induce modifications of this surface.

In this project, the modification of copper surfaces by in-liquid plasma treatment is investigated. On copper surfaces, growth of Cu<sub>x</sub>O nanocubes can be induced. One application of these nanocubes is the catalysis of the electrochemical reduction of CO<sub>2</sub>. The activity of these nanocube catalysts decreases with use over time. Therefore, the catalytically active surface needs to be replaced regularly. It is postulated that by an in-situ in-liquid plasma treatment a re-activation of the surface could be achieved, thereby extending the lifetime of the copper oxide catalysts.

P 13.6 Wed 17:45 KH 01.020

**Enhancing plasma-surface interaction at atmospheric pressure by multiscale aeromaterials** — •KERSTIN SGONINA<sup>1</sup>, JANNIS CHRISTIANSEN<sup>1</sup>, JONAS LUMMA<sup>2</sup>, RAINER ADELUNG<sup>2,3</sup>, FRANKO GREINER<sup>1,3</sup>, and JAN BENEDIKT<sup>1,3</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University, Germany — <sup>2</sup>Department of Materials Science, Kiel University, Germany — <sup>3</sup>Kiel Nano, Surface and Interface Science (KINSIS), Kiel University, Germany

The field of plasma-assisted catalysis is continuously growing in the last few years. However, a large breakthrough is still pending. One problem that has received more attention lately [1] is the huge distance between the plasma and the catalytic material that hinders the plasma activated species to interact with the materials surface. To overcome this challenge, multiscale aeromaterials could be the game changer, which have not been studied in this respect until now. With their high porosity, ultra low density and therefore extremely high surface area (several 100 m<sup>2</sup>/g), they could enhance the plasma-surface interaction at atmospheric pressure.

Different reactor types have been used to, on the one hand, prove the feasibility of plasma ignition inside aeroglass at atmospheric pressure using high voltages at kHz, and on the other hand, prove the transparency of aeromaterials for ions. The ions transmitting through different thicknesses of aeromaterials of different plasmas at sub-atmospheric pressure (ranging from 20 to 80 mbar) has been detected using an ion mass spectrometer.

[1] Van Turnhout *et al.*, EES Catalysis 3, 669–693, 2025.

P 13.7 Wed 18:00 KH 01.020

**Post-Plasma Catalysis Schemes in Ammonia Synthesis** — •DANIEL HENZE and ACHIM VON KEUDELL — Ruhr Universität Bochum, 44801 Bochum, Germany

Current research in plasma catalysis focuses on in-plasma catalysis, where the plasma is operated directly in front of the catalyst surface. This approach poses significant scientific challenges, as the plasma-catalyst interaction may lead to



synergisms or anti-synergisms when aiming at maximizing species conversion or species selectivity. This question is explored for plasma catalysis for ammonia production. We use a kHz DBD plasma jet array to study the role of plasma-generated species in ammonia synthesis. The discharge initiates guided streamers that impinge on the catalyst surface as shown in a previous experiment with a comparable plasma source [1]. Due to their short lifetime, the plasma-catalyst contact occurs only for about 2% of the pulse duration. This reduces the coupling of the plasma and the catalyst, to separate the plasma dynamics from the surface

chemistry. The jet array consists of two sets of three individual jets. Each set of electrodes is powered independently and fed with different gases. They are operated sequentially to separate nitridation and hydrogenation steps in time similar to chemical looping for thermal catalysis. We characterize the discharge setup and investigate the impact of species injection and discharge timing on the ammonia yield by measuring the product density via a sampling orifice coupled to a molecular beam mass spectrometer.

[1] Daniel Henze et al 2025 Plasma Sources Sci. Technol. 34 095017

## P 14: Magnetic Confinement V

Time: Thursday 11:00–12:30

Location: KH 02.016

P 14.1 Thu 11:00 KH 02.016

**Understanding the impact of the divertor configuration on the L-H transition in the ASDEX Upgrade tokamak** — •ROXÁNA TAKÁCS<sup>1</sup>, MICHAEL DUNNE<sup>1</sup>, GREGOR BIRKENMEIER<sup>1</sup>, MATTHIAS WILLENSDORFER<sup>1</sup>, and THE ASDEX UPGRADE TEAM<sup>2</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>See author list of H. Zohm et al, 2024 Nuclear Fusion

Future fusion devices, such as ITER, will operate in high-confinement mode (H-mode) to achieve the plasma confinement required for sustained energy production. H-mode is characterized by increased stored energy and the formation of a steep pressure gradient at the plasma edge. In the leading interpretation, the transition into H-mode occurs when the ExB shear becomes strong enough to suppress edge turbulence. Previous studies from many major tokamaks have shown that the power threshold for the L–H transition ( $P_{LH}$ ) depends on various parameters, including the main isotope, plasma shape, and plasma density. This study investigates how the  $P_{LH}$  varies with different divertor configurations in the ASDEX Upgrade tokamak. The experimental dataset consists of lower- and upper single null plasma discharges, in low and high density regimes, with different divertor configurations. Significant variations in  $P_{LH}$  are observed across the different divertor configurations. This work presents an analysis of the divertor conditions as well as kinetic profiles at the midplane which aids in understanding the underlying physics of the L–H transition and improving our ability to optimize H-mode access in future fusion reactors.

P 14.2 Thu 11:25 KH 02.016

**Multi-Color Gas Puff Imaging in the ASDEX Upgrade Divertor** — •MANUEL HERSCHER<sup>1,2</sup>, MICHAEL GRIENER<sup>1</sup>, FELIX ALBRECHT<sup>1,2</sup>, ALESSANDRO MANCINI<sup>1</sup>, OU PAN<sup>1</sup>, CHRISTOPH PITZAL<sup>1</sup>, TIM HAPPEL<sup>1</sup>, ULRICH STROTH<sup>1,2</sup>, and THE ASDEX UPGRADE TEAM<sup>3</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>Technical University of Munich, Physics Department, Chair for Plasma Edge and Divertor Physics, Garching, Germany — <sup>3</sup>H. Zohm et al. 2024 Nucl. Fusion **64** 112001

The divertor will play a critical role in a future magnetic confinement fusion power plant. It distributes heat and particle loads onto the plasma-facing materials and controls impurity influx into the main plasma volume.

To study the newly constructed upper divertor at the ASDEX Upgrade fusion experiment, it has been equipped with a variety of novel plasma diagnostics. One of these diagnostics is a Multi-Color Gas Puff Imaging (GPI) system to study fast (tens of  $\mu$ s) events in the divertor volume. The GPI system uses a small injection of helium gas to emit line radiation depending on local plasma parameters, which is detected by a fast camera.

The design of the diagnostic, operational challenges and results from the first experiments are presented. Various comparisons with other diagnostics and numerical turbulence simulations are shown.

P 14.3 Thu 11:50 KH 02.016

**Characterization of Neutral Helium Beam Injection at ASDEX Upgrade** — •MANUEL MATSUMOTO<sup>1,2</sup>, ATHINA KAPPATOU<sup>2</sup>, LUCÍA SANCHIS<sup>3</sup>, MICHAEL DUNNE<sup>2</sup>, CHRISTIAN HOPF<sup>2</sup>, THOMAS PÜTTERICH<sup>2</sup>, GREGOR BIRKENMEIER<sup>1,2</sup>, RACHAEL M McDERMOTT<sup>2</sup>, and ASDEX UPGRADE TEAM<sup>2</sup> — <sup>1</sup>Technical University of Munich, Germany — <sup>2</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>3</sup>University of Sevilla, Spain

The confinement and slowing-down behaviour of energetic alpha particles are critical for the performance of future reactors, as they are expected to heat the background plasma. Pulses with helium neutral beam injection (NBI) have been carried out at ASDEX Upgrade to produce an energetic helium population. Charge Exchange Recombination Spectroscopy (CXRS) measurements reveal a slowing down feature characteristic of the fast helium ion population.

To interpret the measurements, an ASCOT5 based particle tracking model is used to describe the helium beam ionization and slowing-down process in a fusion plasma. A forward model allows direct comparison between experimental CXRS spectra and synthetic spectra generated from ASCOT5 distribution functions. This approach allows the interpretation of the CXRS measurements, and the validation of the ASCOT5 model itself against the measurements.

Additionally, an analysis of the beam emission components of the measured spectra allows for a detailed characterisation of the helium neutral beam and its attenuation. The results quantify the impact of metastable populations in reproducing the CXRS spectra.

P 14.4 Thu 12:05 KH 02.016

**Toward a nonlinear Schrödinger equation for the description of geodesic-acoustic-modes in tokamaks** — •DAVID KORGER<sup>1</sup>, EMANUELE POLI<sup>1</sup>, FULVIO ZONCA<sup>2</sup>, MATTEO VALERIO FALESSI<sup>2</sup>, RICCARDO STUCCHI<sup>1</sup>, ALBERTO BOTTINO<sup>1</sup>, and THOMAS HAYWARD-SCHNEIDER<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Garching, 85748, Germany — <sup>2</sup>Center for Nonlinear Plasma Science and C.R. ENEA Frascati, C.P. 65, 00044 Frascati, Italy

The geodesic-acoustic-mode (GAM) is a plasma oscillation observed in fusion reactors with toroidal geometry and is recognized to be the nonstationary branch of the zonal flows (ZFs). Prior studies have established that as a direct consequence of nonlinear gyrokinetic theory, the GAM dynamics is well described by an equation of Schrödinger type - i.e., an equation whose linear contribution is exactly of the same form as the linear Schrödinger equation, while the nonlinear dynamics necessitates an integro-differential expression.

The presented work takes a closer look into the nonlinear contributions by deriving approximate, but well-defined analytic expressions from the (exact) integro-differential operators. At the lowest order of accuracy, prior numerical studies anticipate the retrieval of a cubic nonlinear Schrödinger equation. This may come unexpected since nonlinear interactions usually have a quadratic structure, such as e.g. the  $E \times B$ -nonlinearity. The third power is found to stem from an interaction of quadratic structures generated by the GAMs (with oscillation frequencies that are either zero or twice the GAM frequency) with the GAM itself. Analytic results are compared to gyrokinetic simulations.

## P 15: High Energy Density Physics II

Time: Thursday 11:00–12:30

Location: KH 01.020

### Invited Talk

P 15.1 Thu 11:00 KH 01.020

**Demonstration of X-ray Diagnostics for Heavy-Ion-Heated Matter** — •JULIAN LÜTGERT — Universität Rostock, Germany.

In the transition between solid and plasma, a sample reaches the Warm Dense Matter regime, characterized by ambient densities and temperatures between 10,000 and 1,000,000 K. Typical schemes for the generation of such conditions use ultra-fast heating or shockwaves. However, these methods only create states with lifetimes up to tens of nanoseconds. Heavy ion beams can provide a different driving scheme enabling probing times on the order of microseconds, and thereby close the gap between experiments in the lab and real-world phenomena.

Such experiments are now within reach, with the next generation of heavy ion synchrotrons, like FAIR at GSI (Germany), or HIAF (China), currently under construction.

As optical measurements typically fail for dense plasmas, X-ray based methods have been developed by the community. Here, we present first experiments combining heating by accelerated ions with laser-driven X-ray diagnostics, conducted at the currently available GSI infrastructure. We measure temperature and the graphitization threshold of a diamond target by comparison of spectrally resolved scattering signal to *ab-initio* simulations. Simultaneous X-ray diffraction and imaging measurements give insight into the integrity of the sample,

indicating the onset of a temperature-driven phase transition around 2000 K. We identify unique challenges in integrating the established diagnostics with ion beams and propose initial mitigation strategies toward successful experiments at upgraded facilities.

P 15.2 Thu 11:30 KH 01.020

**Model-free interpretation of X-ray Thomson scattering experiments with warm dense matter** — •TOBIAS DORNHEIM — Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01328 Dresden, Germany — Center for Advanced Systems Understanding (CASUS) at Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-02826 Görlitz, Germany  
Warm dense matter is an extreme state that occurs in a variety of astrophysical objects (brown dwarfs, giant planet interiors, ...), and which is of key importance for technological applications such as inertial fusion energy. There are many ways to generate warm dense matter in the laboratory, but diagnostics even of basic parameters such as the temperature is difficult and often depends on models. Here, I summarize recent progress on the model-free diagnostics of warm dense matter from x-ray Thomson scattering measurements [1,2].

[1] T. Dornheim et al., Nature Commun. 13, 7911 (2022) [2] T. Dornheim et al., Nature Commun. 16, 5102 (2025)

P 15.3 Thu 11:45 KH 01.020

**Electron dynamic and static structure factors in warm dense matter from density functional theory** — •ZHANDOS MOLDABEKOV<sup>1,2</sup> and TOBIAS DORNHEIM<sup>1,2</sup> — <sup>1</sup>Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01328 Dresden, Germany — <sup>2</sup>Center for Advanced Systems Understanding (CASUS), D-02826 Görlitz, Germany

Understanding the behavior of warm dense matter is crucial for modeling compact astrophysical objects and advancing research in inertial confinement fusion. Density functional theory (DFT) is the standard theoretical tool used in this regime. We introduce a new approach that combines time-dependent DFT calculations of the dynamic structure factor with static DFT results for the density response [1], enabling accurate predictions of the electron-electron static structure factor in warm dense matter. We also present our recent methodological and computational advances in applying linear-response time-dependent DFT (LR-TDDFT) to calculate the electron dynamical structure factor [2-8].// [1] Z. Moldabekov et al., Matter Radiat. Extremes 11 (2), 025401 (2026).// [2] Z. Moldabekov et al., Matter Radiat. Extremes 10 (4), 047601 (2025).// [3] Z. Moldabekov et al., J. Chem. Theor. Comput. 19, 1286\*1299 (2023).// [4] Z. Moldabekov et al., Prog. Part. Nucl. Phys. 140, 104144 (2025).// [5] T. Gawne, Z. Moldabekov et al., Phys. Rev. B 109, L241112 (2024).// [6] T. Gawne, Z. Moldabekov et al., Electron.

Struct. 7 025002 (2025).// [7] Z. Moldabekov et al., Phys. Rev. Research 6, 023219 (2024).// [8] D. Bespalov, U. Zastra, Z. Moldabekov et. al., arXiv:2509.10107 (2025).

P 15.4 Thu 12:00 KH 01.020

**Collective modes of dense hydrogen plasmas from semi-classical molecular dynamics simulations** — •HANNO KÄHLERT and DANIELS KRIMANS — Christian-Albrechts-Universität zu Kiel, ITAP, Germany

Dense hydrogen occurs in the interior of giant planets and during laser-driven fusion. Its properties, such as the equation of state or transport coefficients, are of high interest for modeling applications. The dynamic structure factor (DSF) is related to many thermodynamic and transport coefficients. Here, the DSF is computed from semi-classical molecular dynamics (MD) simulations [1] using the improved Kelbg potential [2]. It is shown that the structural properties are in good agreement with first-principle quantum Monte Carlo simulations. The DSF is compared with wave-packet MD simulations [3]. While the electron-electron DSF from the two methods agrees qualitatively, excellent agreement is found for the ion sound speed extracted from the ion-ion DSF. The latter can be reproduced accurately with a Yukawa one-component plasma (YOCP) model. A method to determine the screening and coupling parameters of a YOCP solely from structural properties is discussed [4].

[1] H. Kählert, submitted (2025).

[2] A. V. Filinov, V. O. Golubnychiy, M. Bonitz, W. Ebeling, and J. W. Dufty, Phys. Rev. E 70, 046411 (2004).

[3] P. Svensson, Y. Aziz, T. Dornheim, S. Azadi, P. Hollebon, A. Skelt, S. M. Vinko, and G. Gregori, Phys. Rev. E 110, 055205 (2024).

[4] D. Krimans and H. Kählert, submitted (2025).

P 15.5 Thu 12:15 KH 01.020

**Opacity of Jupiter's and Saturn's interior from ab initio simulations** — •MARTIN PREISING<sup>1,2</sup> and RONALD REDMER<sup>1,2</sup> — <sup>1</sup>Universität Rostock — <sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf

We calculate the Rosseland mean opacity along the pressure-temperature conditions of Jupiter's and Saturn's interior by using ab initio molecular dynamics simulations based on density functional theory. We evaluate the Kubo-Greenwood formula for the dynamic conductivity and derive the absorption coefficient and, thereby, the opacity via the dielectric function.

The opacity determines the effectiveness of radiation transport mechanisms from the hot center to the cool surface of a planet. Our results will inform interior and thermal evolution models for Jupiter and Saturn as prototypical gas giant planets, in particular for the region of warm dense matter in their deep interior where quantum and correlation effects are important.

## P 16: Poster Session Plasma Physics

Time: Thursday 13:45–15:45

Location: Redoutensaal

P 16.1 Thu 13:45 Redoutensaal

**GPU Acceleration and Portability of the TRIMEG Code for Global Gyrokinetic Plasma Simulations using OpenMP** — •GIORGIO DANERI, ZHIXIN LU, and MATTHIAS HOELZL — Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany

The TRIangular MESH-based Gyrokinetic (TRIMEG) code solves the gyrokinetic equations using a particle-in-cell (PIC) scheme to simulate electromagnetic instabilities throughout the full tokamak volume.

In this work, we focus on the acceleration and portability of the TRIMEG code on multiple GPU architectures. The OpenMP framework is chosen as the methodological approach for GPU offloading in Fortran on NVIDIA and AMD platforms. The particle pushing procedure, as well as particle-to-grid operations have been adapted for GPU execution. The kernels were analyzed with the available profiling tools to gather metrics about resource occupancy, throughput, and memory usage. Their performance was evaluated by carrying out GPU grid size exploration, as well as multi-node scalability studies. In addition, the efficiency of hybrid MPI-OpenMP offloading parallelization was assessed.

The Ion Temperature Gradient (ITG) mode was simulated using the GPU-accelerated version for the economical Cyclone case and the TCV case, and its correctness was verified by comparing the physics results in terms of the energy growth rate and the two-dimensional mode structures.

P 16.2 Thu 13:45 Redoutensaal

**Impact of RMPs on plasma rotation in ASDEX Upgrade** — •MARGHERITA SALERNO<sup>1</sup>, MATTHIAS WILLENSDORFER<sup>1</sup>, RACHAEL MCDERMOTT<sup>1</sup>, TUOMAS TALA<sup>2</sup>, ATHINA KAPPATOU<sup>1</sup>, and TABEA GLEITER<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, 85748 Garching, Germany — <sup>2</sup>VTT Technical Research Centre of Finland

Tokamaks, though designed for perfect axi-symmetry, experience unavoidable symmetry breaking from sources like toroidal field coil ripples, error fields, and

resonant magnetic perturbation (RMP) coils used for ELM suppression. These non-axisymmetric perturbations are important as they drive non-ambipolar radial particle fluxes, resulting in the Neoclassical Toroidal Viscous (NTV) torque. This torque typically acts on the plasma by spinning-up or breaking the rotation, depending on the contributions from electrons and ions. For future devices like ITER, it is crucial to quantify the NTV torque as, in this device, it may be comparable to other applied and intrinsic torques and thus make a more important contribution to the momentum balance than typically observed in present-day beam-heated devices. This work will study the impact of RMPs on plasma rotation in ASDEX Upgrade. Our investigation will focus on i) radial distribution of the torque source via coil current modulations, ii) impact of the poloidal spectrum of the RMP coils on the torque and iii) impact of the ExB rotation frequency of the torque. The experimental results will be analyzed with GPEC, which is a linear code that works generalizing the perturbed equilibrium, and then benchmarked with other codes, like MARS-K and NEO-2.

P 16.3 Thu 13:45 Redoutensaal

**Experimental Investigation into the Influence of Carbon on the Mechanical Properties of Tungsten** — •SEBASTIAN ESTERMANN<sup>1,2</sup>, ALEXANDER FEICHTMAYER<sup>1</sup>, TILL HÖSCHEN<sup>1</sup>, JOHANN RIESCH<sup>1</sup>, THOMAS SCHWARZSELINGER<sup>1</sup>, and RUDOLF NEU<sup>1,2</sup> — <sup>1</sup>Max Planck-Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching — <sup>2</sup>Technical University Munich, Boltzmannstr. 15, 85748 Garching

Fusion power plants are a promising alternative for the electricity production with low CO<sub>2</sub> emission. In such power plants prevail extreme conditions, so likely used materials for plasma contact such as tungsten (W) must be well characterized for safe operation. It is known, that even little amount of impurities, e.g. carbon (C) which can be present during manufacturing, can change the properties of W. Subject of this research is the change in mechanical properties of thin, ductile W wires under the influence of C. The embrittlement of W by C

has so far only been investigated at temperatures well above 1100 °C. As materials behaviour also changes with temperature, there are two impacts combined. By irradiating the W wires with C ions, the implantation of C atoms into the W lattice is possible at temperatures below 1100 °C. This way the influence of the temperature from the influence of C itself can be separated. A comparison to unirradiated samples that have been heat-treated for 8 h at 900 °C is done. For evaluation, the reduction in area at the fracture surface serves as a measure of ductility. In the range 0-2700 ppm C content, the wires retained their ductility and no systematic changes were observed.

P 16.4 Thu 13:45 Redoutensaal

**Beat wave generation in the ion cyclotron frequency range by high power microwaves and how to measure them** — •NIKLAS SIMON POLEI, LAURENT KRIER, HEINRICH PETER LAQUA, DMITRY MOSEEV, SERGIY PONOMARENKO, TORSTEN STANGE, and W7-X TEAM — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

The overlap of two waves will create a third wave beating with the frequency difference ( $\Delta f$ ) of the two original waves. For the beat wave generation in the ion cyclotron frequency (ICF) range two gyrotrons of the electron cyclotron resonance heating system of Wendelstein 7-X (W7-X) are used. The gyrotrons are frequency stabilized by a phase locked loop, so that they are oscillating by 100kHz at most [1]. The  $\Delta f$  is set to the ICF in the overlap region, typically 35MHz to 37MHz.

The microwave beams can be either overlapped in the resonance region [2] or before the resonance region. Different processes are then transferring energy to the ions. In the latter case the overlap creates a strong electric field gradient, this results in an electron density wave created by the ponderomotive force. If the k-vector of the electron wave is chosen appropriately it can couple to the ion Bernstein waves.

So far only the ICRH antenna of W7-X was used in measurements. However, no waves or ion heating could be observed. Therefore, it is planned to use the collective Thomson scattering (CTS) system and the fast ion loss detector (FILD) to detect ion heating or fast ions.

[1] L. Krier, et al. doi: 10.1109/IRMMW-THz50926.2021.9566847

[2] H.P. Laqua, et al. 2018 Nucl. Fusion 58 104003

P 16.5 Thu 13:45 Redoutensaal

**Investigation of the Effects of Anomalous Heat Transport and Diffusion in the W7-X SOL** — •ANJA HOFFMEISTER<sup>1</sup>, NATHAN BARBE<sup>2</sup>, KELLY GARCIA<sup>1</sup>, NASSIM MAAZIZ<sup>2</sup>, FELIX REIMOLD<sup>2</sup>, VICTORIA WINTERS<sup>1</sup>, and W7-X TEAM<sup>2</sup> — <sup>1</sup>University of Greifswald, Institut für Physik, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany — <sup>2</sup>Max Planck Institute for Plasma Physics, Wendelsteinstraße 1, 17491 Greifswald, Germany

Anomalous heat and particle transport are expected to affect the performance of the Wendelstein 7-X (W7-X) island divertor scrape-off-layer (SOL). While the underlying physical principles are not yet well-understood, mean-field simulation codes like EMC3-Eirene require a suitable parameterization to mock-up their effects on the transport. Typically, this is done via specific input parameters to the simulation. However, previous simulation studies using EMC3-Eirene have indicated unexpected behavior of the plasma parameters with changes of the input anomalous heat and particle diffusion coefficients. The reason has thus far been poorly understood. This work presents a first systematic study of how the anomalous heat and particle diffusion input parameters independently affect the performance of the W7-X SOL in EMC3-Eirene simulations. The investigation focuses on heatflux widths and density build up at the divertor target plate. First investigations have found that, at least in a convective regime, the anomalous heat diffusion coefficient influences divertor density build-up more strongly than the anomalous particle diffusion coefficient. Behavior at different plasma densities will be presented.

P 16.6 Thu 13:45 Redoutensaal

**Gyrokinetic Turbulence in ECRH Reintroduction Scenarios in W7-X** — •EMIL OVERDUIN, JOSEFINE HENRIETTE ELISE PROLL, SEBASTIAN BANNMANN, and MICHAEL JEFFREY GERARD — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Recently, the neoclassically optimized stellarator Wendelstein 7-X (W7-X) has seen an increase in core ion temperature above the  $\approx 2$  keV clamping limit in the presence of peaked density profiles. Of special interest for this work are scenarios where the strong density gradient is created by Neutral Beam Injection (NBI), which is followed by an Electron Cyclotron Resonance Heating (ECRH) reintroduction.

The ECRH reintroduction leads to an increase of the ion temperature above the clamping limit in W7-X, while at the same time the core density peaking rate is reduced (ECRH pump-out). If the ECRH power is large enough a back-transition to a higher heat transport regime is observed. The ECRH power required for a back transition to occur is strongly dependent on the magnetic configuration of W7-X. This dependence is not well understood.

Using the local gyrokinetic code GENE the microinstabilities present in the plasma at parameters relevant for the pump-out and back-transition are inves-

tigated. The aim is to contribute to understanding the effect of turbulence on the density pump-out and back-transition. To this end, the simulations are performed at different radial locations in different configurations, and use experimentally consistent equilibria, corresponding to multiple time points during the discharges.

P 16.7 Thu 13:45 Redoutensaal

**Integrated modelling of sawtooth cycles in tokamak plasmas** — •FEDERICO STEFANELLI, EMILIANO FABLE, CLEMENTE ANGINI, MICHAEL BERGMANN, DAVIDE BRIOSCHI, ANJA GUDE, PHILIPP LAUBER, OLEG SAMOYLOV, RICCARDO STUCCHI, MARKUS WEILAND, HAOWEI ZHANG, and HARTMUT ZOHN — Max Planck Institute for Plasma Physics, Garching

Sawtooth cycles are periodic relaxations of the plasma core commonly observed in tokamak discharges. The cycle is characterized by a rapid MHD-driven collapse of the core temperature, density and current profiles, followed by a profile recovery driven by continued heating. Sawtooth cycles limit core pressure and thus lower the plasma performance. Even more critically, they can trigger secondary MHD instabilities, which in turn can lead to disruptions. On the other hand, the crash expels impurities from the core, aiding in the control of impurity and, in a reactor, helium ash accumulation. For these reasons, accurate modelling is essential for predictive transport simulations and reliable control of plasma behavior in future devices. An integrated model of these cycles is presented, which includes also the effects of additional MHD activity. The phases of a sawtooth cycle: (1) onset criterion, (2) collapse and (3) the recovery phase are modelled either via first-principles (1) and (3) or with an ad-hoc relaxation model (2). The collapse of the fast particle population and rotation profiles are also considered, as they actively and passively affect the sawtooth cycle and are in turn affected by it. The results are validated on ASDEX Upgrade discharges in presence of NBI and ECRH heating schemes.

P 16.8 Thu 13:45 Redoutensaal

**Scaling observations of heat transport in the island divertor of W7-X** — •SEBASTIAN THIEDE<sup>1</sup>, YU GAO<sup>1</sup>, MARCIN JAKUBOWSKI<sup>1</sup>, PETER MANZ<sup>2</sup>, and THE W7-X TEAM<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Wendelsteinstraße 1, 17491 Greifswald, Germany — <sup>2</sup>Institut für Physik, Universität Greifswald, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany

Efficient power exhaust is one of the most important aspects of magnetic confinement devices due to the risk of overloading plasma-facing components (PFCs). Scaling laws of important heat transport parameters are readily available for tokamaks, allowing educated extrapolation to reactor relevant regimes. In the case of stellarators extrapolations are more difficult to justify due to significantly less data being available. Wendelstein 7-X (W7-X) is one of the most advanced stellarators to date. In its recent operational phases the scanned device parameter range was expanded greatly, facilitating the derivation of empirical heat transport scaling laws. A key diagnostic for this derivation is the thermography system that monitors all 10 divertor units of W7-X. Together with the finite-difference code DELVER it is used to get estimates of the impinging heat flux patterns on PFCs. These can be seen as "fingerprints" of different transport processes, and are the main interest of this work. From the variation of the magnetic configuration, the magnetic field strength and direction, heating power and plasma density we hope to extract trends and possibly quantitative assessment of the relative importance that different transport channels in the scrape-off-layer (SOL) have.

P 16.9 Thu 13:45 Redoutensaal

**Fluid Turbulence Simulations in Geometries with Internal Magnetic Islands** — •MIGUEL MADEIRA<sup>1</sup>, ANDREAS STEGMEIR<sup>2</sup>, CHRISTOPH PITZAL<sup>2</sup>, BARNABAS CSILLAG<sup>2</sup>, FELIX REIMOLD<sup>1</sup>, and PETER MANZ<sup>3</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — <sup>2</sup>Max-Planck-Institut für Plasmaphysik, Garching, Germany — <sup>3</sup>University of Greifswald, Institute of Physics, Greifswald, Germany

Understanding edge turbulence is crucial for improving plasma confinement. Magnetic islands are especially relevant for the island divertor concept and their potential involvement in the formation of internal transport barriers. The plasma fluid turbulence code GrilliX now supports 3D geometries, including circular toroidal equilibria with magnetic islands and MGRID equilibria. The latter enables simulating the neoclassically optimized stellarator W7-X, with validation currently underway.

W7-X can operate in various magnetic configurations. In several limiter configurations, where the 5/5 islands lie inside the last closed flux surface, the plasma energy increases, peaking in the so-called FMM configuration. This study aims to validate GrilliX's new capabilities and to investigate turbulence around W7-X's 5/5 magnetic island chain in limiter configurations. A critical island width for ExB flow around the islands is shown in a circular toroidal geometry consistent with previous studies. In the first W7-X simulations, the perpendicular plasma flow shape previously measured for the FMM configuration is reproduced, showing the characteristic "W" shape.

P 16.10 Thu 13:45 Redoutensaal

**RF resolved measurements of the plasma and beam properties in ion sources for the ITER NBI** — •JASPER KNAACK, CHRISTIAN WIMMER, ARACELI NAVARRO, and URSEL FANTZ — Max Planck Institute for Plasma Physics, Boltzmannstraße 2, Garching bei München, Germany

The neutral beam injectors (NBI) for ITER will require powerful negative ion sources. In such a device, a plasma is ignited in a set of cylindrical drivers. The negative ions are then generated by surface production. Part of the ITER NBI design is the use of RF plasma drivers. The frequency of the RF power that is injected into the driver is 1 MHz. The plasma parameters, such as the plasma potential, of an RF plasma can strongly vary during an RF cycle. Predictions drawn from numerical simulations have also shown large electron flux oscillations in the RF timescale. It is not known how these variations in the plasma parameters influence the extraction of negatively charged particles and thus the beam properties on the RF timescale. In order to study the oscillations in the plasma parameters, diagnostics will be implemented at the Batman UpGrade (BUG) testbed to measure the plasma parameters in an RF-resolved manner. First tests with an avalanche photo-diode have proved to be successful. Moreover, high-speed beam diagnostics will be implemented to study the effect of these plasma parameter variations on the resulting beam. This contribution discusses the planned diagnostics to be implemented in BUG.

P 16.11 Thu 13:45 Redoutensaal

**Expanding the physics modeling capabilities of ASTRA from core to SOL and from tokamak to stellarator towards application in a multi-device flight simulator** — •FABIAN SOLFERONK<sup>1,2</sup>, EMILIANO FABLE<sup>1</sup>, PIERRE DAVID<sup>1</sup>, MATTHIAS BERNERT<sup>1</sup>, ELISA BUGLIONE-CERESA<sup>1</sup>, GIOVANNI TARDINI<sup>1</sup>, MARCO ZANINI<sup>3</sup>, SEHYUN KWAK<sup>3</sup>, ULRICH STROTH<sup>1</sup>, OU PAN<sup>1</sup>, HARTMUT ZOHN<sup>1,2</sup>, THE ASDEX UPGRADE TEAM<sup>4</sup>, and THE W7-X TEAM<sup>5</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — <sup>2</sup>Ludwig-Maximilians-Universität München, 80539 München, Germany — <sup>3</sup>Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany — <sup>4</sup>see the author list of H. Zohm et al. 2024 NF 64 112001 — <sup>5</sup>see the author list of O. Grulke et al. 2024 NF 64 112002 This work aims at augmenting the ASTRA transport code capabilities of simulating magnetic confinement fusion devices. In parallel, two avenues are pursued:

First, a generic equation for the current diffusion compatible with stellarator geometry is implemented, and the code is coupled to the equilibrium solver VMEC. The equation is benchmarked against theoretical expectations and validated using experimental data from Wendelstein 7-X.

Second, a reduced XPR model, predicting XPR radiation, position, and stability, is developed and implemented in ASTRA. The model is validated against ASDEX Upgrade discharges in the Fenix flight simulator.

P 16.12 Thu 13:45 Redoutensaal

**Characterization of plasma turbulence during ELM suppression with Resonant Magnetic Perturbations in ASDEX Upgrade** — •BOJANA STEFANOSKA<sup>1</sup>, WOLFGANG SUTTROP<sup>1</sup>, MATTHIAS WILLENSDORFER<sup>1</sup>, RACHAEL M. McDERMOTT<sup>1</sup>, FLORIAN RATH<sup>2</sup>, ARTHUR PEETERS<sup>2</sup>, and THE ASDEX UPGRADE TEAM<sup>3</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, 85748 Garching, Germany — <sup>2</sup>University of Bayreuth, 95447 Bayreuth, Germany — <sup>3</sup>see author list of H. Zohm et al. 2024 Nucl. Fusion 64 112001

ELMs pose a major challenge for future fusion reactors due to their potentially unsustainable heat loads on plasma-facing components. Resonant magnetic perturbations (RMPs) can mitigate or suppress ELMs, but the underlying physics of RMP-induced suppression remains unclear. Previous ASDEX Upgrade experiments have shown that the application of RMPs coincides with the onset of a characteristic turbulence regime at the plasma edge, leading to enhanced radial particle transport and a significant reduction of the pedestal density. However, the driving instability, the nonlinear saturation mechanism, and the structure of this turbulence remain open questions. The recently upgraded ECEI diagnostic at ASDEX Upgrade provides high-resolution, 2D measurements of electron temperature fluctuations and is expected to play a central role in the upcoming campaign. In preparation, we perform a systematic multi-diagnostic analysis of turbulence data in previous AUG RMP discharges to identify the dependencies of RMP-driven turbulence on plasma parameters and to guide future experimental strategies. The poster will present an overview of these findings.

P 16.13 Thu 13:45 Redoutensaal

**Island divertor studies in 3D using GRILLIX** — •BARNABAS CSILLAG<sup>1</sup>, ANDREAS STEGMEIR<sup>1</sup>, CHRISTOPH PITZAL<sup>1</sup>, KONRAD EDER<sup>1</sup>, MIGUEL MADEIRA<sup>2</sup>, MARION FINKBEINER<sup>1</sup>, and FRANK JENKO<sup>1</sup> — <sup>1</sup>MPI for Plasma Physics, Garching, Germany — <sup>2</sup>MPI for Plasma Physics, Greifswald, Germany

Understanding and predicting heat exhaust properties is one of the main challenges on the path towards a stellarator power plant. The island divertor is a key feature in the Scrape-Off Layer of most current stellarator reactor designs, and it is also experimentally investigated in the Wendelstein 7-X (W7-X) stellarator. Numerical modeling of island divertors usually relies on transport codes. However, discrepancies between these predictions and experimental data highlight the need for more sophisticated approaches.

In this work, we employ the transcollisional fluid turbulence code GRILLIX to simulate a simplified island divertor geometry. The configuration involves a helically perturbed circular toroidal magnetic field, generating a magnetic island chain at a rational surface. These islands are intersected by discrete target plates aligned with the island chain, mimicking the divertor topology of W7-X. Such model enables the investigation of general island divertor phenomena, including the structure of the electrostatic potential, and the influence of sheared poloidal flows. By analyzing these features, we advance our understanding of island divertor physics in tractable geometries - an essential step before tackling more complex geometries, like W7-X.

P 16.14 Thu 13:45 Redoutensaal

**Predicting MANTIS performance in W7-X: Synthetic Modeling of the Expected Operational Regime Using EMC3-EIRENE** — •JOEY LOUWE<sup>1</sup>, FELIX REIMOLD<sup>1</sup>, VALERIA PERSEO<sup>1</sup>, VICTORIA WINTERS<sup>1</sup>, NASSIM MAAZIZ<sup>1</sup>, ALEXANDER KNIEPS<sup>2</sup>, HENRY GREVE<sup>1</sup>, MOHAMMAD FOISAL SIDDIKI<sup>1</sup>, and W7-X TEAM<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — <sup>2</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management\*Plasma Physics, 52425 Jülich, Germany

Modern large-scale magnetic confinement fusion devices use divertors to optimize particle and heat exhaust. At the Wendelstein 7-X stellarator (W7-X), this is achieved with an Island Divertor concept, where magnetic islands guide particles and heat along field lines to dedicated target plates. Due to its 3D geometry, diagnosing transport across the island is challenging with existing diagnostics. To address this, the new MANTIS imaging system will be combined with helium gas puffs in upcoming campaigns to provide localized measurements of island plasma parameters and infer transport dynamics. Simulation studies using the EMC3-EIRENE plasma fluid transport code were conducted and a new synthetic forward modeling tool to assess MANTIS performance and operational viability was developed. These predictions, informed by existing W7-X data (helium puff spread, electron temperature, and density profiles), enable optimized MANTIS system design and deployment. This contribution presents simulation results, MANTIS performance predictions, and its current integration status.

P 16.15 Thu 13:45 Redoutensaal

**Simulations and experiments of early-heating reversed-shear discharges**

— •LEA HOLLENDONNER<sup>1</sup>, ALEXANDER BOCK<sup>1</sup>, THOMAS PÜTTERICH<sup>1</sup>, JÖRG STÖBER<sup>1</sup>, JÖRG HOBIRK<sup>1</sup>, and THE ASDEX UPGRADE TEAM<sup>2</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>See author list of H. Zohm et al. 2024 Nucl. Fusion 64 112001

Negative magnetic shear can lead to the suppression of microinstabilities and the formation of internal transport barriers (ITBs). These scenarios hold the potential of improved core confinement and high bootstrap-current fraction but may also lead to impurity accumulation in the core. In order to make predictions based on these scenarios, codes like TGLF must be able to capture the effects of negative shear on transport and quantitatively match experimental profiles in this regime. A prerequisite for these investigations is to achieve stable, distinct regions of negative shear in experiments, and to measure the q-profile with sufficient accuracy. The focus of this poster lies on the early-heating approach which slows down current diffusion of inductive current from the edge to the core region during the ramp-up phase of the discharge. Experiments of early-heating are presented that employ central counter-current ECCD during ramp-up. Based on these discharges, the timing and deposition of ECCD as well as the plasma current ramp is varied in simulations in order to investigate the effects of these actuators on the q-profile evolution.

P 16.16 Thu 13:45 Redoutensaal

**Spontaneous density peaking in overdense W7-X plasmas** — •MARTINA LICHELLI, JOSEFINE PROLL, GOLO FUCHERT, HÅKAN SMITH, ANDREAS LANGENBERG, and TORSTEN STANGE — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

Achieving reactor-relevant confinement in stellarators requires reducing both neoclassical and turbulent transport, which limit core temperature and density. In Wendelstein 7-X (W7-X), plasmas with peaked density profiles show reduced energy transport, likely linked to suppressed ion-temperature-gradient turbulence. Such profiles have mostly appeared in pellet- or NBI-fueled discharges, and how these scenarios scale to reactor conditions remains unclear.

A promising alternative is the spontaneous density peaking in overdense, O<sub>2</sub>-heated plasmas fueled solely by gas puffing. These plasmas exhibit a stable inward particle pinch under pure electron heating, attractive features for reactor operation. However, it is still uncertain whether the resulting density gradients are strong enough to suppress turbulence or whether the pinch mechanism itself changes, leaving important aspects of the scenario's physics unresolved.

This work presents experimental evidence of spontaneous density peaking in overdense W7-X plasmas, with measurements of density profiles, radial electric fields and transport coefficients showing changes in particle transport. Linear and nonlinear simulations identify microinstabilities in different regimes and preliminary analyses of the inward pinch are included. These results offer insight into density peaking and its potential relevance for future stellarator reactors.

P 16.17 Thu 13:45 Redoutensaal

**Asymmetric scrape-off layer plasma parameter changes and their implications for diagnostic comparability in W7-X** — •F SCHARMER<sup>1</sup>, A VON STECHOW<sup>1</sup>, C KILLER<sup>1</sup>, SG BAEK<sup>2</sup>, S BALLINGER<sup>2</sup>, Y GAO<sup>1</sup>, O GRULKE<sup>1,3</sup>, S HÖRMANN<sup>1</sup>, M JAKUBOWSKI<sup>1</sup>, E MARAGKOUAKIS<sup>1</sup>, S THIEDE<sup>1</sup>, A TSIKOURAS<sup>1</sup>, M VECSEI<sup>1</sup>, and THE W7-X TEAM<sup>1</sup> — <sup>1</sup>MPI for Plasma Physics, Greifswald (Garching), Germany — <sup>2</sup>MIT PSFC, Cambridge, USA — <sup>3</sup>Department of Physics, TU Denmark, Lyngby, Denmark

The Wendelstein 7-X stellarator experiment uses the island divertor concept for power and particle exhaust. To characterize the scrape-off layer (SOL), different diagnostics view different magnetic islands. The five-fold toroidal symmetry is typically used to combine measurements of separate quantities from different islands. The gas puff imaging (GPI) diagnostic observes complex drift flow patterns in the islands. These flow patterns and SOL profiles are strongly dependent on the magnetic geometry of the island and discharge parameters, such as power and density. GPI measurements show sudden shifts in light emission and fluctuation parameters, indicating changes in plasma conditions. These transitions are not reflected in global core plasma parameters. In addition, divertor heat flux measurements and further SOL diagnostics viewing different islands show that these sudden transitions are often isolated to just one of the five islands. In this contribution, we investigate the prevalence and asymmetry of these SOL plasma parameter changes, as well as their implications for the comparability of physical quantities in different islands.

P 16.18 Thu 13:45 Redoutensaal

**Profile Analysis of the Midplane Helium Beam for Scrape-off Layer Characterization at Wendelstein 7-X** — •FOISAL B.T. SIDDIKI<sup>1,2</sup>, OLIVER SCHMITZ<sup>1</sup>, MACIEJ KRYCHOWIAK<sup>2</sup>, FREDERIK HENKE<sup>2</sup>, DOROTHEA GRADIC<sup>2</sup>, and MIKLOS VECSEI<sup>2</sup> — <sup>1</sup>University of Wisconsin-Madison, Madison, USA — <sup>2</sup>Max Planck Institute for Plasma Physics, Greifswald, Germany

Optimizing the heat and particle exhaust system of Wendelstein 7-X (W7-X) requires a quantitative understanding of scrape-off layer (SOL) transport, informed by measurements of the electron temperature ( $T_e$ ) and density ( $n_e$ ). To investigate SOL transport, a new helium-beam system was installed at the midplane of W7-X and operated during the OP2.2 and OP2.3 experimental campaigns. The midplane helium-beam diagnostics consist of a controlled gas injection system and a high-resolution spectrometer, from which  $T_e$  and  $n_e$  are inferred using helium line ratios based on a collisional radiative model of atomic helium. In this work, we present the first results from the midplane helium beam and benchmark them against co-located alkali-beam measurements. Initial analysis of the midplane profiles reveals two distinct SOL transport regimes. SOL characteristic decay lengths and heat-flux width scaling derived from these profiles will also be presented.

P 16.19 Thu 13:45 Redoutensaal

**Development of multi-diagnostic Bayesian analysis system for inference of plasma parameters in the W7-X edge** — •LINNÉA BJÖRK<sup>1</sup>, FELIX REIMOLD<sup>1</sup>, CHRIS BOWMAN<sup>2</sup>, TAKASHI NISHIZAWA<sup>3</sup>, and GABRIELE PARTESOTTI<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Greifswald, Germany — <sup>2</sup>Culham Centre for Fusion Energy, Culham Science Centre, United Kingdom — <sup>3</sup>Kyushu university, Kasuga, Japan

The W7-X machine is an experimental fusion device designed to study the reactor relevance of the stellarator concept. Its complex three-dimensional geometry makes it difficult to measure the full field of plasma parameters, particularly in the scrape-off layer (SOL), where plasma behaviour can be highly localized. For future reactor design it is important to understand the physics and transport mechanisms in this region. Consequently, a system for integrated Bayesian analysis is implemented for W7-X which will enable the reconstruction of key plasma parameters from a limited diagnostic coverage.

The first steps in the building of the analysis tool and its adaptation to W7-X geometry are here presented. For benchmarking of the system, inversions of bolometry data have been performed and compared to results from Gaussian Process tomography. The two methods agree well, with the full Bayesian inference scheme handling large errors better but being more computationally costly. Further results include introducing divertor spectroscopy both as constraints to the tomographic inversions and as part of the later effort to infer electron density and temperature.

P 16.20 Thu 13:45 Redoutensaal

**Helium exhaust studies in ASDEX Upgrade** — •SIMON KRUMM<sup>1</sup>, ATHINA KAPPATOU<sup>1</sup>, ANTONELLO ZITO<sup>1</sup>, VOLKER ROHDE<sup>1</sup>, GERD SCHALL<sup>1</sup>, MARCO WISCHMEIER<sup>1</sup>, RACHAEL M. MCDERMOTT<sup>1</sup>, and THE ASDEX UPGRADE TEAM<sup>2</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — <sup>2</sup>see the author list of H. Zohm et al. 2024 NF 64 112001

Helium is one of the product of the fusion reaction used in future fusion power plants. Thermalised helium dilutes the fuel and has to be efficiently removed to sustain the fusion process. Recent work at ASDEX Upgrade (AUG) investigated the helium removal in Type-I ELMy H-modes both experimentally and numerically [A. Zito et al. 2023 Nucl.Fusion 63 096027 & 2025 Nucl.Fusion 65 046022].

Helium removal is hindered by its high wall retention in tungsten, as well as the inefficiency of active pumping in AUG. Most importantly, because of helium's high ionisation energy, its divertor retention is low compared to other impurities, leading to inefficient transport from the divertor to the pumping surfaces. The next step is to investigate reactor relevant scenarios - especially those compatible with power exhaust - to also assess their compatibility with helium exhaust. For this, neutral partial pressure measurements in the divertor are needed. We employ optical in-situ and ex-situ Penning gauges, as well as Threshold Ionization Mass Spectrometry in the pumping ducts. Additionally, utilising these diagnostics, the new activated charcoal cryopump [G. Schall et al. 2021 Fusion Eng. Des. 166 112316] recently installed on AUG can be characterised for its helium pumping capability.

P 16.21 Thu 13:45 Redoutensaal

**Characterisation of phase velocities and dispersion relations in Wendelstein 7-X turbulence, assisted by sensitivity analysis of poloidal correlation reflectometry** — SANDER DE KOKER<sup>1,2</sup>, GAVIN WEIR<sup>2</sup>, CARSTEN LECHTE<sup>3</sup>, ANDREAS KRÄMER-FLECKEN<sup>4</sup>, •THOMAS WINDISCH<sup>2</sup>, OLAF GRULKE<sup>2</sup>, and PETER MANZ<sup>1,2</sup> — <sup>1</sup>University of Greifswald, Institute of Physics, Greifswald, Germany — <sup>2</sup>Max Planck Institute for Plasma Physics, Greifswald, Germany — <sup>3</sup>Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, University of Stuttgart, Stuttgart, Germany — <sup>4</sup>Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, Forschungszentrum Jülich GmbH, Jülich, Germany

Different instabilities in plasmas differ in terms of their phase velocity, which is therefore used to identify them. One diagnostic well suited for this is poloidal correlation reflectometry. The sensitivity of its measurement capabilities and its dependence on various parameters is however not fully understood. In order to improve the understanding of turbulence dispersion relations and phase velocities, an initial goal is to investigate and characterise this sensitivity. As a first step, full wave simulations have been performed, showing a dependence of the sensitivity on both turbulence poloidal wavenumber as well as antenna separation.

P 16.22 Thu 13:45 Redoutensaal

**Towards photonic radiometry: Electron Temperature and Density profiles from broadband ECE spectra** — •TAURINO REICHERT<sup>1</sup>, DMITRY MOSEEV<sup>1</sup>, SERGIY PONOMARENKO<sup>1</sup>, VESSEN VASILEV<sup>2</sup>, RUWAN UDAYANGA<sup>2</sup>, PETER ANDREKSON<sup>2</sup>, ANNINA MOSER<sup>3</sup>, and BENEDIKT BAEUERLE<sup>3</sup> — <sup>1</sup>Max Planck Institut für Plasmaphysik, Greifswald, Germany — <sup>2</sup>Chalmers University of Technology, Göteborg, Sweden — <sup>3</sup>Polariton Technologies AG, Adliswil, Switzerland

The trend towards higher magnetic fields in future fusion experiments adds complexity to the design of heterodyne Electron Cyclotron Emission (ECE) radiometers used for measurement of electron temperature ( $T_e$ ) profiles. The evaluation of a single ECE harmonic might require the acquisition of a broadband signal, effectively calling for multi stage systems or multiple separate radiometers. This work outlines the development of a proof-of-concept single stage broadband radiometer at W7-X. Here, ECE spectra between 140 GHz to 220 GHz will be acquired through up-conversion to the Short Wavelength Infrared (SWIR) range around 1550 nm using a plasmonic Mach-Zehnder-Modulator (MZM). The optical signals will be evaluated with a SWIR spectrometer.  $T_e$  profiles are directly obtained from the optically thick second harmonic X-mode (X2) while  $n_e$  profiles are reconstructed from the optically thin third harmonic X-mode (X3) using the ray-tracing code TRAVIS. The diagnostic is expected to yield ECE spectra with a frequency resolution of 1 GHz. The time resolution is yet to be found, aiming at a range between 1 ms to 10 ms.

P 16.23 Thu 13:45 Redoutensaal

**Development of a surface retention model for plasma-wall interactions simulations in the SOLPS-ITER code package** — •REMO IANNINI<sup>1,2</sup>, ANTONELLO ZITO<sup>1</sup>, TIM HAPPEL<sup>1</sup>, DAVID COSTER<sup>1</sup>, KLAUS SCHMID<sup>1</sup>, GREGOR BIRKENMEIER<sup>1,2</sup>, and THE ASDEX UPGRADE TEAM<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching bei München, Germany — <sup>2</sup>Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany

In a fusion reactor, particles escaping the last closed flux surface (LCFS) inevitably interact with the first-wall materials. These surfaces can behave as both sinks and sources for plasma particles, as these can be either absorbed or recycled. Accurately modelling these processes is therefore essential to predict the impact of plasma-wall interactions on plasma transport and exhaust. At present, the SOLPS-ITER code package represents the standard framework for plasma edge modelling. Processes contributing to a long-term retention of plasma particles within the wall surfaces are, however, not currently included within the code capabilities. This PhD project aims to develop a fully integrated, self-consistent wall retention module for the SOLPS-ITER framework, enabling more realistic simulations of plasma-wall interactions by allowing the presence of a temporary wall inventory of plasma particles. This would enable the assessment of impurity dynamics during plasma discharges, the long-term evolution of fuel retention in wall materials, and the prediction of the boronization layer lifetime for ITER.

P 16.24 Thu 13:45 Redoutensaal

**GPU Acceleration of Hybrid Fluid-Kinetic Simulations of Runaway Electrons in JOREK** — •EDOARDO CARRÀ, PATRIK RÁC, HANNES BERGSTRÖM, and MATTHIAS HÖLZL — Max Planck Institute for Plasma Physics

JOREK is a 3D nonlinear, extended magneto-hydrodynamic and hybrid fluid-kinetic code for investigating large scale transient plasma dynamics in realistic tokamak and stellarator fusion plasmas. In high-current tokamaks such as ITER, loss of plasma confinement in a disruption can generate highly energetic “runaway” electrons (REs), which can pose a serious threat to plasma-facing components. Understanding and predicting RE dynamics is therefore essential for safe operation of future fusion reactors. While JOREK supports MPI + OpenMP parallelization on CPUs, hybrid RE simulations span widely different timescales, making them computationally prohibitively expensive on conventional CPU architectures. This work addresses that challenge by porting the fluid and kinetic components of hybrid RE simulations to GPUs. Using OpenMP directives, we ensure portability and transparency across hardware platforms while achieving significant performance improvements. We detail the optimization strategies employed and present a comprehensive performance and verification study on NVIDIA and AMD accelerated architectures by benchmarking the linear growth rate of plasma instabilities in the presence of REs and performing a highly nonlinear RE beam termination event as first large-scale physics application.

P 16.25 Thu 13:45 Redoutensaal

**Characterising the Influence of  $E_r$  Magnitude and Shear on Turbulent Fluctuations in Wendelstein 7-X** — •JAN RICKEN, J. PROLL, H. SMITH, A. LANGENBERG, J. BÄHNER, G. FUCHERT, E. MARAGKOUAKIS, and G. WEIR — Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

In neoclassically optimised stellarators such as Wendelstein 7-X (W7-X), turbulence is the main driver of heat and particle losses, making its regulation crucial to understand. Although the radial electric field,  $E_r$ , and its shear are known to suppress turbulent transport in tokamaks, their quantitative impact in W7-X remains to be studied.

In this work, we present first results from a comprehensive database that link experimentally measured  $E_r$  profiles to (turbulent) fluctuations and transport indicators across a diverse set of W7-X programs. The database enables a systematic comparison of turbulence characteristics with both the magnitude and shear of  $E_r$ .

Experimentally observed trends are compared with neoclassical predictions from the code Neotransp to assess the consistency between measured and expected  $E_r$  profiles. In addition to providing neoclassical  $E_r$  estimates, Neotransp is also used to infer the level of turbulent transport required to satisfy power balance, thereby offering an estimate of turbulence-driven fluxes for a given  $E_r$  profile. Complementarily, GENE flux tube simulations are employed to isolate and quantify the sensitivity of turbulent fluctuations to experimentally relevant variations in the  $E_r$  shear.

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**Implementation of the non-linear Fokker-Planck collision operator for gyrokinetic codes using a moment approach** — •ANDREW IVAN SULIMRO<sup>1</sup>, PHILIPP ULBL<sup>1</sup>, BAPTISTE FREI<sup>1</sup>, and FRANK JENKO<sup>1,2</sup> — <sup>1</sup>Max-Planck Institute for Plasma Physics — <sup>2</sup>University of Texas at Austin

The performance of future magnetic confinement fusion power plants is primarily influenced by plasma confinement which is driven by turbulence. High-fidelity gyrokinetic simulations are key tools to investigate turbulence in fusion devices.

Accurate modeling of collisional physics is essential for these simulations. As the collision frequency is proportional to the square of the ion charge, a realistic collision operator is especially crucial for studying high-Z impurities. On the other hand, the full Fokker-Planck collision operator is computationally expensive due to its integro-differential form.

In this work, the non-linear Fokker-Planck collision operator is solved using a moment approach. This approach provides a systematic manner to capture collisions up to a desirable accuracy while maintaining performance. The implementation is verified through relaxation and conservation studies. We will also demonstrate the physical impact of collisions in zonal flow damping.

P 16.27 Thu 13:45 Redoutensaal

**Neural ODEs for Density and radiated Power Modeling** — •VADIM MUNTEANU, DANIEL BÖCKENHOFF, and MACIEJ KRYCHOWIAK — Wendelsteinstraße 1, 17491 Greifswald, Germany

Real-time capable simulations of plasma in experimental fusion devices, known as flight simulators, are of interest for fusion research as they permit more informed session planning and the development and validation of control schemes before experimentation. Although for tokamaks mature simulators exist at relevant fidelity, because of stellarator’s more complex geometry, similar models are much more costly, rendering them unfeasible for flight simulation. Recently, with the advent of computing power, data abundance and democratization of machine-learning tool-boxes, data-driven methods became feasible in solving the above mentioned shortcomings of traditional modelling techniques.

We are investigating if neural controlled differential equations, a deep learning architecture designed for modelling of irregular time series, can efficiently represent plasma dynamics and serve as a potential simulator for control tasks. We train the model on a small dataset from the last experimental campaign of W7-X to model the evolution of several plasma diagnostics under control parameters such as gas fueling, impurity seeding and electron cyclotron heating. We show that the model is able to capture correlations between actuators and plasma diagnostics. Next we plan to increase the dataset and to extend plasma state with additional diagnostics, and perform a hyper-parameter search.

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**Equilibrium and stability of an electron plasma in a levitated dipole trap** — •PATRICK STEINBRUNNER<sup>1</sup>, ADAM DELLER<sup>1,2</sup>, THOMAS O’NEIL<sup>2</sup>, VERONIKA BAYER<sup>1,3</sup>, MATTHEW STONEKING<sup>4</sup>, and EVE STENSON<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, 85748 Garching, Germany — <sup>2</sup>University of California San Diego, La Jolla, California, 92093 USA — <sup>3</sup>Technical University of Munich, 80333 Munich, Germany — <sup>4</sup>Lawrence University, Appleton, Wisconsin, 54911 USA

As part of the APEX collaboration (An Electron Positron eXperiment) this work supports the experimental results obtained with pure electron plasmas in a levitated dipole trap using two distinct computational methods. The levitated dipole trap confines electrons on closed, purely poloidal magnetic field lines around a superconducting coil that is floating in a vacuum chamber due to external magnetic fields. In combination with positrons coming from NEPOMUC (Neutron induced Positron source MUnich) this trap will ultimately confine a first of its kind, non-relativistic pair plasma. First measurements of the local space charge potentials are used to reconstruct the electron density distribution assuming a local thermal equilibrium along magnetic field lines and solving the Poisson-Boltzmann equation. In addition, results of a 2D drift kinetic model are presented that extend a linear stability analysis conducted previously. This model resembles the large-aspect-ratio limit of the levitated dipole trap, an infinite, current-carrying wire. The implementation of the actual magnetic dipole field is subject to a future study.

P 16.29 Thu 13:45 Redoutensaal

**Applications of Plasma-KG, a knowledge graph for low-temperature plasma physics** — •MARKUS M. BECKER<sup>1</sup>, IHDA CHAERONY SIFFA<sup>1</sup>, HIDIR ARAS<sup>2</sup>, HOLGER ISRAEL<sup>3</sup>, THOMAS KOPRUCKI<sup>4</sup>, BURKHARD SCHMIDT<sup>4</sup>, and MARKUS STOCKER<sup>3</sup> — <sup>1</sup>Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — <sup>2</sup>FIZ Karlsruhe – Leibniz Institute for Information Infrastructure, Eggenstein-Leopoldshafen, Germany — <sup>3</sup>TIB – Leibniz Information Centre for Science and Technology, Hanover, Germany — <sup>4</sup>Weierstrass Institute (WIAS), Berlin, Germany

Knowledge graphs (KGs) play an important role in the structured representation and linking of data, information, and knowledge. As a result, knowledge graphs are finding broad application in the field of research data management. Building on the established plasma metadata schema Plasma-MDS and the plasma ontology Plasma-O, the development of Plasma-KG (<https://vivo.plasma-mds.org>) was initiated to represent reusable entities with persistent identifiers in the field of low-temperature plasma physics. This contribution introduces the essential concepts of Plasma-KG and shows how various data sources can be connected via these formally described entities. The addressed fields of application include content enrichment from knowledge graphs for patents, scientific articles, and mathematical models. It is demonstrated how the future physics information service ‘FID Physik’ can benefit from Plasma-KG as a semantic data platform.

Funded by the BMFT (projects 16KOA013A, 16KOA013B) and DFG (projects 460135501, 496963457, 558452925).

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**ERO2.0 code validation using boron erosion experiments at PSI-2** — •ANDRIY TARASENKO<sup>1,2</sup>, CHRISTOPH BAUMANN<sup>1</sup>, JURI ROMAZANOV<sup>1</sup>, SEBASTIJAN BREZINSEK<sup>1,2</sup>, MARC SACKERS<sup>1</sup>, and ARKADI KRETER<sup>1</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany — <sup>2</sup>Faculty of Mathematics and Natural Sciences, Heinrich Heine University Düsseldorf

Reliable predictions of plasma-wall interactions are essential for the design and operation of future fusion devices. In this work, the impurity transport code ERO2.0 is benchmarked against boron (B) erosion experiments performed at the linear plasma device PSI-2. Thin B layers on tungsten substrates were exposed to deuterium (D) plasmas with ion energies near the physical sputtering threshold, and erosion was quantified through post-mortem FIB-cuts analysis and optical emission spectroscopy. Experimentally inferred sputtering yields exceed classical BCA predictions, confirming earlier observations, such as those by Hecht et al. of enhanced near-threshold B erosion. The exceeding yield can be caused by chemical erosion, which was investigated and compared with measured BD band emission. Using experimental plasma profiles, SDTrimSP sputter data, and synthetic emission line modelling, ERO2.0 reproduces key features of the measured impurity distribution and B emission profiles. The comparison highlights parameter sensitivities and demonstrates the capability of ERO2.0 to interpret PSI-2 measurements and support predictive modelling for ITER.



P 16.31 Thu 13:45 Redoutensaal

**Secondary electron emission from coated plasma walls** — •FRANZ XAVER BRONOLD and FELIX WILLERT — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

Having in mind dielectrically coated metal electrodes, used in barrier discharges, we investigate—from a theoretical solid-state physics point of view—the emission of secondary electrons from solid structures consisting of a thin dielectric layer on top of a metallic or semiconducting halfspace. We thus extend the invariant embedding principle for the electron backscattering function, which we used so far for halfspaces [1], to a stack of two materials. In addition to two backscattering functions, one for the coating and one for the supporting material, the electron transmission function for the coating has to be computed now as well. Focusing on low energies, and describing the solid structure by a randerium-jellium model, containing electron-phonon, electron-ion-core, and electron-electron scattering (leading to impact ionization inside the two materials), we obtain, as a function of layer thickness, the electron surface scattering kernel for the total structure as well as the energy- and angle-resolved secondary electron emission yield. Besides showing results for  $\text{SiO}_2/\text{Si}$  and  $\text{SiO}_2/\text{Au}$ , we also discuss the numerics used for integrating the set of matrix Riccati/Sylvester differential equations for the backscattering and transmission functions of the coatings, which now appear along with the algebraic equation for the support's backscattering function. [1] F.X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024). Supported by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)—495729137.

P 16.32 Thu 13:45 Redoutensaal

**Microphysical boundary condition for the electron Boltzmann equation of a plasma** — FELIX WILLERT<sup>1</sup>, •CLEMENS HOYER<sup>1</sup>, GORDON K. GRUBERT<sup>2</sup>, and FRANZ X. BRONOLD<sup>1</sup> — <sup>1</sup>Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany — <sup>2</sup>Universitätsrechenzentrum, Universität Greifswald, 17489 Greifswald, Germany

We set up an energy- and angle-dependent boundary condition for the electron Boltzmann equation containing the electron microphysics inside the wall [1]. At low energies the boundary condition is based entirely on a computed electron surface scattering kernel [2], while at higher energies measured emission yields are, in addition, fed into the microscopic model to obtain plausible data also in this energy range. We incorporate the kernel within the expansion approach of solving the electron Boltzmann equation, expanding the electron distribution function in Legendre polynomials and linking the expansion coefficients to the moments of the electron flux at the plasma-wall interface, but it can be also implemented in a PIC-MCC simulation of the plasma's electron kinetics. Numerical results for argon, helium, and oxygen plasmas in contact with Si and  $\text{SiO}_2$  surfaces are presented, showing in particular the significance of the inelasticity of the microphysics-based boundary condition compared to an energy- and angle independent phenomenological one. [1] F. Willert et al., arXiv:2511.20346 (2025). [2] F.X. Bronold and F. Willert, Phys. Rev. E **110**, 035207 (2024). F.X.B. and F.W. acknowledge support by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)—495729137.

P 16.33 Thu 13:45 Redoutensaal

**Progress in modelling of shattered pellet injection experiments in fusion plasma** — •ANSH PATEL<sup>1</sup>, GERGELY PAPP<sup>1</sup>, AKINOBU MATSUYAMA<sup>2</sup>, MENGDI KONG<sup>3</sup>, STEFAN JACHMICH<sup>4</sup>, UMAR SHEIKH<sup>3</sup>, JAVIER ARTOLA<sup>4</sup>, PAUL HEINRICH<sup>1</sup>, and ERIC NARDON<sup>5</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>Kyoto University, Uji, Kyoto, Japan — <sup>3</sup>EPFL, Swiss Plasma Center (SPC), Lausanne, Switzerland — <sup>4</sup>ITER Organization, France — <sup>5</sup>CEA, IRFM, France

Large tokamaks like ITER will require a disruption mitigation system (DMS) like the shattered pellet injection (SPI) to ensure machine protection during disruptions. The SPI system injects cryogenic pellets that are shattered before entering the plasma. For the DMS design validation, the effectiveness of SPI must be assessed by numerical simulations. For this purpose, reduced modelling is applied to scan the wide system parameter space available for optimisation and to understand experimental trends. In this poster, we present recent progress in the modelling of the SPI experiments at ASDEX Upgrade (AUG) and JET tokamaks using the INDEX code. We investigate the pre-thermal-quench (pre-TQ) duration trends for varying neon fraction injections in AUG, an important optimization parameter for multiple injections. We have also implemented a recently developed rocket-force model in INDEX and present some initial model estimates for AUG. Additionally, we also present simulation results of recent plasmoid-drift suppression experiments at JET with neon doping.

P 16.34 Thu 13:45 Redoutensaal

**EMC3-EIRENE predictions of radiative detachment scenarios in W7-X equipped with a tungsten based divertor** — •DANIIL RYNDYK<sup>1</sup>, DEREK HARTING<sup>1</sup>, SHUAI XU<sup>1</sup>, YUHE FENG<sup>4</sup>, FLORIAN EFFENBERG<sup>3</sup>, HEINKE FRERICH<sup>2</sup>, SEBASTIAN BREZINSEK<sup>1</sup>, and W7-X TEAM<sup>4</sup> — <sup>1</sup>FZJ GmbH, IFN-1, Jülich, Germany — <sup>2</sup>University of Wisconsin-Madison, Madison, WI, USA — <sup>3</sup>PPPL, Princeton, NJ, USA — <sup>4</sup>MPG IPP, Greifswald, Germany

The nuclear fusion experiment Wendelstein 7-X (W7-X) currently operates with carbon-fiber composite (CFC) plasma-facing components (PFC) forming the island divertor used for particle and power exhaust. In a future fusion reactor, carbon-based PFCs are not tolerable due to unacceptably high fuel retention. An alternative PFC material for a fusion reactor is tungsten (W), which shows in general low sputtering, low fuel retention, and good thermomechanical properties.

As a first systematic approach to study the impact of potential W PFCs in W7-X, we use EMC3-EIRENE as plasma boundary simulation code for 3D magnetic configurations. We investigate detachment scenarios with the standard magnetic configuration of W7-X equipped with a W divertor based on the current divertor geometry and analyze the dependence of detachment relevant parameters (e.g. target heat loads) on operation conditions (e.g. plasma density). In a comparison with the detachment behavior of the current C divertor, we discuss the accessibility of similar, impurity radiation determined detachment and the relevance of volume recombination processes.

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**Computational modeling of hot-cathode ionization gauges for fusion applications** — •ALEXANDER GLOCK<sup>1,2</sup>, MICHAEL GRIENER<sup>1</sup>, CHRISTIAN DROBNY<sup>1</sup>, GREGOR BIRKENMEIER<sup>1,2</sup>, HANS MEISTER<sup>1</sup>, and GEORG SCHLISIO<sup>1</sup> — <sup>1</sup>Max Planck Institute for plasma physics (IPP), Garching/Greifswald, Germany — <sup>2</sup>Technical University of Munich (TUM), Munich, Germany

In magnetic confinement fusion, the measurement of neutral gas densities is an essential metric for plasma control. Hot-cathode ionization gauges are commonly used for this purpose. The so-called ASDEX gauge is a diagnostic instrument designed to provide local and temporally resolved measurements of neutral gas pressure in the presence of strong magnetic fields. It is a hot-cathode ionization gauge with a linear geometry. Its operation relies on the measurement of an ion current produced when electrons emitted from the hot cathode collide with neutral gas particles. This gauge type has been successfully adapted for use in ASDEX Upgrade and Wendelstein 7-X, with further modifications developed for ITER. However, the linear geometry can also introduce signal instabilities due to complex particle interactions within the gauge head. The present project aims to deepen the understanding of the physical processes inside the gauge and to investigate these effects using a detailed computational model validated against experimental data. The gauge system is modeled with a kinetic Boltzmann approach solved through the particle-in-cell (PIC) method with Monte Carlo collisions (MCC), capable of performance prediction and design optimizations toward a robust and universal fusion diagnostic.

P 16.36 Thu 13:45 Redoutensaal

**Towards neoclassical tungsten transport calculations in the edge and island divertor region of optimized stellarators** — •DIOGO MENDONÇA<sup>1,2</sup>, MATTHIAS HOELZL<sup>1</sup>, ORIN VARLEY<sup>1,2</sup>, MATE SZUCS<sup>1,2</sup>, and LUCA VENERANDO GRECO<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — <sup>2</sup>TUM School of Natural Sciences, Boltzmannstraße 10, 85748 Garching, Germany

The successful operation of future nuclear fusion power plants requires strict control over tungsten (W) impurity transport during plasma discharges. If these high-Z impurities accumulate within the plasma, they may severely degrade fusion performance, or make it impossible altogether. This critical issue is not yet fully understood in tokamaks, and even less so in stellarators, which have recently seen renewed interest as promising magnetic confinement concepts. This contribution presents the first studies of collisional W transport using the kinetic model developed in the JOREK code, combined with its recently implemented reduced magnetohydrodynamics (MHD) stellarator model, focusing specifically in the trace impurity limit. By varying the initial positions of W particles within a fixed W7-AS stellarator equilibrium, we aim to quantify the influence of collisions, the electric field, and temperature around magnetic islands on the transport of W in the edge and island divertor region.

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**Reduced Modelling of MHD instabilities and Internal Transport Barriers** — •ERIK EIDSVIG<sup>1,2</sup>, PHILIPP LAUBER<sup>1,2</sup>, and THE ASDEX UPGRADE TEAM<sup>2</sup> — <sup>1</sup>Technical University of Munich — <sup>2</sup>Max Planck Institute for Plasma Physics

Experimentally, fishbones have been observed before the Internal Transport Barrier (ITB) formation in ASDEX Upgrade. In this work, the goal was to investigate the relationship between the fishbone instability and the internal transport barriers. As a first step, reduced models describing the fishbone dynamics and its relationship to turbulence were implemented numerically. The fishbone instability is connected to the turbulence through the current it generates, which drives a poloidal shear flow which can break up turbulent eddies. It was found that the deposition rate of trapped energetic particles, D was the most important factor for setting up the Internal Transport Barrier (ITB), agreeing with the findings from Liu and Fu (2023). The reduced models were tested on ASDEX Upgrade discharge #37114, and the simplified flow shear approximation alone is not sufficient to explain the temperature peaking in the shot. This may indicate that the magnetic shear plays a role in the ITB state observed in the shot.



P 16.38 Thu 13:45 Redoutensaal

**A dual machine learning framework for electron density profile reconstruction** — •CHRISTOS VAGKIDIS, MIRKO RAMISCH, GÜNTER TOVAR, and ALF KÖHN-SEEMANN — IGVP, University of Stuttgart, Germany

Machine learning algorithms can be used either as surrogate models to replace high-fidelity codes or as tools to provide some physical information. In this work, a random decision forest is applied to replace a 3D full-wave model and a deep neural network (DNN) to reconstruct the electron plasma density profile.

The COMSOL Multiphysics software is used for the 3D modeling. A microwave is propagating through an axially symmetric plasma. The spatial power distribution of the wave is measured after the interaction with the plasma. The random forest is trained on these data and is able to predict the wave power for a given electron density profile.

A new dataset is created with the random forest and is used to train the DNN, which is used as an inverse model. By using the beam power as input, the DNN predicts the electron density. The final step is to test the DNN on actual experimental conditions. For this purpose, an atmospheric plasma torch will be used.

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**Full-wave Simulations of Helicon Waves for Plasma Wakefield Accelerators** — •LUIS CARLOS HERRERA QUESADA<sup>1</sup>, NILS FAHRENKAMP<sup>2</sup>, STEFAN KNAUER<sup>2</sup>, PETER MANZ<sup>2</sup>, GÜNTER TOVAR<sup>1</sup>, and ALF KÖHN-SEEMANN<sup>1</sup> — <sup>1</sup>IGVP, University of Stuttgart — <sup>2</sup>University of Greifswald

The plasma wakefield mechanism appears as a solution to produce particles with higher energies than circular accelerators. To achieve the necessary high electric fields, the plasma medium must have a large electron density to create strong gradients. Helicon plasma discharges allow to achieve the plasma densities necessary for effective plasma wakefield accelerators. This study aims to understand helicon wave propagation in linear devices for plasma wakefield optimization and the influence of different antenna geometries on the efficiency of helicon wave excitation. Furthermore, the evolution of the radial plasma density gradient on the coupling to the helicon wave is studied. Numerical modeling of helicon discharges is made using a finite element method (FEM) analysis through the COMSOL Multiphysics code package. Antennas are modeled using the AC/DC and RF modules, then the plasma column response is simulated using the Plasma module. In parallel, the 3D finite-difference time-domain (FDTD) code FHELI (FOCAL for HELIcon) is used for comparative analysis. The code solves the Maxwell equations in conjunction with the fluid motion equation for electrons in a cold magnetized plasma. The numerical scenarios are based on the VINETA.75 device parameters and geometry.

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**Influence of a spatially variable plasma on a cavity's resonance structure for use in a multimodal microwave cavity resonance spectroscopy approach using 3D EM-simulations** — •JOHANNA VOGT<sup>1</sup>, MICHAEL FRIEDRICH<sup>1</sup>, ANDREAS PETERSEN<sup>2</sup>, FRANKO GREINER<sup>2</sup>, and JENS OBERATH<sup>1</sup> — <sup>1</sup>Modelling and Simulation, South Westphalia University of Applied Sciences, 59494 Soest, Germany — <sup>2</sup>Institute of Experimental and Applied Physics, Kiel University, 24118 Kiel, Germany

Several techniques have been developed to bridge the gap between measurable inputs and important plasma parameters, one group of which is active plasma resonance spectroscopy (APRS). In it, a wide-band electromagnetic (EM) signal is coupled into the plasma, and the frequency response of the system is evaluated via a model to yield certain parameters, which can then be used to determine the electron density. One such method is the microwave cavity resonance spectroscopy (MCRS), which analyses the shift of resonance frequencies of a cavity inside a reactor. A promising application due to its non-invasive nature is the characterisation of nanodusty plasmas, and a multimodal approach may yield a spatially resolved electron density profile.

To achieve this, a 3D-EM simulator is used to compare the spectra of a cavity filled with a spatially variable plasma to a vacuum case, and the resulting frequency shifts are analysed to determine local profiles.

We thank the Deutsche Forschungsgemeinschaft for funding this project under grant no. 531667910.

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**Probing Ion Drag and Electric Field Forces in CCRF Plasmas with Optical Tweezers** — •JESSICA NIEMANN, VIKTOR SCHNEIDER, and HOLGER KERSTEN — Institute of Experimental and Applied Physics, Christian-Albrechts-University Kiel, Germany

Many different diagnostics can be used to measure the spatial distribution and temporal evolution of plasma parameters. Over the past decade, the concept of utilizing externally injected microparticles as non-invasive probes, influenced by various forces and energy fluxes in plasmas, has been implemented. Information about local electric fields, energy fluxes, and momentum transfer by ions to the particles can be obtained based on their behavior in the plasma. Especially, the manipulation of microparticles by an optical tweezer is of interest, as it enables the microparticle to be positioned in areas of the plasma typically inaccessible to conventional diagnostic methods, such as the plasma sheath. In this study, optically trapped microparticles in a highly focused laser beam are used to investigate

both the electrostatic field force in the sheath and the ion drag force in the presheath of a capacitively coupled radio-frequency discharge. These forces differ by roughly one order of magnitude, requiring adjustments of the trapping laser power to control the sensitivity of the optical trap accordingly. By observing the displacement of the trapped particle under varying gas pressure and phase angle in dual-frequency discharges, the spatial structure and parameter dependence of both forces are resolved. These measurements allow the experimental reconstruction of the fundamental plasma structure comprising bulk, presheath, and sheath.

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**In-vacuo DBD-XPS surface study of Au and Ag electrodes exposed to N<sub>2</sub>/H<sub>2</sub> plasmas** — •A.A. BEN YAALA<sup>1</sup>, R. ANTUNES<sup>1</sup>, T. HÖSCHEN<sup>1</sup>, A. MANHARD<sup>1</sup>, A. HECIMOVIC<sup>1</sup>, and U. FANTZ<sup>1,2</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching, Germany — <sup>2</sup>University of Augsburg, 86149 Augsburg, Germany

Dielectric barrier discharge (DBD) reactors are one of the most commonly studied discharges for plasma-assisted ammonia (NH<sub>3</sub>) synthesis due to their simplicity, low gas temperatures, and compatibility with catalytic materials. However, the limited access to the catalyst's surface in conventional DBD designs hinders a detailed fundamental understanding of the plasma-surface chemistry responsible for NH<sub>3</sub> formation.

In this work, an in-vacuo planar DBD-XPS (X-Ray Photoelectron Spectroscopy) setup developed to investigate the chemistry of electrode surfaces exposed to N<sub>2</sub>/H<sub>2</sub> plasmas is introduced. The use of noble surfaces such as gold (Au) and silver (Ag) prevents formation of metallic nitrides and enables studying the effect of adsorbed NH<sub>x</sub> species. This contribution compares the concentrations of the adsorbates resulting from various plasma conditions with the ammonia synthesis rates determined with mass spectrometry.

P 16.43 Thu 13:45 Redoutensaal

**Investigation and characterization of a linearly extended microwave plasma source for a metal foil pump** — •TIM WERZ, STEFAN MERL, ANDREAS SCHULZ, MATTHIAS WALKER, and GÜNTER TOVAR — University of Stuttgart, Germany

Future fusion power plants use only a fraction of the fuel materials. Being able to separate and recirculate tritium and deuterium from the exhaust gas is a critical step towards industrialization. A promising design to achieve isotope separation is a metal foil pump (MFP). The MFP utilizes superpermeation of atomic hydrogen isotopes to separate it from molecular hydrogen, helium and plasma enhancing gases. This separation technique can even be used against a pressure gradient.

In order to generate the atomic isotopes on the upstream side, the Duo-Plasmaline, a linearly extended and highly scalable microwave plasma source, is utilized. This plasma source is being investigated via a number of different analysis techniques, such as optical emission spectroscopy and Langmuir-Probes. A energy dispersive mass spectrometer is used to obtain information about the ion energy and types. The plasma density, temperature, distribution and type of ions, as well as impurities and non metallic layers on the metal foil play a critical role in its performance. Besides hydrogen species, heavier atoms and ions such as carbon, nitrogen and oxygen are being investigated.

P 16.44 Thu 13:45 Redoutensaal

**Design and simulation of a Cylindrical Deflection Analyzer** — •LEO ZEIDLER, THOMAS TROTTEBERG, and HOLGER KERSTEN — Christian-Albrechts-Universität Kiel

Electric propulsion (EP) thrusters have become standard in satellite systems since the 1990s [1]. The growing demand for space missions has accelerated the development and refinement of new thruster concepts [2]. The Ref4EP project, a collaboration between Kiel University, Giessen University, and IOM Leipzig, aims to standardize pre-flight testing procedures for EP devices. This involves the development of a 127° Cylindrical Deflection Analyzer (CDA) which is an alternative to traditional Retarding Potential Analyzers (RPAs) for measuring ion energy distribution functions (IEDFs) in ion beams. While on-flight diagnostics typically rely on robust top-hat analyzers, the CDA offers advantages for laboratory environments due to simple electrode geometry and higher energy resolution.

The final CDA design along with numerical simulations are presented.

[1] K. Holste et al., Rev. Sci. Instrum. 91 (2020) 061101

[2] T. Trottenberg et al., EPJ Tech. Instrum. 8 (2021) 16

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**The ALBATOR project: A 3.5-year visionary project pioneering a contactless solution for space debris removal** — •VIKTOR SCHNEIDER for the ALBATOR-Collaboration — Institute of Experimental and Applied Physics, Christian-Albrechts University Kiel

ALBATOR, proposes the use of the Ion Beam Shepherd method as a concept for contactless space debris removal, which relies on momentum transfer from a collimated, multiple charged plasma beam. The project focuses on designing and developing an Electron Cyclotron Resonance (ECR)-like ion beam system. To achieve that ambition, ALBATOR will optimize the ion beam system by gaining

a deep understanding of plasma discharge and plume expansion physics. It will create advanced models to simulate plasma discharge and its interaction with debris, accounting for factors such as multiple charged ions, electromagnetic wave behavior, and materials interactions like sputtering, which influence momentum transfer. A series of vacuum chamber tests will be conducted to characterize the ion beam's properties, such as ion current, energy, and composition, under simulated space conditions. Additionally, the interaction of the ion beam with various satellite materials will be studied to assess its efficiency in momentum transfer. The systems versatility will also be tested using different propellants. The results from these tests will contribute to simulations of various mission scenarios, including debris deorbiting and detumbling.

P 16.46 Thu 13:45 Redoutensaal

**Simulation of a Birdcage Antenna for Efficient Helicon-Mode Excitation** — •BENNET SCHAHL, LUIS HERRERA QUESADA, ALF KÖHN-SEEMANN, and GÜNTER TOVAR — IGVP, University of Stuttgart, Germany

Helicon discharges can generate plasma densities significantly higher than those of conventional radio-frequency sources at comparable input power, making them attractive for applications ranging from plasma wakefield accelerators and plasma propulsion to fusion-relevant experiments and semiconductor manufacturing. Helicon waves are bounded whistler waves belonging to the family of right-hand polarized waves.

Birdcage antennas offer a promising geometry for coupling RF power into magnetized low-temperature plasmas. They form resonant network structures consisting of repeated parallel assemblies of inductive and capacitive elements that support distinct sets of resonant modes. This work focuses on optimizing a birdcage antenna for efficient excitation of electromagnetic waves in the so-called "helicon regime".

The study is conducted using COMSOL Multiphysics with the primary objective of optimizing the birdcage antenna design. The electromagnetic properties of the antenna are modeled to identify parameters that maximize field structures favorable for helicon-mode excitation. Based on these optimized configurations, the model may optionally be extended to include a plasma domain, enabling the evaluation of power deposition, mode formation, and the resulting plasma response.

The combined results aim to guide the design of future experimental setups.

P 16.47 Thu 13:45 Redoutensaal

**Simulation of electron swarms in cylindrical magnetrons and their interaction with a boundary** — •GIBRAN BRUNE<sup>1</sup>, LUKAS VOGELHUBER<sup>1</sup>, KEVIN KÖHN<sup>1</sup>, DENNIS KRÜGER<sup>1</sup>, JENS KALLÄHN<sup>1</sup>, YULIA SHAROVA<sup>1</sup>, LIANG XU<sup>2</sup>, DENIS EREMIN<sup>1</sup>, and RALF PETER BRINKMANN<sup>1</sup> — <sup>1</sup>Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — <sup>2</sup>School of Physical Science and Technology, Soochow University, Suzhou 215006, China

In this work, the motion of electrons in a cylindrical magnetron is simulated using predefined analytical electric and magnetic fields. Electrons are modeled as particles with an initial Maxwell-Boltzmann velocity distribution and are uniformly initialized within the simulation domain. Particle trajectories are computed using the Boris algorithm formulated in cylindrical coordinates. Due to the underlying geometry, the magnetic field exhibits azimuthal symmetry typical of cylindrical planar magnetron configurations. A diagnostic routine is employed to evaluate electron impacts on the cathode. This simplified simulation yields characteristic impact profiles in a realistic geometry and provides insights into electron dynamics and their dependence on the magnetic field configuration. Furthermore, more complex boundary interactions are investigated under simplified conditions.

P 16.48 Thu 13:45 Redoutensaal

**Electron dynamics in a linear magnetron magnetic field configuration** — •ZAHRA ALINIA<sup>1</sup>, LUKAS VOGELHUBER<sup>1</sup>, KEVIN KÖHN<sup>1</sup>, DENNIS KRÜGER<sup>1</sup>, JENS KALLÄHN<sup>1</sup>, YULIA SHAROVA<sup>1</sup>, LIANG XU<sup>2</sup>, DENIS EREMIN<sup>1</sup>, and RALF PETER BRINKMANN<sup>1</sup> — <sup>1</sup>Institute of Theoretical Electrical Engineering, Ruhr University Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany — <sup>2</sup>School of Physical Science and Technology, Soochow University, Suzhou 215006, China

Magnetrons are essential devices in both scientific research and industrial applications. They are highly versatile and are used in a wide range of geometrical configurations. Two prominent configurations are the cylindrical magnetron, characterized by its inherent azimuthal symmetry, and the linear magnetron, which is structurally more complex but of greater industrial relevance. In this work, we employ a particle-based simulation to study electron dynamics in a linear magnetron magnetic configuration. Electrons are traced using the Boris pusher in cartesian coordinates. The magnetic field is modeled analytically based on a spatial arrangement of magnetic dipoles. An optimal structuring of these dipoles produces a magnetic field geometry that closely resembles the field configuration of a linear industrial magnetron in a so-called "stadium geometry". Electrons moving in this magnetic field experience the Lorentz force and are therefore confined near the racetrack region. Electron dynamics in this stadium geometry are numerically investigated and analyzed.

P 16.49 Thu 13:45 Redoutensaal

**Wave phenomena in plasmas - a students' experiment** — •ALF KÖHN-SEEMANN<sup>1</sup> and BAYANE MICHOTTE DE WELLE<sup>2</sup> — <sup>1</sup>IGVP, Uni Stuttgart, Germany — <sup>2</sup>NASA, Goddard Space Flight Center

This presentation describes a plasma physics experiment developed as part of a Master's level student lab course at the University of Stuttgart. The experiment is designed to convey fundamental plasma properties through the investigation of wave phenomena such as oscillations at the plasma frequency and ion acoustic waves. The plasma is generated by thermionic discharges in a double-plasma device. A multi-cusp magnetic field, produced by permanent magnets mounted on the vacuum vessel wall, leads to relatively high plasma densities while maintaining a magnetic field-free region in the plasma bulk. This enables clear observation of fundamental wave phenomena under well-controlled conditions. The experimental set-up allows great flexibility in the external control parameters, enabling students to gain hands-on experience with plasma diagnostics and wave excitation. The experiment has proven a versatile and robust platform for teaching key concepts in plasma physics.

P 16.50 Thu 13:45 Redoutensaal

**System-theoretic view of the pMRP** — •PARIA KERAMATBAKSH<sup>1</sup>, DENNIS KRÜGER<sup>1</sup>, JENS OBERRATH<sup>2</sup>, CRISPIN EWUNTOH<sup>2</sup>, and RALF PETER BRINKMANN<sup>1</sup> — <sup>1</sup>Ruhr-University Bochum, Germany — <sup>2</sup>South Westphalia University of Applied Sciences, Germany

The term *Active plasma resonance spectroscopy (APRS)* denotes a family of diagnostic methods which exploit the ability of low-pressure plasmas to exhibit pronounced resonances when excited by a signal in the radio-frequency range. The *planar multipole resonance probe (pMRP)* implements this time-honored concept in a wall-embedded, non-intrusive geometry suited for industrial environments.

For modeling purposes, a system-theoretic point of view is adopted. The radio-frequency signal source is coupled via a 50 Ω coaxial transmission line to a spatially extended probe structure, which is interpreted as a four-port network. Through a planar interface, the probe is coupled to the plasma, represented as a two-port characterized by its spectral admittance  $Y(k, \omega)$ . Earlier studies have established a quantitatively accurate representation of  $Y(k, \omega)$  based on kinetic theory [1]. In the present work, the focus is instead on the mathematical formulation of the coupling itself. As a deliberate simplification, the plasma response is described by the classical Drude model. This reduced description provides a transparent baseline for analyzing probe-plasma coupling and enables systematic comparison with commercial electromagnetic simulations.

[1] C. Wang et al. *Plasma Sources Sci. Technol.* **30**, 105011 (2021)

P 16.51 Thu 13:45 Redoutensaal

**ICCD-Measurements of rf-discharges in the Zyflex chamber** — •BALDO BÁN KABUSS, CHRISTINA KNAPEK, and ANDRÉ MELZER — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

In dusty plasmas the properties of the discharge strongly affect how clouds of embedded microparticles behave. Usually forces created by the plasma induce a large void in the center of the dust cloud. The Zyflex chamber is a device with four independent rf electrodes which is capable of creating homogeneous dust clouds under microgravity conditions. In this contribution the shape and intensity of the plasma glow is observed on a nanosecond time scale using a very light-sensitive ICCD-camera. From this data the spatially and time resolved excitation is calculated. The investigation allows deeper understanding of how phase and/or amplitude differences between electrodes change the plasma and thus affect dust cloud shape and structure.

P 16.52 Thu 13:45 Redoutensaal

**Dust particle dynamics in a pulsed discharge in microgravity** — •CHRISTINA A. KNAPEK, DANIEL P. MOHR, STEFAN SCHÜTT, DANIEL MAIER, and ANDRÉ MELZER — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany

The charge of micrometer-sized particles immersed in a low-temperature plasma is determined mainly by the electron temperature. If the plasma is operated in a pulsed mode, it is partially in temporal afterglow, and the time-averaged electron temperature decreases. This is expected to impact the particle charge, as well as observable interactions and particle dynamics.

Experiments were performed as part of a parabolic flight campaign with the Zyflex chamber, a versatile plasma chamber designed for the future microgravity complex plasma facility COMPACT. Particles were injected into the plasma during the microgravity phase, while the plasma source, a four-channel radio-frequency generator connected to four separate electrodes, was operated in a pulsed mode. Different operation scenarios were applied (e.g. random successive pulsing of the four channels). One operation mode introduced "off"-times, during which the plasma was in the temporal afterglow for a short while. First experimental results of the impact of the pulsed mode on particle dynamics, and complementary plasma diagnostic measurements are presented.

This work was and is funded by DLR/BMWi (FKZ 50WM2161, 50WM2561).

P 16.53 Thu 13:45 Redoutensaal

**Optical system for COMPACT** — •DANIEL P. MOHR, STEFAN SCHÜTT, CHRISTINA A. KNAPEK, DANIEL MAIER, and ANDRE MELZER — Institute of Physics, University of Greifswald, 17489 Greifswald, Germany  
The future complex plasma facility COMPACT [1] will allow the investigation of large three-dimensional complex plasmas under microgravity conditions aboard a space station. COMPACT is a project with international scientific contributions, supported by space agencies (DLR, NASA, ESA) and NSF.

Camera-based observation of dust particles is the most important diagnostic for complex plasma experiments. So far, however, measuring their three-dimensional positions has not been possible in low Earth orbit.

For COMPACT a sophisticated optical system is foreseen, including 2D and 3D diagnostics. This system consists of the camera setup, the recording hardware and software as well as the evaluation software (e. g. [2]). We will present concepts/design for the camera setup as well as concepts for the evaluation.

This work was and is funded by DLR/BMWi (FKZ 50WM2161, 50WM2561).

[1] C. A. Knapek et al., DOI: 10.1088/1361-6587/ac9ff0

[2] D. P. Mohr et. al., DOI: 10.3390/jimaging5020030

P 16.54 Thu 13:45 Redoutensaal

**Effects of electrode geometry and circuit on electric breakdown in atmospheric-pressure argon** — ALEKSANDAR JOVANOVIĆ, •MARGARITA BAEVA, and MARKUS M. BECKER — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

Electrical breakdown and subsequent re-breakdown are pivotal phenomena for the performance of switching and protective devices. This contribution presents a detailed modelling study of the electrical breakdown in argon at atmospheric pressure under direct current (DC) voltage in pin-plane geometry. A time-dependent and spatially two-dimensional fluid-Poisson model is employed to capture the spatio-temporal evolution of the discharge. An external electrical circuit involves the DC power supply, a series resistor, and an external capacitor. A parametric study of the influence of the resistance, capacitance and electrode shapes reveals distinct operation regimes, ranging from a low-current corona discharge to a high-current transient spark. The observed mode transitions are caused by the interplay of the circuit components and the discharge configuration. In all regimes, the gas and electrode temperatures differ considerably. Maximum temperature is localised in the cathode sheath, where the electric field is strongest and affects the cathode heating. The results reveal the coupling between geometry, electrical circuit and discharge, providing insights for optimisation of high-frequency switching and ignition devices.

The study was supported by the DAAD in the framework of Projekt-ID 57703239.

P 16.55 Thu 13:45 Redoutensaal

**Analysis of spatio-temporal ignition patterns in dielectric barrier discharges** — •CRISTIAN FLORES, HANS HÖFT, KLAUS-DIETER WELTMANN, and MARKUS M. BECKER — Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany

The occurrence of a repetitive spatio-temporal filament pattern in a dielectric barrier discharge (DBD) is analysed with a combined experimental, modelling, and equivalent circuit approach. The symmetric multi-filament DBD arrangement consists of two parallel tube electrodes (alumina-covered metal rods) separated by a 1 mm gas gap in synthetic air at atmospheric pressure. The system is driven by a high-voltage sinusoidal waveform with 11 kV<sub>pp</sub> at 10 kHz. Under these conditions, it is observed that the filaments ignite in two stages at alternating positions during each half-period. A fluid-Poisson model is used to study the dynamics of the DBD and to validate the estimations of the filament ignition times obtained from the equivalent electric circuit (EEC) in terms of the breakdown voltage, transferred charge, and an initial condition for the gap voltage. The validated expressions of the EEC model are then used to interpret the experimentally observed filament ignition patterns. The results suggest that a spatial variation in the gap voltage is responsible for the observed effects.

This work was funded by the Deutsche Forschungsgemeinschaft (DFG), project number: 535827833.

P 16.56 Thu 13:45 Redoutensaal

**CO<sub>2</sub> Conversion and Oxygen Removal in the Effluent of a Plasma** — •KATHARINA WIEGERS<sup>1</sup>, THOMAS SCHIESTEL<sup>2</sup>, RODRIGO ANTUNES<sup>3</sup>, ANDREAS SCHULZ<sup>1</sup>, MATTHIAS WALKER<sup>1</sup>, and GÜNTER TOVAR<sup>1</sup> — <sup>1</sup>University of Stuttgart, Stuttgart, Germany — <sup>2</sup>Fraunhofer IGB, Stuttgart, Germany — <sup>3</sup>Max-Planck-Institute IPP, Garching b. München, Germany

Plasmas offer a promising pathway for energy-efficient CO<sub>2</sub> conversion into CO. However, their performance is strongly influenced by the chemistry in the plasma effluent. Consequently, the suppression of back-reactions is essential, which can be achieved by employing tailored gas nozzle designs. This study investigates how the nozzle geometry enhances CO<sub>2</sub> conversion by modifying the effluent flow. A major challenge in CO<sub>2</sub> plasma conversion is the formation of oxygen in the product gas, which reduces the efficiency of subsequent reactions. Oxygen-conducting hollow-fiber membranes are employed to selectively extract

O<sub>2</sub> from the effluent of an atmospheric microwave plasma torch. The influence of microwave power on the temperature distribution in the plasma membrane reactor and the resulting oxygen permeation flux is analyzed. Furthermore, the effect of a nozzle positioned between the plasma and the membrane module is examined; it alters flow and species distribution in the effluent, significantly affecting O<sub>2</sub> permeation. Finally, integration of up to 21 hollow-fiber membranes into the effluent stream demonstrates efficient and scalable oxygen removal.

P 16.57 Thu 13:45 Redoutensaal

**Electron densities and temperatures of a microsecond pulsed plasma in water** — •OLIVER KRETTEK, PIA-VICTORIA POTTKÄMPER, NEIL UNTEREGGE, SVEN WELLER, NILS HUBER, and ACHIM VON KEUDELL — Experimental Physics II, Ruhr-Universität Bochum, 44801 Bochum, Germany

Plasma ignition in liquids enables a wide range of applications, including the production of hydrogen peroxide, nanoparticle formation in solution and on surfaces, and plasma-assisted electrolysis, for example in the reactivation of copper catalysts for electrochemical reduction of CO<sub>2</sub>. While nanosecond pulsed plasmas typically generate higher yields of reactive species, microsecond pulsed plasmas offer the advantage of easier integration into electrolysis cells. To better understand the behavior of such plasmas prior to their use in an electrochemical system, key plasma characteristics must be determined. In this study, optical emission spectroscopy is applied to investigate the H-alpha and O 777 nm emission lines of a microsecond pulsed plasma in water. By fitting the measured line profiles with a model incorporating Stark, van der Waals, and Doppler broadening, electron densities of up to 10<sup>22</sup> m<sup>-3</sup> and electron temperatures around 2500 K are obtained for different ignition voltages and pulse frequencies. Additionally, the ignition behavior as a function of electrode distance is examined. Experimental ignition thresholds for varying electrode gaps and voltages are compared with a simulation, showing very good agreement. Remaining discrepancies in the observed slopes may be related to transient bubble formation caused by Joule heating during ignition.

P 16.58 Thu 13:45 Redoutensaal

**CH<sub>4</sub> Conversion with a microwave plasma torch** — •CLEMENS KRANIG<sup>1</sup>, ANTE HEČIMOVIĆ<sup>1</sup>, and URSEL FANTZ<sup>1,2</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstr. 2 — <sup>2</sup>University of Augsburg, Universitätsstr. 1, D-86159 Augsburg

The use of microwave plasmas for converting various gases into value added chemicals is a promising technology, as the process relies solely on electrical power input and offers short start-up times - both advantageous when integrating such a technology with renewable power in terms of energy storage. In that regard, methane is an attractive feedstock due to its high volumetric hydrogen content. In a plasma torch, a low-temperature plasma with gas temperatures of 4000 - 6000 K is generated, enabling endothermic reactions such as methane pyrolysis (CH<sub>4</sub> → 2H<sub>2</sub> + C<sub>s</sub>) and dry reforming of methane (CH<sub>4</sub> + CO<sub>2</sub> → 2H<sub>2</sub> + 2CO). Deposition of solid carbon and post-plasma water condensation complicate atomic balances (H, C, O), posing key challenges for process analysis. This contribution investigates the conversion of CH<sub>4</sub> and CH<sub>4</sub>/CO<sub>2</sub> mixtures for H<sub>2</sub> or syngas production. Plasma characterization is performed via optical emission spectroscopy, complemented by downstream gas analysis using gas chromatography and mass spectrometry.

P 16.59 Thu 13:45 Redoutensaal

**Modelling and experimental study of decomposition dynamics of nitric oxide in a helium radio frequency atmospheric pressure discharge** — •MARJAN STANKOV<sup>1</sup>, FLORIAN SIGENEGGER<sup>1</sup>, RONNY BRANDENBURG<sup>1,2</sup>, EVA WOLFE<sup>3</sup>, ADITYA BHAN<sup>3</sup>, and PETER BRUGGEMAN<sup>4</sup> — <sup>1</sup>Leibniz Institute for Plasma Science and Technology (INP), Greifswald, Germany — <sup>2</sup>Institute of Physics, University of Rostock, Rostock, Germany — <sup>3</sup>Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, MN, USA — <sup>4</sup>Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN, USA

The reduction of nitric oxide (NO) in a helium radio frequency (13.56 MHz) atmospheric pressure plasma jet has been investigated using combined modelling and experimental approaches. The plasma jet under investigation comprises a quartz tube, a tungsten needle as the inner electrode, and a copper ring as the outer electrode. Using a plug-flow model, the modelling study couples particle balance equations for the considered species, mean electron energy equation and a heat equation, taking into account He-NO chemistry involving approximately 300 volume and surface reactions. The modelling results are validated using molecular beam mass spectrometry measurements of NO, N<sub>2</sub>, O<sub>2</sub>, O and NO<sub>2</sub> over a range of input powers, gas flow rates and initial NO concentrations. The model reproduces the measured trends, identifies the production and loss channels for the species considered, and reveals how varied parameters influence NO decomposition. This work has been funded by the DFG-NSF project no. 509169873.

P 16.60 Thu 13:45 Redoutensaal

**CO<sub>2</sub>-to-CO conversion in a micro cavity dielectric barrier discharge and initial data-driven analysis** — •MICHAEL ROLOFF, HENRIK VAN IMPEL, DAVID EISELT, VOLKER SCHULZ-VON DER GATHEN, MARC BÖKE, and JUDITH GOLDA — PIP, Ruhr-University Bochum, D-44801 Bochum

The micro cavity plasma array (MCPA) is an atmospheric pressure dielectric barrier discharge [1]. It serves as a research reactor to investigate ways of improving conversion by adding a catalyst. Fourier-transform infrared spectroscopy quantifies CO<sub>2</sub>-to-CO conversion under different conditions. We present experiments using 1 slm helium with 0.1 % CO<sub>2</sub> and up to 2 W power, yielding conversion rates of 15.5 % (no catalyst), 14.5 % (SrTiO<sub>3</sub>), and 12 % (BaTiO<sub>3</sub>). Additionally, the gas flow pattern were optimized in order to increase conversion efficiency.

A second separately aspect of the project covers data-driven methods to extract useful information from plasma diagnostics. In first tests, we applied neural networks and simple statistical tools to measured signals (e.g. current or spectra) to understand method behavior and interpret basic plasma characteristics.

The experiments and data-driven analysis are intended to be combined in the future to enable machine learning-based parameter estimation.

Supported by DFG within project A6 (SFB 1316)

[1] Dzikowski et al. 2020 Plasma Sources Sci. Technol. 29 035028

P 16.61 Thu 13:45 Redoutensaal

**A novel reactor to observe changes in ion composition *in operando* by continuously changing the plasma facing material** — •MAURICE ARTZ<sup>1</sup>, JANNIS CHRISTIANSEN<sup>1</sup>, KERSTIN SGOINNA<sup>1</sup>, and JAN BENEDIKT<sup>1,2</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University, Germany — <sup>2</sup>Kiel Nano, Surface and Interface Science (KiNSIS), Kiel University, Germany

In atmospheric pressure plasmas it is difficult to observe *in operando* the formation of ionic species. However, this observation is crucial e.g. for the understanding of the correlation of materials and plasma properties in the field of plasma-assisted catalysis. Therefore, a sub-atmospheric pressure radio frequency (RF) reactor was developed to bridge this research question. It allows for the *in operando* speciation analysis during the continuous change of the plasma facing material. The influence of the material facing the plasma region on the plasma composition can be observed in this reactor.

The sub-atmospheric RF reactor is operated in a pressure range from 20 to 80 mbar. The reactor is mounted atop the sampling orifice of an ion mass spectrometer, acting as a grounded electrode, so that the plasma is directly ignited above the orifice and created ions can be studied. Halfly coated walls can be moved along the plasma by continuously measuring the changes of ion fluxes. In first measurements the walls were coated with carbon for etching experiments or cobalt containing catalysts for conversion experiments.

P 16.62 Thu 13:45 Redoutensaal

**Validation of nitrogen-seeded XPR simulations and comparison with other impurities on ASDEX Upgrade using JOREK** — •MATE SZUCS<sup>1,2</sup>, ANDRES CATHEY<sup>1</sup>, MATTHIAS HÖLZL<sup>1</sup>, YU-CHIH LIANG<sup>1</sup>, MATTHIAS BERNERT<sup>1</sup>, OU PAN<sup>1</sup>, DANIEL MARIS<sup>3</sup>, SVEN KORVING<sup>2</sup>, JAVIER ARTOLA<sup>2</sup>, RICHARD PITTS<sup>2</sup>, and THE ASDEX UPGRADE TEAM<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>ITER Organization, St. Paul Lez Durance Cedex, France — <sup>3</sup>DIFER, Eindhoven, Netherlands

The X-Point Radiator (XPR) regime is a promising exhaust solution for future large-size tokamaks, featuring a cold, dense, highly radiative region above the X-point, inside the confined region. Such regimes have been achieved experimentally on several tokamaks, with different seeded impurities, and ELM suppression is seen when the XPR reaches a threshold height. Modeling with several codes has successfully reproduced several features seen in experiments. However the effects on the pedestal which results in ELM suppression has not been studied. In this contribution, we present the current status of modeling of the XPR regime on the ASDEX Upgrade (AUG) tokamak with the visco-resistive nonlinear MHD code JOREK. An extension treats neutrals and impurities kinetically, including their interactions with the background fluid plasma. This extension is under constant development, allowing for benchmarking with other codes and experimental validation. Nitrogen-seeded simulations are compared to SOLPS-ITER and AUG experiments, further modeling is presented using different impurity species such as argon and neon.

P 16.63 Thu 13:45 Redoutensaal

**Algorithms and optimizations for global non-linear hybrid fluid-kinetic finite element stellarator simulations** — •LUCA VENERANDO GRECO<sup>1</sup>, MATTHIAS HOELZL<sup>1</sup>, GUIDO HUIJSMANS<sup>2</sup>, and EDOARDO CARRA<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching b. M., Germany — <sup>2</sup>CEA, IFRM, F-13108 Saint-Paul-lez-Durance, France

Predictive modeling of stellarator plasmas is crucial for advancing nuclear fusion energy, yet it faces unique computational difficulties. One of the main challenges is accurately simulating the dynamics of specific particle species that are not well captured by fluid models, which necessitates the use of hybrid fluid-kinetic models. The non-axisymmetric geometry of stellarators fundamentally couples the

toroidal Fourier modes, in contrast to what happens in tokamaks, requiring different numerical and computational treatment.

This work presents a novel, globally coupled projection scheme inside the JOREK finite element framework. The approach ensures a self-consistent and physically accurate transfer of kinetic markers to the fluid grid, effectively handling the complex 3D mesh by constructing and solving a unified linear system that encompasses all toroidal harmonics simultaneously. To manage the computational complexity of this coupling, the construction of the system's matrix is significantly accelerated using the Fast Fourier Transform (FFT). The efficient localization of millions of particles is made possible by implementing a 3D R-Tree spatial index, which supports this projection and ensures computational tractability at scale.

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**High-strength material for fusion reactor magnet sections** — •FAREEHA ASHRAF<sup>1,2</sup>, ZAHRA ABBASI<sup>2</sup>, and KLAUS-PETER WEISS<sup>2</sup> — <sup>1</sup>IGVP, University of Stuttgart, Germany — <sup>2</sup>Karlsruhe Institute of Technology (KIT), Institute for Technical Physics, Germany

The demand for high-strength materials for the magnet sections of future fusion reactors requires a structural material that can sustain exceptional mechanical performance at cryogenic temperatures. Conventionally used steels, such as 316LN, JK2LB, Incoloy 908, and JJ1, face limitations in achieving the target properties of Yield Strength yield strength yield strength (YS) > 1500 MPa and fracture toughness (KIC) > 130 MPa m<sup>1/2</sup>. XM-19, a non-magnetic, Corrosion-resistant austenitic stainless steel offers high strength and toughness; however, its performance at cryogenic temperatures has not yet been finalized. This work focuses on XM-19 manufactured by controlled casting, forging, and heat-treatment routes. The mechanical testing, including tensile testing, fracture toughness evaluation, and fatigue assessment, combined with optical and electron microscopy, will be used to correlate material response with deformation modes, grain characteristics, and precipitate stability. The results focus on the structural evaluation of XM-19 under cryogenic operations and its potential for large-scale fusion applications.

P 16.65 Thu 13:45 Redoutensaal

**Density dynamics of shattered pellet injection using a dispersion interferometer** — •ANDREW MOREAU<sup>1,2</sup>, ALEXANDER BOCK<sup>1</sup>, STEFAN JACHMICH<sup>3</sup>, UMAR SHEIKH<sup>4</sup>, GERGELY PAPP<sup>1</sup>, ANSHKUMAR PATEL<sup>1</sup>, and THOMAS PÜTTERICH<sup>1,2</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>Ludwig Maximilian University, Munich, Germany — <sup>3</sup>ITER Organization, St Paul Lez Durance Cedex, France — <sup>4</sup>Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

High-current tokamaks contain a severe risk from unmitigated disruptions. Loss of plasma confinement in these scenarios could lead to excessive heat and force loads on a reactor and create runaway electron beams capable of causing intense localized damage inside the device. Shattered pellet injection is a promising candidate for disruption mitigation, controlling the thermal and current quenches during an unavoidable disruption.

The core density evolution following injected hydrogenic and neon-doped hydrogenic fragments is a key indicator of the disruption mitigation effectiveness. At ASDEX Upgrade, the line-integrated electron density through the core is evaluated using a dispersion interferometer. Results from the 2025 campaign show how a small quantity of neon doping (~ 0.1%) in a deuterium shattered pellet injection can result in significantly higher density retention (~ 4 · 10<sup>20</sup> m<sup>-2</sup>) at much later phases in the current quench. Furthermore, the multiple pellet injection schemes have been shown to achieve high densities while lengthening the duration of the pre-thermal quench.

P 16.66 Thu 13:45 Redoutensaal

**Self-consistent eddy and halo current coupling of a 3D non-linear MHD plasma with 3D realistic wall structures** — •RAFFAELE SPARAGO<sup>1,2</sup>, JAVIER ARTOLA<sup>2</sup>, MATTHIAS HOELZL<sup>1</sup>, NICOLA ISERNIA<sup>3</sup>, GUGLIELMO RUBINACCI<sup>4</sup>, NINA SCHWARZ<sup>2</sup>, SALVATORE VENTRE<sup>5</sup>, and FABIO VILLONE<sup>3</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — <sup>2</sup>ITER Organization, 13067 St. Paul Lez Durance Cedex, France — <sup>3</sup>Università degli Studi di Napoli Federico II, Via Claudio 21, 80125 Napoli, Italy — <sup>4</sup>CREATE Consortium, Via Claudio 21, 80125 Napoli, Italy — <sup>5</sup>Università di Cassino e del Lazio Meridionale, Via Gaetano di Biasio 43, 03043 Cassino, Italy

Plasma disruptions in tokamak machines determine the interruption of confinement and the development of loss channels for the thermal and magnetic energies stored within the reactants into the containment structure, posing a threat for the machine's integrity. In this regard, tokamak design can be well informed by numerical codes modelling the electromagnetic interaction of the MHD plasma with the surrounding conducting structures. The latter provide predictions regarding disruptive plasma instabilities and the ensuing stresses on the walls. The here presented modelling activities have accomplished the self-consistent plasma-wall coupling of the induced (eddy) and source-sink (halo) currents flowing in the machine's structures during plasma instabilities; the framework leverages the interplay of the non-linear MHD code JOREK with the

3D wall codes STARWALL (thin) and CARIDDI (volumetric). The first reproduced instabilities are shown.

P 16.67 Thu 13:45 Redoutensaal

**Study of finite Larmor radius physics with the gyrokinetic turbulence code GENE-X** — •JOSE ANGEL CAPITAN GARCIA<sup>1</sup>, PHILIPP ULBL<sup>1</sup>, BAPTISTE J. FREI<sup>1</sup>, and FRANK JENKO<sup>1,2</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, 85748 Garching bei München, Deutschland — <sup>2</sup>University of Texas at Austin, Austin, Texas 78712, USA

Turbulence is the primary driver of transport losses in magnetically confined plasmas, particularly in tokamaks and optimized stellarators, where it significantly impacts confinement. To optimize energy confinement in a reactor, minimizing turbulent losses is crucial. Achieving a deeper understanding of turbulence in the plasma core as well as the edge and scrape-off-layer (SOL) is essential to this goal.

The GENE-X code, an Eulerian solver of the full- $f$ , collisional, electromagnetic gyrokinetic Vlasov equation, was developed to capture the physics of turbulence in the plasma edge and SOL. Until now, however, it relied on a long-wavelength model, limiting its ability to describe core turbulence and regions with steep gradients, where finite Larmor radius (FLR) effects become essential to capture the physics accurately.

In this work, we present an extension of GENE-X that incorporates FLR effects through Padé-approximated gyro-averaging operators. We will discuss the theoretical basis and first simulations investigating the impact of FLR corrections. This development enables GENE-X gyrokinetic simulations to extend across the entire plasma volume, from edge to core, for the first time in the code.

P 16.68 Thu 13:45 Redoutensaal

**Impact of fishbone modes on core microturbulence with global gyrokinetic simulations** — •DAVIDE BRIOSCHI<sup>1</sup>, ALESSANDRO DI SIENA<sup>1</sup>, ROBERTO BILATO<sup>1</sup>, ALBERTO BOTTINO<sup>1</sup>, THOMAS HAYWARD-SCHNEIDER<sup>1</sup>, PHILIPP LAUBER<sup>1</sup>, ALEXEY MISHCHENKO<sup>2</sup>, EMANUELE POLI<sup>1</sup>, ALESSANDRO ZOCCO<sup>3</sup>, and FRANK JENKO<sup>1,3</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, 85748 Garching, Germany — <sup>2</sup>Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — <sup>3</sup>Institute for Fusion Studies, The University of Texas at Austin, Austin, TX, USA

Fishbone instabilities (FBs) are a class of plasma modes which develop in tokamaks around rational surfaces. They are the energetic particle-driven branch of the  $n=m$  kink mode (with  $n$  and  $m$  toroidal and poloidal mode numbers). Numerical and experimental results show a possible relation between a suppression of (detrimental) turbulent transport inside tokamaks and the trigger of FBs. However, a clear causal relation between the destabilization of FBs and the core turbulent transport reduction has not been found yet. Therefore, it is clear the need for a description of the interaction of FBs with plasma turbulence. Our work aims to study such an interaction via gyrokinetic simulations with the codes GENE and ORB5, including both a FB mode and the ITG branches. These simulations are performed for an AUG discharge characterized by the presence of fishbone activity and plasma temperature peaking. Since the latter can be used as a proxy for core turbulence suppression, studying this case we can explore the physics of the interaction between FB instabilities and turbulence.

P 16.69 Thu 13:45 Redoutensaal

**On the Nonlinear Excitation of Zero Frequency Zonal Flows by Alfvén Eigenmodes** — •RICCARDO STUCCHI<sup>1,2</sup>, PH. LAUBER<sup>1</sup>, X. WANG<sup>1</sup>, F. ZONCA<sup>3,4</sup>, M. V. FALESSI<sup>3</sup>, N. CHEN<sup>1,4</sup>, F. STEFANELLI<sup>1</sup>, and D. KORGER<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics — <sup>2</sup>Technical University of Munich — <sup>3</sup>Center for Nonlinear Plasma Science and C.R. ENEA Frascati — <sup>4</sup>Institute of Fusion Theory and Simulation, Zhejiang University

As magnetic fusion plasmas move closer to ignition, increasing interest is raised by energetic particles (EPs) and Alfvén eigenmodes (AEs). As hinted by simulations and experiments, the interplay of EPs, AEs and background plasma can potentially lead to regulation of turbulence, and the aim of the present work is to build a reduced model to assess the impact on confinement of one particular mechanism of such interplay: the nonlinear generation of zero frequency zonal flows (ZFZFs) by AEs. The work is currently focused on modelling and understanding the beat-driven generation by AEs of ZFZFs in the context of nonlinear gyrokinetic (GK) theory: on the one hand, we refine previous analytical expressions in the simplified case of well-circulating particles in circular cross section geometry; on the other hand we formulate a semi-analytical approach, presently being implemented in a linear GK eigenvalue code, valid in axis-symmetric toroidal geometry for both trapped and circulating particles. Future work including the comparison with nonlinear GK PIC simulations, the investigation of the nonlinear saturation regime for both AEs and ZFZFs, and the assessment of the impact of ZFZFs on the plasma confinement is foreseen.

P 16.70 Thu 13:45 Redoutensaal

**Recent Advances in Efficient Preconditioning Techniques for 3D Nonlinear MHD Simulations in JOREK** — •PATRIK RÁC<sup>1</sup>, OMAR MAJ<sup>1</sup>, VANDANA DWARKA<sup>2</sup>, ERIC SONNENDRÜCKER<sup>1</sup>, and MATTHIAS HÖLZL<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>Delft University of Technology, Delft, Netherlands

Enabling next-generation simulations of realistic magnetic confinement fusion devices is crucial for understanding and controlling large-scale plasma instabilities. JOREK is a leading simulation code that simulates plasma dynamics by solving the magnetohydrodynamic (MHD) equations in 3D toroidal geometry using a higher-order isoparametric finite element method in the poloidal plane and a spectral decomposition in the toroidal direction. To effectively address the rising computational demands linked to more detailed simulations, the code must exploit cutting-edge HPC systems in an optimal way to meet current and future needs. The linear systems arising in JOREK are large, sparse, and ill-conditioned. Thus, iterative solvers, such as GMRES, require optimized preconditioning to converge. Current preconditioning techniques rely on the direct factorization of sub-blocks corresponding to the toroidal modes of the global system. However, this approach limits scalability, performance, and portability to accelerated systems. We present recent developments in preconditioning methods for the iterative solution of the reduced MHD models in JOREK. Current research focuses, in particular, on deflation-based methods and novel multiphysics block and equation splitting approaches.

P 16.71 Thu 13:45 Redoutensaal

**Statistical Analysis of Plasmoid Properties from Pellet Injections in Wendelstein 7-X** — •EDGARDO VILLALOBOS GRANADOS<sup>1</sup>, JÜGEN BALDZUHN<sup>1</sup>, NAOKI TAMURA<sup>1</sup>, AMEER MOHAMMED<sup>2</sup>, LARRY BAYLOR<sup>3</sup>, and NEREA PANADERO<sup>4</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Greifswald, MV, Germany — <sup>2</sup>Princeton Plasma Physics Laboratory, Princeton, New Jersey, United States — <sup>3</sup>Oak Ridge National Laboratory, Oak Ridge, TN, USA — <sup>4</sup>Laboratorio Nacional de Fusión, CIEMAT, Madrid, Spain

Hydrogen pellet injection is essential for core fueling in magnetic confinement fusion devices, such as stellarators. In particular, the Wendelstein 7-X (W7-X) stellarator aims to achieve steady state operation and demonstrate long pulse operation at high performance, which includes continuous particle fueling with the use of cryogenic hydrogen pellets. Understanding the dynamics of pellet ablation and the resulting plasmoid characteristics is a fundamental step for optimizing fueling strategies and improving plasma confinement. A statistical analysis of plasmoid properties generated during pellet injection in the W7-X. Plasmoid properties were inferred from visible range spectroscopic measurements of the hydrogen Balmer series. A dataset of over 2000 pellet injections across multiple magnetic configurations was analyzed to extract statistical distributions of plasmoid temperatures (typically 1-2 eV), densities on the order of  $1e24\text{ m}^{-3}$ , and corresponding pressure. The correlation between these properties and pellet and background plasma conditions was investigated. These results provide important experimental constraints for modeling pellet-plasma interactions

P 16.72 Thu 13:45 Redoutensaal

**Overview of a MANTIS-II installation in AUG for runaway electron studies using synchrotron imaging** — •ANDRES ORDUNA<sup>1,2</sup>, ANDREAS BURCKHART<sup>1</sup>, GERGELY PAPP<sup>1</sup>, TIJS WIJAMP<sup>3</sup>, MATHIAS HOPPE<sup>4</sup>, ARTUR PEREK<sup>5</sup>, YANIS ANDREBE<sup>5</sup>, TILMANN LUNT<sup>1</sup>, RALPH DUX<sup>1</sup>, and ASDEX UPGRADE TEAM<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>Ludwig-Maximilians-Universität München — <sup>3</sup>Dutch Institute for Fundamental Energy Research — <sup>4</sup>KTH Royal Institute of Technology, Stockholm, Sweden — <sup>5</sup>Ecole Polytechnique Fédérale de Lausanne, Swiss Plasma Center

The study of runaway electrons (RE) dynamics in present-day tokamak experiments requires the analysis of the RE momentum-space distribution function. Synchrotron radiation (SR) imaging using multispectral systems has proven capable of providing this information in TCV and AUG. For this purpose, the multispectral imaging system MANTIS consisting of 6 filtered cameras is being commissioned in AUG.

Technical considerations, such as filter wavelength, view port location, neutron flux, among others, have to be taken into account for the installation of the system. Synthetic images for the corresponding wavelengths and views are simulated using the SOFT synthetic diagnostic framework.

To validate the system performance and resilience in real conditions, a first commissioning phase was pursued. The first images of a RE synchrotron spot using a multispectral imaging system in AUG are presented.

P 16.73 Thu 13:45 Redoutensaal

**Observed toroidal radiated power variations in Wendelstein 7-X** — •ANASTASIOS TSIKOURAS<sup>1</sup>, FELIX REIMOLD<sup>1</sup>, GABRIELE PARTESOTTI<sup>1</sup>, KEVIN ANDREA SIEVER<sup>1</sup>, TAKASHI NISHIZAWA<sup>2</sup>, MACIEJ KRYCHOWIAK<sup>1</sup>, and DAHONG ZHANG<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Greifswald, Germany — <sup>2</sup>Kyushu University, Kasuga, Japan

An accurate total radiated power ( $P_{rad}$ ) proxy is important for the efficient and safe operation of a nuclear fusion device. Specifically in 3D devices such as the

Wendelstein 7-X stellarator (W7-X), the  $P_{rad}$  distribution varies toroidally [1]. This poses a challenge in precise calculation the total  $P_{rad}$ . Although shown with synthetic data [1], the distribution of the radiation needs to be validated experimentally. This contribution presents the observed asymmetries on different  $P_{rad}$  proxies from different bolometer systems in W7-X. Data from different cross-sections reveal up to 8-fold increase in toroidal asymmetries for low plasma densities. The effect reduces with the increase in the density. For higher input powers the asymmetry increases. Furthermore, configurations with higher field line pitch and reduced plasma wall interaction exhibit a decrease in the asymmetries. In seeded cases, the asymmetries decrease with the increase in the fraction of radiated power which is directly linked with the impurity content in the machine. These results support the formulation of a more precise  $P_{rad}$  proxy.

[1] G. Partesotti, PhD thesis (Greifswald 2025)

P 16.74 Thu 13:45 Redoutensaal

**ECRH power deposition measurements using ECE radiometers at W7-X** — •VAISHNAVI MURUGESAN, MATTHIAS HIRSCH, GAVIN WEIR, TORSTEN STANGE, JUAN FERNANDO GUERRERO ARNAIZ, MELINA ARVANITOU, NEHA CHAUDHARY, ROBERT C WOLF, and THE W7-X TEAM — Max Planck Institute for Plasma Physics

Electron Cyclotron Resonance Heating (ECRH) is a prominent heating scheme in many modern fusion devices. The narrow deposition width of ECRH makes it an effective tool for plasma profile shaping and turbulence control. The experimental validation of said narrow power deposition, however, has proved to be challenging, limited by the diagnostic capabilities and heat diffusion. ECRH modulation and switching experiments offer a unique way of deriving power deposition profiles in magnetically confined plasmas. ECRH modulation initiates perturbations in local electron temperature ( $T_e$ ) that are observed as an immediate response in the Electron Cyclotron Emission (ECE) signals. The instantaneous response of the ECE channels probing the magnetic flux surfaces in the vicinity of heating is used to derive power deposition profiles. This work presents narrow ECRH power deposition profiles measured using standalone calibrated ECE radiometers at Wendelstein 7-X (W7-X). Experimental results are discussed alongside mathematically derived ray-tracing profiles for plasma discharges from the experimental campaign 2.3 at W7-X.

P 16.75 Thu 13:45 Redoutensaal

**Advancing Tokamak Edge Stability Predictions with Extended-MHD Modelling** — •MICHAEL SIEBEN<sup>1</sup>, MICHAEL DUNNE<sup>1</sup>, JONAS PUCHMAYR<sup>1</sup>, ROXANA TAKACS<sup>1</sup>, and THE ASDEX UPGRADE TEAM<sup>2</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany — <sup>2</sup>See author list of H. Zohm et al 2024 Nucl. Fusion 64 112001

The high-confinement mode (H-mode) is an operational regime achieved in many present tokamaks, including ASDEX Upgrade (AUG), and is expected to be accessed in the future by ITER. In H-mode, a transport barrier, the so-called pedestal, forms at the plasma edge, where steep temperature and density gradients can drive magnetohydrodynamic (MHD) instabilities and trigger rapid heat and particle losses that can be hazardous for plasma-facing components. Predicting pedestal stability limits is therefore essential for H-mode operation. MHD models combined with an assumption on the transport in the pedestal, such as IPED [1], can be used to predict the pedestal structure prior to such events. Here, we present three extensions to IPED that improve edge stability predictions: (1) high-precision equilibrium reconstruction using the GVEC code [2]; (2) inclusion of extended-MHD physics through integration of CASTOR3D [3]; and (3) a robust growth-rate prediction based on an iterative search in the complex eigenvalue space. We demonstrate how these extensions affect predicted stability limits in both predictive and interpretive analyses of H-mode plasmas at AUG. [1] Dunne M.G. et al. 2017, [2] Hindenlang F. et al. 2019, [3] Strumberger E. et al. 2016.

P 16.76 Thu 13:45 Redoutensaal

**Investigation of boron transport in the pedestal of ASDEX Upgrade** — •LUCAS RÄSS<sup>1</sup>, RACHAEL MCDERMOTT<sup>1,2</sup>, TABEA GLEITER<sup>1</sup>, DIRK STIEGLITZ<sup>1</sup>, THOMAS PÜTTERICH<sup>1,2</sup>, KIERA MCKAY<sup>3</sup>, RALPH DUX<sup>1</sup>, ELISABETH WOLFRUM<sup>1,4</sup>, and THE ASDEX UPGRADE TEAM<sup>5</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik — <sup>2</sup>Ludwig-Maximilians-Universität München — <sup>3</sup>University of Seville — <sup>4</sup>TU Wien — <sup>5</sup>See author list of H. Zohm et al, 2024 Nucl. Fusion

Impurity transport across the edge of the confined plasma (pedestal) is of special interest for future fusion reactors, as it sets boundary conditions for the core impurity concentration. The transport is generally determined by a combination of collisional (neoclassical) and anomalous contributions, where neoclassical predictions for future reactors result in favourable hollow impurity density profiles. This study investigates pedestal impurity transport between type-I edge localised modes (ELMs) in the high confinement regime (H-mode) at ASDEX Upgrade across a wide range of plasma parameters. For this purpose, a database of suitable discharges was established and for a subset the ratio of drift velocity to diffusion coefficient is inferred from experimental boron measurements and compared to neoclassical predictions. Our results support prior findings of transport near neoclassical levels in the steep gradient region, with most discharges agreeing

well with neoclassical predictions while singular outliers, that occur in particular at low collisionality, are present. Due to uncertainties in these discharges, however, further analysis is needed to prove or disprove significant anomalous transport at low collisionality.

P 16.77 Thu 13:45 Redoutensaal

**Flight-Simulators for the ASDEX Upgrade Tokamak: Development of a New Software-In-the-Loop Tool and Controller Design for Advanced Divertor Configurations** — •MARCO BIASIZZO<sup>1,2</sup>, PIERRE DAVID<sup>1</sup>, MATTHIAS GEHRING<sup>1</sup>, RENAT KERMENOV<sup>1</sup>, MARIANO RUIZ<sup>2</sup>, BERNHARD SIEGLIN<sup>1</sup>, WOLFGANG TREUTTERER<sup>1</sup>, HARTMUT ZOHN<sup>1</sup>, and THE ASDEX UPGRADE TEAM<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, 85748 Garching, Germany — <sup>2</sup>Grupo de Investigación en Instrumentación y Acústica Aplicada, Universidad Politécnica de Madrid, 28031 Madrid, Spain

Flight-simulators (FS) for tokamaks ingest a discharge program and return the time evolution of plant and plasma variables, enabling rapid testing of scenarios and control algorithms. The current ASDEX Upgrade (AUG) FS, Fenix, uses a physics-based model for the plasma and a Simulink model of the tokamak control system. An alternative software-in-the-loop (SIL) version is under development; it runs an exact replica of the control system, removing modelling limits and reducing execution time. Synchronization and communication between the control system and the plasma and plant models are presented.

The SIL simulator will be used to implement and test a novel controller to regulate desired advanced divertor configurations (ADCs) and key plasma shape geometric descriptors. Model-based controller synthesis has begun with ADCs data obtained from the current FS. Fenix results were benchmarked against recent AUG experiments, showing quantitative agreement. This integrated approach promises faster, reliable controller development while saving experimental time.

P 16.78 Thu 13:45 Redoutensaal

**Modelling the Pellet-Produced Plasmoid Dynamics in Stellarators with JOREK** — •CARL WILHELM ROGGE<sup>1</sup>, KSENIA ALEYNIKOVA<sup>1</sup>, PAVEL ALEYNIKOV<sup>1</sup>, ROHAN RAMASAMY<sup>2</sup>, MATTHIAS HOELZL<sup>1</sup>, and NIKITA NIKULSIN<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Greifswald and Garching — <sup>2</sup>Proxima Fusion, München

Cryogenic pellet injection is expected to be a key technique for refuelling future fusion reactors based on the stellarator concept. While this technique is more mature in tokamak experiments, the departure from axisymmetry in stellarators introduces unique challenges and opportunities that remain insufficiently explored.

Here, we employ the stellarator extension of the 3D nonlinear MHD code JOREK to study the radial drift of a fully ionised plasmoid. Since this drift depends on the pressure evolution within the pellet-produced plasmoid, the parallel expansion has a strong impact on the final deposition profile of the injected material. Consequently, particular attention must be paid to accurately modelling the reheating of the plasmoid by hot background plasma particles, which drives the parallel expansion. Because the mean free path of background electrons in core-fuelling scenarios is very long, non-local heat transport effects need to be incorporated into the fluid description.

Two non-local heating schemes have been newly implemented in JOREK and verified against analytical theory. These new schemes are then applied to stellarator geometries, where the radial drift following complete pellet ionisation is investigated.

P 16.79 Thu 13:45 Redoutensaal

**Investigating drift effects in island divertors with the mean-field Braginskii model** — •TOBIAS TORK<sup>1,2</sup>, FELIX REIMOLD<sup>1</sup>, DAVID BOLD<sup>1</sup>, BEN DUDSON<sup>3</sup>, ANDREAS STEGMEIR<sup>4</sup>, and PETER MANZ<sup>2,1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — <sup>2</sup>Institute of Physics, University of Greifswald, 17489 Greifswald, Germany — <sup>3</sup>Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore CA 94550, USA — <sup>4</sup>Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

The inclusion of drifts has been shown to be critically important for the boundary physics of tokamaks and has a significant impact on the predictions of divertor heat loads and impurity transport. Current state-of-the-art stellarator boundary simulations like EMC3-Eirene do not include drifts, but experiments in W7-X already show numerous indications of drift effects. Such effects could significantly alter the heat loads on the divertors or redistribute the plasma profiles.

In this contribution, we present the development of a 3D simulation for island diverted stellarators. The model is derived from the Hermes-2 physics model by parameterizing the divergence of the polarization drift with a set of anomalous diffusion coefficients. The simulation tool allows for the analysis of potential and current distributions in stellarators.

We will show results of drift effects in an island divertor. Stagnation points of the parallel ion flow demonstrate a significant poloidal shift which depends on the magnetic field direction.



P 16.80 Thu 13:45 Redoutensaal

**Analysis on the plasma edge fluctuations in the X-point radiator regime in ASDEX Upgrade** — •YU-CHIH LIANG<sup>1,2</sup>, OU PAN<sup>1</sup>, MATTHIAS BERNERT<sup>1</sup>, TIM HAPPEL<sup>1</sup>, ULRICH STROTH<sup>1,2</sup>, GUSTAVO GRENFELL<sup>1</sup>, SEBASTIAN HÖRMANN<sup>1</sup>, ALESSANDRO MANCINI<sup>1</sup>, KONRAD EDER<sup>1</sup>, MATE SZUECS<sup>1,2,3</sup>, and THE ASDEX UPGRADE TEAM<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, 85748 Garching, Germany — <sup>2</sup>TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — <sup>3</sup>ITER Organization, 13067 St. Paul Lez Durance Cedex, France

The power exhaust problem in large-scale fusion reactors necessitates operational regimes that can avoid extreme heat fluxes onto the plasma-facing components. One promising regime is the X-point radiator (XPR), featuring a highly radiative plasma volume forming above the X-point. Additionally, suppression of edge localized modes (ELMs) can be achieved when the XPR moves inside the confined region.

This contribution focuses on the plasma edge, where the complexity arises from the turbulence around the XPR volume, the interactions between the edge modes and the XPR, and the influence of the XPR on the edge turbulence transport. Using the thermal He beam diagnostics, the diode bolometry, and the magnetic coils in ASDEX Upgrade, the edge fluctuations in the XPR regimes both with and without large ELMs are studied. Furthermore, the presented analysis on the fluctuation measurements is extended from the outer midplane to the XPR volume, aiming to improve understanding on the interactions between the outer midplane plasma profile and the XPR.

P 16.81 Thu 13:45 Redoutensaal

**Operational space of the ASDEX Upgrade tokamak and its proximity to that of future devices with burning plasma** — •DANIELA KROPÁČKOVÁ, EMILIANO FABLE, ONDŘEJ KUDLÁČEK, HARTMUT ZOHM, and ASDEX UPGRADE TEAM — Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, Garching, D-85748, Germany

Present-day tokamaks are unable to capture the dynamic interaction between alpha heating and the plasma operational scenario during changing operating conditions as expected in future reactors. To enable these investigations, a method for emulating dominant alpha heating in existing tokamak experiments was introduced in [FableNF2023].

In this contribution, a database of operational scenarios of ASDEX Upgrade (AUG), covering ELM-free regimes such as EDA and QCE, scenarios with ELM suppression via resonant magnetic perturbations (RMPs), flux-pumping scenarios, and operation with a X-point radiator (XPR), is presented. The interesting operational space is characterized in terms of key non-dimensional parameters, e.g.,  $v_{\text{eff}}$ ,  $\beta_N$ ,  $p^*$ , and  $q_{95}$ . These parameters are compared with the expected values for a few considered fusion reactors, and the conditions under which relevant physical parameters can be matched are identified.

The selected scenarios are then used to calibrate the alpha heating power proxy through simulations performed with the flight simulator Fenix. Experimental validation of the obtained results is planned for a future campaign, followed by burn control studies.

P 16.82 Thu 13:45 Redoutensaal

**Comparison of experimental radiation dynamics in the scrape-off layer of Wendelstein 7-X with transport simulations** — •KEVIN ANDREA SIEVER<sup>1</sup>, FELIX REIMOLD<sup>1</sup>, SATOSHI TOGO<sup>2</sup>, GABRIELE PARTESOTTI<sup>1</sup>, TAKASHI NISHIZAWA<sup>3</sup>, DAIHONG ZHANG<sup>1</sup>, NASSIM MAAZIZ<sup>1</sup>, ANASTASIOS TSIKOURAS<sup>1</sup>, VALERIA PERSEO<sup>1</sup>, VICTORIA WINTERS<sup>1</sup>, MASAHIRO KOBAYASHI<sup>4</sup>, BYRON PETERSON<sup>4</sup>, and KIYOFUMI MUKAI<sup>4</sup> — <sup>1</sup>Max Planck Institute, Greifswald, Germany — <sup>2</sup>Plasma Research Center, University of Tsukuba, Tsukuba, Japan — <sup>3</sup>Kyushu University, Kasuya, Japan — <sup>4</sup>National Institute for Fusion Science, Toki, Japan

At Wendelstein 7-X (W7-X) the strongly 3D topology of the scrape-off layer (SOL) leads to a complex behavior of the impurity radiation structure. In this context, the 3D transport code EMC3-Eirene is often used to assess its SOL. This contribution aims at the validation of such simulations with experimental data, focusing on the radiation distribution. In the work [S. Togo et al (submitted) Plasma Phys. Control. Fusion], density scans have been simulated with EMC3-Eirene for 5 configurations corresponding to different radial positions of the islands. Matching W7-X density scan-experiments are chosen and data from the 3 available bolometry systems analyzed. In order to compare the simulated radiation structure to the experimental data, synthetic diagnostic data generation and 2D tomographic inversions are employed. This allows to compare with the simulations the experimental poloidal evolution of the emissivity localization as density is increased, for the different geometries.

P 16.83 Thu 13:45 Redoutensaal

**Modelling of Island Divertor Topology and Edge MHD Instabilities in Stellarators with JOREK** — •ORIN VARLEY<sup>1</sup>, ROHAN RAMASAMY<sup>2</sup>, JONAS PUCHMAYR<sup>1</sup>, SAMET KOÇBAY<sup>1</sup>, and MATTHIAS HOELZL<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>Proxima Fusion, Munich, Germany

Large-scale MHD dynamics shape key aspects of stellarator performance, especially island divertor geometry and edge instabilities. This work examines these

phenomena and summarizes recent advances in modelling capabilities.

Island divertors are the leading concept for particle and heat exhaust in stellarators, but their performance is highly sensitive to magnetic topology. Increasing plasma  $\beta$  can shift island position and width, enhance chaos, and, in some optimized quasi-isodynamic configurations, even induce phase transitions within the island structure. Using JOREK, we model these  $\beta$ -driven transitions, compare with HINT, and investigate the mechanisms that reshape island topology.

We also study MHD-driven edge instabilities with improved physics models, supported by ongoing developments in the JOREK stellarator framework, including a no-wall boundary condition and diamagnetic drift effects.

This poster presents an overview of these model improvements and their first applications to island divertor physics and edge instability studies, forming a basis for future work on plasma exhaust, detachment, and wall loading in stellarators.

P 16.84 Thu 13:45 Redoutensaal

**The avalanche source for a 3D particle in cell model of runaway electrons**

— •FIONA WOUTERS<sup>1</sup>, MATTHIAS HOELZL<sup>1</sup>, HANNES BERGSTROEM<sup>1</sup>, GUIDO HUIJSMANS<sup>2,3</sup>, and JAN VAN DIJK<sup>2</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — <sup>2</sup>Eindhoven University of Technology, Groene Loper 3, 5612 AE Eindhoven, the Netherlands — <sup>3</sup>CEA, IRFM, 13115 Saint-Paul-lez-Durance, France

Disruptions, i.e. major instabilities in which plasma confinement is lost, are a significant threat to tokamak operation not only because of the large in vessel forces involved, but also because they may lead to the acceleration of some electrons to relativistic speeds. These so-called runaway electrons (REs) can exponentially multiply due to large-angle collisions with thermal electrons during the RE avalanche. As the RE avalanche is exponentially sensitive to the pre-disruption plasma current, this can lead to multi-MA RE beams in large future devices, which may cause severe localized wall damage. Therefore, simulations including the RE sources in realistic 3D fields are needed to further the understanding of RE generation and losses and develop viable mitigation scenarios. For this purpose 3D nonlinear MHD code JOREK contains a hybrid fluid-kinetic model that describes the REs with a full-f relativistic particle in cell (PiC) approach using either full-orbit or drift kinetic RE descriptions. We present the implementation of the relativistic large-angle collision operator and a resampling technique needed to limit the number of markers, along with first applications.

P 16.85 Thu 13:45 Redoutensaal

**Radiative power exhaust in Alternative Divertor Configurations at ASDEX Upgrade**

— •ALESSANDRO MANCINI, MATTHIAS BERNERT, TILMANN LUNT, DOMINIK BRIDA, FELIX ALBRECHT, and THE ASDEX UPGRADE TEAM — Max Planck Institute for Plasma Physics (IPP Garching)

Power exhaust is a major challenge in the development of tokamaks as fusion reactors. The unmitigated power flux in a reactor is expected to be several orders of magnitude higher than the heat load limit for tungsten plasma facing components (PFCs).

Alternative Divertor Configurations (ADCs) feature an increased flux expansion and/or secondary X-Points to lower the heat load on the PFCs by easing the access to detachment, where the plasma recombines before reaching the wall. Therefore, ADCs may be taken into consideration for future tokamak reactors. The ASDEX Upgrade tokamak was recently upgraded with a new upper divertor that can produce ADCs, like X-Divertor (XD), Snowflake Minus (SF-), super Compact Radiative Divertor (sCRD). This work focuses on the power exhaust capabilities of ADCs, in particular on the radiated power distribution. Bolometer data is complemented by Langmuir probe data to characterize the detachment.

It is observed that ADCs highly modify the radiation distribution. The SF-configuration facilitates X-Point Radiators (XPR), even at low impurity seeding levels. Fast transitions in the radiation pattern are observed even with a slow variation of the ADC configuration.

P 16.86 Thu 13:45 Redoutensaal

**Equilibrium reconstruction and toroidal current density analysis for high- $\beta$  Wendelstein 7-X plasmas** — •E. HAUSTEN<sup>1</sup>, K. RAHBARNIA<sup>1</sup>, H. THOMSEN<sup>1</sup>, L. VAN HAM<sup>1</sup>, C. BRANDT<sup>1</sup>, T. ANDREEVA<sup>1</sup>, C. BÜSCHEL<sup>1</sup>, M. KELLY<sup>1</sup>, P. PONS-VILLALONGA<sup>1</sup>, S. VAZ MENDES<sup>1</sup>, S. LAZERSON<sup>2</sup>, and THE WENDELSTEIN 7-X TEAM<sup>1</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany — <sup>2</sup>Gauss Fusion GmbH, Parkring 29, 85748 Garching bei München, Germany

Accurate knowledge of the magnetohydrodynamic equilibrium is essential for interpreting diagnostics and inferring non-measurable plasma parameters in fusion experiments such as the Wendelstein 7-X (W7-X) stellarator. Equilibria can be reconstructed from experimental data using the STELLOPT code [1], which employs optimization methods to find equilibria that best match diagnostic measurements. A key challenge in reconstructions is determining the toroidal plasma current density, for which only limited experimental information is directly accessible. This becomes particularly relevant in high- $\beta$  scenarios, where increased pressure gradients can drive stronger currents. In this contribution, we present reconstructed current density profiles for high- $\beta$  plasmas obtained



in W7-X experiments. We analyze the influence on rotational transform and Shafranov shift and compare with predictions from the current-evolution code THRIFT [2].

[1] S. A. Lazerson, 2015, Nucl. Fusion 55

[2] L. van Ham et al, 2025, Nucl. Fusion 65

P 16.87 Thu 13:45 Redoutensaal

**On the role of density-potential coupling in the interplay of zonal-flow and intermittency formation** — •LILIAN HARUMI YOSHIDA, MIRKO RAMISCH, and RALPH SARKIS — IGVP, University of Stuttgart, Germany

The destabilization of density perturbations in drift-wave turbulence is based on the decoupling of density ( $\tilde{n}$ ) and potential ( $\tilde{\phi}$ ) fluctuations. This decoupling mechanism is promoted by electron collisionality, which in turn tends to change the turbulent behaviour from adiabatic into a hydrodynamic one, where density becomes passively advected and resembles the intermittent vorticity. Decoupling is also intrinsic to the interchange drive of filamentary, intermittent density structures - so-called blobs - in the scrape-off layer (SOL). In contrast to blobs, strong coupling is essential for the Reynolds-stress drive of zonal-flows (ZF). However, recent studies showed a causal link between blob detachment from the bulk plasma and ZF generation inside the separatrix. In this experimental work, multiple Langmuir-probe arrays are used at the TJ-K stellarator to untangle the interplay of  $\tilde{n} - \tilde{\phi}$  coupling with ZF and intermittency formation. Conditional sampling reveals a temporal correlation between net turbulent particle flux and zonal intermittency levels, which is in-line with the associated drift-wave destabilization. Furthermore, the coupling and intermittency dynamics across the separatrix is examined, shedding light on the role of blobs in ZF formation.

P 16.88 Thu 13:45 Redoutensaal

**ECRH as a candidate for electron temperature and -density profile shaping towards confinement improvements in W7-X** — •MELINA ARVANITOU, MATTHIAS HIRSCH, KAI JAKOB BRUNNER, NEHA CHAUDHARY, GOLO FUCHERT, JUAN FERNANDO GUERRERO ARNAIZ, VAISHNAVI MURUGESAN, MIKLOS VECSEI, GAVIN WEIR, ROBERT WOLF, and THE W7-X TEAM — Max Planck Institute for Plasma Physics

At present  $T_e$  gradient clamping inhibits the establishment of high-confinement regimes in Wendelstein 7-X (W7-X) plasmas. Overcoming this constraint requires finite density gradients at mid-radius, which are believed to suppress ITG turbulence. Although achievable with deep fueling by Neutral Beam Injection (NBI) and pellets, both methods pose challenges for reactor-scale implementation. Since Electron Cyclotron Resonance Heating (ECRH) is already envisaged as the primary heating system in future reactor-scale stellarator concepts, any intrinsic profile-shaping capability would represent a built-in advantage for optimizing confinement. ECRH is well known to provide control over the  $T_e$ -profile while simultaneously impacting particle and impurity transport through mechanisms such as density pump-out. On- and off-axis application of localized X2 ECRH has been conducted to investigate its profile-shaping properties, with the resulting density and temperature profiles provided by Thomson scattering (TS) and alkali metal beam spectroscopy. Small heat-wave-like temperature perturbations in the Electron Cyclotron Emission (ECE) traveling away from the ECRH deposition zone indicate an associated transport effect.

P 16.89 Thu 13:45 Redoutensaal

**Core neutral density measurements from Balmer- $\alpha$  emission at Wendelstein 7-X** — •LUCAS NITZSCHE<sup>1</sup>, SEBASTIAN BANNMANN<sup>1</sup>, OLIVER FORD<sup>1</sup>, FELIX REIMOLD<sup>1</sup>, and ROBERT WOLF<sup>1,2</sup> for the w7-x team-Collaboration — <sup>1</sup>Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany — <sup>2</sup>Technical University of Berlin, Strasse des 17.Juni 135, 10623 Berlin, Germany

Wendelstein 7-X (W7-X) is a current state-of-the-art magnetic confinement fusion device of the stellarator type.

It was shown at W7-X, that the energy confinement time of its plasmas depends strongly on their density profile shape. This in turn is linked directly to controlling and knowing the particle-transport. Although the particle fueling of recycling neutrals into the confined region is an important quantity in corresponding calculations, it is not routinely measured and must be approximated by simplified modeling. Accessing this particle fueling is possible by measuring the density of neutral particles  $n_0$  inside the plasma and combining it with ionization rates.

In this work, passive Balmer- $\alpha$  emissions from the confined region are analysed to estimate  $n_0$ -profiles along each measured line-of-sight (LOS). The previous modeling of the emissions was improved by including charge-exchange-reactions in the emission coefficients. From the evaluations, the  $n_0$ -distributions inside W7-X plasmas were estimated and compared to modeling with EMC3-EIRENE. Results are compared for two spectrometers at different toroidal positions at W7-X.

P 16.90 Thu 13:45 Redoutensaal

**hybrid kinetic-MHD simulations of energy-dependent effects of runaway electron beams on MHD Instabilities** — •SHIJIE LIU, HANNES BERGSTROEM, HAOWEI ZHANG, and MATTHIAS HOELZL — Max Planck Institute for Plasma Physics, Garching b.m., Germany

Runaway electrons (REs) are of particularly importance to the safe operation of tokamaks. Electrons may be accelerated by the large toroidal electric field arising during a major disruption. Without adequate mitigation measures, these energetic electrons may eventually hit the first wall of the device focusing on an extremely localized area, which poses a serious threat to the safe operation of the device. To predict the runaway dynamics during a disruption and develop mitigation strategies, the mutual interaction between REs and the bulk plasma should be carefully considered.

In a cold plasma with a high-energetic runaway beam, the equilibrium cannot be force-free, and the RE curvature drift introduces an energy-dependent outward shift of magnetic flux surfaces. We investigate how these RE-induced orbit shifts affect both linear and nonlinear MHD instabilities, with a particular focus on tearing modes. A poloidal mode coupling mechanism is now observed due to (1,0) component of the RE curvature drift. Future work will extend efforts by comparing the resistive layer width with the characteristic width of RE orbits.

P 16.91 Thu 13:45 Redoutensaal

**Turbulent Transport Mechanism in Island Divertors** — •RALPH SARKIS<sup>1</sup>, MIRKO RAMISCH<sup>1</sup>, and PETER MANZ<sup>2</sup> — <sup>1</sup>IGVP, University of Stuttgart, Germany — <sup>2</sup>Institute of Physics, University of Greifswald, Germany

Island divertors have demonstrated strong promise in controlling particle and heat exhaust. Considering the long parallel and short binormal connection lengths at the island divertor, it becomes clear that transport in the binormal direction plays an important role. This can broaden perturbations and modify the convective and diffusive transport, ultimately determining the divertor heat and particle flux pattern. In this contribution, we present an overview of an envisaged research project dedicated to the understanding of the fundamental dynamics in island divertors. This objective will be pursued through an integrated experimental and computational approach, jointly carried out by research groups at the University of Stuttgart and the University of Greifswald, thereby combining complementary expertise in diagnostics, modeling, and theoretical analysis to achieve a comprehensive understanding of transport in the island divertor.

P 16.92 Thu 13:45 Redoutensaal

**Influence of Flow Shear Modulation on Turbulent Transport Regulation** — •CARMEN SOFIA VERGARA INTERIAN, MIRKO RAMISCH, and RALPH SARKIS — IGVP, University of Stuttgart, Germany

In magnetically confined toroidal plasmas, zonal flows play a crucial role in regulating the cross-field turbulent transport. While this relation has been widely established, the detailed interrelation of transport with flow shear modulation has yet to be clarified. Hence, the spatiotemporal evolution of turbulent particle transport, together with the scale-resolved density and potential power distributions, is experimentally investigated with respect to modulation in the zonal potential as measured by a Langmuir probe array at the TJ-K stellarator. Contrary to positive zonal potential amplitudes, negative potentials are found to be associated with an increased particle flux, pointing to a weakened shear effect. Moreover, the density power spectrum reveals a cascading-like redistribution of power from small to large scales. This could indicate a mechanism in which turbulence both drives and responds to modulation in zonal potential. The effects of negative and positive zonal potential events are compared on the basis of their characteristic time scales and their influence on density-potential coupling with respect to the turbulent particle flux in magnetically confined fusion plasmas.

P 16.93 Thu 13:45 Redoutensaal

**Study of boronization history effects on impurity control in Wendelstein 7-X** — •PEI REN<sup>1,3</sup>, YUNFENG LIANG<sup>1,3</sup>, SHUAI XU<sup>1</sup>, FREDERIK HENKE<sup>2</sup>, ALEXANDER KNIPE<sup>1</sup>, MACIEJ KRYCHOWIAK<sup>2</sup>, BIRGE BUTTENSCHÖN<sup>2</sup>, ALICE BONCIARELLI<sup>2</sup>, SEBASTIAN BREZINSEK<sup>1</sup>, DOROTHEA GRADIC<sup>2</sup>, DAHONG ZHANG<sup>2</sup>, CARSTEN KILLER<sup>2</sup>, LUO YU<sup>1,3</sup>, MARCIN JAKUBOWSKI<sup>2</sup>, PETRA KORNEJEW<sup>2</sup>, and ERHUI WANG<sup>1</sup> for the w7-x team-Collaboration — <sup>1</sup>Institute of Fusion Energy and Nuclear Waste Management, Forschungszentrum Jülich GmbH, Jülich, Germany — <sup>2</sup>Max Planck Institute for Plasma Physics, Greifswald, Germany — <sup>3</sup>Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, Düsseldorf, Germany

Boronization is routinely applied for wall conditioning on W7-X, significantly improving plasma performance. This work investigates the history effects on impurity control using visible and UV spectroscopy. Results show that boronization strongly suppresses oxygen impurities, and although this effect gradually weakens, overall impurity control remains robust. Spearman correlation analysis indicates that, over time, oxygen impurity radiation becomes decoupled from total radiation, while carbon sputtering reaches a steady state. Analysis of OP2.2 data under identical conditions 1 day, 2 days, and 2 weeks after fresh boroniza-

tion shows consistent trends: oxygen radiation slightly increases over time but remains within controlled levels. These findings confirm that multiple boronizations effectively maintain good wall conditioning.

P 16.94 Thu 13:45 Redoutensaal

**Measurement of electron-temperature dynamics in TJ-K plasmas** — •RIMAE LAMARA MHEND, ALF KÖHN-SEEMANN, and MIRKO RAMISCH — IGVP, University of Stuttgart, Germany

Heat-flux analyses for energy confinement studies in magnetized plasmas require the resolution of the fast plasma-temperature dynamics. While the electron temperature  $T_e$  can be deduced from swept Langmuir probes, extending this procedure to time scales in the microsecond range is experimentally challenging. A simple approach using a triple probe diagnostic system, measuring the potential of a biased double probe against that of a single floating probe, provides direct access to fluctuations in  $T_e$ . In this work, a triple probe is set up for use in the magnetized plasmas of the torsatron TJ-K and tested against swept single-probe characteristics. Statistical properties of  $T_e$  fluctuations measured along radial profiles are presented and characterized under variation of the drift scale  $\rho_s = \sqrt{T_e M_i / eB}$  for ion masses  $M_i$  ranging from hydrogen over helium to argon.

P 16.95 Thu 13:45 Redoutensaal

**Preliminary study of boronization effect on divertor density regime in the standard configuration on W7-X** — •MUZHI TAN<sup>1,2</sup>, SHUAI XU<sup>1</sup>, YUNFENG LIANG<sup>1,2</sup>, YU LUO<sup>1,2</sup>, PEI REN<sup>1,2</sup>, YUHE FENG<sup>3</sup>, DETLEV REITER<sup>1</sup>, DAIHONG ZHANG<sup>3</sup>, ARUN PANDEY<sup>3</sup>, and GOLO FUCHER<sup>3</sup> for the w7-x team-Collaboration — <sup>1</sup>Forschungszentrum Jülich GmbH, IFN-1 Plasma Physics, Jülich, Germany — <sup>2</sup>HHU Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf, Germany — <sup>3</sup>Max-Planck-Institute für Plasmaphysik, Greifswald, Germany

Boronization is widely applied in magnetic confinement devices to sustain high-performance, steady-state plasma operation. In this work, we present a preliminary study of the boronization effect on divertor density regimes by comparing two density-ramp discharges with identical ECRH heating power (3 MW). Experimental observations show that boronization significantly suppresses intrinsic oxygen impurity sources. Before boronization, the downstream ion saturation current ( $I_{sat}$ ) increases slightly with rising radiated power; after boronization it rises much more rapidly and exhibits a clear roll-over when the radiation fraction exceeds 50%. Motivated by these experimental trends, EMC3-EIRENE simulations were performed to assess the impact of boronization on divertor density regimes. By comparing impurity transport at the same radiated power, simulations illustrate how oxygen influences the transition of divertor density regime. Simulations without oxygen impurities reproduce the  $I_{sat}$  roll-over and highlight the beneficial role of boronization on modifying transport in W7-X.

P 16.96 Thu 13:45 Redoutensaal

**First L-Mode experiments in Alternative Divertor Configurations in ASDEX Upgrade** — •FELIX ALBRECHT<sup>1,2</sup>, DOMINIK BRIDA<sup>1</sup>, OU PAN<sup>1</sup>, TILMANN LUNT<sup>1</sup>, MICHAEL FAITSCH<sup>1</sup>, BERNHARD SIEGLIN<sup>1</sup>, and ASDEX Upgrade TEAM<sup>3</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>2</sup>Technical University of Munich, Physics Department, Garching, Germany — <sup>3</sup>see author list of H. Zohm et al. 2024 *Nucl. Fusion* **64** 112001

All fusion devices need to exhaust the plasma heating power in a separate region from the core plasma called the divertor. There, most of the heat flux must be radiated away through plasma-neutral interactions, typically by seeded impurities, to protect the divertor target plates. If the impurity concentration is high enough, a favorable state of detachment can be reached, where the plasma recombines in front of the target. However, the required impurity concentrations might be too high for good core performance. Recent hardware upgrades in the tokamak ASDEX Upgrade enable access to alternative divertor configurations (ADCs), a possible solution to facilitate detachment with less impurities. Through increased flux expansion at the target (X-divertor, XD) or the introduction of another X-point in the divertor plasma (snowflake minus, SF<sup>-</sup>), ADCs have been shown in other machines to be favorable for detachment [Theiler NF 2017].

We present the first L-Mode experiments in ASDEX Upgrade with ADCs. In XD and SF<sup>-</sup>, an earlier detachment of the primary strikepoint compared to single null was found. The results are interpreted with the plasma and neutral transport code SOLPS-ITER.

P 16.97 Thu 13:45 Redoutensaal

**Towards the Application of the Gyrokinetic Code GENE-X to Tokamak and Stellarator Scrape-Off Layer Turbulence** — •YANTONG TAO<sup>1</sup>, PHILIPP ULBL<sup>1</sup>, and FRANK JENKO<sup>1,2</sup> — <sup>1</sup>Max Planck Institute for Plasma Physics, Boltzmannstraße 2, 85748 Garching, Germany — <sup>2</sup>University of Texas at Austin, Austin, TX 78712, USA

Predicting heat loads in the scrape-off layer (SOL) is a major challenge for future fusion divertors, largely due to the complex interplay between turbulence and boundary plasma physics. Gyrokinetic simulations provide a powerful tool for investigating SOL turbulence; however, their predictive capability critically depends on the incorporation of plasma sheath physics at the divertor targets.

The plasma sheath plays a key role in regulating turbulent transport and heat exhaust, and its proper treatment is therefore crucial for reliable heat flux predictions and divertor design.

In this work, we will apply sheath boundary conditions to the full-f gyrokinetic turbulence code GENE-X in full tokamak and stellarator geometry, and present some preliminary results. Since the sheath structure cannot be fully resolved in gyrokinetic simulations, we start from a reduced sheath model that captures the essential physics while omitting the sheath complexity at the same time. Then we will study the impact of sheath boundary conditions and compare the results with TCV-X21 validation case.

P 16.98 Thu 13:45 Redoutensaal

**Neural network surrogate-assisted Bayesian inference for input parameter of edge plasma simulations** — •YU LUO<sup>1,2</sup>, SHUAI XU<sup>1</sup>, YUNFENG LIANG<sup>1,2</sup>, ERHUI WANG<sup>1</sup>, JIANQING CAI<sup>1</sup>, YUHE FENG<sup>3</sup>, DETLEV REITER<sup>2</sup>, ALEXANDER KNIEPS<sup>1</sup>, SEBASTIAN BREZINSEK<sup>1,2</sup>, DEREK HARTING<sup>1</sup>, MACIEJ KRYCHOWIAK<sup>3</sup>, DOROTHEA GRADIC<sup>3</sup>, PEI REN<sup>1,2</sup>, DAIHONG ZHANG<sup>3</sup>, YU GAO<sup>3</sup>, GOLO FUCHERT<sup>3</sup>, ARUN PANDEY<sup>3</sup>, and MARCIN JAKUBOWSKI<sup>3</sup> for the w7-x team-Collaboration — <sup>1</sup>Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425 Jülich, Germany — <sup>2</sup>Faculty of Mathematics and Natural Science, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany — <sup>3</sup>Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany

We present a neural network-accelerated workflow to efficiently infer EMC3-EIRENE input parameters from measurements on Wendelstein 7-X. A database of 3D EMC3-EIRENE edge-transport simulations is generated by varying key inputs, and a feed-forward neural-network surrogate is trained to map parameters to synthetic diagnostic signals. Embedded in a Bayesian inference framework with Dynamic Nested Sampling, the surrogate enables fast likelihood evaluations, explicitly incorporates diagnostic uncertainties, and yields posterior distributions and maximum a posteriori (MAP) estimates. EMC3-EIRENE simulations at these MAP parameters reproduce the measurements while greatly reducing computational cost and manual tuning, and the approach is transferable to other modeling tools.

P 16.99 Thu 13:45 Redoutensaal

**Transient non-equilibrated plasma phases in the Wendelstein 7-X stellarator** — •CHRISTIAN BRANDT, CHARLOTTE BÜSCHEL, EDITH VICTORIA HAUSTEN, KIAN RAHBARNIA, HENNING THOMSEN, SARA VAZ MENDES, TAMARA ANDREEVA, MARTIN CLIFTON KELLY, ULRICH NEUNER, and PEDRO PONS VILLALONGA — Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

Selected Wendelstein 7-X stellarator plasmas are investigated far away from an equilibrium state in certain experimental scenarios. A stable plasma phase was actively perturbed, e.g. by heating power steps, the injections of cryogenic pellets or impurities. Moreover, internal events temporarily destabilized the plasma, triggered by MHD instabilities. Analysis of highly spatiotemporally resolved soft X-ray (SX) tomographic measurements help to understand these transient phases by studying the topologic evolution of the SX emissivity in a poloidal cross section. An experimental survey of several types of transient phases analyzed by SX tomography is presented. Besides details of the plasma startup phase – sometimes accompanied by mode activity – we focus on the stability of high energy plateau phases.

P 16.100 Thu 13:45 Redoutensaal

**High Frequency Dispersion Interferometry for Alfvén Mode Studies** — •VINEETA NAIR — Max Planck Institute for Plasma Physics, Greifswald

Dispersion interferometry is emerging as a preferred diagnostic for measuring line-integrated electron density in many fusion devices, offering a robust alternative to the traditional dual-color interferometers because its phase measurements are inherently immune to mechanical vibrations of optical components. At Wendelstein 7-X (W7-X), a phase-modulated dispersion interferometer based on a continuous-wave CO<sub>2</sub> laser (10.6  $\mu\text{m}$ ) serves as the standard electron density diagnostic. Phase modulation in the current diagnostic setup is performed using a photo-elastic modulator, which offers a good modulation depth ( $\rho$ ), but is limited to modulation frequencies ( $\omega\text{m}$ ) of only a few kHz due to its mechanical resonance based modulation. With the current diagnostic, fluctuations in electron density can be measured only up to 50 kHz. To investigate several instabilities\*such as MHD modes, kinetic ballooning modes, and fast-ion\*driven Alfvén modes\*it is essential to extend the capabilities of the standard single-channel dispersion interferometer to a high-frequency, multi-channel system capable of localized electron density measurements. To achieve higher modulation frequency, a 40 MHz GaAs electro-optical modulator is planned for implementation. Using multiple plasma sightlines together with appropriate inversion techniques will allow spatially resolved, high-frequency electron density fluctuation measurements. This poster will outline the project plan, present the current status, and discuss the main technical challenges.

P 16.101 Thu 13:45 Redoutensaal

**Quantification of tungsten content in Wendelstein 7-X** — •BIRGER BUTTEN-SCHÖN, DAIHONG ZHANG, CHRISTIAN BRANDT, FELIX REIMOLD, and W7-X TEAM — Max Planck Institute for Plasma Physics, Greifswald, Germany

The high-Z material tungsten (W) is one of the most promising candidates for the use as first wall material in magnetic confinement fusion devices. Its capability to bear high particle and energy loads makes it ideal for the first wall. However, plasma-wall interaction can release W into the confined plasma, where even small impurity concentrations give rise to significant radiative power losses. Especially in a stellarator, which tends to accumulate impurities in relevant scenarios, the knowledge of tungsten sources and transport and the control of total tungsten concentration is crucial for reliable high performance operation.

In this contribution, we present our current knowledge about the W content in Wendelstein 7-X (W7-X) plasmas. The evaluation comprises deliberate impurity injections, interpretation of the radiation structures observed by bolometry and x-ray tomography, and finally an estimate of the background intrinsic tungsten concentration during standard W7-X operation.

P 16.102 Thu 13:45 Redoutensaal

**JANUS: a composite HTS tape for improved magnetic field performance** — •TITOUAN ATANE, PAUL HUSLAGE, and EVE STENSON — Max-Planck-Institut für Plasmaphysik, Garching b. München, Germany

ReBCO (Rare-earth barium copper oxide) high-temperature superconducting (HTS) tapes are a promising technology for the generation of strong magnetic fields (with potentially reduced cryogenic cooling requirements). Due to anisotropy of the crystal lattice however, the critical current ( $I_c$ ) is strongly dependant on the magnetic field angle ( $\theta$ ) as well as magnetic field strength ( $|\mathbf{B}|$ ), which puts challenging constraints on coil optimization and manufacturing, particularly for non-planar coils (often used, e.g. in stellarator design). To solve this problem, the proposed JANUS composite tape consists of two HTS tapes (with different  $I_c$  vs  $\theta$  orientations) soldered together. This concept can allow for a higher critical current, and it can make JANUS more robust against coil manufacturing errors. It is planned to further develop initial feasibility calculations to get a reliable description of the tape's response in a coil winding pack, then validate these experimentally.

P 16.103 Thu 13:45 Redoutensaal

**Electric Field Reconstruction via Impurity-Induced Rotation in Wendelstein 7-X** — •THOMAS WEGNER, HENNING THOMSEN, CHRISTIAN BRANDT, and THE W7-X TEAM — Max-Planck-Institute for Plasma Physics, Greifswald, Germany

In stellarators, a self-generated radial electric field arises to fulfill ambipolarity and strongly shapes neoclassical transport by modifying particle orbits through the resulting ( $E \times B$ ) drift. In this contribution, we present an experimental method to infer the radial electric field from the dynamics of impurities injected via laser blow-off and analyzed through tomographic inversion of line-integrated soft-X-ray measurements. The analysis of the poloidal motion of the resulting radiation pattern, driven by the ( $E \times B$ ) drift, enables a reconstruction of the radial electric field. This method is applied and compared across similar plasma scenarios with forward and reversed magnetic field configurations.

P 16.104 Thu 13:45 Redoutensaal

**Localized probe measurements across magnetic islands: implications for divertor operation in W7-X** — •ALICE BONCIARELLI<sup>1</sup>, CARSTEN KILLER<sup>1</sup>, OLAF GRULKE<sup>1</sup>, ALEXANDER KNIIPS<sup>1,2</sup>, YU GAO<sup>1</sup>, SEBASTIAN THIEDE<sup>1</sup>, MARCIN JAKUBOWSKI<sup>1</sup>, ARUN PANDEY<sup>1</sup>, and W7-X TEAM<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald, Germany — <sup>2</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management, Plasma Physics, 52425 Jülich, Germany

The optimized stellarator Wendelstein 7-X (W7-X) employs an island divertor. In this configuration, the scrape-off layer (SOL) is organized by a chain of resonant magnetic islands, which intersect the divertor targets placed accordingly. The latter act as a heat and particle exhaust system. The energy and particle transport processes are particularly challenging to disentangle in the complex three-dimensional magnetic geometry of the island divertor SOL. To investigate these complex edge regions, a suite of diagnostics is used, including a multi-user platform for reciprocating Langmuir probe measurements, that provides highly localized measurements of electron temperature and density as well as floating potential with high temporal resolution. The measurements indicate a complex distribution of plasma parameters in the island SOL, with well-localized features that presumably correlate to the island geometry and connection length distribution. By tracing magnetic field lines from the reciprocating probe sampling region to the divertor targets, local SOL measurements can be directly linked to divertor heat fluxes and plasma parameters.

P 16.105 Thu 13:45 Redoutensaal

**Development of a Synthetic Helium Beam Diagnostic at ASDEX Upgrade** — •PIETRO PECCHINI, MICHAEL GRIENER, SEBASTIAN HOERMANN, WLADIMIR ZHOLOBENKO, KAIYU ZHANG, and ONDREJ GROVER — Max Planck Institute for Plasma Physics, Garching

Turbulent plasma behavior in the edge and scrape-off layer is a key factor for magnetic confinement fusion. Physics-based plasma boundary codes like GRILLIX, based on a two-fluid description of the plasma, can model these dynamics by simulating fundamental plasma parameters, such as electron density and temperature. However, experimental diagnostics - such as the helium beam diagnostic - measure derived quantities like spectral line emission intensities, making a direct comparison of measurement and simulation outputs challenging. To quantitatively validate the code output with experimental data, a synthetic helium beam diagnostic that translates simulation outputs into experimentally accessible signals is developed. A first implementation of this synthetic diagnostic for ASDEX Upgrade GRILLIX simulations is presented, and its performance is evaluated by comparing it with simplified models to quantify the impact of key effects. The importance of computing the ionization of the helium, considering simultaneously the time evolution of both helium particles and plasma, is investigated. The synthetic emission profile is decomposed to illustrate its dependence on electron density, helium density, and photon emissivity coefficients, for both an individual spectral line and the ratio between two spectral lines.

P 16.106 Thu 13:45 Redoutensaal

**Absorption of high-intensity laser pulses in plasma gratings** — •SOPHIE OPARA and GÖTZ LEHMANN — Heinrich-Heine-Universität, Düsseldorf

Plasma transmission gratings are transient, periodic density structures in underdense plasmas that enable the manipulation of high-intensity laser pulses beyond the damage threshold of conventional solid-state optics. They are generated by the ponderomotive force of interfering driving pulses and can be reproducibly created on a shot-to-shot basis. With lifetimes on the picosecond timescale, they are well suited for controlling high-power femtosecond laser pulses. Potential applications include polarizers, wave plates, Bragg-type mirrors, and holographic lenses, among many others.

The optical response of these gratings is governed by their grating period, modulation depth, and plasma parameters, which in turn determine their transmission, reflection, and absorption characteristics. At sufficiently high intensities, a probe laser pulse can modify the density modulation and excite collective plasma dynamics, leading to energy absorption. This work investigates the absorption mechanisms in plasma transmission gratings and their dependence on laser and plasma parameters such as wavelength and plasma density. The results provide guidelines for their use either as efficient beam blockers or as low-loss, damage-free optical elements for high-intensity laser systems.

P 16.107 Thu 13:45 Redoutensaal

**Laser pulse duration as a key parameter in plasma grating formation** — •GÖTZ LEHMANN and KARL-HEINZ SPATSCHKE — Heinrich-Heine-Universität, Düsseldorf

Prompted by early experimental realizations of plasma-optical components, we examine how finite formation times affect the quality and scaling behavior of a plasma grating induced by the ponderomotive potential of two counter-propagating pump laser beams. Besides the plasma density, the ratio of thermal to ponderomotive pressure is known to be an important factor. Via full Vlasov simulations we show that the ratio of the laser pulse duration to the characteristic ion reaction time is another important parameter. These simulations also reveal that (linearized) kinetic models for electron-temperature-dependence need to be extended in order to recover the correct behavior for gratings generated by short laser pulses. A generalized simple hydrodynamic model allows to study the dependence of the grating amplitude on the pump laser amplitude  $a_0$ .

P 16.108 Thu 13:45 Redoutensaal

**Particle Acceleration and Emission Signatures in Relativistic AGN Jets** — •NIKITA NIKITA, FRANK RIEGER, and FRANK JENKO — Max Planck Institut für Plasmaphysik

Relativistic jets from active galactic nuclei (AGNs) are among the most energetic phenomena in the universe, extending over kilo-parsec scales and interacting with their surrounding environment in highly complex ways. These jets develop complex structures through different MHD instabilities and turbulence, which strongly influence non-thermal particle acceleration in these systems. Using 3D RMHD simulations with PLUTO, we investigate jet-driven turbulence as a site for stochastic (second-order Fermi) acceleration in regimes where strong shocks are absent and magnetization is sufficient for stochastic processes to become relevant. We explore a semi-analytical treatment of turbulent acceleration and examine how different prescriptions for momentum diffusion coefficients and escape timescales shape the particle energization and the resulting spectra. By coupling these models to synthetic synchrotron emission, we aim to examine how variations in diffusion physics manifest in observable radio signatures from active galaxies, providing new constraints on the physical processes underlying particle acceleration in large-scale AGN jets.

P 16.109 Thu 13:45 Redoutensaal

**energy dissipation in collisionless shocks: MMS observations** — •VALENTINA VILLAFLOR, ARTEM BOHDAN, and FRANK JENKO — Max Planck Institute for Plasma Physics, Garching, Germany

Collisionless shocks play a key role in space and astrophysical plasmas, enabling the conversion of large-scale kinetic energy into heat and non-thermal particle populations without relying on binary Coulomb collisions. Instead, these shocks are sustained by collective effects such as wave-particle interactions that are inherently kinetic and nonlinear. Despite significant observational and theoretical efforts, the precise mechanisms of energy dissipation in collisionless shocks remain debated. While it is widely accepted that dissipation occurs within the shock ramp, observations have shown that energy conversion may also extend involving other shock structures.

We analyze high-resolution measurements from the Magnetospheric Multi-scale (MMS) mission across multiple quasi-perpendicular bow shock crossings. We quantify energy contribution of different particle species within a vicinity of the shock ramp to analyze energy transfer among electrons, ions. By correcting the measured ion and electron distribution functions for instrumental effects, we isolate the energy contributions of each species and examine how they vary throughout the shock structure. We calculate the theoretically expected values for thermal energy from mass conservation principles and Rankine-Hugoniot conditions to analyze the observed deviation from adiabatic behavior in collisionless shocks. Finally, we discuss how energy transfer between species depends on various shock parameters.

P 16.110 Thu 13:45 Redoutensaal

**First interpretative local ERO2.0 modelling of tungsten erosion experiments at W7-X** — •CLAUDIO MARIA DE SIMONE<sup>1</sup>, CHANDRA-PRAKASH DHARD<sup>1</sup>, DIRK NAUJOKS<sup>1</sup>, JURI ROMAZANOV<sup>2</sup>, and SEBASTIJAN BREZINSEK<sup>2</sup> — <sup>1</sup>Max-Planck Institute for Plasma Physics, Wendelsteinstrasse 1, 17491 Greifswald, Germany — <sup>2</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany

Tungsten has been chosen as the most promising material for plasma-facing components (PFCs), in future fusion devices, due to its favorable thermomechanical properties, low fuel retention, and low sputtering. While in tokamak devices tungsten erosion, deposition and transport has been extensively investigated, in stellarators such studies remain limited. This work aims to extend PWI knowledge for W7-X with the use of ERO2.0 developed by FZJ. This 3D Monte-Carlo is used to model local W erosion and migration for some baffle modules equipped with W tiles. Different 3D plasma solutions and scenarios as generated by EMC3-EIRENE will be used as an input for ERO2.0 modeling. A material-mixing model will be applied to consider the change of W surface concentration due to the impact of carbon impurity ions. The results of these simulations will be validated against in-situ spectroscopy and post-mortem analysis of exposed samples.

P 16.111 Thu 13:45 Redoutensaal

**Evaluation of wall boiling models for plasma facing components** — •AHMET KILAVUZ<sup>1,2</sup>, JEONG-HA YOU<sup>2,3</sup>, BOSJAN KONCAR<sup>4,5</sup>, and RUDOLF NEU<sup>1,2</sup> — <sup>1</sup>Technical University of Munich — <sup>2</sup>Max Planck Institute for Plasma Physics — <sup>3</sup>University of Ulm — <sup>4</sup>Jožef Stefan Institute — <sup>5</sup>University of Ljubljana

Subcooled flow boiling in fusion-device cooling channels can occur under conditions far beyond those of conventional nuclear applications, with plasma-facing components exposed to heat fluxes up to 40 MW m<sup>-2</sup> and mass fluxes approaching 20,000 kg m<sup>-2</sup> s<sup>-1</sup>. This study compares several wall-boiling models, including the Rensselaer Polytechnic Institute (RPI) model and the Massachusetts Institute of Technology Boiling (MITB) model, together with multiple bubble-parameter correlations, against fusion-relevant high heat- and mass-flux experiments. The RPI model shows intrinsic limitations at high mass fluxes, producing non-physical negative boiling-curve slopes within the partially developed nucleate boiling regime. It is suggested that this behaviour cannot be corrected by adjusting bubble-parameter correlations. The MITB model mitigates these issues through a sliding-conduction mechanism that scales with flow velocity, which is particularly important at high mass fluxes. This leads to more physically consistent behaviour and reduces the mean absolute error by approximately 65% compared to generic wall-boiling formulations.

P 16.112 Thu 13:45 Redoutensaal

**Testing of Tungsten-Copper Joints for Plasma-Facing Components by Means of Cyclic High Heat Flux Loading** — •SIMONE COCCHI<sup>1,2</sup>, ALEXANDER VON MÜLLER<sup>2</sup>, DAVID DELLASEGA<sup>1</sup>, ROBERT LÜRBKE<sup>2,3</sup>, AHMET KILAVUZ<sup>2,3</sup>, JULIEN SCHACHTER<sup>2</sup>, JOHANN RIESCH<sup>2</sup>, and BERND BÖSWIRTH<sup>2</sup> — <sup>1</sup>Politecnico di Milano, 20156 Milan, Italy — <sup>2</sup>Max Planck Institute for Plasma Physics, 85748 Garching, Germany — <sup>3</sup>Technical University of Munich, 85748 Garching, Germany

In magnetic-confinement fusion devices, plasma-facing components (PFCs) have to face extreme heat loads. Decades of plasma-wall interaction research point to a design with plasma-facing tungsten tiles joined to a copper (Cu)-based heat sink. In so-called "flat-tile" configurations, thermal gradients and the coefficient of thermal expansion (CTE) mismatch between W and Cu induce critically high stresses at the material interface, often leading to component failure. To mitigate this, tailored W-Cu interfaces represent a possible solution to improve PFCs durability - now possible due to developments in additive man-

ufacturing technologies. An experimental design was devised to test relevant W-Cu joint specimens under high heat loads. FEA simulations were conducted to model thermomechanical loading at the flat-tile joint, aiding design of a dedicated mock-up joint geometry for testing under thermal cycling in the high heat flux test facility GLADIS. Results were obtained for DEMO-relevant tile dimensions with different interface architectures.

P 16.113 Thu 13:45 Redoutensaal

**Investigation of Grain Boundary Transport in Tungsten by Hydrogenography** — •FAHRUDIN DELIC<sup>1,2</sup>, ARMIN MANHARD<sup>2</sup>, and UDO VON TOUSSAINT<sup>2</sup> — <sup>1</sup>Technical University of Munich, Munich, Germany — <sup>2</sup>Max Planck Institute for Plasma Physics, Garching, Germany

The permeation of deuterium through grain boundaries in tungsten was studied on recrystallized foils using the hydrogenography method, employing tungsten trioxide as a hydrogen indicator. The temperature dependence of grain boundary transport was analyzed on 50  $\mu$ m foils up to 700 K, revealing an overall increase in permeation activity with rising temperature. At around 630 K, a distinct *halo* structure forms around several grain boundaries, indicating the onset of deuterium desorption from the boundaries and the gradual transition toward bulk-dominated permeation. To investigate geometrical influences on permeation behavior, the 50  $\mu$ m results were compared with measurements on 25  $\mu$ m foils. In thinner foils, the grain geometry facilitates bulk transport, and a depletion region of hydrogen permeation around certain grain boundaries becomes visible. The hydrogenography analysis is furthermore complemented by grain orientation mapping via EBSD.

P 16.114 Thu 13:45 Redoutensaal

**Exploiting Tungsten Fibre-Reinforcement for Plasma-Facing Component Design** — •THOMAS FOX<sup>1,2</sup>, ALEXANDER VON MUELLER<sup>1</sup>, and RUDOLF NEU<sup>1,2</sup> — <sup>1</sup>Technical University Munich, Boltzmannstr. 15, 85748 Garching — <sup>2</sup>Max Planck-Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching

The divertor of a magnetic confinement fusion device has extreme requirements for materials design due to the high heat fluxes combined with plasma erosion and neutron flux considerations. Current leading designs centre around tungsten (W) surface armouring joined to a copper (Cu)-based heat sink. The mismatch in coefficient of thermal expansion (CTE) between these base materials leads to high thermomechanical stresses during heat loading that can cause cracking and delamination of the W armouring. This can significantly hamper the performance and shorten the service lifetime of a divertor plasma-facing component (PFC).

In this work, a design will be presented, in which W-fibre reinforcement will be utilised to mitigate the CTE mismatch while also strengthening and toughening the W/Cu joint with cross-interface connections. By taking advantage of textile processes, complex fibre preforms can be constructed out of ductile, potassium-doped W fibres. These preforms can first undergo chemically vapour infiltration of W and then melt infiltration of Cu or Cu-based alloys for creating a highly damage resistant fibre-reinforced composite PFC design. The overall goal of this work is to design, manufacture and test a scalable concept that meets the extreme requirements of a fusion reactor divertor.

P 16.115 Thu 13:45 Redoutensaal

**Dynamic evolutions of radiation and divertor target behavior during detachment with an island divertor configuration on J-TEXT** — •YUTONG YANG<sup>1</sup>, YUNFENG LIANG<sup>1,2</sup>, WEI YAN<sup>2</sup>, JIANKUN HUA<sup>2</sup>, and SONG ZHOU<sup>2</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management Plasma Physics, Jülich, Germany — <sup>2</sup>International Joint Research Laboratory of Magnetic Confinement Fusion and Plasma Physics, Huazhong University of Science and Technology, Wuhan, China

On J-TEXT, the temporal evolution of the heat flux distribution on the divertor plate has been measured using an infrared camera with an island divertor configuration. In previous experiments employing this configuration, partial detachment was achieved by SMBI gas fuelling when the radiation front approached the last closed flux surface (LCFS). This observation is consistent with the results obtained on the W7-X stellarator. We conducted a series of experiments under different island divertor configurations to further validate this conclusion. By reconstructing the 2D radiation profile using AXUV arrays, we investigated the dynamic characteristics of edge radiation, heat and particle fluxes on divertor target during the detachment. The results highlight the critical role of magnetic topology in the onset and development of detachment, providing important insights into realizing stable detachment under 3D boundary conditions.

P 16.116 Thu 13:45 Redoutensaal

**Additive manufacturing for tailored tungsten copper joints in plasma-facing components** — •ALBERTO AMBROGINI<sup>1,2</sup>, ALEXANDER VON MÜLLER<sup>1</sup>, and RUDOLF NEU<sup>1,2</sup> — <sup>1</sup>Technical University of Munich — <sup>2</sup>Max Planck Institute for Plasma Physics

Additive manufacturing (AM) technology has progressed significantly in recent years and holds the potential to become a decisive technology for the fabrication of plasma-facing components (PFCs). In highly heat loaded divertor PFCs,

issues regarding the joining of plasma-facing tungsten materials with copper based heat sink materials represent a major engineering challenge, considering the differing thermomechanical properties of these two materials. Under heat flux loadings in magnetic confinement fusion devices, this leads to stress concentrations at the joining interface, that in turn can lead to undesired failure of PFCs. One possible solution for improving such material joints is the tailoring of the interface between the two materials with the help of AM that enables control of the geometry, composition, and microstructure at the interface. This allows the creation of a tailored interfacial region where common failure mechanisms, like joint delamination, might be avoided. The contribution will present relevant AM technologies considered to be suitable for the realisation of tailored tungsten-copper interfaces and approaches to the design of such joints. Furthermore, plans for their testing under relevant loading situations will be outlined.

P 16.117 Thu 13:45 Redoutensaal

**Quantum kinetic methods for dense quantum plasmas in nonequilibrium** — •CHRISTOPHER MAKAIT and MICHAEL BONITZ — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

## P 17: Plasma Wall Interaction II

Time: Thursday 16:15–18:15

Location: KH 02.016

### Invited Talk

P 17.1 Thu 16:15 KH 02.016

**Energetic proton damage for simulating fusion relevant neutron damage on reactor materials** — •RAHUL RAYAPROU — Forschungszentrum Jülich, Jülich, Germany

As fusion research progresses from experimental devices to reactors, it is imperative to comprehend the effects of fusion neutron damage and its impact on plasma-facing materials (PFMs). At present, the study of neutron damage is predominantly conducted through the use of fission reactors, which exhibit a distinct neutron-energy flux spectrum. Hence, the fission neutron damage leads to damage ingrowth as compared to that of a fusion reactor. Ion irradiation is a well-established method and is frequently used as a surrogate for neutron damage. It is a more accessible method than nuclear reactors and simultaneously offers superior control over experimental conditions. Until recently, the focus has been on the use of heavy ions to replicate the displacement effects of neutron damage on the PFMs lattice. However, the heavy-ion irradiation method has a very shallow damage depth and is unable to take macroscopic effects into consideration. Energetic protons offer a solution and have been shown to deliver damage in depths ranging from 500  $\mu\text{m}$  to 1 mm. They produce a combination of displacement and nuclear-transmutation damage that is comparable to fusion neutrons. However, the irradiated area is constrained to the beam spot size, and the samples like fission irradiations are radioactive. In the absence of a fusion neutron source, this method can be used to study the development and influence of fusion relevant neutron damage in PFMs.

P 17.2 Thu 16:45 KH 02.016

**Influence of the presence of deuterium on damage evolution in tungsten** — •ZEQING SHEN<sup>1,2</sup>, THOMAS SCHWARZ-SELINGER<sup>2</sup>, MIKHAIL ZIBROV<sup>2</sup>, ARMIN MANHARD<sup>2</sup>, and MARTIN BALDEN<sup>2</sup> — <sup>1</sup>Technische Universität München, 85747 Garching, Germany — <sup>2</sup>Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany

A systematic investigation was conducted to examine the effects of ion flux during deuterium (D) exposure of self-ion-damaged tungsten (W). The samples were heated to four temperatures within the range of 470–770 K during the plasma loading process. Two plasma conditions were applied during annealing: a low flux of 6e19 D/m<sup>2</sup>/s and a high flux of 5e20 D/m<sup>2</sup>/s, both using an ion energy of 5 eV/D. For comparison, annealing experiments were also carried out in vacuum. The depth distribution of deuterium was determined by 3He nuclear reaction analysis (NRA), while its total inventory was evaluated using both NRA and thermal desorption spectroscopy (TDS). Morphological modifications at the surface were analysed by confocal laser scanning microscopy (CLSM). For the flux condition of 6e19 D/m<sup>2</sup>/s, the results revealed a decrease in deuterium retention with increasing annealing temperature for both plasma annealing and vacuum annealing. The presence of D during annealing has only a small stabilizing effect on the defects. In contrast, exposure to a higher flux of 5e20 D/m<sup>2</sup>/s induces additional damage, producing micrometer-wide blisters only a few tens of nanometers high.

P 17.3 Thu 17:10 KH 02.016

**Hydrogen Isotope Exchange in Tungsten Displacement Damaged at High Temperature** — •LAURIN HESS<sup>1,2</sup> and THOMAS SCHWARZ-SELINGER<sup>2</sup> — <sup>1</sup>Technical University Munich, Munich, Germany — <sup>2</sup>Max-Planck-Institute for Plasma Physics, Garching, Germany

Retention of hydrogen fuel in tungsten is an active area of research, as it is an integral part of modelling the tritium inventory and certification of future fu-

sion reactors. It has been shown that hydrogen retention increases significantly due to displacement damage produced by 14 MeV fusion neutrons. Over the last years, a basic understanding of the behaviour of hydrogen in point defects was acquired. However, damage at high temperatures can also produce nm-sized voids. To gain understanding of hydrogen in nm-sized voids, tungsten single crystals were self-damaged by irradiation with 20 MeV tungsten ions at 1370 K and decorated with <5 eV deuterium (D) from a low-temperature plasma. The retained deuterium was then exchanged for protium (P) using the same plasma loading process. D depth profiles were measured after D loading and periodically during P loading using <sup>3</sup>He-NRA. After the loading, the retained hydrogen isotopes were measured using TDS. This showed that hydrogen in voids does not exchange at temperatures up to 370 K. At higher temperatures exchange starts to happen, with almost all hydrogen exchanged within hours during exposure at 460 K. The results were compared to the model proposed by Zibrov and Schmid [1].

[1] H. Haberland et al, Phys. Rev. E 64, 026405 (2001)

[2] G. Stefanucci, R. van Leeuwen, “Nonequilibrium Many-Body Theory of Quantum Systems: A Modern Introduction”

[3] M. Bonitz, “Quantum Kinetic Theory”, 2nd ed. Springer 2016

[4] E. Schroedter et al, Condensed Matter Physics, 2022, vol. 25, No. 2, 23401

sion reactors. It has been shown that hydrogen retention increases significantly due to displacement damage produced by 14 MeV fusion neutrons. Over the last years, a basic understanding of the behaviour of hydrogen in point defects was acquired. However, damage at high temperatures can also produce nm-sized voids. To gain understanding of hydrogen in nm-sized voids, tungsten single crystals were self-damaged by irradiation with 20 MeV tungsten ions at 1370 K and decorated with <5 eV deuterium (D) from a low-temperature plasma. The retained deuterium was then exchanged for protium (P) using the same plasma loading process. D depth profiles were measured after D loading and periodically during P loading using <sup>3</sup>He-NRA. After the loading, the retained hydrogen isotopes were measured using TDS. This showed that hydrogen in voids does not exchange at temperatures up to 370 K. At higher temperatures exchange starts to happen, with almost all hydrogen exchanged within hours during exposure at 460 K. The results were compared to the model proposed by Zibrov and Schmid [1].

[1] M. Zibrov, K. Schmid, Nucl. Mat. Eng. 30 (2022) 101121

P 17.4 Thu 17:35 KH 02.016

**Effect of high displacement damage at different dose rates and temperatures on Deuterium retention in Eurofer97** — •ABDULRAHMAN ALBARODI<sup>1,2</sup>, THOMAS SCHWARZ-SELINGER<sup>2</sup>, DINA MERGIA<sup>3</sup>, and DIMITRIOS PAPADAKIS<sup>3</sup> — <sup>1</sup>Technical University of Munich, Garching, Germany — <sup>2</sup>Max Planck Institute for Plasma Physics, Garching, Germany — <sup>3</sup>NCSR Demokritos, Athens, Greece

Open-volume defects in irradiated metals are attributed to increased gas retention. In this study, deuterium (D) retention was used as an indicator for the evolution of open-volume defects at different temperatures and dose-rates. EUROFER97 samples were irradiated with a defocused continuous 11.6 MeV Au beam with a dose rate of 2.5–16.5 dpa/hr using ions to peak displacement damage doses of 50–100 dpa at 100–400°C. Rutherford-backscattering (RBS) with 4 MeV helium was used on aluminum surrogates to characterize the Au implantation profile. The Au depth profile showed a region of high displacement damage of 500 nm that is gold-free for uncontaminated defect analysis. X-ray diffraction showed clear differences in the lattice constant and the width of the Bragg peaks between damaged samples and undamaged reference. The samples were subsequently exposed to D-plasma at 100°C and low energy (<5 eV/D) until full D defect decoration. D depth profiles were measured using 3He nuclear reaction analysis. D-retention results are comparable with previous low-dose (0.6 dpa) irradiated samples at 100°C. For the sample damaged at 300–400°C, it is comparable to undamaged EUROFER97. NRA and XRD results show recovery of open-volume defects at 400°C.

P 17.5 Thu 18:00 KH 02.016

**Developing Tritium Diffusion Barrier Materials for Plasma-Facing Components in Fusion Reactors** — •MARKUS HERMANSKI<sup>1,3</sup>, LIANG GAO<sup>1</sup>, ARKADI KRETER<sup>1</sup>, JAN WILLEM COENEN<sup>1</sup>, RONGXING YI<sup>1</sup>, SEBASTIJAN BREZINSEK<sup>1,2</sup>, and CHRISTIAN LINSMEIER<sup>1,2</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management — Plasmaphysics (IFN-1), Jülich 52425, Germany — <sup>2</sup>Ruhr-Universität Bochum, Faculty of Physics and Astronomy, Bochum 44801, Germany — <sup>3</sup>RWTH Aachen University, Faculty of Geosciences and Materials Engineering, Aachen 52072, Germany

Fuel permeation and retention in wall materials of fusion reactors, especially Tritium (T), are important aspects to be prevented to achieve commercial viability of fusion power in the future. For this reason, T diffusion barrier materials have

been developed, however, focusing on applications at the coolant side. Preventing T permeation into the coolant, they cannot address the degradation of wall materials induced by H isotopes from plasma. Here, a diffusion barrier made of tungsten carbides (WxC) is proposed and will be developed for applications at plasma-facing surfaces.

WxC coatings will be fabricated via field assisted sintering technique (FAST) on W and G91 steel substrates, followed by deuterium (D) plasma exposure, where laser induced breakdown spectroscopy (LIBS), nuclear reaction analysis (NRA) and thermal desorption spectroscopy (TDS) measurements will be employed to measure the D depth profile after plasma exposure.

## P 18: High Energy Density Physics III

Time: Thursday 16:15–17:30

Location: KH 01.020

### Invited Talk

P 18.1 Thu 16:15 KH 01.020

**High-energy-density and high-pressure states investigated with x-ray imaging at HED-HiBEF** — •ALEJANDRO LASO GARCIA — Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany

The High Energy Density - Helmholtz International Beamline for Extreme Fields (HED-HiBEF) at the European XFEL combines the x-ray beam, with unparalleled spatial and temporal coherence and brilliance, with powerful optical drivers to probe and study extreme states of matter.

With the high-intensity short-pulse laser, ReLaX, reaching intensities of  $10^{20}$  W/cm<sup>2</sup> on target, is used to isochorically heat matter and generate blastwaves in materials. It can also generate high-pressure states via cylindrical compression in micrometer-sized wires. Thanks to the narrow energy bandwidth of the XFEL beam, the energy can be tuned to be resonant with the transition energy between the K- and L- shell of specific charge states in the plasma.

The DiPOLE-100X, the high-energy nanosecond pulse duration laser is used to generate planar shocks in materials and study equation-of-state of highly compressed matter via shock compression.

All these experiments make use of the x-ray imaging platform developed at HED-HiBEF. In this talk we will provide a description of the platform and the spatial resolution achieved (better than 500 nm) as well as its application to all the cases mentioned above.

P 18.2 Thu 16:45 KH 01.020

**A Megajoule Experiment at an XFEL: High-repetition Rate XRTS Measurements in Shock Compressed Plastics** — •THOMAS GAWNE<sup>1,2</sup>, OLIVER S HUMPHRIES<sup>3</sup>, TOBIAS DORNHEIM<sup>2,1</sup>, and THOMAS R PRESTON<sup>3</sup> — <sup>1</sup>CASUS, Görlitz, Germany — <sup>2</sup>HZDR, Dresden, Germany — <sup>3</sup>European XFEL, Schenefeld, Germany

The properties of plastics under laser compression are of broad importance due to their prevalence as ablators in shock-compression experiments and laser-driven inertial fusion energy schemes. Accurate measurements of their equation of state and electronic structure are therefore of paramount importance for predicting achievable conditions in laser-driven systems. Here we report on results from a recent experiment at the European XFEL, where the DiPOLE-100X laser was used to shock compress plastics at a repetition rate of 1 Hz with ~30 J laser energy in  $2\omega$ . In the three day experiment, more than 34,000 laser shots were collected, and more than 1 MJ of laser energy fired at the targets. The systems were probed using simultaneous forward and backwards XRTS. Ultrahigh resolution measurements of the elastic feature in backscattering reveal the shock dynamics via the combined thermal Doppler broadening and shock-driven Doppler shift. Forward scattering measurements at multiple scattering angles show pronounced changes in the shape of the plasmon scattering between the different plastics, providing insights into the differences in their electronic properties and structures under shock compression. The setup and results presented here represent an important development for future laser compression experiments at XFEL facilities.

P 18.3 Thu 17:00 KH 01.020

**Hydrodynamic equations for strongly coupled plasmas** — •DANIELS KRIMANS, HANNO KÄHLERT, and MICHAEL BONITZ — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

In strongly coupled plasmas, particle correlations dominate the dynamics, making theoretical descriptions challenging. To provide an alternative to computationally intensive particle-based methods, we present a hydrodynamic model obtained from the least action principle [1, 2]. In this approach, the pair distribution function is included directly into the Lagrangian, allowing correlation effects to be treated consistently while conserving energy and momentum.

We apply this framework to Coulomb [1] and Yukawa [2] one-component plasmas and analyze the linearized hydrodynamic equations by computing longitudinal and transverse modes. The obtained dispersion relations agree closely with molecular dynamics simulations over a wide range of coupling strengths and screening parameters, up to finite wavelengths comparable to the interparticle spacing.

We also outline how this variational framework may be extended to the quantum regime, thereby generalizing earlier formulations of quantum hydrodynamics [3] to strongly coupled systems. The resulting equations are expected to be relevant for inertial confinement fusion.

[1] D. Krimans and S. Putterman, *Phys. Fluids* **36**, 037131 (2024).

[2] D. Krimans and H. Kählert, arXiv:2506.23006v1 (2025).

[3] Zh. A. Moldabekov, M. Bonitz, and T. S. Ramazanov, *Phys. Plasmas* **25**, 031903 (2018).

P 18.4 Thu 17:15 KH 01.020

**Matsubara Local Field Correction of Warm Dense Beryllium** — •MAXIMILIAN BOEHME<sup>1</sup>, TOBIAS DORNHEIM<sup>2</sup>, JAN VORBERGER<sup>2</sup>, and ZHANDOS MOLDABEKOV<sup>2</sup> — <sup>1</sup>Lawrence Livermore National Laboratory — <sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf

Recent studies, including Dornheim et al. [EPL 147, 36001 (2024)], have highlighted the role of dynamical quantum effects encoded in the imaginary-time correlation function of the uniform electron gas in the warm dense matter (WDM) regime. In this work, we extend these efforts by employing the Fourier-Matsubara expansion framework introduced by Tolia et al. [J. Chem. Phys. 160, 181102 (2024)] to compute the Matsubara density-response function of warm dense beryllium using path-integral Monte Carlo simulations. We consider temperatures from 155.5 to 190 eV and densities between 7.5 and 30 g/cc, spanning a representative region of the WDM phase space. This approach provides access to electronic correlations and localization phenomena within the imaginary-time formalism. Furthermore, the resulting Matsubara density-response enables the extraction of the corresponding local field correction (LFC), thereby revealing the imaginary-frequency dependence of exchange-correlation effects in beryllium. Our results offer new insight into the microscopic dynamical behaviour of partially ionized systems and support the development of improved theoretical models for WDM.

## P 19: Atmospheric Pressure Plasmas III

Time: Thursday 17:30–18:15

Location: KH 01.020

P 19.1 Thu 17:30 KH 01.020

**Upscaling Microwave CO<sub>2</sub> Plasma Torches: Transitioning to 915 MHz Operation** — •MARC BRESSER, KATHARINA WIEGERS, IRINA SEMJONOV, ANDREAS SCHULZ, MATTHIAS WALKER, and GÜNTER TOVAR — IGVP, University of Stuttgart, Germany

The continuous rise in Earth's surface temperature makes a reduction of the emission of climate gasses essential. The chemical industry, as one of the largest emitters of CO<sub>2</sub>, must find new processes to replace fossil routes with renewable alternatives. A promising approach is to use CO<sub>2</sub> as a feedstock and close the carbon cycle. One innovative technology is the activation of CO<sub>2</sub> with an atmospheric microwave plasma torch, which produces CO and O<sub>2</sub>. The produced CO can be used together with green hydrogen to form syngas and to be a feedstock for processes like Fischer-Tropsch. One advantage of the microwave plasma is the

flexibility of power, small turn on times, and the use of the fluctuations of renewable intermittent energy sources like wind or solar. This work investigates the upscaling of CO<sub>2</sub> splitting with an atmospheric plasma torch from 2.45 GHz to 915 MHz. The process at 2.45 GHz was examined up to 6 kW and gas flow-rates of 74 slm. To improve conversion efficiency, the quenching of the effluent plasma was explored using a gas nozzle and different cooler positions. The cold product gas is analyzed with absorption Fourier-transform infrared spectroscopy and a X-Stream gas analyzer. Based on these findings, a 915 MHz plasma torch was designed and constructed. The first conversions results are presented.

P 19.2 Thu 17:45 KH 01.020

**Using the AD8302 phase detector for power measurements of RF-driven plasmas** — •STEFFEN SCHÜTTLER<sup>1</sup>, MICHAEL ROLOFF<sup>1</sup>, SVEN WELLER<sup>2</sup>, MICHAEL KONKOWSKI<sup>2</sup>, and JUDITH GOLDA<sup>1</sup> — <sup>1</sup>Plasma Interface Physics, Ruhr University Bochum, Bochum, Germany — <sup>2</sup>Chair for Experimental Physics II - Reactive Plasmas, Ruhr University Bochum, Bochum, Germany

The use of reference standards for plasmas in laboratories guarantees reproducible results. By this, plasma processes can be thoroughly investigated, as the results are comparable and the focus is on plasma physics rather than on comparing different plasma sources. This was the idea behind the design of the COST reference plasma jet [1]. However, the measured values for plasma characterisation are still diverse. Some groups measure the dissipated plasma power while others only provide the applied voltage, as proper power measurements require a high-resolution oscilloscope (expensive and not everywhere available) to measure the phase shift between voltage and current. But the applied voltage is an external parameter that provides poor insights into the plasma itself. For example, the dissipated plasma power differs at the same external voltage for different feed gases and reactive admixtures. In this work, we provide a new method that uses the AD8302 phase detector to measure the phase shift between voltage and current of the COST reference plasma jet. This offers an easy-to-implement and low-cost alternative for measuring the dissipated plasma power of RF-driven plasmas such as the COST reference plasma jet.

[1] Golda et al. J. Phys. D: Appl. Phys. 49 (2016) 084003 (11pp)

P 19.3 Thu 18:00 KH 01.020

**Particle Dynamics and Characteristics during In-Flight Iron Oxide Reduction in an Ar-H<sub>2</sub> Microwave Plasma** — •JONAS THIEL, LENNART KULIK, MORITZ PETERSEN, MARC BÖKE, and ACHIM VON KEUDELL — Experimental Physics II - Reactive Plasmas, Ruhr University Bochum, Bochum, Germany

The climate-neutral production of metallic iron from iron ore is an emerging research topic, as the iron and steel industry is one major emitter of CO<sub>2</sub>. In this work, an atmospheric argon-hydrogen microwave plasma torch is deployed to investigate the in-flight reduction of iron oxide particles. These plasmas provide fast reaction kinetics, a fine control of energy consumption and promising scale-up options. The experimental setup enables a wide range of operating conditions to optimize the process. OES, XRD and spatially resolved RGB pyrometry using two CCD cameras, complemented by a heat transport model and gas-flow simulation, are applied to evaluate parameter variations and the overall reduction efficiency. The resulting phase compositions of the treated particles are correlated with particle size and process parameters, revealing favorable process conditions. Additionally, we observe significant emission trails from the hot particles in the downstream region, which are caused by friction with the much faster gas flow. These formations, which depend on gas-flow dynamics and the particle surface temperature, provide insight into particle size dynamics and evaporation. Overall, the results indicate the potential of in-flight oxide reduction in atmospheric plasmas while also emphasizing challenges such as particle evaporation and surface coatings.

## P 20: Members' Assembly

Time: Thursday 18:30–19:30

Location: KS H C

All members of the Plasma Physics Division are invited to participate.

## P 21: Codes and Modeling II

Time: Friday 9:00–10:30

Location: KH 01.013

### Invited Talk

P 21.1 Fri 9:00 KH 01.013

**Performance Pitfalls and Design Principles of Retarding Potential Analyzers** — •THOMAS TROTTEBERG — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

Retarding potential analyzers (RPAs) are standard diagnostics for ion energy distribution measurements, yet their performance is often limited by subtle but critical mechanical design choices. Grid alignment, aperture geometry, grid thickness, and spacing can strongly affect the measured current-voltage characteristics and may introduce non-monotonic behavior and artificial humps.

In this talk, experimental results and trajectory simulations of a four-grid RPA with drilled grids are presented, systematically quantifying the impact of grid orientation and hole geometry. It is shown that certain grid alignments introduce strong correlation effects between adjacent grids, resulting in enhanced transparency and pronounced anomalies close to the falling edge in the characteristics.

These findings reveal fundamental performance pitfalls of RPAs and form the basis for practical design guidelines. Concrete recommendations for grid geometry and alignment are derived, aiming at robust, monotonic characteristics and reliable ion energy distribution functions.

### Invited Talk

P 21.2 Fri 9:30 KH 01.013

**Microwave cavity resonance spectroscopy: a novel approach for spatially resolved electron density measurements** — •JENS OBERRATH — Modeling and Simulation, South Westphalia University of Applied Sciences, Soest, Germany

Electron density is a critical parameter of plasma. Its non-invasive measurement becomes particularly challenging when spatial resolution is required. A promising technique for this purpose is Microwave Cavity Resonance Spectroscopy (MCRS), where electromagnetic waves are coupled into a plasma-filled cavity to excite resonances. These resonances, which also occur in vacuum, are shifted by the presence of the plasma. MCRS has been known since the 1950s. While significant improvements have been made over the past few decades, a robust approach for measuring spatially resolved electron densities has yet to be fully developed. The scattering behavior of a plasma-filled cavity with a finite number of connected waveguides can be described by the shell-model approach developed by Mahaux and Weidenmüller. Using functional analytic methods, the scattering matrix  $S$  for such a cavity can be derived. Assuming a cold plasma model for the electrons, the calculated elements of  $S$  (reflection and transmission coefficients) contain the spatially dependent electron density. For a specific type of plasma, a density profile can be assumed and expanded as a function with a certain number of unknown parameters. By comparing the calculated elements of  $S$  with the measured ones, these unknown parameters in the density profile can be determined, enabling the spatially resolved measurement of electron densities.

P 21.3 Fri 10:00 KH 01.013

**Event-driven simulation of X-ray Thomson scattering for warm dense matter probing** — •UWE HERNANDEZ ACOSTA<sup>1,2</sup>, THOMAS GAWNE<sup>1,2</sup>, JAN VORBERGER<sup>1</sup>, HANNAH BELLENBAUM<sup>1,2</sup>, and TOBIAS DORNHEIM<sup>1</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf, Germany — <sup>2</sup>Center for Advanced Systems Understanding, Görlitz, Germany

X-ray Thomson scattering (XRTS) is a central diagnostic for investigating matter under extreme conditions, including laser-driven pump-probe experiments at X-ray free-electron lasers that probe high-energy-density states such as warm dense matter and the compression path of inertial confinement fusion capsules. The analysis of XRTS spectra is often challenging due to low photon counts, evolving sample conditions, and strong geometric and instrumental effects, which are only partially captured by conventional forward-modeling approaches based on convolutions of the dynamic structure factor with simplified source and instrument functions.

We present a proof-of-principle event-driven approach to XRTS modeling that directly connects microscopic electronic-structure physics with realistic detector simulations. Individual scattering events are sampled from the XRTS differential cross section and propagated through a detector model, naturally incorporating instrument response, geometry, and counting statistics. Focusing on non-resonant XRTS in a synthetic diagnostic setup, we demonstrate the technical feasibility and physical consistency of the method and benchmark it against conventional forward models.

P 21.4 Fri 10:15 KH 01.013

**Characterising strongly compressed Beryllium using a combined ray tracing and forward-fitting approach** — •HANNAH BELLENBAUM<sup>1,2,3</sup> and TOBIAS DORNHEIM<sup>2,1</sup> — <sup>1</sup>Center for Advanced Systems Understanding, Untermarkt 20, 02826 Görlitz, Deutschland — <sup>2</sup>Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden/Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Deutschland — <sup>3</sup>Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, 18059 Rostock, Deutschland

X-ray Thomson scattering (XRTS) is a commonly used diagnostic in the warm dense matter regime, as it can be used to simultaneously characterise density, temperature and ionisation degree. Extracting these parameters however commonly relies on a forward-modelling approach where a simple model is fitted to experimental data, since the measured spectrum is a convolution of the dynamic structure factor (DSF) describing the plasma conditions and the source-instrument function (SIF) of the detector. This introduces a number of uncertainties and model-dependencies, and fundamentally relies on the model chosen for the SIF. Here, we present a forward-fit using a new open-source XRTS code



(xDave) in combination with the ray tracing code HEART to analyse spectra measured for imploding Beryllium capsules at the National Ignition Facility. The coupling of this ray tracing code with a reduced model for the DSF introduces

far fewer uncertainties in both the instrument response function and the source spectrum, allowing us accurately study a typical NIF capsule during implosion.

## P 22: Plasma Wall Interaction III

Time: Friday 9:00–10:30

Location: KH 01.012

### Invited Talk

P 22.1 Fri 9:00 KH 01.012

**ERO/ERO2.0 modelling for tokamaks, stellarators and linear plasma devices** — •JURI ROMAZANOV<sup>1</sup>, HENRI KUMPULAINEN<sup>1</sup>, CHRISTOPH BAUMANN<sup>1</sup>, SEBASTIAN RODE<sup>1</sup>, ANDRIY TARASENKO<sup>1</sup>, ANDREAS KIRSCHNER<sup>1</sup>, GEORGII TIMKOVSKI<sup>1</sup>, DMITRY MATVEEV<sup>1</sup>, SEBASTIJAN BREZINSEK<sup>1</sup>, JET TEAM<sup>2</sup>, and W7-X TEAM<sup>3</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, IFN-1, 52425 Jülich, Germany — <sup>2</sup>See the author list of "Overview of T and D-T results in JET with ITER-like wall" by C.F. Maggi et al. Nucl. Fusion 64, 112012 (2024). — <sup>3</sup>Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

This contribution summarizes PWI research using the ERO2.0 code for erosion and material migration in magnetic confinement fusion devices. Code validation is demonstrated using experiments in the linear plasma device PSI-2, where B sample exposures were analyzed using spectroscopy of atomic B and molecular BD emission. Another validation study was conducted at JET, where interpretative plasma reconstructions were combined with predictive W modelling across all plasma regions and compared with experimental W profiles inferred from multiple diagnostics. Predictive studies are presented for several future devices. These include assessments of replacing C with W PFCs in W7-X, W erosion and prompt redeposition in ITER during limiter ramp-up and diverted operation with neon seeding, and lifetime predictions for diagnostic first mirrors. We conclude with EU-DEMO results and discuss challenges stemming from extrapolating plasma profiles to reactor walls.

P 22.2 Fri 9:30 KH 01.012

**Initial predictive modeling of plasma-wall interactions using ERO2.0 for W7-X with tungsten wall divertor** — •GEORGII TIMKOVSKI<sup>1</sup>, JURI ROMAZANOV<sup>1</sup>, SEBASTIJAN BREZINSEK<sup>1,2</sup>, DANIIL RYNDYK<sup>1</sup>, HENRI KUMPULAINEN<sup>1</sup>, and W7-X TEAM<sup>3</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, IFN-1 - Plasma Physics, Jülich, Germany — <sup>2</sup>Mathematisch-Naturwissenschaftliche Fakultät, HHU Düsseldorf, Düsseldorf, Germany — <sup>3</sup>Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Plasma-wall interaction (PWI) is a critical aspect of fusion device operation, influencing material lifetime, fuel retention, and overall plasma performance. In addition to interpretive modelling used to analyze and understand physics experiments, predictive modeling with validated codes like ERO2.0 becomes essential for anticipating system behavior and guiding design or operational decisions as required for an exchange of the wall material in Wendelstein 7-X (W7-X). ERO2.0 is a fully kinetic Monte Carlo code dealing with PWI processes at the surface and incorporating phenomena such as drifts, ionization, and impurity-ion collisions in the plasma. While there have been multiple ERO2.0 studies of stellarators - including cases with some tungsten components - no systematic investigation exist for a fully metallic stellarator with a tungsten divertor. In this work, PWI and impurity transport for the W7-X stellarator are studied with focus on the planned wall material exchange from a carbon wall to a tungsten wall. The influence of the resolution of existing 3D grids on the resulting PWI and impurity transport is analyzed.

P 22.3 Fri 9:45 KH 01.012

**Spectroscopic Time-of-Flight Spatial Distribution Measurements of Neon-Sputtered Monocrystalline W at the Linear Plasma Device PSI-2** — •MERLIN KLEIN<sup>1</sup>, OLEKSANDR MARCHUK<sup>1</sup>, MARC SACKERS<sup>1</sup>, ARKADI KRETER<sup>1</sup>, and SEBASTIJAN BREZINSEK<sup>1,2</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, IFN-1 — <sup>2</sup>HHU Düsseldorf, Faculty of Mathematics and Natural Sciences

Tungsten (W) is a plasma-facing material (PFM) for fusion reactors. By erosion W atoms can enter the plasma and cool it through radiation losses. The quantity and spatial distribution of sputtered W atoms from PFMs therefore has a direct impact on reactor performance. For energy impacts in the keV range, the

sputtered W atoms follow a cosine angular distribution. For lower energies, as typically exist in the divertor region as well, experimental data shows a discrepancy to existing models.

In this experiment, poly- and monocrystalline (111) W is exposed to a linear Neon plasma at kinetic energies of about 100 eV. Further excitations of W atoms sputtered into the plasma column allow for the acquisition of multiple line shapes in a spectroscopic time-of-flight (ToF) measurement. The total sputtering yield can be deduced from multiple acquisitions. In this ToF measurement it is possible to differentiate between angular distributions of sputtered W flux, while all other experimental parameters stay fixed.

These new experimental results show deviations in angular distributions between lattice structures and their orientations which can be used to support modelling of low temperature plasma-wall interactions.

P 22.4 Fri 10:00 KH 01.012

**Near-surface hydrogen inventory response to picosecond laser pulses in tungsten.** — •MARIA POPOVA, DMITRY MATVEEV, SEBASTIJAN BREZINSEK, CHRISTOPH KAWAN, and ERIK WÜST — Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany

Tungsten is a leading plasma-facing material; neutron damage creates traps for hydrogen isotopes. Near-surface fuel inventory and release can be probed with LIA-QMS.

A FENICS/FESTIM framework for picosecond laser pulse trains is presented, addressing depths <1 mm. Transient heat conduction is coupled to a near-surface trapping-detrapping scheme. Coarse ablation is represented as removal of a surface layer, tens of nanometers thick, at the start of each pulse, updating thermal and hydrogen boundary conditions. Per-pulse release is obtained from the desorption-flux integral; initial fuel distributions are taken from NRA depth profiles on proton-irradiated and self-damaged, deuterium-decorated tungsten.

Results indicate that heating-induced release dominates for the first ~10 pulses; subsequent ablation mostly removes a layer partially depleted by prior heating. Including a simple defect-annealing term enables comparison to LIA-QMS depth reconstructions with good agreement.

P 22.5 Fri 10:15 KH 01.012

**Fabrication of tungsten fibre-reinforced composites by combining Chemical Vapour Deposition and Field Assisted Sintering** — •PATRICK SCHOLZ<sup>1</sup>, ALEXANDER LAU<sup>1</sup>, JAN WILLEM COENEN<sup>1</sup>, and FLORIAN KLEEMISS<sup>2</sup> —

<sup>1</sup>Forschungszentrum Jülich GmbH, Institut of Fusion Energy and Nuclear Waste Management - Plasmaphysics (IFN-1), Jülich 52425, Germany — <sup>2</sup>Institut für Anorganische Chemie, RWTH Aachen, Landoltweg 1a, 52074 Aachen, Germany

Many promising materials for high-temperature or oxidizing environments, including chromium aluminium carbide ( $Cr_2AlC$ ), titanium aluminium carbide ( $Ti_2AlC$ ), and self-passivating metal alloys with reduced thermo-oxidation (SMART), are limited by their inherent brittleness, restricting their suitability as structural components. Tungsten fibre-reinforced tungsten has demonstrated that embedding ductile fibres in a brittle matrix can produce pseudo-ductile fracture behaviour below the ductile-to-brittle transition temperature (DBTT). To transfer this toughening concept to these alternative matrices, the tungsten fibres must be protected from direct interaction with embrittling species, particularly chromium and carbon. This work investigates sacrificial tungsten coatings deposited by chemical vapour deposition (CVD). These coatings act as controlled sinks for matrix ingress during sintering, ensuring that the fibres remain unaffected. The study focuses on determining the coating thickness required for reliable fibre incorporation into each matrix system and evaluating the resulting mechanical performance.

## P 23: Low Pressure Plasmas IV

Time: Friday 11:00–11:30

Location: KH 01.012

P 23.1 Fri 11:00 KH 01.012

**Double probe calibration in different plasma regimes using microwave cavity resonance spectroscopy** — •ANDREAS PETERSEN<sup>1</sup>, JOHANNA VOGT<sup>2</sup>, JENS OBERATH<sup>2</sup>, JULIAN HELD<sup>3</sup>, and FRANKO GREINER<sup>1,4</sup> — <sup>1</sup>Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — <sup>2</sup>South West-

phalia University of Applied Sciences, Soest, Germany — <sup>3</sup>Eindhoven University of Technology, Eindhoven, Netherlands — <sup>4</sup>KINSIS, Kiel, Germany

Probe-based diagnostics remain a cornerstone of plasma characterization, offering spatially resolved measurements through precise positioning of the ex-

posed probe tip. But factors like RF compensation and surface contamination can complicate matters. Also, the correct ion current model must be selected: while the ABR theory assumes collisionless, non-orbiting ions, the BRL framework incorporates ion orbiting and weak collisionality. For strongly collisional regimes the modified Talbot-Chou model is an option. This makes model selection nontrivial. We present a comparative study of simultaneous double-probe and microwave cavity resonance spectroscopy (MCRS) measurements, because MCRS is very sensitive and can detect changes in electron density of the order of  $10^{10} \text{ m}^{-3}$ . These results pave the way for future applications in nanodusty and electronegative plasma systems.

We gratefully acknowledge funding by Deutsche Forschungsgemeinschaft (DFG), Project No. 531667910

P 23.2 Fri 11:15 KH 01.012

**Numerical studies on extreme-ultraviolet-induced low density hydrogen plasmas** — •ADELIND ELSHANI<sup>1</sup>, AHMET AKSOY<sup>1</sup>, LINUS NAGEL<sup>1</sup>, SASCHA BROSE<sup>1,2</sup>, ROLF WESTER<sup>2</sup>, ANNIKA BONHOFF<sup>1</sup>, and CARLO HOLLY<sup>1,2</sup> — <sup>1</sup>RWTH Aachen University TOS, Aachen — <sup>2</sup>Fraunhofer Institute for Laser Technology ILT, Aachen

The interaction of extreme-ultraviolet (EUV) radiation with low-pressure hydrogen gas induces a low-density hydrogen plasma. Understanding the underlying chemical and dynamic processes is essential but complicated due to plasma formation complexity and correlated influencing factors during experiments. Dedicated stand-alone setups using discharge-produced plasma EUV radiation sources allow for reduction of experimental complexity and simplified setups. In addition, experimental parameters can be systematically varied and adjusted leading to controllable boundary conditions. As a result, fundamental dependencies with mostly unbiased parameters can be experimentally investigated, covering intensity or power optimized exposures at 13.5 nm, with narrow to broadband spectral distributions in hydrogen gas atmospheres. An according modeling framework, adaptable to these setups is developed to link the experimental data with theoretical models. The combination of experiment and simulation enables an in-depth understanding of the EUV-induced hydrogen plasma formation. The presentation covers the key components of the modeling framework based on a kinetic approach, along with an analysis of the electron dynamics for high-intensity EUV exposure configurations.

## P 24: Laser Plasmas

Time: Friday 11:00–12:00

Location: KH 01.013

P 24.1 Fri 11:00 KH 01.013

**Characterization of Reflected Light Properties in PIC Simulations** — •VIDISHA RANA<sup>1,2</sup>, MILENKO VESCOVI<sup>1,2</sup>, MARVIN E.P. UMLANDT<sup>1,2</sup>, FRANZISKA PASCHKE-BRÜHL<sup>1,2</sup>, RICHARD PAUSCH<sup>1</sup>, PENGJIE WANG<sup>1</sup>, TIM ZIEGLER<sup>1</sup>, KARL ZEIL<sup>1</sup>, ULRICH SCHRAMM<sup>1,2</sup>, and THOMAS KLUGE<sup>1</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf — <sup>2</sup>Technische Universität Dresden

Laser-driven ion accelerators offer several advantages over the conventional ones due to their potential of achieving high accelerating gradients over small distances. Recent experiments have demonstrated that one can achieve significantly high proton energies by modifying the temporal profile and controlling the spectral phase of laser pulses, specifically using Group Delay Dispersion (GDD). However, the entire mechanism still needs to be understood.

Reflected light properties provide a powerful diagnostic tool for understanding these interactions and optimizing proton energies. Experiments involving ultrashort laser pulses interacting with thin foils reveal prominent spectral shifts across changing GDD values. These shifts can offer valuable insights into plasma dynamics, relativistic surface motion, and laser contrast effects, which have a direct impact on proton energies but remains difficult to interpret solely through experiments. This challenge can be addressed by employing Particle-in-Cell codes to simulate these interactions to analyze the underlying mechanisms. By bridging the gap between experimental observations and theoretical predictions, this work aims to advance our understanding of laser-plasma interactions and optimize laser-driven ion acceleration.

P 24.2 Fri 11:15 KH 01.013

**Expansion of Nano Rods under Realistic Laser Contrast in 2D PIC Simulations** — •FRANZISKA-LUISE PASCHKE-BRÜHL<sup>1,2</sup> and THOMAS KLUGE<sup>1</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf — <sup>2</sup>Technische Universität Dresden We present a computational study investigating the pre-expansion of 10  $\mu\text{m}$  long, 100 nm thick Silicon nano rods under realistic laser contrast of a  $10^{20} \text{ W/cm}^2$ , 30fs laser pulse. The 2D particle-in-cell simulations give insight into the expansion of the electron density and thus where the laser is getting reflected. Significant expansion under the relativistic intensities in the leading laser ramp cause the peak intensities to be reflected before reaching the solid rod structure. Based on that, we investigate which conditions allow the propagation of the highest intensities into an intact nano rod structure. This allows a coulomb explosion to happen, accelerating Silicon ions to fuel a fusion reaction.

P 24.3 Fri 11:30 KH 01.013

**Optical probing of plasma dynamics in laser-driven nanostructured targets** — ANKIT DULAT<sup>1</sup>, CONSTANTIN BERNERT<sup>1</sup>, THOMAS COWAN<sup>1</sup>, THOMAS KLUGE<sup>1</sup>, GEORG KORN<sup>2</sup>, FRANZISKA PASCHKE-BRÜHL<sup>1,3</sup>, DANIEL RIVAS<sup>2</sup>, HARTMUT RUHL<sup>2</sup>, MARIUS SCHOLLMEIER<sup>2</sup>, ULRICH SCHRAMM<sup>1,3</sup>, KARL ZEIL<sup>1</sup>, •TIM ZIEGLER<sup>1</sup>, and MORE COLLABORATORS<sup>1,2,3</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — <sup>2</sup>Marvel Fusion GmbH, Munich, Germany — <sup>3</sup>Technische Universität Dresden, Dresden, Germany

Nanostructured solid targets are of strong interest in high-intensity laser-plasma interactions because they enhance absorption and particle acceleration. However, experimentally accessing the relevant interaction dynamics remains challenging due to their ultrafast and nanoscale nature. In particular, laser pre-pulses can pre-ionize and expand the target, modifying the nanostructure and degrading performance, making these dynamics critical to resolve for reliable modeling and target optimization.

We present an optical pump-probe setup to study pre-plasma dynamics in the interaction of an ultrashort high-power laser with nanostructured targets. Using combined scattering and Doppler spectrometry, we measure target expansion and particle dynamics under different laser contrast conditions, providing insight into how nanostructure modification influences laser-plasma coupling and ion acceleration.

P 24.4 Fri 11:45 KH 01.013

**Spin Polarization in Plasma Accelerators** — GUDRID MOORTGAT-PICK<sup>1,2</sup>, •MARYAM HAMIDI<sup>1</sup>, MAXENCE THEVENET<sup>2</sup>, and KRISTJAN PÖDER<sup>2</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>Deutsches Elektronen Synchrotron

Plasma based compact accelerators are extremely attractive due to their ultra-high acceleration gradients. A key property of the electron beam is stable and high spin-polarisation. Spin-polarised beams are substantial for many aspects of fundamental research. However, it is still unclear how a polarised beam behaves in a plasma accelerator. The aim of this project is to study the physics of spin depolarisation in plasma accelerators and to understand the effect of beam parameters on final polarisation. First conceptual ideas for the experimental realization of a spin-polarised plasma accelerator will be discussed. Given a pre-polarised electron source, these spin-aligned electrons must be injected into the plasma accelerator cavity without misaligning the spins to be further accelerated to result in a highly-polarised high-energetic electron beam. A status report of the planned experimental set-up is given and simulations results are discussed.

## P 25: Plasma Wall Interaction IV

Time: Friday 11:30–12:00

Location: KH 01.012

P 25.1 Fri 11:30 KH 01.012

**Improving The Sinterability Of WfW By Alloying** — •CHONGYANG LIU<sup>1,4</sup>, JAN WILLEM COENEN<sup>1</sup>, YIRAN MAO<sup>1</sup>, MEHRDAD MOUSAPOUR<sup>1</sup>, TOMISLAV DAMJANOVIC<sup>1</sup>, CHRISTIAN LINSMEIER<sup>1,2</sup>, and MARTIN BRAM<sup>3,4</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management, 52425 Jülich, Germany — <sup>2</sup>Ruhr-Universität Bochum, Faculty of Physics and Astronomy, Bochum 44801, Germany — <sup>3</sup>Forschungszentrum Jülich GmbH, Institute of Energy Materials and Devices,

52425 Jülich, Germany — <sup>4</sup>Ruhr-Universität Bochum, Faculty of Mechanical Engineering, Bochum 44801, Germany

In this work, tungsten fiber\*reinforced tungsten (Wf/W) composites were modified by adding vanadium (V) to enhance densification while maintaining fiber ductility. W-V powders were produced by mechanical alloying and consolidated by FAST/SPS under varied V contents, temperatures, and holding times. Density was measured by the Archimedes method, and SEM/EDX analyzed microstructure and V diffusion. Three-point bending and fracture observations evaluated

fiber behavior. The results show that small V additions, together with reduced sintering temperature and holding time, significantly improve matrix densification while keeping the fibers predominantly ductile. In contrast, higher temperatures or longer holding promote excessive V diffusion and fiber embrittlement. Overall, V alloying with optimized FAST/SPS parameters offers an effective route to improve Wf/W densification without sacrificing fiber integrity.

P 25.2 Fri 11:45 KH 01.012

**Design-by-Analysis of Tungsten Fibre-Reinforced Tungsten for Divertor Plasma-Facing Components** — •TOMISLAV DAMJANOVIĆ<sup>1,2</sup>, JAN WILLEM COENEN<sup>1</sup>, YIRAN MAO<sup>1</sup>, MEHRDAD MOUSAPOUR<sup>1</sup>, CHRISTIAN LINSMEIER<sup>1,2</sup>, and UTE WILKINSON<sup>3</sup> — <sup>1</sup>Forschungszentrum Jülich GmbH, Institut of Fusion Energy and Nuclear Waste Managment - Plasmaphysics (IFN-1), Jülich 52425, Germany — <sup>2</sup>Ruhr-Universität Bochum, Faculty of Physics and Astronomy, Bochum 44801, Germany — <sup>3</sup>Dr. Fritsch Sondermaschinen GmbH, Fellbach 70736, Germany

Tungsten remains the leading material for plasma-facing components in fusion devices, yet its brittleness, limited thermal shock resistance, and irradiation-induced degradation raise concerns for long-term divertor operation. Embedding ductile tungsten fibres into a tungsten matrix (Wf/W) offers a route toward enhanced toughness and improved damage tolerance.

This contribution presents a design-by-analysis approach to optimize Wf/W composites for divertor-relevant thermo-mechanical loads. The microscale behavior is represented through homogenized material models using rule-of-mixtures and Mori-Tanaka schemes. These effective properties feed into a mesoscale description based on classical laminate theory to explore fiber volume fractions, orientations, and stacking configurations. Optimized composite layouts are then assessed in component-level finite-element simulations with realistic boundary conditions representative of divertor operation.

## Radiation and Medical Physics Division Fachverband Strahlen- und Medizinphysik (ST)

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### Overview of Invited Talks and Sessions

(Lecture hall KH 01.013; Poster Redoutensaal)

#### Plenary Talk

See plenary section for details.

PV XII    Thu    9:00– 9:45    AudiMax    **AI in the context of medical images — •STEFAN WESARG**

#### Invited Talks

|        |     |             |           |                                                                                                                                                                                                             |
|--------|-----|-------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ST 4.1 | Wed | 16:15–16:45 | KH 01.013 | <b>Introduction to modern nuclear medicine: almost one century of interdisciplinary innovations — •STEPHAN NEKOLLA</b>                                                                                      |
| ST 4.2 | Wed | 16:45–17:15 | KH 01.013 | <b>Personendosimetrie in der Nuklearmedizin — •FELIX BÄRENFÄNGER</b>                                                                                                                                        |
| ST 4.3 | Wed | 17:15–17:45 | KH 01.013 | <b>Dosimetry in Targeted Radionuclide Therapy: Challenges, Concepts, and Perspectives — •JOHANNES TRAN-GIA</b>                                                                                              |
| ST 5.1 | Thu | 11:00–11:30 | KH 01.013 | <b>Prompt-Gamma-Based Range Verification — •BEATRICE FOGLIA</b>                                                                                                                                             |
| ST 5.2 | Thu | 11:30–12:00 | KH 01.013 | <b>Carbon-ion radiotherapy monitoring with charged nuclear fragments — •MARIA MARTISIKOVA, LAURENT KELLETER, REBEKKA KIRSCHGÄSSNER, PAMELA OCHOA, SEMI HARRABI, JAN JAKUBEK, OLIVER JÄKEL, JÜRGEN DEBUS</b> |
| ST 5.3 | Thu | 12:00–12:30 | KH 01.013 | <b>Radioactive ion beams for real-time PET-guided adaptive particle therapy — •DARIA BOSCOLO FOR THE BARB COLLABORATION</b>                                                                                 |
| ST 5.4 | Thu | 12:30–13:00 | KH 01.013 | <b>Helium as a Range Probe in Carbon-Ion Therapy: From Concept to Mixed-Beam Experiments — •LENNART VOLZ FOR THE PROMISE COLLABORATION</b>                                                                  |
| ST 8.1 | Thu | 16:45–17:15 | KH 01.013 | <b>Healing Patients, Heating the Planet: Why Circularity Matters in Healthcare — •KATHARINA HESELS</b>                                                                                                      |

#### Sessions

|            |     |             |              |                                                              |
|------------|-----|-------------|--------------|--------------------------------------------------------------|
| ST 1.1–1.5 | Tue | 11:00–12:15 | KH 01.013    | <b>Medical Imaging</b>                                       |
| ST 2.1–2.4 | Tue | 16:15–17:15 | KH 01.013    | <b>Detectors for Treatment Monitoring</b>                    |
| ST 3.1–3.7 | Wed | 13:45–15:30 | KH 01.013    | <b>Detectors for Medical Applications</b>                    |
| ST 4.1–4.3 | Wed | 16:15–17:45 | KH 01.013    | <b>DPG meets DGMP: Dosimetry in Nuclear Medicine</b>         |
| ST 5.1–5.4 | Thu | 11:00–13:00 | KH 01.013    | <b>Focus Session: Range Verification in Particle Therapy</b> |
| ST 6.1–6.5 | Thu | 14:15–15:45 | Redoutensaal | <b>Poster Session</b>                                        |
| ST 7.1–7.2 | Thu | 16:15–16:45 | KH 01.013    | <b>Radiation Therapy</b>                                     |
| ST 8.1–8.1 | Thu | 16:45–17:15 | KH 01.013    | <b>Keynote Session</b>                                       |
| ST 9       | Thu | 17:15–17:45 | KH 01.013    | <b>Prize Ceremony and Closing Session</b>                    |
| ST 10      | Thu | 17:45–18:45 | KH 01.013    | <b>Members' Assembly</b>                                     |

#### Members' Assembly of the Radiation and Medical Physics Division

Thursday    17:45–18:45    KH 01.013

## Sessions

– Invited Talks, Contributed Talks, and Posters –

### ST 1: Medical Imaging

Time: Tuesday 11:00–12:15

Location: KH 01.013

ST 1.1 Tue 11:00 KH 01.013

**Investigation of a Simulation Framework for the Two-Plane Imaging System** — PATRICIA BORREGO JIMÉNEZ, KEVIN KRÖNINGER, HENDRIK SPEISER, ANNSOFIE TAPPE, •HELEN THEWS, JENS WEINGARTEN, and SOPHIA WORTMANN — TU Dortmund, department of physics, Dortmund, Germany

In radiotherapy for cancer treatment, proton therapy is an important treatment due to the steep dose gradient, which leads to a high conformal dose distribution while sparing healthy tissue. However, anatomical changes of the patient have a high impact on the range of the protons; this uncertainty leads to larger safety margins. One opportunity to minimize this uncertainty is to use proton imaging in adaptive proton therapy.

A Two-Plane Proton Imaging System (TPIS) consisting of two ATLAS IBL pixel detector planes offers the opportunity to take water-equivalent-thickness (WET) images of the patient. These WET images can be used to identify anatomical changes in the patient's body. To take a look at the reachable WET resolution and the full-body dose, a simulation framework is being developed, which is validated using RayStation. The simulation framework mainly consists of TOPAS to simulate the dose in the patient's body and the deposited energy in the sensor. The detector readout is afterward simulated in Allpix Squared.

This talk will introduce the TPIS and its current status. Then the simulation framework is discussed. Finally, the first results of simulation studies using this simulation framework are shown.

ST 1.2 Tue 11:15 KH 01.013

**Clinical studies on the proton radiography system** — •SOPHIA WORTMANN, PATRICIA BORREGO JIMÉNEZ, KEVIN KRÖNINGER, HENDRIK SPEISER, HELEN THEWS, and JENS WEINGARTEN — TU Dortmund Department of Physics, Dortmund, Germany

In proton radiography the water-equivalent thickness (WET) is determined to characterize material and density distributions with high precision. In adaptive proton therapy this information can be used to detect range changes that arise from anatomical variations between treatment fractions. A two-plane imaging system (TPIS) was developed for this purpose and a corresponding simulation framework was created. The goal of this project is to validate the framework by comparing its results with calculations from the RayStation treatment-planning system and to prepare it for use in preclinical studies.

In this work the experimental measurements with the TPIS are reproduced in TOPAS and WET reconstructions that allow quantitative comparison are generated. The validation starts with simple PLA plate phantoms and is later extended to a more complex skull phantom. For all phantoms the achievable spatial resolution, the WET accuracy and the deposited dose are evaluated. These results provide an initial evaluation of the imaging performance of the system and are intended to support its use in future preclinical proton radiography studies.

ST 1.3 Tue 11:30 KH 01.013

**From Compton Kinematics to Physics-Informed Neural Network Reconstruction for High-Energy Gamma Imaging** — •YAZEED BALASMEH, ATHARVA BAHEKAR, IVOR FLECK, MARA FRIES, LARS MACZEY, and DEVANSHI MEHTA — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Compton cameras enable collimator-free imaging of high-energy gamma rays and are attractive for medical imaging, online range verification in cancer ther-

apy, and targeted alpha therapy. This work presents a physics-informed neural network for Compton-camera image reconstruction that converts measured interaction positions and energies into a 2D source probability map. The objective is a general-purpose model that is computationally efficient, accurate, and stable across operating conditions, including incident energies from about 500 keV to 2 MeV and sources with varying sizes, shapes, and spatial distributions. Physical consistency is encouraged through physics-inspired inputs (e.g., reconstructed scatter angle, interaction-ordering cues, and detector-geometry features) and loss terms that penalize violations of Compton kinematics and constrain predictions to physically feasible Compton cones. A major focus is performance in low-statistics regimes relevant to Ac-225 targeted alpha therapy, where only a small number of detectable 1.57 MeV photons is available. We train and evaluate on Geant4-based simulations spanning count levels, energy spectra, and source configurations, and report energy- and statistics-dependent SSIM and peak-distance error.

ST 1.4 Tue 11:45 KH 01.013

**Dark-field imaging of cancerous breast tissue** — •MARKUS KRAFT, MARKUS SCHNEIDER, GISELA ANTON, MARTIN RONGEN, VERONIKA LUDWIG, CON- STANTIN RAUCH, and STEFAN FUNK — ECAP FAU, Erlangen, Deutschland

Talbot-Lau X-ray phase-contrast imaging provides, next to the attenuation of X-rays, additional information about the phase shift in the object. This yields two additional image modalities, the differential phase image and the dark-field image, which results from small-angle scattering.

For breast-cancer detection, the dark-field signal is particularly valuable, as it yields a higher sensitivity to fine structures like microcalcifications. Those can be an indicator for ductal carcinoma in situ (DCIS), which accounts for 20-30% of breast cancer cases.

Currently, in at about 30% of DCIS operations, the cancer is not completely removed and a second operation is necessary. The goal of our project is to investigate the edges of the freshly removed cancer tissue for microcalcifications, via a dark-field CT. Ideally, this will enable us to provide immediate feedback to the surgeon if an increase of the surgical margin is necessary and, thereby preventing a second surgery.

Currently, we are optimizing the dark-field CT setup and are investigating sealed cancer-tissue samples provided by the "Pathologie Uniklinikum Erlangen" to verify the feasibility of the localization of microcalcifications.

ST 1.5 Tue 12:00 KH 01.013

**Reconfigurable Metamaterials in MRI** — •DENNIS PHILIPP<sup>1,2</sup>, JOHANNES MUELLER<sup>1,2</sup>, and MATTHIAS GUENTHER<sup>1,2</sup> — <sup>1</sup>Fraunhofer MEVIS, Bremen, Germany — <sup>2</sup>University of Bremen, Bremen, Germany

Reconfigurable metamaterials (MTMs), operated in Tx and/or Rx during an MRI scan are an exciting new technology to leverage the full potential of MRI towards new imaging paradigms and potentially overcome existing limitations in terms of, e.g., SNR and imaging speed. They allow for on-demand RF field shaping during and/or between acquisitions and, thus, introduce new degrees of freedom into MRI. The potential advantages are, e.g., tailored local and spatio-temporal SNR enhancement for manifold applications.

Reconfigurable MTM prototypes are studied in simulations to infer a suitable geometry and parameter range of lumped elements for use in a 3T scanner. Prototypes are manufactured on rigid/flexible substrates and validated.

### ST 2: Detectors for Treatment Monitoring

Time: Tuesday 16:15–17:15

Location: KH 01.013

ST 2.1 Tue 16:15 KH 01.013

**Online Range Monitoring in Heavy-Ion Therapy** — •SEBASTIAN SCHROEDER<sup>1</sup>, DEVIN HYMER<sup>1</sup>, OLGA BERTINI<sup>2</sup>, JOHANN HEUSER<sup>2</sup>, JOERG LEHNERT<sup>2</sup>, CHRISTIAN JOACHIM SCHMIDT<sup>2</sup>, STEPHAN BRONS<sup>3</sup>, and DENNIS MUECHER<sup>1</sup> — <sup>1</sup>University of Cologne, Cologne, Germany — <sup>2</sup>GSI, Darmstadt, Germany — <sup>3</sup>HIT, Heidelberg, Germany

Interaction Vertex Imaging (IVI) is a proposed method for online range verification during heavy-ion therapy to determine relative range shifts in Bragg peak position (BP) with a sub-mm precision as previous experiments at HIT in

Heidelberg have shown. This allows to add a safety interlock during treatment, which pauses irradiation if an incorrect BP position is detected. IVI tracks the secondary ions produced by beam-patient reactions with a purpose-built tracking system that uses the sensors developed by GSI for the Compressed Baryonic Matter experiment. These highly segmented, double sided silicon strip detectors have a 58  $\mu\text{m}$  pitch, and cover a large sensitive area of up to 72  $\text{cm}^2$ . In combination with the readout electronics count rates of up to 250 kHz per segment are capable. While the system has already shown its tracking performance at 2.35 MHz event rate with less than 0.002% pileup, there was so far no real online

analysis. The technical aspects of IVI and online analysis, as well as tests using Muons and a  $^{12}\text{C}$  beam at clinical intensities will be discussed in this contribution.

ST 2.2 Tue 16:30 KH 01.013

**A PWO Scintillator Range-Telescope for Real-Time Depth-Dose Measurement in Low-Dose Environments for Proton Therapy** — •NICLAS FIEDLER<sup>1,2</sup>, DZMITRY KAZLOU<sup>1</sup>, HANS-GEORG ZAUNICK<sup>1</sup>, KAI-THOMAS BRINKMANN<sup>1</sup>, and KILIAN-SIMON BAUMANN<sup>2,3</sup> — <sup>1</sup>2<sup>nd</sup> Physics Institute, Justus Liebig University Giessen — <sup>2</sup>University of Applied Sciences Giessen — <sup>3</sup>Marburg Ion-Beam Therapy Center

Proton therapy provides highly localized dose delivery to tumors while sparing surrounding healthy tissue. Heterogeneous media along the beam path, such as lung tissue, introduce range uncertainties that broaden the Bragg peak and obscure the distal fall-off, an effect quantified by the modulation power. A direct measurement will reduce these uncertainties. However, currently available detectors are designed for high-dose, high-flux environments making them unfit for imaging.

The work presents a novel PbWO<sub>4</sub>-based detector system developed to measure the depth-dose distribution of protons for low-dose environments in real-time. First beam tests with high-energy, low-flux proton beams were conducted using homogeneous and heterogeneous phantoms. Unfolding techniques are applied to extract accurate depth-dose curves, determining the modulation power. These initial results demonstrate the detector's suitability for precise characterization of Bragg-peak degradation in heterogeneous media.

ST 2.3 Tue 16:45 KH 01.013

**Measurement and Geant4 simulation of Cherenkov radiation with an electron monochromator** — •ATHARVA BAHEKAR, YAZEED BALASMEH, IVOR FLECK, MARA FRIES, LARS MACZEY, and DEVANSHI MEHTA — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

High-energy electron detection techniques require monoenergetic electrons for detector response validation and optical simulations. This work characterizes a custom-built magnetic electron monochromator developed in the Compton Camera group at Universität Siegen, benchmarked by a detailed Geant4 simulation.

Electrons from a  $^{90}\text{Sr}/^{90}\text{Y}$  source are propagated into a fixed magnetic field and a collimator. A motorized linear and rotational stage positions the source for precise selection of electron energies. These selected electrons are then detected by a calibrated system of a ( $\text{Gd}_3\text{Al}_2\text{Ga}_3\text{O}_{12} : \text{Ce} : \text{Ce}$ ) (GAGG) scintillation crystal coupled to a photomultiplier tube (PMT). A corresponding Geant4 setup reproduces the source, magnetic optics and detector geometry. A direct comparison of the mean energies of simulated electrons to the experimentally obtained mean electron energies for various source configurations provides a quantitative validation of the Geant4 setup, subject to agreement between simulation and measurement.

This validated framework will be used to measure Cherenkov photon production in a PMMA radiator for fixed electron energies. This will provide credible data for neural network-based image reconstruction algorithms in our Compton Camera project.

ST 2.4 Tue 17:00 KH 01.013

**Absorption Point Reconstruction and Energy Measurement in Scintillation Material for Medical Imaging** — ATHARVA BAHEKAR, YAZEED BALASMEH, IVOR FLECK, MARA FRIES, •LARS MACZEY, and DEVANSHI MEHTA — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Scintillators are central to many imaging technologies that rely on gamma detection, where accurately reconstructing both the photon's absorption point and deposited energy is essential. The work presented here is motivated by the Compton camera project at the University of Siegen but is applicable to other imaging modalities in medicine.

This talk summarises results from measurements using inorganic scintillation crystals such as GAGG and LGSO coupled to SiPMs from Broadcom and Hamamatsu, with signal acquisition performed via the TOFPET v2c ASIC from PETsys Electronics. Several methods for reconstructing the absorption point are compared, including the centroid method, maximum-likelihood fitting and a machine-learning approach. Challenges encountered in achieving a reliable energy calibration are discussed as well as measurements of the depth of interaction (DOI) using a double-sided SiPM readout. Finally, I present and discuss different design strategies for the scintillator layer, ranging from a segmented crystal array to a monolithic crystal approach, and for the SiPM layer, ranging from small-sized analogue SiPM arrays to large-area position-sensitive SiPMs.

## ST 3: Detectors for Medical Applications

Time: Wednesday 13:45–15:30

Location: KH 01.013

ST 3.1 Wed 13:45 KH 01.013

**electronCT - A Candidate for Image Guidance in VHEE Radiotherapy** — •AENNE ABEL<sup>1,2</sup>, LETICIA BRAGA DA ROSA<sup>1,2</sup>, PAUL SCHÜTZE<sup>1</sup>, MALINDA DE SILVA<sup>1</sup>, and SIMON SPANNAGEL<sup>1</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg — <sup>2</sup>University of Hamburg, Hamburg, Germany

electronCT (eCT) is an imaging method, which uses multiple scattering of electrons to acquire images of unknown objects. This imaging method is a candidate for image guided radiotherapy with very high energy electrons (100-250 MeV). For eCT, a low emittance pencil beam is propagated through an object and the scattering of the beam is quantified. The widening of the beam is dependent on the radiation length of the materials traversed by the beam. A measurement of the opening angle then allows for a reconstruction of the material properties of the sample. In this contribution eCT is introduced as a method, proof of concept studies are shown and the performance is discussed with respect to the obtained tomographic reconstructions.

ST 3.2 Wed 14:00 KH 01.013

**Evaluation of the KLauS Chip for Measurement of Scintillation and Cherenkov Light** — ATHARVA BAHEKAR, YAZEED BALASMEH, IVOR FLECK, •MARA FRIES, LARS MACZEY, and DEVANSHI MEHTA — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Detecting and imaging ionising radiation is essential in fields ranging from fundamental physics to medical diagnostics, where precise reconstruction of high-energy  $\gamma$ -ray interactions remains a key challenge. Conventional Compton Cameras show promising results but are typically optimised for  $\gamma$ -rays below 1 MeV, limiting their applicability in high-energy imaging scenarios. The Cherenkov Compton Camera concept uses a novel approach by introducing a thicker scattering layer in order to use Cherenkov light to track the Compton electron. This enables a determination of the direction of the recoil electron, thereby extending the energy range of Compton Cameras beyond 1 MeV.

In this talk, I will present results from the ongoing development of the Cherenkov Compton Camera, focusing on the KLauS ASIC designed by the University of Heidelberg and its possible use in both the scattering and absorption layers. The KLauS ASIC has been tested with large scintillation signals from GAGG and LGSO crystals, as well as fast Cherenkov signals in UV-transparent

PMMA. Characterization using UV-sensitive Broadcom SiPMs allows us to assess the suitability and operating performance of the KLauS readout for a high-energy Cherenkov Compton Camera.

ST 3.3 Wed 14:15 KH 01.013

**SiPM Characterisation for the Construction of a Compton Camera Prototype** — ATHARVA BAHEKAR, YAZEED BALASMEH, IVOR FLECK, MARA FRIES, LARS MACZEY, and •DEVANSHI MEHTA — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The development of a next-generation Compton camera capable of operating beyond the current energy limitations of conventional nuclear medical imaging requires highly efficient and low-noise gamma detectors. As part of the ongoing Compton camera project at the University of Siegen, this work focuses on the characterization of UV-sensitive Silicon Photomultipliers (SiPMs), which will form a key component of the detector system. In this work, I will present the characterization of Hamamatsu SiPMs compared to Broadcom, focusing on noise behaviour, breakdown characteristics and photon detection efficiency. Staircase measurements were performed to study breakdown behaviour and noise characteristics. Furthermore, I will present the dependence of noise on bias voltage and temperature, including the integration of a cooling system to improve stability. Alongside UV tests, we are checking how the SiPMs perform with scintillators such as GAGG and LGSO, focusing on PDE in the visible range.

ST 3.4 Wed 14:30 KH 01.013

**Diamond detector for proton therapy based on the readout system of the LHCb Beam Conditions Monitor** — JOHANNES ALBRECHT, •NICHOLAS OLD-MAN, DIRK WIEDNER, and LUKAS WITOLA — TU Dortmund University, Dortmund, Germany

Due to their exceptional radiation hardness and approximate tissue equivalence, synthetic diamonds make a promising candidate as detector material for the beam analysis in quality assurance at clinical proton therapy centers. At CERN, such diamonds are already in use as detectors at the so-called Beam Conditions Monitor (BCM) at the LHCb experiment.

The BCM features fast readout electronics that process the signal current from the detector diamonds with a time resolution of 40  $\mu\text{s}$ . Based on the operating

principle of the BCM, a novel detector system is being developed that aims to implement the use of diamond detectors into the clinical setting. Synthetic polycrystalline diamonds grown by chemical vapor deposition are used for this detector system. They are coated with metallic electrodes to obtain position-sensitive detectors with sub-millimeter spatial resolution. The readout electronics of the BCM are utilized to achieve a fast signal sampling rate.

The progress made in the development of this novel detector system will be presented. Using a simple readout chain, a first test setup is constructed to prepare future measurements of the beam at a proton therapy center.

ST 3.5 Wed 14:45 KH 01.013

**Fast beam monitoring for ion beam therapy with an HV-CMOS detector system** — •THOMAS RENKHOFF<sup>1</sup>, ALEXANDER DIERLAMM<sup>1,2</sup>, ULRICH HUSEMANN<sup>1</sup>, MARKUS KLUTE<sup>1</sup>, IVAN PERIĆ<sup>2</sup>, and BOGDAN TOPKO<sup>1</sup> — <sup>1</sup>Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — <sup>2</sup>Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology (KIT)

Ion beam therapy is a well-established cancer treatment available at more than one hundred centers worldwide. Compared to more common photon-based radiation therapy, ion beam therapy allows for more precise dose deposition into the tumor volume. A conformal dose deposition to the tumor volume requires a beam monitor that needs to be fast, radiation tolerant and should have a low material budget to reduce the beam particle scattering.

To meet these requirements we are developing a beam monitor based on HitPix sensors. The HitPix sensors are monolithic active pixel sensors produced in high-voltage CMOS technology. HV-CMOS technology comes with several advantages, including high radiation tolerance, thin sensors and better affordability compared to hybrid pixel detectors. HitPix sensors feature hit-counting pixels with on-sensor hit projection-calculation, radiation tolerance and frame-based readout.

The talk evaluates readout speed and performance after irradiation of the HitPix sensors. In order to test beam parameters, a quasi-online reconstruction, the estimator block, is integrated into the existing FPGA-firmware and tested.

ST 3.6 Wed 15:00 KH 01.013

**Dosimetry of high intensity electron beams for FLASH radiotherapy using Dosepix detectors and nitrogen fluorescence** — •FLORIAN BEISSER for the NitroFLASH-Collaboration — ECAP, FAU Erlangen-Nürnberg, Erlangen, Germany

FLASH radiation therapy with high-intensity electrons, where the full dose is delivered in a very short time frame, has been proven to be a very promising evolution of radiation therapy. Yet there currently exist no established methods for online dosimetry and position determination as the established detector concepts, such as monitor chambers, saturate in the high intensity beams. We here explore two possible technologies: the detection of stray electrons using Dosepix solid-state detectors and nitrogen fluorescence in air. The response of the Dosepix detectors showed clear monotonous trends with respect to distance and bunch charge, enabling the determination of the beam position and intensity from that data. Additionally, a UV camera was mounted perpendicular to the beam axis to detect the emitted nitrogen fluorescence photons as the beam traverses air, thus imaging the electron beam and reconstructing its full position and width. Although a fluorescence signal of the beam could be detected with the UV-camera, the observed intensity was too low to meaningfully reconstruct beam parameters for ARES. However, much higher intensities are expected for the FLASHlab at PITZ.

ST 3.7 Wed 15:15 KH 01.013

**Active Eye Lens Dosimetry with Dosepix: Influence of Measurement Position and Lead Glass Shielding** — •LEONIE ULLMANN<sup>1</sup>, FLORIAN BEISSER<sup>1</sup>, ROLF BEHRENS<sup>2</sup>, STEFAN FUNK<sup>1</sup>, GERHARD HILGERS<sup>2</sup>, OLIVER HUPE<sup>2</sup>, JÜRGEN ROTH<sup>2</sup>, TOM TRÖLTZSCH<sup>3</sup>, HAYO ZUTZ<sup>2</sup>, and THILO MICHEL<sup>1</sup> — <sup>1</sup>Erlangen Centre for Astroparticle Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — <sup>2</sup>Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — <sup>3</sup>Karlsruher Institut für Technologie, Karlsruhe, Germany

Due to its sensitivity to radiation, the eye lens is subject to strict dose limits. Since exceeding these limits can lead to cataracts, precise monitoring of the dose in the eye is necessary. For this purpose, an active personal dosimeter for the eye lens has been developed for use by medical personnel. Previous investigations have shown that the prototype of this dosimeter delivers reliable results. Since the eye lens dosimeter is intended to be worn on the side of the head, follow-up studies now examined the effects of the measurement position for frontal and lateral positioning.

Furthermore, it is common practice for medical personnel to wear radiation protection glasses. As an approach to reproduce the absorption of such glasses, the attachment of lead glass pieces to the dosimeter was investigated. The resulting dose values were compared to those of thermoluminescent dosimeters (TLDs) behind radiation protection glasses.

## ST 4: DPG meets DGMP: Dosimetry in Nuclear Medicine

Time: Wednesday 16:15–17:45

Location: KH 01.013

### Invited Talk

ST 4.1 Wed 16:15 KH 01.013

**Introduction to modern nuclear medicine: almost one century of interdisciplinary innovations** — •STEPHAN NEKOLLA — TUM Klinikum, München, Germany

Nuclear medicine began in the 1940s with the clinical use of radioisotopes for diagnosis and therapy, evolving through gamma cameras and SPECT to PET. Early progress depended on advances in radiochemistry, detector physics, and instrumentation, which translated laboratory approaches into clinical applications. Nuclear medicine is inherently interdisciplinary: physicists are involved in tasks ranging from design detectors to reconstruction algorithms; radiochemists synthesize tracers; biologists identify molecular targets; and clinicians apply findings to patients. Current advances include digital PET and SPECT with improved detector materials, and integrated theranostic approaches that combine imaging with targeted therapy. Especially the latter resulted in an unprecedented interest and investments of the pharmaceutical industry. Where is this going to? The emphasis is most likely a precision nuclear medicine with personalized radiopharmaceuticals, AI-enhanced image reconstruction and interpretation, and harmonized hybrid modalities that integrate molecular imaging with other data. Nuclear medicine's trajectory is defined by the open dialogue between interdisciplinary partners: in this particular context, physics supplies tools, models, and quantification; medicine supplies biological context and clinical questions. Sustained progress will require an open mindset, collaborative research infrastructures, cross-disciplinary training, and predictable regulatory pathways.

### Invited Talk

ST 4.2 Wed 16:45 KH 01.013

**Personendosimetrie in der Nuklearmedizin** — •FELIX BÄRENFÄNGER — Universität Witten/Herdecke, Alfred-Herrhausen-Str. 50, 58453 Witten  
Im Vergleich zu anderen \*strahlenden\* Disziplinen ist das Personal in der Nuklearmedizin häufiger messbaren Strahlenexpositionen ausgesetzt. Ursache hierfür sind der routinemäßige Umgang mit offenen radioaktiven Stoffen, nicht ortsfeste Strahlenquellen in Form der Patienten sowie komplexe, zeitlich und räumlich variable Strahlenfelder unterschiedlicher Nuklide. Diese Besonderheiten stellen sowohl die amtliche Personendosimetrie als auch den praktischen Strahlen-

schutz vor Herausforderungen. Neben der externen Exposition müssen häufig auch Kontaminationen und mögliche Inkorporationen als relevante Expositionspfade berücksichtigt werden. Die Auswertung des SSR-Registers für das Jahr 2024 zeigt, dass Grenzwertüberschreitungen in der Nuklearmedizin im Rahmen der amtlichen Personendosimetrie selten auftreten. Dennoch liefert die systematische Analyse der Personendosis bei der Anwendung von Dosisrichtwerten wertvolle Hinweise auf strukturelle, organisatorische oder arbeitsplatzbezogene Optimierungspotenziale. Personendosimetrie wird damit nicht nur zum Instrument der Grenzwertüberwachung, sondern zu einem aktiven Werkzeug der Qualitätssicherung im Strahlenschutz. Der Vortrag gibt einen Überblick über Möglichkeiten, Herausforderungen und Limitationen der Personendosimetrie in der Nuklearmedizin. Darauf aufbauend werden sinnvolle ergänzende Dosimetrie-konzepte sowie praxisnahe Maßnahmen zur Reduktion der Personendosis diskutiert.

### Invited Talk

ST 4.3 Wed 17:15 KH 01.013

**Dosimetry in Targeted Radionuclide Therapy: Challenges, Concepts, and Perspectives** — •JOHANNES TRAN-GIA — Universitätsklinikum Würzburg

Targeted radionuclide therapy (TRT) has emerged as a rapidly expanding modality in nuclear medicine, driven by highly effective  $\beta$ - and  $\alpha$ -emitting radiopharmaceuticals. Unlike external beam radiation therapy (EBRT), where radiation dose delivery can be planned and verified with high spatial and temporal precision, TRT involves internally distributed, time-dependent radiation exposure from radiopharmaceuticals whose biodistribution and kinetics vary substantially between patients. Consequently, dosimetry in TRT poses distinct physical and methodological challenges, including limited imaging sensitivity and spatial resolution, complex decay schemes, and the need for quantitative SPECT or PET imaging over multiple time points.

This talk introduces the principles of dosimetry in TRT and highlights key differences compared to EBRT from a physics perspective. Current clinical practice, which largely relies on fixed administered activities, is discussed in the context of historical and technical constraints. At the same time, growing evidence for absorbed dose\*effect relationships for tumor response and normal-tissue toxicity



motivates a shift toward dosimetry-guided treatment planning and verification. Recent advances in quantitative imaging, standardization, and computational methods offer promising pathways toward routine patient-specific dosimetry.

The talk concludes with an outlook on how these developments may enable individualized and optimized TRT.

## ST 5: Focus Session: Range Verification in Particle Therapy

Time: Thursday 11:00–13:00

Location: KH 01.013

**Invited Talk** ST 5.1 Thu 11:00 KH 01.013

**Prompt-Gamma-Based Range Verification** — •BEATRICE FOGLIA — Ludwig-Maximilians-Universität München, Department of Medical Physics, Garching b. Muenchen, Germany

Prompt gammas (PG) are high-energy (~MeV) photons emitted immediately after nuclear interactions of ions with matter along nearly the entire beam path. As such, PG emission can provide valuable information on the ion beam range, making it a promising tool for in vivo range verification. Their nanosecond-scale emission and detection enable real-time monitoring, which is particularly attractive for adaptive therapy and is driving strong interest in the radio- and hadrontherapy community. Since the first proposal by Stichelbaut and Jongen at the PTCOG meeting in 2003, PG-based range verification has become a topic of worldwide research interest. Several workflows have been developed, generally relying on comparisons between measured PG profiles and expected signals obtained from Monte Carlo simulations or analytical models. Various PG detection modalities have been proposed and optimized to address challenges such as low PG yields and the broad, high-energy PG spectrum. Moreover, although PG emission and dose deposition arise from different physical processes, recent studies have demonstrated the feasibility of reconstructing dose distributions from PG signals. This talk will provide an overview of widely used PG-based range verification workflow, PG detection modalities and analytical PG modeling, and recent advances extending PG applications beyond range verification toward dose reconstruction and adaptive treatment strategies will be discussed.

**Invited Talk** ST 5.2 Thu 11:30 KH 01.013

**Carbon-ion radiotherapy monitoring with charged nuclear fragments** — •MARIA MARTISIKOVA<sup>1,2,3</sup>, LAURENT KELLETER<sup>1,2,3</sup>, REBEKKA KIRSCHGÄSSNER<sup>1,2,4</sup>, PAMELA OCHOA<sup>1,2,4</sup>, SEMI HARRABI<sup>5,6</sup>, JAN JAKUBEK<sup>7</sup>, OLIVER JÄKEL<sup>1,2,3,5</sup>, and JÜRGEN DEBUS<sup>2,3,5,6</sup> — <sup>1</sup>Heidelberg Institute for Radiation Oncology HIRO, National Centre for Research in Radiation Oncology NCRO — <sup>2</sup>German Cancer Research Centre DKFZ, Department of Medical Physics in Radiation Oncology — <sup>3</sup>National Center for Tumor Diseases (NCT) Heidelberg — <sup>4</sup>Department of Physics and Astronomy, Heidelberg University — <sup>5</sup>Department of Radiation Oncology, Heidelberg University Hospital — <sup>6</sup>Heidelberg Ion-Beam Therapy Center (HIT) — <sup>7</sup>ADVACAM s.r.o., U pergamenny 12, Prague, Czech Republic

Our group has been investigating the potential of measured secondary ion emission profiles to assess delivered dose distributions. A secondary-ion tracking system has been developed and successfully implemented in the clinical environment of the Heidelberg Ion Beam Therapy Facility. Within the InViMo clinical trial, secondary ion emission profiles have been measured during at least two treatment fractions for 35 patients to date. While the measured profiles were consistent between fractions for the majority of patients, pronounced inter-fractional changes were observed in several cases. These differences correlate with plausible anatomical locations.

**Invited Talk** ST 5.3 Thu 12:00 KH 01.013

**Radioactive ion beams for real-time PET-guided adaptive particle therapy** — •DARIA BOSCOLO FOR THE BARB COLLABORATION — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Heavy ion particle therapy offers superior dose conformity compared to conventional radiotherapy, but its clinical potential is limited by high sensitivity to range uncertainties at the distal edge of the Bragg peak. To ensure tumor coverage, large safety margins are often applied, partially negating the benefits of particle therapy. Online range verification methods are therefore essential, particularly for adaptive treatment strategies. Positron emission tomography (PET) is among the most established techniques for in-beam range verification; however, in conventional 12C-ion therapy its accuracy is constrained by low signal-to-noise ratios, spatial mismatches between activity and dose peaks, and long acquisition times. The direct use of  $\beta^+$ -emitting radioactive ion beams for both treatment and imaging offers a promising solution to these limitations. Within the BARB project, the feasibility of 11C-ion beams combined with real-time in-beam PET imaging has been extensively investigated. We report the first demonstration of real-time adaptive particle therapy using radioactive ion beams in a living mouse model, showing that dynamic beam repositioning produces spatially resolved PET signals correlated with distinct treatment outcomes. These results provide compelling evidence that 11C-beams-based imaging can enable precise range verification, adaptive treatment delivery, and improved tumor control with reduced toxicity.

**Invited Talk** ST 5.4 Thu 12:30 KH 01.013

**Helium as a Range Probe in Carbon-Ion Therapy: From Concept to Mixed-Beam Experiments** — •LENNART VOLZ FOR THE PROMISE COLLABORATION — GSI Helmholtz Zentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Carbon ion therapy offers superior dose conformity compared to conventional radiotherapy, but its full potential is limited by the lack of real-time, in-beam range verification. The PROMISE project (ERC Grant No. 101124273) investigates a novel approach based on mixed ion beams to enable simultaneous treatment delivery and particle-based imaging. Carbon and helium ions have nearly identical charge-to-mass ratios and can therefore be accelerated simultaneously to the same velocity in a synchrotron. At equal velocity, helium ions have a three-fold larger range than carbon ions. While the carbon component delivers the therapeutic dose, the helium ions act as a low-dose imaging probe. This contribution reports on the first experimental realization of mixed beam range verification and imaging at GSI's SIS18 synchrotron. Experiments on a lung-cancer-mimicking setup reveal that a mixed beam enables tracking a spherical tumor at sub-millimeter accuracy, with high sensitivity to range changes down to <0.1% of the beam range using a particle imaging scintillator detector. Simulations on patient CT data are used to explore the clinical potential of this technique. This work represents an important step toward fully image-guided heavy-ion therapy.

## ST 6: Poster Session

Time: Thursday 14:15–15:45

Location: Redoutensaal

ST 6.1 Thu 14:15 Redoutensaal

**WO3-based polymer composites for radiation protection** — •MARIA STEFANOVA<sup>1</sup>, STEFANI BOGOEVA<sup>1</sup>, VLADIMIRA VIDEVA<sup>1</sup>, STRAHIL GEORGIEV<sup>2</sup>, DIMITRINA PETROVA<sup>1,3</sup>, VERA MARINOVA<sup>1</sup>, and DIMITRE DIMITROV<sup>1,4</sup> — <sup>1</sup>Institute of Optical Materials and Technologies, Bulgarian Academy of Sciences, Sofia, Bulgaria — <sup>2</sup>Faculty of Physics, Sofia University, 1164 Sofia, Bulgaria — <sup>3</sup>Faculty of Engineering, South-West University, 2700 Blagoevgrad, Bulgaria — <sup>4</sup>Institute of Solid State Physics, BAS, 1784 Sofia, Bulgaria

Lead-based radiation shielding materials, though effective, are limited by their toxicity, rigidity, and environmental hazards. This study explores a polymer composite incorporating tungsten trioxide (WO3) as a lead-free alternative for gamma and X-ray protection. WO3 was selected for its high atomic number, density and chemical stability, offering efficient attenuation with lower ecological impact. Composites with varying WO3 concentrations were synthesized and evaluated for mechanical properties, microstructural uniformity and radiation shielding efficiency. Preliminary results indicate that WO3-polymer composites achieve comparable attenuation to conventional lead materials while exhibit-

ing superior flexibility, lower weight and non-toxicity. These findings demonstrate the potential of WO3-filled polymers as sustainable materials for radiation-protective equipment.

**Acknowledgments** The research was supported by the scientific infrastructure INFRAMAT, part of the National Roadmap of Bulgaria for scientific infrastructure, financially supported by the Ministry of Education and Science.

ST 6.2 Thu 14:15 Redoutensaal

**Tracking Polymeric Residues in Silicone Implants and Adjacent Tissue via Raman Spectroscopy and CNN-Based Classification** — •HOANG THINH NGUYEN<sup>1</sup>, SUSANNE GRAMSALL<sup>2</sup>, RIMA NUWAYHID<sup>3</sup>, and PAUL-TIBERIU MICLEA<sup>1,2</sup> — <sup>1</sup>Martin Luther University Halle-Wittenberg, Institute of Physics, MicroMD Group — <sup>2</sup>Fraunhofer Center for Silicon Photovoltaics, Halle (Saale), Germany — <sup>3</sup>University Hospital Leipzig, D-04103 Leipzig, Germany

Silicone breast implants are widely used in reconstructive and aesthetic surgery. While silicone is generally considered biologically inert, concerns remain regarding long-term biocompatibility and potential microplastic release. Six sam-

ples (2 explanted implants, 4 surrounding tissue specimens) were analyzed using Raman spectroscopy combined with CNN-based spectral classification. Implant surfaces were examined directly, while tissue samples underwent KOH digestion and filtration onto silicon membrane filters (1 micrometer pore size). A Mask R-CNN model trained on about 50 reference spectra with an 8:2 split outperformed SVM and KNN. Raman mapping detected PVC on implant surfaces. In tissue, polymeric residues were found (primarily silicone), but also non-silicone polymers such as PS and PVC, near 960 cm<sup>-1</sup> and 1600 cm<sup>-1</sup>. These results suggest migration of polymer components into surrounding tissue and support links to implant-related inflammatory responses.

ST 6.3 Thu 14:15 Redoutensaal

**Comparison of Proton Beam Dose Profiles in matRad and Geant4 Simulations** — •MARIAM ABULADZE<sup>1</sup>, REVAZ SHANIDZE<sup>2</sup>, BEKA BOCHORISHVILI<sup>2</sup>, NIKOLOZ TCHIKADZE<sup>3</sup>, and ACHIM STAHL<sup>4</sup> — <sup>1</sup>Kutaisi International University, Kutaisi, Georgia — <sup>2</sup>Tbilisi State University, Tbilisi, Georgia — <sup>3</sup>Todua Clinic, Tbilisi, Georgia — <sup>4</sup>RWTH Aachen University, Aachen, Germany

Cancer treatment is one of the most pressing issues in the modern world, and proton therapy is one of the main methods used to combat this disease. Protons Coulomb Interactions with electrons and nuclei there are well tested methods that describe these interactions very well. In contrast nuclear interactions are more complicated to describe so accurately as Coulomb interactions. In order to account for nuclear interactions in dose calculations, it is necessary to use higher-precision Monte Carlo modeling. In this work we compare doses calculated by two software tools, one uses Monte Carlo calculations the other not. In order to compare calculated doses by these two software tools we study simplest case: homogeneous water medium and monochromatic proton beams. The study investigates absorbed doses obtained using two software tools: matRad and Geant4 and obtained dose distributions and lateral profiles are compared. According to the results besides some differences in dose profiles dose distributions are closer enough according to clinical standards.

ST 6.4 Thu 14:15 Redoutensaal

**Thin Film Scintillators for  $\alpha$ -Particle Detection** — •KIM TABEA GIEBENHAIN, HANS-GEORG ZAUNICK, and KAI-THOMAS BRINKMANN — <sup>2nd</sup> Physics Institute, Justus Liebig University, Giessen, Germany

Reliable detection of  $\alpha$ -particles is one of the core tasks in Radon detection, since relevant Radon isotopes decay by  $\alpha$ -emission.

For the development of an efficient and cheap Radon detector, multiple thin scintillator materials were tested to increase the effective area of an existing detector system, while still maintaining a low-cost photodetection setup and good background suppression.

This works present the findings on the light transport of 50  $\mu$ m thick Polyethylene-Naphthalate foils and thin coatings of scintillating paint EJ-296 on acrylic glass, read out by a dual-SiPM system.

ST 6.5 Thu 14:15 Redoutensaal

**Design-Oriented Monte Carlo Evaluation of Tungsten Oxide-Loaded Flexible Polymer Shields for Diagnostic Photon Energies** — •TÜRKAN ALKAN<sup>1</sup> and HAKAN EPIK<sup>2</sup> — <sup>1</sup>Vocational School of Health Services, Izmir University of Economics, Balçova, Izmir 35330, Turkey — <sup>2</sup>Department of Physics, Faculty of Science, Dokuz Eylül University, Buca, Izmir 35160, Turkey

Flexible and lead-free radiation shielding materials have attracted significant attention as safer alternatives to conventional protective systems. This study aims to systematically evaluate the photon attenuation behavior of tungsten trioxide (WO<sub>3</sub>)-reinforced PVA/PEG polymer composites within the diagnostic X-ray energy interval (20-150 keV) using a Monte Carlo-based modeling approach.

Composite structures containing 0-40% WO<sub>3</sub> by volume were computationally modeled using the GAMOS (GEANT4-based) simulation platform. Energy-dependent mass attenuation coefficients were obtained from transmitted photon fluence under narrow-beam conditions. Linear attenuation coefficients, half-value layer (HVL), tenth-value layer (TVL), and mean free path (MFP) were subsequently derived to quantify shielding efficiency across all compositions.

Increasing WO<sub>3</sub> loading produced a pronounced enhancement in attenuation performance, particularly at lower photon energies dominated by photoelectric interactions. The composite containing 40% WO<sub>3</sub> demonstrated the strongest shielding capability, exhibiting substantial reductions in HVL and MFP compared with the unfilled matrix. These findings indicate that tungsten oxide incorporation significantly improves photon interaction probability while enabling thinner shielding structures.

The simulation outcomes confirm that WO<sub>3</sub>-reinforced PVA/PEG composites represent promising candidates for flexible, lead-free shielding applications in diagnostic radiology. The presented Monte Carlo framework provides a practical tool for guiding material selection and optimizing filler concentration prior to experimental fabrication.

## ST 7: Radiation Therapy

Time: Thursday 16:15–16:45

Location: KH 01.013

ST 7.1 Thu 16:15 KH 01.013

**Investigation of the surface dose distribution of Ru-106 eye plaques using an innovative setup** — •JOHANNES WINTZ<sup>1</sup>, JOHANNES ALBRECHT<sup>2</sup>, and DIRK FLÜHS<sup>1</sup> — <sup>1</sup>Department of Radiotherapy, University Medicine Essen, Essen — <sup>2</sup>TU Dortmund University, Dortmund

Brachytherapy with ruthenium-106 applicators is an established method for treating eye tumours. Due to the manufacturing process, the surface dose distribution is not homogeneous and exhibits so-called hot and cold spots where the dose is higher or lower than at the centre of the eye plaque. According to the manufacturer's production specifications, relative dose deviations of up to  $\pm 11\%$  are permitted. For quality assurance, the dose profile is measured at 33 positions to ensure that this standard is met.

Within the project, measurements of the surface dose distribution are carried out using a bespoke measurement apparatus to determine the dose profile with higher resolution and analyse its influence on therapy. A new method using a plastic scintillator is employed, surrounded by air, which reduces the potential for Cherenkov radiation and thus provides more precise information about the activity on the eye plaque.

The structure of the new measurement system will be presented, along with initial results, which will be compared with the simulations and the manufacturer's specifications.

ST 7.2 Thu 16:30 KH 01.013

**Tabletop setup for in-vitro cell irradiation with low energy electron bunches** — •JULIAN FREIER<sup>1</sup>, LEON BRÜCKNER<sup>1</sup>, LUKAS KUHLMANN<sup>2</sup>, BASTIAN LÖHRL<sup>1</sup>, GIULIA CRAMER<sup>2</sup>, CHRISTOPH BERT<sup>2</sup>, LUITPOLD DISTEL<sup>2</sup>, and PETER HOMMELHOFF<sup>1,3</sup> — <sup>1</sup>Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany — <sup>2</sup>Department of Radiation Oncology, Universitätsklinikum Erlangen, Erlangen, Germany — <sup>3</sup>Department Physik, Ludwig-Maximilians-Universität München (LMU), Munich, Germany

Low-energy electrons (LEE) in the keV range are expected to have a high relative biological effectiveness (RBE) and, due to their limited penetration depth, may enable highly localized cancer therapy [1]. This work presents an ultrafast pulsed electron source based on photoemission from arrays of gold needle tips [2], capable of delivering electron energies up to 50 keV. Human fibroblasts and tumor cell lines were irradiated with LEE and compared to X-ray exposure. DNA double-strand breaks, visualized through  $\gamma$ H2AX staining, show a characteristic depth-dependent pattern under LEE irradiation. Colony formation assays are used to determine the RBE. The emerging results set the ground for further radiobiological assessments and for the development of future therapeutic strategies, particularly in combination with laser-accelerator-on-a-chip technology suitable for endoscopic applications [3]. Ref. [1] Tye, J., et al. R. Soc. Open Sci. 11.11 (2024): 240898. [2] Bruckner, Leon, et al. Nano Lett. 24.16 (2024): 5018-5023. [3] England, R. Joel, et al. Rev. Mod. Phys. 86.4 (2014): 1337-1389.

## ST 8: Keynote Session

Time: Thursday 16:45–17:15

Location: KH 01.013

### Invited Talk

ST 8.1 Thu 16:45 KH 01.013

**Healing Patients, Heating the Planet: Why Circularity Matters in Healthcare** — •KATHARINA HESELS — Siemens Healthineers

Healthcare exists to save lives, yet paradoxically, it is a significant contributor to global warming, a crisis that increases mortality rates as temperatures rise. In

this keynote, I will address this dual responsibility and share how circular economy principles can help reconcile patient care with planetary health. Through examples of refurbishment programmes, eco-design initiatives, and responsible usage of AI, we will explore how MedTech can reduce its carbon footprint without compromising clinical outcomes.

**ST 9: Prize Ceremony and Closing Session**

Time: Thursday 17:15–17:45

Location: KH 01.013

In this last session we would like to take the opportunity to thank all participants for their attendance and contributions. We will announce the winner of this years award for the “Best contribution in the radiation and medical physics division at the DPG Spring Meeting 2026”. We welcome everyone to celebrate all prize winners and a successful conference with us, to provide some final feedback and to take the chance to meet again the other participants of this meeting.

**ST 10: Members’ Assembly**

Time: Thursday 17:45–18:45

Location: KH 01.013

All members of the Radiation and Medical Physics Division Division are invited to participate.

Particle Physics Division

Fachverband Teilchenphysik (T)

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Overview of Invited Talks and Sessions

(Lecture halls AudiMax, KH 00.011, KH 00.014, KH 00.015, KH 00.016, KH 00.020, KH 00.023, KH 00.024, KH 01.011, KH 01.012, KH 01.013, KH 01.014, KH 01.019, KH 01.020, KH 01.022, KH 02.013, KH 02.014, KH 02.016, KH 02.018, KH 02.019, AM 00.014, KS H C, KS 00.004, KS 00.005, KS 00.006, and MED 00.915)

Plenary Talk of the Particle Physics Division

PV X    Wed    9:45–10:30    AudiMax    Precision at the Energy Frontier: What the LHC is revealing about Fundamental Particle Physics — •LUDOVICA APERIO BELLA

Invited Overview Talks

|         |     |             |         |                                                                                                                                |
|---------|-----|-------------|---------|--------------------------------------------------------------------------------------------------------------------------------|
| T 1.1   | Mon | 14:45–15:15 | AudiMax | Top-quark physics in a new regime: precision, effective field theory, and the top-quark pair production threshold — •KNUT ZOCH |
| T 1.2   | Mon | 15:15–15:45 | AudiMax | Monte Carlo event generators for the HL-LHC — •STEFFEN SCHUMANN                                                                |
| T 21.1  | Tue | 11:00–11:30 | AudiMax | Three Decades of Dark Matter Annual Modulation Searches: Overview and Current Status — •KAROLINE SCHAEFFNER                    |
| T 21.2  | Tue | 11:30–12:00 | AudiMax | Status and meaning of current tensions in cosmology — •JULIEN LESGOURGUES                                                      |
| T 21.3  | Tue | 12:00–12:30 | AudiMax | In search of the unknown: Pushing the boundaries in searches for new physics at the LHC — •DANYER PEREZ ADAN                   |
| T 41.1  | Wed | 11:00–11:30 | AudiMax | One of a kind: the Higgs boson — •MATTEO BONANOMI                                                                              |
| T 41.2  | Wed | 11:30–12:00 | AudiMax | Higgs Physics at the LHC and Beyond: Connecting Colliders and the Early Universe — •THOMAS BIEKÖTTER                           |
| T 41.3  | Wed | 12:00–12:30 | AudiMax | Gravitational waves from cosmological phase transitions. — •THOMAS KONSTANDIN                                                  |
| T 63.1  | Thu | 11:00–11:30 | AudiMax | Binary Black Hole Populations: Scientific Perspectives for the Einstein Telescope — •MICHELA MAPELLI                           |
| T 63.2  | Thu | 11:30–12:00 | AudiMax | JUNO’s First Light: High-Precision Reactor Neutrino Oscillations — •MICHAEL WURM                                               |
| T 63.3  | Thu | 12:00–12:30 | AudiMax | Flavour physics at the precision frontier: recent highlights from the LHCb and Belle II experiments — •EVELINA GERSABECK       |
| T 107.1 | Fri | 11:00–11:30 | AudiMax | Beyond the Main Detectors: An Overview of Smaller Experiments at the LHC — •FELIX KLING                                        |
| T 107.2 | Fri | 11:30–12:00 | AudiMax | Pimp my ride: Overhauling the ATLAS and CMS experiments to ride the High Luminosity Highway at the LHC — •STEFAN MAIER         |
| T 107.3 | Fri | 12:00–12:30 | AudiMax | Overview of the solar model and LUNANOVA — •DANIEL BEMMERER                                                                    |

Invited Topical Talks

|        |     |             |         |                                                                                                  |
|--------|-----|-------------|---------|--------------------------------------------------------------------------------------------------|
| T 43.1 | Wed | 13:45–14:15 | AudiMax | Upgrade of the ATLAS tracker for HL-LHC: production status and challenges — •ROLAND KOPPENHOEFER |
| T 43.2 | Wed | 14:15–14:45 | AudiMax | Entering the high-granularity calorimetry era: the CMS HGCal upgrade — •ANTOINE LAUDRAIN         |
| T 43.3 | Wed | 14:45–15:15 | AudiMax | Searching for New Physics in Otherwise Lost LHC Data — •FALK BARTELS                             |

|        |     |             |            |                                                                                                                                                                |
|--------|-----|-------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| T 43.4 | Wed | 15:15–15:45 | AudiMax    | <b>Federated Computing Infrastructures</b> — •INGA LAKOMIEC                                                                                                    |
| T 44.1 | Wed | 13:45–14:15 | MED 00.915 | <b>Probing Heavy New Physics at the Precision Frontier with Effective Field Theory</b> — •PETER STANGL                                                         |
| T 44.2 | Wed | 14:15–14:45 | MED 00.915 | <b>Hadron Spectroscopy at Belle (II)</b> — •STEFAN WALLNER                                                                                                     |
| T 44.3 | Wed | 14:45–15:15 | MED 00.915 | <b>Rare B meson decays at Belle II: indirect searches for new physics at the luminosity frontier</b> — •ANA LUISA MOREIRA DE CARVALHO                          |
| T 44.4 | Wed | 15:15–15:45 | MED 00.915 | <b>Search for CP violation in <math>D^0 \rightarrow K_S^0 K_S^0</math> decays at the LHCb experiment</b> — •GIULIA TUCI                                        |
| T 64.1 | Thu | 13:45–14:15 | AudiMax    | <b>Charting the Higgs Sector with Effective Field Theories</b> — •ILARIA BRIVIO                                                                                |
| T 64.2 | Thu | 14:15–14:45 | AudiMax    | <b>Probing CP invariance of Higgs boson production and decay and its interpretation in effective field theories with the ATLAS detector</b> — •LORENZO ROSSINI |
| T 64.3 | Thu | 14:45–15:15 | AudiMax    | <b>b-tagging unlocks the Higgs potential</b> — •NICOLE HARTMAN                                                                                                 |
| T 64.4 | Thu | 15:15–15:45 | AudiMax    | <b>Modern Machine Learning for LHC Event Generation</b> — •RAMON WINTERHALDER                                                                                  |
| T 65.1 | Thu | 13:45–14:15 | MED 00.915 | <b>Atmospheric neutrino oscillations with IceCube and the IceCube Upgrade</b> — •JAN WELDELT                                                                   |
| T 65.2 | Thu | 14:15–14:45 | MED 00.915 | <b>Exploring the Gravitational Wave Universe with Pulsar Timing Arrays</b> — •ANDREA MITRIDATE                                                                 |
| T 65.3 | Thu | 14:45–15:15 | MED 00.915 | <b>Supernova Remnants as Accelerators of Galactic Cosmic Rays</b> — •ROBERT BROSE                                                                              |
| T 65.4 | Thu | 15:15–15:45 | MED 00.915 | <b>Supermassive black holes and their relativistic jets: a beacon into the early universe</b> — •LEA MARCOTULLI                                                |

## Sessions

|              |     |             |           |                                             |
|--------------|-----|-------------|-----------|---------------------------------------------|
| T 1.1–1.2    | Mon | 14:45–15:45 | AudiMax   | <b>Invited Overview Talks I</b>             |
| T 2.1–2.8    | Mon | 16:15–18:15 | AudiMax   | <b>Neutrino Physics I</b>                   |
| T 3.1–3.7    | Mon | 16:15–18:00 | KH 00.014 | <b>Standard Model Physics I</b>             |
| T 4.1–4.8    | Mon | 16:15–18:15 | KH 00.016 | <b>Higgs Physics I</b>                      |
| T 5.1–5.8    | Mon | 16:15–18:15 | KH 00.020 | <b>Methods in Particle Physics I</b>        |
| T 6.1–6.8    | Mon | 16:15–18:15 | KH 00.023 | <b>Electronics, Trigger, DAQ I</b>          |
| T 7.1–7.8    | Mon | 16:15–18:15 | KH 00.024 | <b>Data, AI, Computing, Electronics I</b>   |
| T 8.1–8.8    | Mon | 16:15–18:15 | KH 01.011 | <b>Flavour Physics I</b>                    |
| T 9.1–9.6    | Mon | 16:15–17:45 | KH 01.012 | <b>Silicon Detectors I</b>                  |
| T 10.1–10.7  | Mon | 16:15–18:00 | KH 01.013 | <b>Axions/ALPS I</b>                        |
| T 11.1–11.8  | Mon | 16:15–18:15 | KH 01.014 | <b>Gaseous Detectors I</b>                  |
| T 12.1–12.8  | Mon | 16:15–18:15 | KH 01.022 | <b>Silicon Detectors II</b>                 |
| T 13.1–13.8  | Mon | 16:15–18:15 | KH 02.013 | <b>Higgs Physics II</b>                     |
| T 14.1–14.8  | Mon | 16:15–18:15 | KH 02.014 | <b>Data, AI, Computing, Electronics II</b>  |
| T 15.1–15.8  | Mon | 16:15–18:15 | KH 02.018 | <b>Searches/BSM I</b>                       |
| T 16.1–16.8  | Mon | 16:15–18:15 | AM 00.014 | <b>Search for Dark Matter I</b>             |
| T 17.1–17.8  | Mon | 16:15–18:15 | KS H C    | <b>Neutrino Astronomy I</b>                 |
| T 18.1–18.8  | Mon | 16:15–18:15 | KS 00.004 | <b>Methods in Astroparticle Physics I</b>   |
| T 19.1–19.8  | Mon | 16:15–18:15 | KS 00.005 | <b>Gravitational Waves I</b>                |
| T 20.1–20.6  | Mon | 16:15–17:45 | KS 00.006 | <b>Cosmic Rays I</b>                        |
| T 21.1–21.3  | Tue | 11:00–12:30 | AudiMax   | <b>Invited Overview Talks II</b>            |
| T 22.1–22.9  | Tue | 16:15–18:30 | AudiMax   | <b>Neutrino Physics II</b>                  |
| T 23.1–23.8  | Tue | 16:15–18:15 | KH 00.011 | <b>Top Physics I</b>                        |
| T 24.1–24.8  | Tue | 16:15–18:15 | KH 00.014 | <b>Standard Model Physics II</b>            |
| T 25.1–25.8  | Tue | 16:15–18:15 | KH 00.016 | <b>Higgs Physics III</b>                    |
| T 26.1–26.5  | Tue | 16:15–17:30 | KH 00.020 | <b>Methods in Particle Physics II</b>       |
| T 27.1–27.8  | Tue | 16:15–18:15 | KH 00.023 | <b>Muon Detectors</b>                       |
| T 28.1–28.10 | Tue | 16:15–18:45 | KH 00.024 | <b>Data, AI, Computing, Electronics III</b> |
| T 29.1–29.8  | Tue | 16:15–18:15 | KH 01.011 | <b>Flavour Physics II</b>                   |
| T 30.1–30.9  | Tue | 16:15–18:30 | KH 01.012 | <b>Silicon Detectors III</b>                |
| T 31.1–31.8  | Tue | 16:15–18:15 | KH 01.014 | <b>Scintillator Detectors I</b>             |
| T 32.1–32.9  | Tue | 16:15–18:30 | KH 01.019 | <b>Higgs Physics IV</b>                     |
| T 33.1–33.8  | Tue | 16:15–18:15 | KH 01.022 | <b>Silicon Detectors IV</b>                 |
| T 34.1–34.10 | Tue | 16:15–18:45 | KH 02.014 | <b>Data, AI, Computing, Electronics IV</b>  |
| T 35.1–35.9  | Tue | 16:15–18:30 | KH 02.018 | <b>Searches/BSM II</b>                      |
| T 36.1–36.9  | Tue | 16:15–18:30 | AM 00.014 | <b>Search for Dark Matter II</b>            |
| T 37.1–37.9  | Tue | 16:15–18:30 | KS H C    | <b>Neutrino Astronomy II</b>                |
| T 38.1–38.9  | Tue | 16:15–18:30 | KS 00.004 | <b>Methods in Astroparticle Physics II</b>  |

|               |     |             |            |                                                                         |
|---------------|-----|-------------|------------|-------------------------------------------------------------------------|
| T 39.1–39.6   | Tue | 16:15–17:45 | KS 00.005  | <b>Gravitational Waves II</b>                                           |
| T 40.1–40.9   | Tue | 16:15–18:30 | KS 00.006  | <b>Cosmic Rays II</b>                                                   |
| T 41.1–41.3   | Wed | 11:00–12:30 | AudiMax    | <b>Invited Overview Talks III</b>                                       |
| T 42.1–42.1   | Wed | 12:40–13:40 | KS H C     | <b>Annual Meeting of Young Scientists in High Energy Physics (yHEP)</b> |
| T 43.1–43.4   | Wed | 13:45–15:45 | AudiMax    | <b>Invited Topical Talks I</b>                                          |
| T 44.1–44.4   | Wed | 13:45–15:45 | MED 00.915 | <b>Invited Topical Talks II</b>                                         |
| T 45.1–45.9   | Wed | 16:15–18:30 | AudiMax    | <b>Neutrino Physics III</b>                                             |
| T 46.1–46.7   | Wed | 16:15–18:00 | KH 00.011  | <b>Top Physics II</b>                                                   |
| T 47.1–47.8   | Wed | 16:15–18:15 | KH 00.014  | <b>Higgs Physics V</b>                                                  |
| T 48.1–48.8   | Wed | 16:15–18:15 | KH 00.020  | <b>Methods in Particle Physics III</b>                                  |
| T 49.1–49.8   | Wed | 16:15–18:15 | KH 00.023  | <b>Electronics, Trigger, DAQ II</b>                                     |
| T 50.1–50.7   | Wed | 16:15–18:00 | KH 00.024  | <b>Data, AI, Computing, Electronics V</b>                               |
| T 51.1–51.10  | Wed | 16:15–18:45 | KH 01.011  | <b>Flavour Physics III</b>                                              |
| T 52.1–52.8   | Wed | 16:15–18:15 | KH 01.012  | <b>Silicon Detectors V</b>                                              |
| T 53.1–53.9   | Wed | 16:15–18:30 | KH 01.014  | <b>Scintillator Detectors II</b>                                        |
| T 54.1–54.8   | Wed | 16:15–18:15 | KH 01.019  | <b>Higgs Physics VI</b>                                                 |
| T 55.1–55.10  | Wed | 16:15–18:45 | KH 01.022  | <b>Silicon Detectors VI</b>                                             |
| T 56.1–56.6   | Wed | 16:15–17:45 | KH 02.014  | <b>Data, AI, Computing, Electronics VI</b>                              |
| T 57.1–57.9   | Wed | 16:15–18:30 | KH 02.016  | <b>Outreach I</b>                                                       |
| T 58.1–58.7   | Wed | 16:15–18:00 | KH 02.018  | <b>Searches/BSM III</b>                                                 |
| T 59.1–59.9   | Wed | 16:15–18:30 | KS H C     | <b>Neutrino Astronomy III</b>                                           |
| T 60.1–60.9   | Wed | 16:15–18:30 | KS 00.004  | <b>Methods in Astroparticle Physics III</b>                             |
| T 61.1–61.6   | Wed | 16:15–17:45 | KS 00.005  | <b>Gamma Astronomy I</b>                                                |
| T 62.1–62.8   | Wed | 16:15–18:15 | KS 00.006  | <b>Cosmic Rays III</b>                                                  |
| T 63.1–63.3   | Thu | 11:00–12:30 | AudiMax    | <b>Invited Overview Talks IV</b>                                        |
| T 64.1–64.4   | Thu | 13:45–15:45 | AudiMax    | <b>Invited Topical Talks III</b>                                        |
| T 65.1–65.4   | Thu | 13:45–15:45 | MED 00.915 | <b>Invited Topical Talks IV</b>                                         |
| T 66.1–66.7   | Thu | 16:15–18:00 | AudiMax    | <b>Neutrino Physics IV</b>                                              |
| T 67.1–67.7   | Thu | 16:15–18:00 | KH 00.011  | <b>Top Physics III</b>                                                  |
| T 68.1–68.6   | Thu | 16:15–17:45 | KH 00.014  | <b>Standard Model Physics III</b>                                       |
| T 69.1–69.6   | Thu | 16:15–17:45 | KH 00.020  | <b>Methods in Particle Physics IV</b>                                   |
| T 70.1–70.7   | Thu | 16:15–18:00 | KH 00.023  | <b>Electronics, Trigger, DAQ III</b>                                    |
| T 71.1–71.7   | Thu | 16:15–18:00 | KH 00.024  | <b>Data, AI, Computing, Electronics VII</b>                             |
| T 72.1–72.8   | Thu | 16:15–18:15 | KH 01.011  | <b>Flavour Physics IV</b>                                               |
| T 73.1–73.6   | Thu | 16:15–17:45 | KH 01.012  | <b>Calorimeters I</b>                                                   |
| T 74.1–74.7   | Thu | 16:15–18:00 | KH 01.014  | <b>Gaseous Detectors II</b>                                             |
| T 75.1–75.8   | Thu | 16:15–18:15 | KH 01.019  | <b>Higgs Physics VII</b>                                                |
| T 76.1–76.8   | Thu | 16:15–18:15 | KH 01.022  | <b>Silicon Detectors VII</b>                                            |
| T 77.1–77.8   | Thu | 16:15–18:15 | KH 02.013  | <b>Higgs Physics VIII</b>                                               |
| T 78.1–78.8   | Thu | 16:15–18:15 | KH 02.014  | <b>Flavour Physics V</b>                                                |
| T 79.1–79.6   | Thu | 16:15–17:45 | KH 02.018  | <b>Searches/BSM IV</b>                                                  |
| T 80.1–80.6   | Thu | 16:15–17:45 | KH 02.019  | <b>Axions/ALPs II</b>                                                   |
| T 81.1–81.6   | Thu | 16:15–17:45 | AM 00.014  | <b>Search for Dark Matter III</b>                                       |
| T 82.1–82.7   | Thu | 16:15–18:00 | KS H C     | <b>Neutrino Astronomy IV</b>                                            |
| T 83.1–83.7   | Thu | 16:15–18:00 | KS 00.004  | <b>Methods in Astroparticle Physics IV</b>                              |
| T 84.1–84.6   | Thu | 16:15–17:45 | KS 00.005  | <b>Gamma Astronomy II</b>                                               |
| T 85.1–85.6   | Thu | 16:15–17:45 | KS 00.006  | <b>Cosmic Rays IV</b>                                                   |
| T 86          | Thu | 18:30–19:30 | AM 00.014  | <b>Members' Assembly</b>                                                |
| T 87.1–87.6   | Fri | 9:00–10:30  | AudiMax    | <b>Neutrino Physics V</b>                                               |
| T 88.1–88.6   | Fri | 9:00–10:30  | KH 00.011  | <b>Top Physics IV</b>                                                   |
| T 89.1–89.6   | Fri | 9:00–10:30  | KH 00.014  | <b>Higgs Physics IX</b>                                                 |
| T 90.1–90.5   | Fri | 9:00–10:15  | KH 00.015  | <b>Calorimeters II</b>                                                  |
| T 91.1–91.5   | Fri | 9:00–10:15  | KH 00.020  | <b>Methods in Particle Physics V</b>                                    |
| T 92.1–92.5   | Fri | 9:00–10:15  | KH 00.023  | <b>Electronics, Trigger, DAQ IV</b>                                     |
| T 93.1–93.5   | Fri | 9:00–10:15  | KH 00.024  | <b>Data, AI, Computing, Electronics VIII</b>                            |
| T 94.1–94.6   | Fri | 9:00–10:30  | KH 01.011  | <b>Flavour Physics VI</b>                                               |
| T 95.1–95.6   | Fri | 9:00–10:30  | KH 01.014  | <b>Gaseous Detectors III</b>                                            |
| T 96.1–96.6   | Fri | 9:00–10:30  | KH 01.020  | <b>Outreach II</b>                                                      |
| T 97.1–97.5   | Fri | 9:00–10:15  | KH 01.022  | <b>Silicon Detectors VIII</b>                                           |
| T 98.1–98.6   | Fri | 9:00–10:30  | KH 02.013  | <b>Higgs Physics X</b>                                                  |
| T 99.1–99.6   | Fri | 9:00–10:30  | KH 02.014  | <b>Searches/BSM V</b>                                                   |
| T 100.1–100.3 | Fri | 9:00– 9:45  | KH 02.016  | <b>Miscellaneous</b>                                                    |

|               |     |             |           |                                    |
|---------------|-----|-------------|-----------|------------------------------------|
| T 101.1–101.6 | Fri | 9:00–10:30  | KH 02.018 | Searches/BSM VI                    |
| T 102.1–102.6 | Fri | 9:00–10:30  | KH 02.019 | Axions/ALPs III                    |
| T 103.1–103.5 | Fri | 9:00–10:15  | AM 00.014 | Search for Dark Matter IV          |
| T 104.1–104.6 | Fri | 9:00–10:30  | KS H C    | Neutrino Astronomy V               |
| T 105.1–105.6 | Fri | 9:00–10:30  | KS 00.004 | Methods in Astroparticle Physics V |
| T 106.1–106.5 | Fri | 9:00–10:15  | KS 00.005 | Gamma Astronomy III                |
| T 107.1–107.3 | Fri | 11:00–12:30 | AudiMax   | Invited Overview Talks V           |

Members’ Assembly of the Particle Physics Division

Thursday 18:30–19:30 AM 00.014



## Sessions

– Invited Overview, Invited Topical, and Contributed Talks –

### T 1: Invited Overview Talks I

Time: Monday 14:45–15:45

Location: AudiMax

#### Invited Overview Talk

T 1.1 Mon 14:45 AudiMax

**Top-quark physics in a new regime: precision, effective field theory, and the top-quark pair production threshold** — •KNUT ZOCH — CERN, Geneva, Switzerland

The top quark, the heaviest known elementary particle, plays a central role in testing the Standard Model and probing physics at the highest energy scales. Building on the legacy of the Run 2 data set and motivated by the growing Run 3 program, the LHC experiments continue to deliver a broad range of results that advance our understanding of top-quark production and interactions.

This talk will review recent experimental highlights from the ATLAS and CMS collaborations, including measurements of top-quark production in association with the Higgs boson, effective field theory interpretations of top-quark observables, improved determinations of the top-quark mass, and first results exploiting Run 3 data. Particular emphasis will be placed on measurements of top-quark pair production near threshold, where bound-state-like effects (“toponium”) become accessible and open a new window on strong-interaction dynamics in the top-quark sector.

Together, these results illustrate how precision measurements and novel kinematic regimes in top-quark physics continue to sharpen our picture of the Standard Model and constrain possible extensions.

#### Invited Overview Talk

T 1.2 Mon 15:15 AudiMax

**Monte Carlo event generators for the HL-LHC** — •STEFFEN SCHUMANN — Institut für Theoretische Physik, Georg-August Universität Göttingen

Monte Carlo event generators are indispensable tools for the analysis and interpretation of high-energy collider experiments. They provide detailed simulations of scattering events at the level of observable particles that reflect our current understanding of the dynamics and interactions of the fundamental constituents of nature. In this talk an overview of the status of Monte Carlo event generators will be given. Guided by the experimental needs and requirements of the High-Luminosity LHC, areas of active developments will be highlighted. This includes, among others, the enhancement of the perturbative accuracy of the predictions and means to improve the computational efficiency of the simulations. A strategic approach of event generator development will allow these tools to be further improved and systematic uncertainties to be reduced, facilitating future experimental success.

### T 2: Neutrino Physics I

Time: Monday 16:15–18:15

Location: AudiMax

T 2.1 Mon 16:15 AudiMax

**Status Report on the ECHO Experiment** — •RAGHAV PANDEY for the ECHO-Collaboration — Kirchhof Institute for Physics, INF 227, Heidelberg 69120

The analysis of the endpoint region of  $\beta$ -decay or electron capture decay spectra is a model independent method for the determination of the effective electron (anti-)neutrino mass. The ECHO collaboration aims to achieve this goal by preparing a high energy resolution and high statistics measurement of the electron capture spectrum in  $^{163}\text{Ho}$ . This experiment uses Metallic Magnetic Calorimeters enclosing samples of the  $^{163}\text{Ho}$  source. The first phase of the experiment — called ECHO-1k — has been completed with the publication of the best limit on the effective electron neutrino mass obtained from  $^{163}\text{Ho}$ ,  $m_{\nu_e} < 15 \text{ eV} (90\% \text{ C.L.})$ .

We present the results obtained in the ECHO-1k experiment and discuss the development of the next phase of ECHO, the ECHO-LE (Large Experiment). In ECHO-LE, 20000 MMC detectors will be read out using a microwave SQUID multiplexing scheme with the goal of acquiring  $10^{13}$  events at a high energy resolution. The achievement of such a spectra allows for a sub-eV sensitivity on the effective electron neutrino mass.

T 2.2 Mon 16:30 AudiMax

**Fitting of the endpoint region of the Ho-163 spectrum in the ECHO-1k experiment** — •LORENZO CALZA — Kirchhoff Institute for Physics, Heidelberg University

The effective electron neutrino mass can be derived from the analysis of the endpoint region of electron capture spectra, since the finite mass distorts the spectral shape near the Q value. In ECHO the shape of the Ho-163 EC spectrum is studied. During the first phase of the ECHO experiment, more than 200 million Ho-163 events were acquired using 2 arrays of metallic magnetic calorimeters enclosing Ho-163. For a reliable analysis of the endpoint region, a precise calibration of the spectrum was obtained by applying a tailored procedure determined in a dedicated calibration measurement. Since theoretical models fail to provide an accurate analytical description of the spectral shape, we have tested two different approaches for the determination of a phenomenological function. The obtained functions were tested for stability of fit in the endpoint region of the acquired Ho-163 spectrum. We present the analysis of the ECHO-1k data leading to the present best limit of  $m(\nu_e) < 15 \text{ eV}$  90% confidence interval ( $m(\nu_e) < 18 \text{ eV}$  95% C.I.) and discuss the study of the systematic uncertainties.

T 2.3 Mon 16:45 AudiMax

**Studies on general neutrino interactions with the KATRIN experiment** — •HANNA HENKE for the KATRIN-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

The Karlsruhe Tritium Neutrino (KATRIN) Experiment aims to determine the neutrino mass using precision spectroscopy of electrons from tritium  $\beta$ -decay. Recently, KATRIN published an improved upper bound of 0.45 eV at 90% C.L. [1] on the effective electron-neutrino mass. Beyond the neutrino mass measurement, KATRIN’s high-precision spectroscopy enables searches for physics beyond the Standard Model, such as general neutrino interactions (GNI). These interactions can manifest as subtle shape deformations in the measured energy spectrum. The GNI framework provides a model-agnostic approach by combining all theoretically allowed interaction terms into an effective field theory, describing energy-dependent spectral contributions as indicators of novel weak processes. Recently, first constraints on GNI based on KATRIN data were released [2]. This talk will give an overview of the GNI framework and analysis, and present further studies using KATRIN data.

This work is supported by the Helmholtz Association and by the Ministry for Education and research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6)

[1] DOI: 10.1126/science.adq9592,

[2] DOI: 10.1103/PhysRevLett.134.251801

T 2.4 Mon 17:00 AudiMax

**Insight into the Analysis of the KATRIN Neutrino Mass Data** — CHLOÉ GOUPY<sup>1</sup>, CHRISTOPH KÖHLER<sup>1</sup>, SUSANNE MERTENS<sup>1</sup>, •JAN PLÖSSNER<sup>1</sup>, RICHARD SALOMON<sup>2</sup>, ALESSANDRO SCHWEMMER<sup>1</sup>, JAROSLAV ŠTOREK<sup>3</sup>, XAVER STRIBL<sup>1,4</sup>, and CHRISTOPH WIESINGER<sup>1</sup> for the KATRIN-Collaboration — <sup>1</sup>Max-Planck-Institut für Kernphysik — <sup>2</sup>Universität Münster — <sup>3</sup>Karlsruher Institut für Technologie — <sup>4</sup>Technische Universität München

The Karlsruhe Tritium Neutrino (KATRIN) experiment probes the effective electron anti-neutrino mass by a precision measurement of the tritium beta-decay spectrum near the endpoint. A world-leading upper limit of 0.45 eV  $c^{-2}$  (90 % C.L.) has been set, including the data of the first five measurement campaigns. With data collection now complete after a total of 19 measurement campaigns, the available statistics have increased by more than a factor of six compared to the initial dataset.

In this presentation, I will provide an update on the current status of the KATRIN neutrino mass analysis, including the data from the first 17 measurement campaigns, and discuss the neural network approach utilized for this analysis.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 2.5 Mon 17:15 AudiMax

**Magnetic-field compatibility of TRISTAN detectors for the KATRIN keV sterile neutrino search** — •SIMON GENTNER — Karlsruhe Institute of Technology (KIT)

At the Karlsruhe Institute of Technology (KIT), a full-scale replica of the KATRIN experiment's detector system was developed to pretest the innovative TRISTAN detectors. This replica enables comprehensive testing and calibration of up to nine TRISTAN detector modules under controlled conditions, ensuring optimal performance before their integration into the KATRIN beamline in 2026. This upgrade will enhance KATRIN's sensitivity in the search for keV-scale sterile neutrinos. Preliminary results demonstrate that the TRISTAN modules deliver exceptional high-resolution for beta spectroscopy, which is essential for precise neutrino mass measurements and the exploration of potential new physics.

During operation in the KATRIN beamline, the detector modules will be exposed to a strong magnetic field. To investigate its influence on critical detector parameters, including energy resolution and signal rise time, dedicated measurements were performed using the replica system. This presentation will discuss these results and highlight the excellent properties of the TRISTAN detector modules.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 2.6 Mon 17:30 AudiMax

**Current status of the next-generation neutrino mass experiment Project 8** — •RENE REIMANN for the Project 8-Collaboration — Johannes Gutenberg Universität Mainz

The Project 8 experiment aims to probe the absolute neutrino mass through direct kinematic measurements of the tritium beta decay spectrum using cyclotron radiation emission spectroscopy (CRES). Future tritium beta decay experiments that aim for neutrino mass sensitivities below  $\sim 200$  meV, must be operated with atomic tritium to avoid effects from rotational and vibrational final states of the daughter nucleus. The CRES technique has been demonstrated successfully with molecular tritium in a small cylindrical wave guide. For a competitive experiment, the CRES technique must be scaled up and be operated in combination with atomic tritium. Currently the CRES cavity apparatus is under commissioning, which will demonstrate the CRES technique with improved energy resolution within a cavity using an event-by-event reconstruction. The low-frequency apparatus is currently in its design phase and should demonstrate the coexistence of CRES electron detection and an atomic trap while increasing the effective volume and lowering the background magnetic field compared to previous CRES experiments. In addition, atomic tritium sources at unprecedented fluxes are under development. In this contribution, I give a short overview of the current demonstrators, which pave the way to a full-scale neutrino mass experiment.

T 2.7 Mon 17:45 AudiMax

**Offline data validation framework for JUNO** — •NURBAKYT AMANBEK<sup>1,2</sup> and LIVIA LUDHOVA<sup>1,2</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstr. 1, D-64291 Darmstadt, Germany — <sup>2</sup>Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose liquid-scintillator detector in China that aims to determine the neutrino mass ordering by measuring reactor antineutrinos at a 52.5 km baseline. The central detector contains 20 kton of liquid scintillator and is instrumented with 17,612 large (20") PMTs and 25,600 small (3") PMTs, providing high light yield and excellent energy resolution. After physics data taking began on August 26, 2025, JUNO reported the most precise measurements of  $\Delta m_{12}^2$  and  $\sin^2 \theta_{12}$  from 59.1 days of data - a level of precision that requires stable detector performance and consistently low-background, high-quality data. To monitor data quality, JUNO operates a semi-automated data-validation framework that performs prompt (online) and offline monitoring. About 10% of the data are validated promptly online to allow us to quickly react in case of major problems, while more detailed offline validation is performed once the full dataset of each run becomes available. We monitor various properties at the level of single channels, events, and the whole run. We also monitor longer-term stability of the detector to identify potential slower changes. This contribution presents the offline validation workflow and highlights its essential role in securing the data quality required for JUNO's precision oscillation program.

T 2.8 Mon 18:00 AudiMax

**Measurement of Solar Neutrino Oscillation Parameters with the First JUNO Data** — •CRISTOBAL MORALES REVECO<sup>1,2,3</sup>, NURBA AMANBEK<sup>1,3</sup>, TIM CHARISSE<sup>1,3</sup>, ZE CHEN<sup>1,3</sup>, LIVIA LUDHOVA<sup>1,3</sup>, MARCO MALABARBA<sup>1,3</sup>, MARIAM RIFAI<sup>1,2,3</sup>, SAHAR SAFARI<sup>1,3</sup>, UJWAL SANTHOSH<sup>1,3</sup>, and ROSMARIE WIRTH<sup>1,3</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — <sup>2</sup>III. Physikalisches Institut B, RWTH Aachen University, 52062 Aachen, Germany — <sup>3</sup>Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator detector experiment located in the Jiangmen region, China. It is situated at an optimal distance of 52.5 km from multiple nuclear reactor cores and is designed for precision measurements of neutrino oscillation parameters and the determination of the neutrino mass ordering (NMO). In December 2024, construction was completed, and commissioning began by fully filling the detector with water. In February 2025, the water in the inner detector started to be replaced with liquid scintillator, a process that continued until the end of August of the same year. This talk presents results from 59.1 days of data, achieving a world-leading measurement of the solar oscillation parameters. It will focus on the analysis strategy: signal event and data-driven background selections, the estimation of residual backgrounds, uncertainties, and the fit strategy used to extract the solar oscillation parameters.

### T 3: Standard Model Physics I

Time: Monday 16:15–18:00

Location: KH 00.014

T 3.1 Mon 16:15 KH 00.014

**Strategy for constraining multi-parton interactions at the LHC using Z boson events** — •EK-ONG ATTHAPHAN and YNYR HARRIS — University of Bonn, Bonn, Germany

Multi-Parton Interactions (MPI) occur in every proton-proton collision at the CERN Large Hadron Collider and play a crucial role in the modelling of soft QCD processes and observables at low momentum transfer. In particular, an accurate description of Z-boson production at low transverse momentum requires a detailed understanding of MPI effects. In this talk, a novel method for directly measuring the number of MPI scatters in individual pp events is presented. The MPI multiplicity is extracted from a fit to the azimuthal two-particle correlation function. A comparison of this method applied to ATLAS data and Pythia Monte Carlo simulations demonstrates sensitivity to the MPI model parameters  $p_{T,0}$  and  $p_{T,min}$ , providing new constraints on their values for LHC collisions.

T 3.2 Mon 16:30 KH 00.014

**Phenomenology of heavy flavour jet angularities at hadron colliders** — ANDREA GHIRA<sup>1</sup>, LORENZO MAI<sup>2</sup>, SIMONE MARZANI<sup>2</sup>, DANIEL REICHELT<sup>3</sup>, STEFEN SCHUMANN<sup>4</sup>, and •LEON STÖCKER<sup>4</sup> — <sup>1</sup>Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — <sup>2</sup>Dipartimento di Fisica, Università di Genova and INFN, Sezione di Genova, Italy — <sup>3</sup>CERN, Theoretical Physics Department, Geneva, Switzerland — <sup>4</sup>Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

We compute resummed and matched predictions for jet angularities in hadronic Z+jet events, where the jet is initiated by a b quark. The analysis is performed both with and without grooming the candidate jets using the SoftDrop algorithm. Mass effects are consistently included at both fixed-order and resummed levels. Our theoretical predictions also incorporate non-perturbative corrections from the underlying event and hadronisation, implemented through parton-to-hadron transfer matrices extracted from dedicated Sherpa Monte Carlo simulations. Finally, we compare our results with previous implementations in order to quantify the impact of mass effects.

T 3.3 Mon 16:45 KH 00.014

**Triple differential Z+Jet cross section measurement** — •CEDRIC VERSTEGE and KLAUS RABBERTZ — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Germany

We present a measurement of the triple-differential production cross section of  $Z(\rightarrow \mu\mu)$ +jet events in proton-proton collisions at  $\sqrt{s} = 13$  TeV recorded with the CMS detector during Run 2, corresponding to  $138 \text{ fb}^{-1}$ . The cross section is measured simultaneously in three dimensions defined by the transverse momentum of the muon pair, half of the absolute rapidity separation between the muon pair and the leading jet, and the rapidity boost of their center-of-mass system. This choice of observables provides sensitivity to the scattering angle and to the fractional momenta of the initial-state partons. After unfolding for detector effects, the results at particle level are compared to NNLO QCD predictions supplemented with electroweak and non-perturbative corrections, as well as to predictions from state-of-the-art Monte Carlo event generators.

T 3.4 Mon 17:00 KH 00.014

**Estimation of  $\alpha_s$  from dijet/Z+jet CMS data** — •JOHANNES GÄSSLER — Schlossgartenstraße 52, 76327 Pfinztal, Germany

In a recent CMS analysis (Eur. Phys. J. C 85, 72 (2025)) the 2016 multidifferential dijet cross sections were published. This also included fits of the strong coupling constant and the proton structure to the data with results of  $\alpha_s = 0.1179 \pm 0.0019$  for the double-differential binning and  $\alpha_s = 0.1181 \pm 0.0022$  for the triple-differential binning respectively. I will present the results of a re-analysis of the data using complete NNLO predictions (taken from Phys.Rev.Lett. 135 (2025) 3, 031903) in comparison to the leading-color approximation employed previously. Moreover, I upgraded the xFitter package to the latest version, providing access to improved theory settings. I am extending the analysis to also include CMS Z+jet data with the ultimate goal of a combined fit using both datasets.

T 3.5 Mon 17:15 KH 00.014

**Data-driven background estimation in EW VBF-Zjj ATLAS Analysis** — •SIMONE RUSCELLI — Technische Universität Dortmund (Germany)

Measurements exploiting weak vector-boson fusion (VBF) processes have become increasingly prominent at the Large Hadron Collider (LHC). Among these are studies of electroweak production of two jets in association with a weak boson (EW Vjj), a process highly sensitive to the VBF mechanism and to the gauge structure of the Standard Model, and potential anomalous weak-boson self-interactions. These measurements rely on precise theoretical predictions and Monte Carlo event generators, which are used to model electroweak processes, optimise event selections, and isolate the electroweak signal from dominant backgrounds. The results presented here employ the ABCD statistical method to estimate the strong-Zjj (QCD Zjj) background in signal-enriched regions, using fits to relevant kinematic distributions. The studies are based on  $\sqrt{s} = 13$  TeV  $pp$  collision data collected by the ATLAS detector between 2015 and 2018.

T 3.6 Mon 17:30 KH 00.014

**Improvement of Parton Distribution Functions through the ATLAS W-boson Measurement at High Transverse Masses** — •LUCA NICASTRO, TIM FREDERIK BEUMKER, FRANK ELLINGHAUS, and JOHANNA WANDA KRAUS — Bergische Universität Wuppertal

High-precision measurements of W bosons at large transverse masses offer sensitivity to the proton's parton distribution functions (PDFs), particularly in the high Bjorken- $x$  region. In this work, the impact of the recently published ATLAS Run-2 measurement of double-differential charged-current Drell-Yan cross sections at  $\sqrt{s} = 13$  TeV is investigated. Using the xFitter framework, the study assesses how this dataset can refine existing PDF sets through profiling. Different analysis strategies, including the treatment of lepton channels, the choice between additive and multiplicative electroweak corrections, and the use of charge asymmetries, are systematically compared. The results demonstrate which configurations yield the strongest quantitative constraints on specific PDF components and illustrate these constraints.

T 3.7 Mon 17:45 KH 00.014

**Production of hadronically-decaying boosted vector bosons reconstructed as large-radius jets at the ATLAS experiment** — •DONNA MARIA MATTERN and CHRIS MALENA DELITZSCH — TU Dortmund, Fakultät Physik

At the Large Hadron Collider (LHC), W and Z bosons are often produced with large Lorentz boosts due to the high energies of the proton-proton collisions. When such boosted vector bosons (BVBs) decay hadronically, they are reconstructed as large-radius jets ( $R = 1.0$ ) at the ATLAS experiment. These large-radius jets pass through a chain of different calibration steps, including an in-situ jet energy scale correction to account for differences between data and Monte Carlo simulation, before they can be used in analyses. To separate BVB jets from the much more abundantly produced background jets from quantum-chromodynamic (QCD) processes at the LHC, their substructure is considered, which describes the energy flow within the large-radius jet. Using a neutral-network based tagger that relies on substructure information and is decorrelated with the input large-radius jet's mass, the background events can be suppressed. This talk discusses important aspects of the cross-section measurement of hadronically-decaying BVBs in association with jets.

## T 4: Higgs Physics I

Time: Monday 16:15–18:15

Location: KH 00.016

T 4.1 Mon 16:15 KH 00.016

**Search for non-resonant Higgs boson pair production in dilepton final states of the  $bbWW$  decay mode at CMS** — •LARA MARKUS, MATTEO BONANOMI, MATHIS FRAHM, JOHANNES HALLER, BALDUIN LETZER, and MATTHIAS SCHRÖDER — Institut für Experimentalphysik, Universität Hamburg

The trilinear coupling of the Higgs boson is related to the shape of the Higgs potential, which makes it a crucial parameter of the Standard Model. The trilinear coupling can be directly probed by measuring the cross section of Higgs boson pair production in proton-proton collisions at the LHC.

A search for non-resonant Higgs boson pair production is presented, targeting final states where one Higgs boson decays to a pair of bottom quarks and the other Higgs boson decays to two W bosons, with subsequent decays of the W bosons into leptons and neutrinos. The analysis is performed on data collected at a center-of-mass energy of 13.6 TeV by the CMS detector in 2022 and 2023, with a corresponding integrated luminosity of  $62.4 \text{ fb}^{-1}$ . Events are selected based on the b-tagged jets multiplicity, and state-of-the-art neural network classifiers are used to enhance the sensitivity to the rare signal topology. Upper limits are set on the Higgs boson pair production cross section and as a function of the trilinear coupling strength.

T 4.2 Mon 16:30 KH 00.016

**Search for Semiboosted Higgs Pair Production From Vector Boson Fusion in the Single Lepton  $bbW^+W^-$  Final State Using the ATLAS Detector** — •STEFAN BRÜCKNER, LARS LINDEN, VALERIO D'AMICO, CELINE STAUCH, PATRICK RUDOLPH SCHUMACHER, and OTMAR BIEBEL — LMU Munich

The discovery of the Higgs boson solved one of the biggest problems in the standard model, the generation of particle masses. However, one property that is still not well known is the quartic coupling of a Higgs boson pair to a pair of electroweak gauge bosons. A process involving this coupling is the Di-Higgs production via vector boson fusion (VBF), which is the second most common production mode at LHC. The analysis in this talk focuses on events in the  $bbW^+W^-$  final state with a single lepton, using a semiboosted approach. In this semiboosted scenario, one of the two objects, either the  $H \rightarrow b\bar{b}$  or the W boson, which decays hadronically, is represented by a large radius jet. Some results of the general kinematics of the process and the event selection strategy for the semiboosted approach will be presented in the talk.

T 4.3 Mon 16:45 KH 00.016

**Search for Boosted Higgs Pair Production From Vector Boson Fusion in the Single Lepton  $bbW^+W^-$  Final State Using the ATLAS Detector** — •CELINE STAUCH, STEFAN BRÜCKNER, LARS LINDEN, VALERIO D'AMICO, PATRICK SCHUMACHER, and OTMAR BIEBEL — LMU Munich

While the discovery of the Higgs boson solved one of the biggest problems in the standard model, even more than 10 years after its discovery, not all of its properties are well known. One of these is the quartic coupling of a Higgs boson pair to a pair of electroweak gauge bosons. A process suited to constrain this coupling is given by Di-Higgs production via vector boson fusion (VBF), the second most common production mode at LHC.

The presented search for VBF Di-Higgs production investigates the  $bbW^+W^-$  final state with a single lepton. For this study a boosted approach is investigated, where Large Radius jets represent the hadronically decaying W and the  $H \rightarrow b\bar{b}$ . This talk presents the Event Selection strategy using ATLAS run 2 datasets and first results for analysis optimizations to increase sensitivity.

T 4.4 Mon 17:00 KH 00.016

**Search for Higgs Boson Pair Production in Three-Lepton Final States with the ATLAS Detector** — ANAMIKA AGGARWAL, VOLKER BÜSCHER, CHRISTIAN SCHMITT, •NIKLAS SCHMITT, and DUC BAO TA — Johannes Gutenberg-University, Mainz

After the discovery of the Higgs boson in 2012 at the LHC, many of its properties have already been determined precisely using  $139 \text{ fb}^{-1}$  of proton-proton collisions at  $\sqrt{s} = 13$  TeV. However, one of the biggest challenges in this field remains the measurement of the coupling of the Higgs boson to itself. It allows for a deep insight into the real shape of the Higgs potential and hence has a big impact on the understanding of the physics of the universe. In order to constrain the trilinear self-coupling, the Di-Higgs production cross section is measured. While decay modes including b-quarks typically have larger branching fractions, leptonic final states are generally much cleaner and have less SM background.

This talk will give an overview about the three-lepton analysis, which relies on neural networks to distinguish the signal processes from all SM backgrounds. In addition, a dedicated treatment of leptons overlapping with jets is described, improving the sensitivity due to spin correlations in semi-leptonic  $H \rightarrow WW$  decays. Finally, the status of the Run 2 plus partial Run 3 analysis, based on a combined dataset of about  $300 \text{ fb}^{-1}$ , will be shown.

T 4.5 Mon 17:15 KH 00.016

**HH Analysis with Multileptons Using Run-2 ATLAS Data** — •ONDREJ KULHANEK and ANDRÉ SOPCZAK — CTU in Prague

The latest results with Run-2 ATLAS data are presented for the search HH in the multilepton channel.

T 4.6 Mon 17:30 KH 00.016

**Studies towards a search for HHH production in the 4b2W channel in dilepton final states with CMS** — •PARTH PATIL, JOHANNES HALLER, LARA MARKUS, MATHIAS FRAHM, MATTEO BONANOMI, and MATTHIAS SCHRÖDER — Institut für Experimentalphysik, Universität Hamburg

The quartic coupling of the Higgs boson is an important parameter of the Standard Model (SM) Higgs sector and is related to the shape of the Higgs potential. Triple Higgs boson (HHH) production offers a direct probe of the quartic coupling. In the SM, HHH production is an extremely rare process evading current experimental sensitivity; however, the HHH production cross section can become large for non-SM scenarios, motivating a search for this process.

In this talk, studies towards a search for HHH production are presented, targeting events in which two Higgs bosons decay into bottom quark-antiquark pairs and one Higgs boson decays into a pair of W bosons, both of which decay leptonically. The analysis uses simulated data of the CMS experiment, corresponding to data-taking conditions at a center-of-mass energy of 13.6 TeV. Events are categorised based on the dilepton mass and b-tagged jet multiplicities, and deep neural networks are employed to discriminate the small signal from SM background processes.

Finally, a maximum likelihood fit is performed to establish expected exclusion limits on the HHH production cross section and constrain the quartic Higgs coupling.

T 4.7 Mon 17:45 KH 00.016

**gg→HH NLO EW corrections in the forward limit** — •DOMINIK GRAU<sup>1</sup>, DANIEL STREMMER<sup>1</sup>, MATTHIAS STEINHAUSER<sup>1</sup>, JOSHUA DAVIES<sup>2</sup>, and KAY SCHÖNWALD<sup>3</sup> — <sup>1</sup>Karlsruher Institut für Technologie, Karlsruhe, Deutschland — <sup>2</sup>University of Liverpool, Liverpool, United Kingdom — <sup>3</sup>Cern, Genève, Switzerland

In this talk, we present the calculation of the NLO EW corrections to di-Higgs production via gluon fusion. We compute the electroweak amplitude using analytical approximations around the forward limit, which cover large parts of the phase space with sufficient accuracy. Our results are given in symbolic form, offering flexibility with respect to parameter value and renormalization scheme choices.

T 4.8 Mon 18:00 KH 00.016

**Electroweak corrections to Higgs boson pair production: The light quark case** — MARCO BONETTI<sup>1</sup>, GUDRUN HEINRICH<sup>2</sup>, •PHILIPP RENDLER<sup>2</sup>, and WILLIAM J. TORRES BOBADILLA<sup>3</sup> — <sup>1</sup>Institute for Theoretical Physics, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — <sup>2</sup>Institute for Theoretical Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — <sup>3</sup>Department of Mathematical Sciences, University of Liverpool, Liverpool L69 3BX, U.K.

We present a fully analytic computation of the electroweak corrections to Higgs-boson pair production mediated by light quarks in both the gluon and quark-antiquark channels. The calculation is performed using the method of differential equations, employing a large mass expansion to generate boundary functions. We implement the results in the POWHEG BOX framework for phenomenological studies. The corrections to the differential cross section are found to be sizable, reaching up to -30% in the gluon channel and +10% in the quark channel near the production threshold. The quark channel has not been considered before in calculations of the NLO electroweak corrections to Higgs-boson pair production.

## T 5: Methods in Particle Physics I

Time: Monday 16:15–18:15

Location: KH 00.020

T 5.1 Mon 16:15 KH 00.020

**Machine Learning Methods for Charged-Particle Identification at Belle II** — •ROBERT MUNDZECK<sup>1,2</sup>, MARTIN BARTL<sup>1</sup>, HANS-GÜNTHER MOSER<sup>1</sup>, and STEFAN WALLNER<sup>1</sup> — <sup>1</sup>Max Planck Institute for Physics, Garching, Germany — <sup>2</sup>Technical University of Munich

We present recent advances in charged-particle identification at the Belle II experiment at KEK, Japan. So far, particle identification at Belle II has relied on a likelihood-based method that combines information from six subdetectors to distinguish between different particle species. Recently, a neural-network-based classifier has been developed that complements and improves upon this conventional approach. We report on a study comparing the neural network performance to an alternative classifier based on boosted decision trees. We also present the approaches of further optimization of the neural network, aimed at optimizing particle identification performance at Belle II.

T 5.2 Mon 16:30 KH 00.020

**Validation of the Graph Neural Network tracking at Belle II** — •JONAS LOTZ and SLAVOMIRA STEFKOVA — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

A novel end-to-end multi-track reconstruction algorithm based on a graph neural network (GNN) architecture was developed for the Belle II collaboration (Comput Softw Big Sci 9, 6 (2025)). These studies demonstrate substantial improvements in key performance metrics such as tracking efficiency, with particularly strong gains for tracks originating from displaced vertices. In addition, different hit-to-track association provides an opportunity for improved event clean-up, which may be particularly useful for missing energy decays. In this presentation, building on this development, the applicability of this GNN-based tracking algorithm in the context of searches for  $B^0 \rightarrow K_S^0 \nu \bar{\nu}$  decays will be studied. We will focus on validating the algorithm against established tracking methods and assessing potential benefits for rare decay searches. The talk will present the status of integrating the new GNN tracking framework into the  $B^0 \rightarrow K_S^0 \nu \bar{\nu}$  analysis.

T 5.3 Mon 16:45 KH 00.020

**Towards a Complete Tracking Concept for ILD@FCC-ee** — FRANK GAEDE<sup>1</sup>, DANIEL JEANS<sup>3</sup>, JENNY LIST<sup>1</sup>, THOMAS MADLENER<sup>1</sup>, and •VICTOR SCHWAN<sup>1,2</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron DESY — <sup>2</sup>Universität Hamburg — <sup>3</sup>Institute of Particle and Nuclear Studies, KEK, Tsukuba, Japan

The International Large Detector (ILD) concept was originally conceived for the International Linear Collider (ILC). In-depth simulations benchmarked against the performance of prototype components have shown that ILD in its ILC incar-

nation is exceptionally well suited to pursuing the physics program of a linear  $e^+e^-$  collider at energies from the Z pole to the TeV regime. Recently, the ILD collaboration has begun investigating how the detector concept would need to be modified to operate successfully in the experimental environment of a circular  $e^+e^-$  collider, and ILD is now being evaluated as a candidate detector concept for FCC-ee. In particular, the interaction region and the machine-detector interface (MDI) require substantial changes to accommodate accelerator elements and to withstand background levels. This contribution presents recent progress on beam-induced background (BIB) estimates in ILD's tracking systems, along with ongoing developments in adapting ILD tracking and reconstruction to FCC-ee operating conditions. Together, these efforts lay the groundwork for enabling full-simulation physics studies with ILD@FCC-ee and for further optimizing the detector concept for the FCC-ee environment.

T 5.4 Mon 17:00 KH 00.020

**Tracking Performance Studies for the Mu3e Experiment** — •ELIJA ENGELHARDT, TAMASI KAR, and ANDRÉ SCHÖNING for the Mu3e-Collaboration — Physikalisches Institut, Universität Heidelberg, Germany

The Mu3e experiment aims to find the charged lepton flavour violating decay  $\mu^+ \rightarrow e^+ e^- e^+$  at the Paul Scherrer Institute (PSI). Phase 1 of the experiment will reach a single event sensitivity of  $2 \times 10^{-15}$  on the branching ratio, and Phase 2 aims for a sensitivity down to  $10^{-16}$  [1]. In order to reach this level of sensitivity, a high muon stopping rate (2 GHz) and a large track reconstruction efficiency are required. The tracking detector comprises of four pixel detector layers based on the HV-MAPS technology for precise position measurements, scintillating fibres, and scintillating tiles for precise timing. The tracking algorithm used is based on the General Triplet Track Fit (GTTF) [2].

The tracking efficiency, purity, and various parameter resolutions are studied and improved using Monte Carlo simulations and data taken during the June 2025 commissioning run. The track reconstruction efficiency and purity are defined with simulation truth as reference. Various track parameter cuts are investigated to balance fake rate and efficiency. Results from the tracking performance optimisation studies will be presented.

[1] The Mu3e Collaboration. Technical design of the phase I Mu3e experiment. doi: 10.1016/j.nima.2021.165679

[2] A. Schöning. A general track fit based on triplets. doi: 0.1016/j.nima.2025.170391

T 5.5 Mon 17:15 KH 00.020

**Vertex Reconstruction Using the General Triplet Track Fit for the Mu3e Experiment** — •THOMAS SCHWARTZE, ANDRÉ SCHÖNING, TAMASI KAR, and DAVID FRITZ for the Mu3e-Collaboration — Physikalisches Institut, Heidelberg University, Germany

The Mu3e Experiment at the Paul Scherrer Institut (PSI) searches for the charged-lepton-flavour-violating decay  $\mu^+ \rightarrow e^+ e^- e^+$ . Mu3e aims to improve the sensitivity to the exclusion-limit of this process by four orders of magnitude. It uses a high-intensity muon beam to deliver up to 2 GHz of muons to a stationary target. To efficiently distinguish signal from background, a fast and accurate reconstruction of the common vertex is essential.

In this talk, an extension to the General Triplet Track Fit (GTTF) [1] is presented that is able to reconstruct the vertex of three-track combinations. The GTTF is a track fitting algorithm based on triplets. It is highly parallelizable and therefore, for example, well suited for GPU implementation. It has been extended to reconstruct the position of the decay vertex by treating it as an additional pseudo-hit. The performance of this vertex reconstruction is evaluated using both Monte Carlo simulations and data from the June 2025 commissioning run at PSI.

[1] A. Schöning, A general track fit based on triplets, doi: 10.1016/j.nima.2025.170391

T 5.6 Mon 17:30 KH 00.020

**Improving secondary vertexing for HL-LHC: Algorithm research using ACTS and ODD** — •DIPTAPARNA BISWAS<sup>1</sup>, MARKUS CRISTINZIANI<sup>1</sup>, MARGRET KEUPER<sup>2</sup>, ADRIAN SZYMON KOSMALA<sup>3</sup>, VADIM KOSTYUKHIN<sup>1</sup>, and PAWEŁ SWOBODA<sup>3</sup> — <sup>1</sup>Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen, Germany — <sup>2</sup>Data and Web Science Group, Universität Mannheim, Germany — <sup>3</sup>Heinrich-Heine-Universität Düsseldorf, Germany

The High-Luminosity Large Hadron Collider (HL-LHC) offers unprecedented discovery potential but introduces extreme pileup conditions that challenge standard reconstruction techniques. Accurate Secondary Vertex (SV) reconstruction is critical for precision flavour physics and BSM searches. This contribution presents research utilizing A Common Tracking Software (ACTS) to develop and benchmark robust SV algorithms tailored for this environment. While ACTS is established for tracking R&D, this work expands its scope to address the distinct complexities of vertexing. Using the Open Data Detector (ODD) for realistic HL-LHC simulations, we evaluate the performance of various algorithmic strategies, ranging from established techniques to novel approaches based on machine learning. We report on the current status in terms of the key metrics including vertex reconstruction efficiency, resolution and fake rates, demonstrating the viability of ACTS as a powerful platform for developing cross-experiment vertexing solutions for the HL-LHC era.

T 5.7 Mon 17:45 KH 00.020

**Towards an implementation of ACTS for the Belle II experiment** — •MARC-PHILIPP THOMAS, GIACOMO DE PIETRO, and TORBEN FERBER — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Track reconstruction is a fundamental component of particle physics experiments, relying critically on robust and precise track fitting algorithms that must perform reliably across a wide range of particle momenta. The Belle II experiment at the asymmetric electron-positron SuperKEKB collider presents particular challenges for track fitting. These include particles with momenta ranging from a few tens of MeV to several GeV, and an asymmetric detector geometry.

In this talk, we discuss the integration of the experiment-independent ACTS (A Common Tracking Software) toolkit into the Belle II reconstruction chain. In the proposed workflow, track finding is performed within the Belle II Analysis Software Framework, while ACTS is used solely for track fitting. We will present the current status of this integration effort, including the first results on ACTS track fitting for the Silicon Vertex Detector, and a comparison with the current Belle II track-fitting approach in terms of reconstruction efficiency, parameter resolution, and robustness for low-momentum tracks.

T 5.8 Mon 18:00 KH 00.020

**Track Reconstruction with the Pixel Detector for the Phase-2 Upgrade of the CMS High-Level Trigger** — •JAN GERRIT SCHULZ<sup>1,2</sup>, ALEXANDER SCHMIDT<sup>1</sup>, MARCO ROVERE<sup>2</sup>, ELENA VERNAZZA<sup>2</sup>, BRUNO ALVES<sup>2</sup>, EMANUELE CORADIN<sup>2,3</sup>, LUCA FERRAGINA<sup>2,4</sup>, MARCO MUSICH<sup>2</sup>, and FELICE PANTALEO<sup>2</sup> — <sup>1</sup>III. Physikalisches Institut A, RWTH Aachen University, Germany — <sup>2</sup>CERN, Switzerland — <sup>3</sup>Università di Padova & INFN, Italy — <sup>4</sup>Università di Bologna, Italy

The CMS detector will undergo an extensive upgrade for the upcoming High-Luminosity LHC, which will include the complete replacement of the inner tracking system. Event reconstruction algorithms must be adapted to the new geometry and the planned denser environment of up to 200 simultaneous proton-proton interactions. An important component of this event reconstruction in the High-Level Trigger (HLT) is pixel tracking, which forms the first step in the track reconstruction chain as well as a fast alternative for full tracking entirely. To exploit the full potential of the improved pixel detector, the CMS pixel tracking algorithm has been improved in various respects. This includes an extension of the coverage to parts of the outer tracker, an optimization of the parameters, and a new DNN-based track selection. This contribution provides an overview of these new developments.

## T 6: Electronics, Trigger, DAQ I

Time: Monday 16:15–18:15

Location: KH 00.023

T 6.1 Mon 16:15 KH 00.023

**Next-Generation Readout ASIC for DEPFET Pixel Detectors in 65-nm CMOS** — •VASILIKI GOGOLOU, HANS KRÜGER, and JOCHEN DINGFELDER — University of Bonn, Germany

The continued evolution of particle-physics experiments places increasing demands on the performance, efficiency, and integration density of readout electronics. As detector systems grow in channel count and as data rates accelerate, high-quality, low-noise readout chains become essential to preserve the precision of the underlying sensor technology. DEPFET (Depleted p-channel field effect transistor) pixel sensors play a key role in this landscape with successful applications ranging from high-energy physics vertex detectors such as those for the ILC and Belle II to advanced medical imaging systems. This work presents a next-generation readout integrated circuit for DEPFET matrices, implemented in a state-of-the-art 65-nm CMOS process node. The transition to a smaller feature size enables improved power-area efficiency while maintaining low noise. Each channel integrates a cascode transimpedance amplifier and a compact single-ended-to-differential stage, optimized to fully drive the input range of a high-speed, low-power SAR ADC (successive-approximation register analog-to-digital converter). The readout architecture is specifically designed to interface seamlessly with such ADCs, enabling a system that meets stringent constraints on power density and pixel pitch while delivering the precision required for future high-rate, high-resolution experiments.

T 6.2 Mon 16:30 KH 00.023

**Firmware developments and hardware tests for the HL-LHC ATLAS Liquid Argon Signal Processor system** — PETER FISCHER, •MARKUS HELBIG, RAINER HENTGES, ARNO STRAESSNER, JOHANN C. VOIGT, and PHILIPP WELLE — Institut für Kern- und Teilchenphysik, TU Dresden

In the HL-LHC era, the ATLAS Liquid Argon Calorimeters will be equipped with the new LAr Signal Processors (LASP). This off-detector processing system based on Altera Agilex 7 FPGAs will perform energy reconstruction for all 182 468 detector cells at every bunch crossing in real time and provide them to the new trigger systems Global Event Processor (GEP) and the Forward Feature Extractor (fFEX) as well as the main readout.

To cope with the higher pile-up, the use of 1-dimensional Convolutional Neural Networks (CNNs) with up to 400 parameters for energy reconstruction has been studied as an alternative to the current Optimal Filter approach. Using efficient FPGA resource allocations, a sufficient number of CNN instances to process up to 384 cells are fit on a single FPGA, leaving enough resources for other components. Their implementation has been verified in standalone hardware setups based on FPGA development kits and LASP testboards.

Furthermore, the first Agilex-based prototype board has recently become available. On this board, the interfaces from the front-end and towards the trigger systems are implemented as optical transceivers using Samtec FireFly modules. Their performance is studied to guarantee reliable data transmission.

T 6.3 Mon 16:45 KH 00.023

**The ATLAS Tile Calorimeter Trigger and Data Acquisition Interface: Final Design Overview and Validation Results** — •MAXIMILIAN KÖPER and THOMAS JUNKERMANN — Kirchhoff-Institut für Physik, Heidelberg University

The ATLAS experiment is undergoing the Phase-II Upgrade to accommodate the High Luminosity LHC (HL-LHC), necessitating a complete redesign of the trigger and readout architectures to handle increased pile-up. This contribution focuses on the Tile Calorimeter's Trigger and Data Acquisition interface (TDAQi), an ATCA Rear Transition Module designed to bridge the off-detector electronics with the ATLAS Level-0 trigger systems.

Equipped with an AMD Kintex UltraScale+ FPGA, the TDAQi receives calibrated cell energies and computes trigger primitives at 40 MHz. Key processing tasks include forming coarse-granularity objects for electron/jet triggers, identifying muon hits, and sorting high-energy cells for the Global Trigger Processor. These operations must be executed within a strict 250 ns latency budget while managing high-speed links up to 11.2 Gbps.

We present the TDAQi design and its role in the real-time data path. The discussion focuses on the final hardware validation and integration tests required before the start of the in-house production phase. We report on the performance of the latest pre-production modules, which serve as the final verification step for the upcoming series assembly.

T 6.4 Mon 17:00 KH 00.023

**Electron algorithm studies for the ATLAS forward Feature Extractor** — •FLORIAN HARZ, HANNES MILDNER, and STEFAN TAPPROGGE — Institut für Physik, JGU, Mainz, Germany

The High-Luminosity LHC upgrade presents unprecedented challenges for real-time event selection in the ATLAS experiment, driven by significantly increased rates, pile-up conditions, and the need for fast, high-precision triggering. The forward Feature Extractor (fFEX) board, based on high-performance FPGAs, will play a central role in the Level-0 calorimeter trigger, enabling low-latency identification of electromagnetic signatures in the forward area. This presentation summarizes recent algorithmic studies performed for the fFEX electron identification pipeline, highlighting strategies that balance physics performance with the stringent timing and resource constraints inherent to FPGA-based processing. A sliding-window algorithm has been implemented in firmware to act as a baseline comparison as it has been used previously used in ATLAS calorimeter triggering. Building on this, the use of machine-learning approaches is explored with the goal to have a full implementation in firmware that surpasses the legacy sliding-window method.

T 6.5 Mon 17:15 KH 00.023

**Development of the clustering algorithm for the LHCb Upgrade II SciFi tracker** — •JAN SOROKOVSKI, MICHAEL LUPBERGER, and MARCO GERSABECK — Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany

The LHCb Upgrade II aims to increase the instantaneous luminosity by a factor of 5. To achieve that, many detector systems have to be upgraded to address the increased detector occupancy and pileup. This includes the new downstream tracker, the Mighty Tracker, which will combine silicon pixel sensors in the high-occupancy region and improved Scintillating Fibres (SciFi) in the remaining region.

One of the key challenges of the SciFi Tracker is the handling of the output of the advanced front-end chip. For that, the development of an efficient, real-time clustering algorithm capable of processing the increased data volume, while maintaining a high spatial resolution and track hit efficiency, is crucial. A major consideration are noise sources, which have to be identified, understood and characterised to provide robustness against noise and to improve overall performance.

In this presentation, an early algorithm design and noise considerations and studies are

T 6.6 Mon 17:30 KH 00.023

**Full Path Data Injection for an FPGA-Based Data Acquisition System** — •BENT BUTTWILL for the Mu3e-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

The Mu3e experiment, located at the Paul Scherrer Institute in Switzerland, aims to study the charged-lepton-flavour violating decay  $\mu^+ \rightarrow e^+ e^+ e^-$ . To achieve the goal of probing the branching fraction beyond  $10^{-15}$  in Phase I, the experiment is designed to detect  $10^8$  muon decays per second.

The FPGA-based data acquisition system for Mu3e is designed to handle a data production rate of approximately 100 Gbit/s. Its hardware is optimized for efficient resource utilization and sustained high-throughput operation. Continuous verification of the data pipeline during development is essential to ensure reliable and performant operation.

Previously, test data was injected into internal memory locations within the FPGA, limiting the scope of the test procedure to a subset of the full pipeline. This work investigates a new data injection approach that enables testing of the complete pipeline. In this approach, data is injected digitally at the optical input interface of the FPGA, allowing the test data to propagate through the entire design, therefore testing every component of the firmware.

T 6.7 Mon 17:45 KH 00.023

**Investigation of Electronic Crosstalk in the Optical Modules of the Pacific Ocean Neutrino Experiment** — •LARS VON DER WERTH for the P-ONE-Collaboration — Technische Universität München

The Pacific Ocean Neutrino Experiment (P-ONE) is a proposed cubic-kilometer-scale neutrino detector to be deployed in the Pacific Ocean. Its fundamental detection units are the P-ONE optical modules (P-OMs), each housing 16 photomultiplier tubes (PMTs) to record Cherenkov light emitted by secondary particles produced in high-energy neutrino interactions. Each P-OM includes a trigger system that performs an initial selection of relevant signals. A detailed understanding of the internal electronic crosstalk is essential for reliable triggering. To characterize these effects, electromagnetic interference (EMI) measurements help identify the dominant noise sources and investigate the pathways through which these couple into the PMT signal. Further, we present how different grounding schemes, cabling configurations, and shielding strategies affect the crosstalk level observed in the different PMT positions within the P-OM.

T 6.8 Mon 18:00 KH 00.023

**Emulator-Based Evaluation of FPGA Algorithms for the ATLAS MDT Trigger Processor** — •MARCEL MARQUES BOONEN, DAVIDE CIERI, OLIVER KORTNER, and SANDRA KORTNER — Max Planck Institute for Physics, Garching, Germany

The Monitored Drift Tube Trigger Processor (MDTTP), a new FPGA-based component of the High-Luminosity LHC upgrade of the ATLAS muon trigger, is being developed to reconstruct muon tracks at the first-level trigger using the information from the MDT detectors. Two proposals for the determination of the muon transverse momenta are currently under investigation: an algorithm that translates the sagitta of the muon trajectory into transverse momentum using pre-defined conversion functions, and a machine-learning approach that exploits the directions and positions of the muon trajectory in the muon chambers.

Both approaches rely on a data processing chain capable of buffering and handling large data streams. To simulate such data processing under realistic conditions, dedicated Monte Carlo data are stored in DDR memories of one MDTTP board and then sequentially injected via optical fibers into the MDTTP board under test. This presentation will describe the implementation of this approach and its application in evaluating the performance of the aforementioned transverse-momentum calculation procedures.

## T 7: Data, AI, Computing, Electronics I

Time: Monday 16:15–18:15

Location: KH 00.024

T 7.1 Mon 16:15 KH 00.024

**Understanding and Expanding the Transformer-Based Neural Network to Analyze Extensive Air Showers at the Pierre Auger Observatory** — •RONJA WESTPHALEN, MAXIMILIAN STRAUB, ALEX REUZKI, NIKLAS LANGNER, JOSINA SCHULTE, and MARTIN ERDMANN — RWTH Aachen University, Aachen, Germany

Determining the mass of ultra-high-energy cosmic rays is crucial to understanding their origin. Ground-based detectors, such as the Pierre Auger Observatory, measure extensive air showers and collect multidimensional, time- and location-dependent signals that contain information on the primary particle. Analyzing these complex signals with a Transformer-based neural network to reconstruct mass-dependent observables, such as the depth of the shower maximum  $X_{\max}$  and the muon content  $R_{\mu}$ , from surface detector (SD) measurements at the Pierre Auger Observatory has been shown to be successful.

This study investigates the working principle of the Transformer in detail. We examine the attention mechanism in the time trace and in spatial analysis to understand how effectively features are reconstructed from these complex mea-

surements. Additionally, we assess the agreement between the data and simulations in the latent network space to determine whether known discrepancies of hadronic interaction models are inherently apparent in the network response. Finally, we want to extend the network by the radio detector, enabling the evaluation of SD measurements in combination with the radio signal for the Auger-Prime setup.

T 7.2 Mon 16:30 KH 00.024

**Reconstruction and Identification of Atmospheric Neutrino Events at JUNO Using Machine-Learning Methods** — •MILO CHARAVET, CAREN HAGNER, DANIEL BICK, and MIKHAIL SMIRNOV — University of Hamburg, Hamburg, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a next-generation multipurpose liquid scintillator detector with a 20-kiloton target mass, located in southern China. One of its primary goals is to determine the neutrino mass ordering (NMO) with a significance of at least  $3\sigma$  by precisely measuring the oscillation pattern of reactor antineutrinos over a 53 km baseline. While JUNO's

NMO sensitivity primarily comes from reactor neutrinos, atmospheric neutrino oscillations provide complementary sensitivity via matter effects and can enhance the overall performance in a joint analysis. The construction of the detector has been completed, and JUNO has already started physics data taking since August 2025. Detecting atmospheric neutrinos in a liquid scintillator detector poses several challenges, such as the reconstruction of complex event topologies and the separation of interaction channels. Advanced machine learning methods, in particular deep-learning based reconstruction techniques, offer promising solutions to address these difficulties. This talk will present recent progress in using such methods to reconstruct the energy, direction, and vertex of atmospheric neutrino events, as well as their performance in particle identification from Monte Carlo studies, highlighting both the challenges and the advantages of these innovative approaches.

T 7.3 Mon 16:45 KH 00.024

**Particle Identification in OSIRIS using Deep Learning** — •MARTIN KANDLEN, ELISABETH NEUERBURG, ACHIM STAHL and CHRISTOPHER WIEBUSCH — RWTH Aachen

In August 2025, the filling of the 20-kton liquid scintillator based Jiangmen Underground Neutrino Observatory (JUNO) was finished. The radiopurity of the liquid scintillator (LS) was monitored by the Online Scintillator Internal Radioactivity Investigation System (OSIRIS). OSIRIS has a cylindrical acrylic vessel for 20-ton batches of LS observed by 64 20" PMTs. The Uranium and Thorium impurities are measured via Bismuth-Polonium coincidence decay signals. I use attention-based deep learning methods for particle identification, where the input consists of the scintillation time profile. Simulation-data-mismatches are overcome by domain adaptation; the model is trained using both simulated and real detector data. In this talk, I present the methodology and performance of the classification.

T 7.4 Mon 17:00 KH 00.024

**Self-Supervised Pretraining of HPGe Waveforms for Pulse-Shape Discrimination for LEGEND** — •NIKO LAY<sup>1</sup>, CHRISTOPH VOGL<sup>1</sup>, TOMMASO COMELLATO<sup>1</sup>, KONSTANTIN GUSEV<sup>1</sup>, BRENNAN HACKETT<sup>2</sup>, BARAN HASHEMI<sup>1</sup>, LUKAS HEINRICH<sup>1</sup>, PATRICK KRAUSE<sup>1</sup>, ANDREAS LEONHARDT<sup>1</sup>, BÉLA MAJOROVITS<sup>2</sup>, MORITZ NEUBERGER<sup>1</sup>, NADEZDA RUMYANTSEVA<sup>1</sup>, MARIO SCHWARZ<sup>1</sup>, MICHAEL WILLERS<sup>1</sup>, and STEFAN SCHÖNERT<sup>1</sup> — <sup>1</sup>Technical University of Munich, Garching, Germany — <sup>2</sup>Max Planck Institute for Physics, Garching, Germany

LEGEND searches for  $(0\nu\beta\beta)$ -decay using HPGe detectors enriched in  $^{76}\text{Ge}$  and operated in instrumented LAr. For LEGEND-1000, underground-sourced Ar, depleted in  $^{42}\text{Ar}$ , constitutes the baseline choice. In the event that such argon is unavailable, a well-established and experimentally validated mitigation strategy is under preparation. Using HPGe detectors operated in  $^{42}\text{Ar}$ -enriched LAr at the SCARF test facility at TUM, we compare three self-supervised pretraining objectives: a transformer-based autoencoder, an autoregressive objective, and masked contrastive modeling. We finetune the pretrained models to classify signal-proxy vs. background, and bulk vs. surface interaction. The resulting pretrained backbones provide a basis for future likelihood-amortization and simulation-based inference workflows, while this talk focuses on their impact on these two PSD tasks. We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS), through the Sonderforschungsbereich SFB 1258, and by TUM MDSI Seed Funds.

T 7.5 Mon 17:15 KH 00.024

**ML-based LAr classification in LEGEND-200** — •JONAS SCHLEGEL and CHRISTOPH WIESINGER for the LEGEND-Collaboration — Max-Planck-Institut für Kernphysik, Germany

LEGEND-200 uses the scintillation properties of liquid argon (LAr) to suppress backgrounds in the search for neutrinoless double beta decay of  $^{76}\text{Ge}$ . The LAr is instrumented with wavelength-shifting fibers coupled to arrays of silicon photomultipliers. The current veto implementation relies on a global threshold and is limited by random coincidences, as it does not exploit spatial information. We

implement a machine-learning (ML) based topology-aware LAr veto that combines the photoelectron pattern with the relative angular position of the triggering high-purity germanium detector. The network is trained on samples of true and random coincidences and outputs an event-by-event veto probability. This implementation achieves improved background discrimination and serves as a proof-of-concept for further improvements, including timing information and alternative neural network architectures.

T 7.6 Mon 17:30 KH 00.024

**Application of FiLM Neural Networks for  $\pi/K$  Separation in the PANDA Barrel DIRC** — •DANIEL MARKHOFF<sup>1,2</sup>, ROMAN DZHYGADLO<sup>2</sup>, JOCHEN SCHWIENING<sup>2</sup>, and YANNIC WOLF<sup>2,3</sup> — <sup>1</sup>University of Edinburgh, Edinburgh, United Kingdom — <sup>2</sup>GSi Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>3</sup>Goethe-Universität Frankfurt, Frankfurt, Germany

Machine learning techniques were investigated as an alternative approach to PID in the PANDA Barrel DIRC at FAIR. FiLM neural-network models were trained on simulated Geant4 photon-hit patterns and achieved  $>2\sigma$   $\pi/K$  separation at 3.5 GeV/c. The models provide a significant reduction in computation time compared to the conventional time-based imaging reconstruction, while retaining competitive classification performance. These results indicate that ML-based PID has strong potential to complement or accelerate traditional DIRC reconstruction methods.

T 7.7 Mon 17:45 KH 00.024

**LSTM Networks for Enhanced Signal Efficiency in the CRESST Experiment** — •PRAVEEN MURALI for the CRESST-Collaboration — Kirchhoff-Institut für Physik, Heidelberg, Germany

Cryogenic experiments, such as CRESST (Cryogenic Rare Event Search with Superconducting Thermometers), frequently encounter time-series pulses from recoil events that are corrupted by distorting artefacts. These artefacts mandate data quality cuts, resulting in a drop in desired signal efficiency. This talk will introduce an application of Long Short-Term Memory (LSTM) networks to solve this problem. More specifically, it will illustrate how LSTM networks can be used to accurately "resurrect" these previously discarded pulses. This method represents a significant opportunity to enhance both the overall signal efficiency and the data yield in these highly sensitive, low-background experiments. Moreover, this method's applicability extends beyond CRESST to encompass other experiments exhibiting similar pulse and noise characteristics.

T 7.8 Mon 18:00 KH 00.024

**Machine learning based Particle Identification in a Diffusion Cloud Chamber.** — •BENJAMIN ROSENDAHL, JASPER VON LEPEL, MARIO SCHWARZ, and STEFAN SCHÖNERT — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

We present a work on a diffusion cloud chamber, which establishes quasi-stationary alcohol vapor diffusion through air by a temperature gradient, generating a supersaturated layer (S) in which ions seed droplet formation. By measuring the vertical temperature profile  $T(y)$  and applying heat and diffusion equations as well as nucleation theory, we characterize local supersaturation and growth kinetics during vapor condensation on ions. Together with a camera setup, a U-Net based machine learning pipeline performs segmentation of particle tracks, followed by skeletonization and vectorisation. The live time setup enables joint thermodynamic and particle physics analyses: Mapping  $T(y)$  and  $S(y)$ , quantifying fluxes of charged particles by both cosmic and ambient radiation (e.g., muons, betas and alphas) calibrated by comparison to radioactive sources and identifying phenomena such as radon decay. Beyond measurement, the instrument functions as an exhibit with high educational value, translating otherwise abstract concepts into observable events. We acknowledge support from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2094 - 390783311 and through the Sonderforschungsbereich (Collaborative Research Center) SFB 1258 'Neutrinos and Dark Matter in Astro- and Particle Physics'.

## T 8: Flavour Physics I

Time: Monday 16:15–18:15

Location: KH 01.011

T 8.1 Mon 16:15 KH 01.011

**Sensitivity study on combined analysis of beyond the Standard Model contributions in  $B^0 \rightarrow D^* \tau^+ \nu_\tau$  decay.** — •MARCO COLONNA — TU Dortmund University

Semileptonic  $b \rightarrow c \ell \nu$  decays are excellent probe for testing Lepton Flavour Universality and New Physics effects. New Physics contributions are measured via their corresponding Wilson coefficients and in several fit configurations including different New Physics operators. A study of sensitivity of a combined measurement of Wilson coefficients using of  $B \rightarrow D^* \tau \nu$  decays in proton-proton

collision data collected by LHCb and electron-positron collision data from Belle II has been done, showing enhanced sensitivity from shared parameters between different datasets. We discuss the most recent progress in developing data reinterpretation techniques, as well as the prospects and challenges for direct measurements of New Physics in semileptonic decays at the collider experiments.



T 8.2 Mon 16:30 KH 01.011

**Search for  $B^- \rightarrow \Lambda_c^+ \bar{p} \ell^- \bar{\nu}_\ell$  at the Belle II experiment** — •VERENA MENDEL, TORBEN FERBER, PABLO GOLDENZWEIG, and RAYNETTE VAN TONDER — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

About 90% of the inclusive semileptonic  $B \rightarrow X_c \ell \nu$  branching fraction can be accounted for by summing the branching fractions of known exclusive  $B \rightarrow D^{(*)}(\pi) \ell \nu$  decays. Semileptonic  $B$  decays to charmed baryons may account for some of the remaining difference. These decays are poorly understood theoretically and may provide additional insight into the longstanding inclusive/exclusive puzzle in determinations of the CKM matrix element  $|V_{cb}|$ .

In this talk, we present the status of the first search for  $B^- \rightarrow \Lambda_c^+ \bar{p} \ell^- \bar{\nu}_\ell$ , which is the lightest final state containing charmed baryons and is expected to be the dominant individual baryonic mode. The analysis is conducted at the Belle II experiment, located at the SuperKEKB asymmetric  $e^+e^-$  collider. We employ a hadronic tagging approach, where the accompanying  $B$  meson in  $e^+e^- \rightarrow Y(4S) \rightarrow B^+B^-$  events is fully reconstructed via hadronic decay chains. The signal side is reconstructed in the electron and muon modes, with the  $\Lambda_c^+$  reconstructed in the decay channels  $\Lambda_c^+ \rightarrow pK^- \pi^+$  and  $\Lambda_c^+ \rightarrow pK_S^0$ .

T 8.3 Mon 16:45 KH 01.011

**Two-loop corrections to the penguin amplitude  $a_6$  in QCD factorization** — GUIDO BELL<sup>1</sup>, KEVIN BRUNE<sup>2</sup>, TOBIAS HUBER<sup>1</sup>, and •SANDRA KVEDARAITĖ<sup>1</sup> — <sup>1</sup>Universität Siegen, Siegen, Germany — <sup>2</sup>Johannes Gutenberg-Universität Mainz, Mainz, Germany

The QCD penguin amplitude plays a central role in understanding CP violation in non-leptonic  $B$ -meson decays. It arises from the loop-induced weak-interaction process  $b \rightarrow D \sum_{q=u,d,s} q \bar{q}$ , where  $D = d, s$ , and can be expressed in terms of the leading-power amplitude  $a_4$  and the higher-twist amplitude  $a_6$ . Even though  $a_6$  is power-suppressed in the heavy-quark limit, chiral enhancement makes it numerically comparable to  $a_4$ , making it relevant for branching ratios and CP-violating observables. While  $a_4$  is known to next-to-next-to-leading order,  $a_6$  is currently available only at next-to-leading order. In this talk, I will present recent progress towards the two-loop calculation of  $a_6$  in the QCD factorization approach to non-leptonic  $B$ -meson decays.

T 8.4 Mon 17:00 KH 01.011

**One-loop improved modelling of hadronic light-cone distributions amplitudes in HQET** — RICCARDO BARTOCCI<sup>1</sup>, PHILIPP BÖER<sup>2</sup>, MAX FERRÉ<sup>3</sup>, THORSTEN FELDMANN<sup>4</sup>, NICO GUBERNARI<sup>5</sup>, and •DANIEL VLADIMIROV<sup>4</sup> — <sup>1</sup>Institut für Theoretische Teilchenphysik, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — <sup>2</sup>CERN, Theoretical Physics Department, CH-1211 Geneva 23, Switzerland — <sup>3</sup>PRISMA+ Cluster of Excellence & Mainz Institute for Theoretical Physics, Johannes Gutenberg University, D-55099 Mainz, Germany — <sup>4</sup>Center for Particle Physics Siegen, Universität Siegen, 57068 Siegen, Germany — <sup>5</sup>Helmholtz-Institut für Strahlen- und Kernphysik (Theorie) and Bethe Center for Theoretical Physics, Universität Bonn, 53115 Bonn, Germany

Light-cone distribution amplitudes (LCDAs) parametrize the relevant hadronic information in factorization-based predictions for exclusive reactions with large energy/momentum transfer. In this talk we focus on the LCDAs of heavy hadrons containing one heavy  $b$ -quark in the framework of heavy-quark effective theory (HQET). We explain how theoretical information about the so-called “radiative tail” in fixed-order perturbation theory can be consistently implemented in the construction of models or generic parametrizations of the LCDAs. As a specific example, we apply our approach to a generalized 3-particle LCDA of the  $B$ -meson, where the light quark and gluon field are separated along *opposite* light-cone directions, and briefly discuss the phenomenological relevance for rare exclusive  $B$ -meson decays.

T 8.5 Mon 17:15 KH 01.011

**Measurement of the Differential Branching Ratio, Lepton Angular Distribution and Determination of the CKM Matrix Element  $|V_{cb}|$  in Inclusive  $B \rightarrow X_c \ell \nu$  Semileptonic Decays using Belle II Data** — •RAJESHWARI ROY, FLORIAN BERNLOCHNER, MARKUS PRIM, and MUNIRA KHAN — Physikalisches Institut der Rheinische Friedrich-Wilhelms-Universität Bonn

We present a measurement of the differential branching ratio and lepton angu-

lar distribution in inclusive semileptonic  $B \rightarrow X_c \ell \nu$  decays using data collected with the Belle II detector corresponding to an integrated luminosity of  $365 \text{ fb}^{-1}$ , recorded at the  $Y(4S)$  resonance. Signal candidates ( $b \rightarrow c \ell \bar{\nu}_\ell$ ) are selected using a tag-side full-event interpretation, enabling precise reconstruction of the kinematics in the inclusive decay. The differential branching ratios as functions of the lepton momentum, momentum transfer  $q^2$ , and lepton helicity angle  $\cos \theta_\ell$  are calculated incorporating efficiency corrections and including a comprehensive evaluation of systematic uncertainties using the SysVAR framework, which provides a consistent treatment of arbitrary correlations arising from systematic effects affecting shapes in simultaneous template fits. A global fit to the measured spectra within the HQE formalism yields an updated determination of the Cabibbo-Kobayashi-Maskawa matrix element  $|V_{cb}|$ , contributing to resolving the difference between inclusive and exclusive determinations of  $|V_{cb}|$ .

T 8.6 Mon 17:30 KH 01.011

**Search for  $B \rightarrow \Lambda_c p \ell \nu$  decays at Belle II** — •TIM MÜLLER, MARKUS PRIM, VALERIO BERTACCHI, and FLORIAN BERNLOCHNER — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The branching fraction of the inclusive semileptonic decays  $B \rightarrow X_c \ell \nu$  is around 10% and is experimentally and theoretically well understood. On the other hand, the exclusive semileptonic decays of the  $B$ -meson add up to only 9% of the branching ratio. This gap might originate from baryonic semileptonic decays such as  $B \rightarrow \Lambda_c p \ell \nu$ , which have not been directly measured yet. We aim to solve this gap by further investigating this decay and determining its absolute branching ratio.

To achieve this, a tag-side full-event interpretation is performed by reconstructing the tag  $B$  meson in both hadronic and semileptonic decay channels to maximize the available statistics. The SysVar framework is then being used to evaluate systematic uncertainties for template fitting via pyhf. In this talk we present the motivation, analysis strategy and preliminary results of this ongoing analysis.

T 8.7 Mon 17:45 KH 01.011

**An effective hadronic field theory for B-meson decays at high recoil** — •JAIME DEL PALACIO LIROLA, THORSTEN FELDMANN, and JACK JENKINS — University of Siegen

We construct an effective hadronic Lagrangian for heavy-meson decays into energetic pseudo-Goldstone bosons of chiral symmetry breaking, by exploring the interplay between two already existing Effective Field Theory frameworks: Heavy Hadron Chiral Perturbation Theory, and Soft-Collinear Effective Theory (SCET). In the new theory, the dynamical degrees of freedom are given by quasi-static heavy meson fields coupled to soft and collinear pions, kaons and  $\eta$  mesons. In this talk we focus on the matching of external heavy-to-light currents in SCET onto effective operators in the hadronic Lagrangian. From our result, we calculate the 1-loop corrections for the external current, which determines the non-analytic dependence on the light meson mass, known as “chiral logarithms”. This information is needed to perform the chiral extrapolation in lattice-QCD data, and to estimate  $SU(3)$  breaking effects in heavy-to-light form factors, both at large recoil (low  $q^2$ ).

T 8.8 Mon 18:00 KH 01.011

**QCDF amplitude estimates for  $B \rightarrow V_L V_L$  decays using a data-driven approach** — •ANSHIKA BANSAL<sup>1</sup>, ARITRA BISWAS<sup>1</sup>, TOBIAS HUBER<sup>1</sup>, JOAQUIM MATIAS<sup>2</sup>, and GILBERTO TETLALMATZI-XOLOCOTZI<sup>1</sup> — <sup>1</sup>Theoretical Particle Physics, Center for Particle Physics Siegen, University of Siegen — <sup>2</sup>Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Campus UAB, 08193 Bellaterra (Barcelona)

QCD factorisation (QCDF) is one of the main theoretical frameworks to compute the amplitudes of non-leptonic decays of  $B$ -mesons. However, these calculations are polluted by infrared divergences arising, for example, from the weak annihilation topologies. These effects cannot be computed using first-principle calculations and can only be parametrised, which leads to sizable theoretical uncertainties. In this talk, I will discuss a data-driven approach to estimate QCDF amplitudes for  $B$ -meson decaying to two charmless vector mesons. This is done by exploiting the relations between QCDF amplitudes and the  $SU(3)$  invariant amplitudes. One key aspect of this analysis is the introduction of  $SU(3)$  breaking effects.

## T 9: Silicon Detectors I

Time: Monday 16:15–17:45

Location: KH 01.012

T 9.1 Mon 16:15 KH 01.012

**Particle Identification Based on the Time-over-Threshold with MuPix11 Sensors** — •EFFROSINI ZACHOU for the HVMAPS HD-Collaboration — Physikalisches Institut, Universität Heidelberg, Germany

The High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) extend the monolithic design concept by embedding the readout electronics in a deep n-well, enabling high voltage operation and fast charge collection via drift. The MuPix11 is a HV-MAPS chip with a pixel size of  $80 \times 80 \mu\text{m}^2$  that can be thinned

to 50  $\mu\text{m}$ , offering low material budget and precise spatial and time resolution.

The analogue pixel signal is digitised in the periphery, producing leading- and trailing-edge timing information from which the Time-over-Threshold (ToT) is computed. Since charged particles deposit different amounts of energy depending on their type and momentum, the ToT provides a useful proxy for measuring energy deposition and distinguishing different particles.

This work presents preliminary results from testbeam campaigns conducted at the Paul Scherrer Institute with the goal of systematically investigating the dependence of the ToT response on particle type and momentum. The measurements were performed with a setup consisting of four layers, each composed of four MuPix11 sensors mounted on a single printed circuit board. By reconstructing particle trajectories across the sensor planes, hits are associated with individual particles, enabling a track-based analysis of the ToT response.

T 9.2 Mon 16:30 KH 01.012

**Noise Analysis in the MuPix11 Sensor for the Mu3e Experiment** — •ANTONIO KONTPOPOULOS, HEIKO AUGUSTIN, and ANDRE SCHÖNING for the Mu3e-Collaboration — Physikalisches Institut Heidelberg

The Mu3e experiment searches for the charged-lepton-flavour-violating decay  $\mu^+ \rightarrow e^+ e^- e^+$  with an ultimate single-event sensitivity on the BR of  $10^{-16}$ , imposing stringent requirements on the noise performance of its ultra-low-mass vertex detector. The MuPix11, a high-voltage monolithic active pixel sensor (HV-MAPS), has been observed to exhibit spatially fixed noise features, necessitating a detailed characterisation of its noise behaviour.

In this contribution, a systematic noise study of MuPix11 is presented, based on cosmic data from the Mu3e vertex detector and quad-module measurements conducted at the Physics Institute in Heidelberg and the Paul Scherrer Institute. Noise characterisation is performed using a frequency-domain analysis to identify spectral features and coherent noise sources. A dedicated reconstruction framework is used to extract per-pixel noise rates, temporal correlations, and spatial noise maps.

First results reveal the dominant noise contributions under varying operating conditions and demonstrate the suitability of the developed methods for supporting sensor optimisation and the qualification of MuPix11 for integration into the Mu3e detector.

T 9.3 Mon 16:45 KH 01.012

**An overview of the European XFEL's bespoke DSSC DEPFET single module detector characteristics and integration** — •MINA MOHEBBI<sup>1,2</sup>, ERIKA GARUTTI<sup>2</sup>, and MONICA TURCATO<sup>1</sup> — <sup>1</sup>European XFEL, Schenefeld, Germany — <sup>2</sup>University of Hamburg, Hamburg, Germany

The unique beam properties of the European XFEL, including its high brilliance and pulse structure, impose stringent requirements on X-ray imaging detectors in terms of dynamic range, signal-to-noise ratio, and readout speed. The DEPFET Sensor with Signal Compression (DSSC) detector, developed by an international consortium together with the European XFEL, addresses these challenges for soft X-ray detection in the 0.5–6 keV range. With a sensitive area of  $241 \times 251 \text{ mm}^2$ , the DSSC enables single-photon sensitivity while providing a dynamic range of several thousand photons at frame rates up to 4.5 MHz. Although the full 1-megapixel DSSC system demonstrates excellent performance, its extensive and complex infrastructure limits portability and broader applicability. To overcome these constraints, a compact single-ladder system, the DSSCsm, has been developed. It features a  $128 \times 512$  pixel sensitive area and incorporates a thermoelectric cooling design that removes the need for bulky cryogenic components. The DSSCsm preserves the dynamic range and fast readout capabilities of the full system while significantly reducing size, weight, and support requirements. This makes it well suited for experiments requiring an active area of  $125 \times 30 \text{ mm}^2$ . This talk will present the DSSCsm design, operating infrastructure, and characterization and calibration techniques.

T 9.4 Mon 17:00 KH 01.012

**Assembly and Characterization of the TRISTAN Detector for the KATRIN Experiment** — •CHRISTIAN FORSTNER for the KATRIN-Collaboration — TUM School of Natural Sciences - Physics Department, Garching, Germany  
Sterile neutrinos, a minimal extension to the Standard Model of particle physics, are a promising dark matter candidate if their mass is in the keV-range. Following the completion of its neutrino mass measurement campaign, the Karlsruhe Tritium Neutrino (KATRIN) experiment will be equipped with a novel silicon drift detector array, the TRISTAN detector, to search for a keV-scale sterile neutrino signature in the tritium  $\beta$ -decay spectrum.  
In this work, we report on the assembly of the TRISTAN detector, which consists of nine TRISTAN detector modules. The talk covers the module testing procedure as well as the characterization using photon and electron sources.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 9.5 Mon 17:15 KH 01.012

**The mechanical rotation system of the P2 tracking detector** — •DHANUSHKA BANDARA for the P2-Collaboration — Institute of Nuclear Physics, Johannes Gutenberg University of Mainz, Johann-Joachim-Becher-Weg 45, 55128 Mainz, Germany.

The P2 experiment will measure the weak mixing angle at low-momentum with unprecedented precision, using the parity violating asymmetry in electron-proton scattering. The experiment will take place at the Mainz Energy-Recovering Superconducting Accelerator (MESA), currently in the advanced stage of construction at Johannes Gutenberg University of Mainz.

A key component in the P2 experiment is the tracking detector, which measures the momentum transfer  $Q^2$  of the scattered electrons. To allow for full azimuthal coverage with a limited size detector, a mechanical system is designed to rotate the tracker modules around the beam axis. The system should be operable in vacuum, withstand the intense radiation and provide precise movement. A scaled model is being built to study and understand the mechanics and the limitations of the rotational system.

This talk gives an overview of the P2 experiment and tracking detector, with the focus on the requirements and challenges of designing the tracker rotation system and how they are addressed.

T 9.6 Mon 17:30 KH 01.012

**Mechanical, Thermal, and Electrical Design of the P2 Tracking Detector Modules** — •LUCAS SEBASTIAN BINN for the P2-Collaboration — Institute of Nuclear Physics, Johannes Gutenberg-University Mainz, Germany

The P2 Experiment at the new Mainz Energy-Recovering Superconducting Accelerator (MESA), which is currently under construction in Mainz, will measure the weak mixing angle  $\sin^2 \theta_W$  in elastic electron-proton scattering at low momentum transfer with unprecedented precision.

A key parameter for the analysis, the momentum transfer  $Q^2$ , and systematic effects, are measured by a low-mass tracking detector consisting of 4 identical modules arranged in two layers. Each module consists of two sensor planes, with silicon pixel sensors glued and wire-bonded on rigid-flex ladders, which are tensioned individually using a spring-loaded mechanism. A laminar flow of cool helium gas across the ladders provides the needed cooling of around 650 W per module. The sensors are read out using a radiation-hard ASIC (lpGBT) developed by CERN.

The mechanical, thermal, and electrical designs have been developed and are currently undergoing testing. For this purpose, dedicated prototypes and test stands for each area have been constructed.

This talk gives an overview of the P2 experiment tracking detector module design, covering the mechanical, thermal, and electrical aspects.

## T 10: Axions/ALPS I

Time: Monday 16:15–18:00

Location: KH 01.013

T 10.1 Mon 16:15 KH 01.013

**Search for the  $K^+ \rightarrow \pi^+ \pi^0 X$  decay** — •MARCO CEOLETTA — JGU Mainz (DE) + CERN (CH)

This analysis aims to search for the hypothetical decay channel  $K^+ \rightarrow \pi^+ \pi^0 X$ , where  $X$  is invisible and can be interpreted as an Axion-like particle (ALP, indicated as  $A$ ) or as a massless Dark Photon ( $a$ ), at the NA62 experiment (CERN). Obtaining a stringent upper limit on  $\text{BR}(K^+ \rightarrow \pi^+ \pi^0 X)$  is important for constraints on several BSM theories. In particular, for  $X = A$  the decay is sensitive to an axial-vector coupling of pseudo-scalar particles to quarks. A search on  $K^+ \rightarrow \pi^+ \pi^0 A$  therefore complements the extensive work already performed on the associated two-body decay  $K^+ \rightarrow \pi^+ A$ , that is sensitive only to the polar-

vector coupling current. A preliminary upper limit of the branching ratio to ALPs, as part of a feasibility study done in 2022, already outperformed the best previous limit using less than 20% of the available data. The presentation describes the analysis, the selection, and the background estimation and gives an outlook on the expected upper limits.

T 10.2 Mon 16:30 KH 01.013

**Search for axion-like particles with gluon couplings in  $B \rightarrow Ka, a \rightarrow \pi^+ \pi^- \pi^0$  at the Belle II experiment** — •KARLINA KRÖHNERT, PRIYANKA CHEEMA, and TORBEN FERBER — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Axion-like particles (ALPs) appear in different theoretical extensions to the Standard Model. This analysis targets ALPs within a mass range of 400 MeV to 1 GeV and with gluon couplings produced in hadronic B decays. A particularly interesting decay mode is  $a \rightarrow \pi^+ \pi^- \pi^0$  since, for ALP-gluon couplings within the reach of the Belle II sensitivity, it produces a long-lived ALP  $a$ .

Although large parts of the parameter space have been explored by beam dump experiments and former prompt searches by BaBar and Belle, the displaced signature of the ALP offers a promising possibility to significantly extend existing ALP-gluon coupling limits.

In this analysis we search for an ALP in  $a \rightarrow \pi^+ \pi^- \pi^0$  using  $B \rightarrow Ka$  decays at Belle II. We highlight how the displaced signature offers the possibility of significantly suppressing the background, but leads to unique challenges regarding the  $\pi^0$  reconstruction from displaced vertices.

This talk will show the status of this search and present sensitivity estimates based on the current Belle II data set.

T 10.3 Mon 16:45 KH 01.013

**Search for Higgs decays into long-lived Axion-Like Particles with the ATLAS Experiment** — •JANEK BOTH, VOLKER BÜSCHER, CHRISTIAN SCHMITT, and EMANUEL MEUSER — Johannes Gutenberg-Universität

Axion-Like Particles (ALPs) or more generally, pseudoscalars that are gauge singlets under the Standard Model gauge group, appear in many well-motivated extensions of the Standard Model. In scenarios where the ALP couples to the Higgs boson, collider searches can provide sensitivity to ALPs in the GeV range and thus offer a complementary approach to other experiments that mainly focus on lighter ALPs. Depending on the ALP lifetime, it might decay displaced from the primary vertex inside the calorimeters of the ATLAS detector. Such a decay leads to an exotic signature that clearly differs from promptly produced backgrounds, but also challenges conventional reconstruction and analysis methods.

In this talk, a search for Higgs boson decays into long-lived ALPs is presented. The analysis makes use of a graph neural network classifier that identifies ALP decays into photons within the ATLAS calorimeters. The analysis uses Run-3 data and a data driven background estimation. The search improves on the existing Run-2 analysis that focuses on promptly decaying ALPs.

T 10.4 Mon 17:00 KH 01.013

**Search for top quark decays to long-lived axion-like particles (ALPs) with ATLAS: ALP candidate reconstruction** — •FREDERIC FISCHER, MARTIN CHRISTIANSEN, LUCIA MASETTI, HENDRIK SMITMANN, JESSICA HÖFNER, and ANNIKA STEIN — Johannes Gutenberg-Universität Mainz, Institut für Physik

The Standard Model (SM), although it agrees with great precision with experimental measurements, is still insufficient to give answers to many fundamental questions. One prime example is the strong CP problem which axions could solve. Axions as well as the broader axion-like particles (ALPs) are introduced as electrically neutral scalar fields extending the SM to accommodate new physics. One way to approach ALPs is to parameterise ALP couplings to SM particles like top quarks. ALPs appear in flavour-changing exotic top decays where the top quark decays into an ALP and an up- or charm-quark. Within this decay mode, parts of the parameter space dictates ALPs to have lifetimes long enough to travel macroscopic distances before decaying. This search is dedicated to look for  $t\bar{t}$  events with one SM leptonically decaying top quark and one exotically decaying top quark. In this topology the focus is on ALP decays in the hadronic calorimeter at ATLAS with a centre-of-mass energy of  $\sqrt{s} = 13.6$  TeV. Being electrically neutral, they leave no signals in the ATLAS tracking system. Moreover, the ratio of signals in the electromagnetic calorimeter and hadronic calorimeter are used to suppress SM backgrounds. This talk presents the reconstruction strategy of the ALP candidate to be used in a search for long-lived ALPs from exotic top decays at ATLAS.

T 10.5 Mon 17:15 KH 01.013

**Search for Axion-Like Particles via Top Quark Decays with ATLAS: Statistical Methods** — •MARTIN CHRISTIANSEN, FREDERIC FISCHER, ANNIKA STEIN, JESSICA HÖFNER, HENDRIK SMITMANN, and LUCIA MASETTI — Johannes Gutenberg-Universität Mainz, Institut für Physik

A search for long-lived Axion-like particles (ALPs) originating from exotic top quark decays is performed using the ATLAS detector at a center-of-mass energy of  $\sqrt{s} = 13.6$  TeV. ALPs can be investigated by parameterizing their couplings to Standard Model (SM) particles. This analysis targets top-antitop events characterized by one top quark decaying leptonically and one decaying via a flavour-changing neutral current  $t \rightarrow a + u/c$ , where  $a$  denotes the ALP. Portions of the viable parameter space predict ALP lifetimes sufficiently long for macroscopic displacement prior to decay. Focusing on ALPs decaying within the ATLAS hadronic calorimeter, the ratio of energy deposits in the electromagnetic and hadronic calorimeters is utilized to mitigate SM backgrounds. Statistical methods play an important role in this context. The event topology is reconstructed based on  $\chi^2$  minimization combined with b-tagging information, and the resulting loglikelihood score becomes relevant also for cutflow optimization. In addition, a Boosted Decision Tree is trained on the background and signal model. With the help of this multivariate analysis technique, variables are identified that are highly discriminative yet statistically independent and that can be used for data-driven methods, further improving the sensitivity of the analysis.

T 10.6 Mon 17:30 KH 01.013

**Sensitivity of the FCC-ee to axion-like particles** — JULIETTE ALIMENA<sup>1</sup>, FREYA BLEKMAN<sup>1,2</sup>, JEREMI NIEDZIELA<sup>1</sup>, GIACOMO POLESSELLO<sup>3</sup>, •ANNA PRZYBYL<sup>1,2</sup>, and LOVISA RYGAARD<sup>1,2</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg — <sup>2</sup>Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — <sup>3</sup>INFN Sezione di Pavia, Via Bassi 6, 27100 Pavia, Italy

The electron-positron stage of the Future Circular Collider (FCC-ee) has incredible potential for particle physics. Not only does the clean collision environment at this stage allow for high-precision measurements, but it also allows for direct searches for new particles. The FCC-ee is preferred by the German particle physics community as the next flagship collider at CERN, and it is scheduled to operate with center-of-mass energies at the Z pole, the WW threshold, the ZH production maximum, and the  $t\bar{t}$  threshold.

Axion-like particles (ALPs) are pseudoscalars that appear in many extensions of the Standard Model of particle physics, and they could potentially explain the nature of dark matter. We study ALPs at the FCC-ee. This talk will present the sensitivity of the FCC-ee to ALPs at all planned center-of-mass energies.

T 10.7 Mon 17:45 KH 01.013

**Searching for ALPs in  $H \rightarrow 4K$  at FCC-ee** — JULIETTE ALIMENA<sup>1</sup>, •SARAH ALSHAMAILY<sup>2</sup>, SOFIA GIAPPICHINI<sup>2</sup>, JOHANNES HORNUNG<sup>2</sup>, MARKUS KLUTE<sup>2</sup>, and MATTEO PRESILLA<sup>2</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — <sup>2</sup>Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

This study investigates a rare Higgs decay at the Future Circular Collider (FCC-ee). The  $e^+e^-$  stage is investigated at a center-of-mass energy of 240 GeV, with an integrated luminosity of  $10.8 \text{ ab}^{-1}$ . Following the axion-like particle (ALP) effective theory framework of Bauer et al., which provides a model-independent description of light pseudoscalar particles that commonly arise in theories beyond the Standard Model, the processes explored are  $e^+e^- \rightarrow ZH$ , where the Higgs boson decays into a pair of ALPs that subsequently decay into pairs of charged kaons. FCC-ee is an excellent experimental environment for such a study due to the improved momentum resolution and clean environment compared to hadronic colliders. We explored the parameter space where ALPs are long-lived particles, where background can be almost fully eliminated by exploiting their displaced decay vertices, obtaining sensitivity contours and limits on the Higgs-ALP coupling.

## T 11: Gaseous Detectors I

Time: Monday 16:15–18:15

Location: KH 01.014

T 11.1 Mon 16:15 KH 01.014

**A Straw Tube Chamber Prototype** — •JULIA OKFEN, OLIVER KORTNER, SANDRA KORTNER, HUBERT KROHA, MAX LOHRMANN, NICK MEIER, GIORGIA PROTO, and JÖRG ZIMMERMANN — Max Planck Institute for Physics, Munich, Germany

The future  $e^+e^-$  collider provides a unique opportunity for precision measurements of the Higgs boson. The Higgs-strahlungs process enables the detection of Higgs bosons through the recoil momentum and thereby allows the determination of its total width in a model independent way. To achieve this, the precise momentum measurement of the Z-boson decay particles is crucial, requiring an accuracy at the level of 0.1% for  $p_T \approx 50 \text{ GeV}/c$ , commensurate with the narrow spread of the center-of-mass energy. As GEANT-4-based studies performed by

the Straw Tracker community reveal, a tracking system consisting of a combination of silicon and gaseous detectors achieves the best momentum resolution. The gaseous detector can be realized using a drift chamber, however, a straw tube tracker also achieves a comparable performance, offering additional advantages, such as functioning as independent detector units. This contribution presents the development and production of a 1.5m-long Straw Tube chamber prototype. It also reports test beam results obtained at CERN's GIF++ facility, including key performance criteria such as efficiency and single tube resolution, which highlight the suitability of the Straw Tube tracker for an inner detector concept of a future  $e^+e^-$  collider experiment. In addition, important lessons learned are discussed that will be essential for designing and building the next 4m-long prototype.

T 11.2 Mon 16:30 KH 01.014

**Spatial Resolution of the SHiP Decay Spectrometer Straw Tracker with SAMPIC Read-Out** — •WEI-CHIEH LEE, CAREN HAGNER, DANIEL BICK, and WALTER SCHMIDT-PARZEFALL — Institute of Experimental Physics, University of Hamburg, Hamburg, Germany

SHiP (Search for Hidden Particles) is a general-purpose beam-dump experiment currently in preparation at CERN SPS. The experiment is designed to look for feebly interacting particles (FIPs) predicted by several theoretical models of the hidden sector. From dumping the high-intensity proton beam from the SPS onto a target, hidden particles would be potentially produced and fly towards a 50 m long decay volume, where they decay into SM particles to be detected. The Decay Spectrometer Straw Tracker (DSST) downstream, consisting of about 10,000 straw tubes of 4 m length and 2 cm diameter, plays the role of tracking the charged decay products and measuring their momentum for the reconstruction of the decay vertex and mass of the hidden particles. A high spatial resolution of the DSST is essential and requires a precise drift time measurement. To achieve this, the use of a waveform time-to-digital converter (WTDC) for read-out, such as SAMPIC with its high timing precision and capability to sample the leading edge of a signal, is currently under investigation.

For testing, a small DSST prototype was taken to DESY and CERN PS for test beams. The results will be presented in this talk. Furthermore, a plan to test a full-scale prototype of 4 m long straw tubes will be discussed.

T 11.3 Mon 16:45 KH 01.014

**Triplet assembly and certification of the new generation of RPC for the ATLAS phase-2 upgrade** — GIORGIA PROTO, •VIKTOR GRINIUSHIN, DAVID SCHULTEISS, OLIVER KORTNER, PAVEL MALY, and DANIEL SOYK — Max Planck Institute for Physics

A new generation of Resistive Plate Chambers have been developed for the ATLAS phase-2 upgrade in sight of the High-Luminosity phase of the Large Hadron Collider. These RPCs consist in three independent 1 mm gas gaps (singlets) equipped with a newly low-threshold Front-End electronics (1 fC), assembled in the same mechanical structure (triplet). The production of the phase-2 RPCs started and the detectors will undergo a certification test before the installation in the ATLAS cavern. The triplet assembly and the certification with cosmic rays of the BIS-type detectors is performed at the Max-Planck-Institute for Physics (MPI) in Munich. The architecture of the cosmic rays test stand has been built at MPI and has been studied in order to provide an efficient and robust structure to ensure an excellent quality control and study precisely the whole RPC performance needed to certify the detectors for the ATLAS experiment. In this presentation the assembly procedure, the architecture of the test stand and the first results on the performance of the Module 0 will be presented.

T 11.4 Mon 17:00 KH 01.014

**Influence of gap parameters in a triple-GEM detector** — ERIK EHLERT, KERSTIN HOEPFNER, •STELLA ISRAEL, DANIEL KLEE, MARKUS MERSCHMEYER, ALEXANDER SCHMIDT, and SHAWN ZALESKI — III. Physikalisches Institut A, RWTH Aachen University

Triple Gas Electron Multiplier (GEM) detectors are used in various experiments with different gap configurations, most notably 3/2/2/2 mm and 3/1/2/1 mm. While previous studies have shown that shorter drift gaps can improve the time resolution in different gas mixtures, a systematic comparison for the commonly used Ar/CO<sub>2</sub> (70/30) mixture is still missing. To investigate the influence on the signal, the gap spacings are varied in a dedicated 10×10 cm<sup>2</sup> test chamber.

This talk offers a first look into the comparison of the different gap configurations operated with the same electric fields. The aim is to clarify the role of the gap parameters in the signal formation of triple-GEM detectors.

T 11.5 Mon 17:15 KH 01.014

**Impact of environmental pressure and temperature variations on triple-GEM detector gas gain** — •ERIK EHLERT, KERSTIN HOEPFNER, FRANCESCO IVONE, GIOVANNI MOCELLIN, ALEXANDER SCHMIDT, and SHAWN ZALESKI — III. Physikalisches Institut A, RWTH Aachen University

The gas electron amplification factor of Gas Electron Multiplier (GEM) detectors depends on the mixture, the temperature and the pressure. While the gas mixture can be adjusted precisely, the gas temperature and pressure are influenced by the fluctuations of the environmental parameters. Correcting for such variations is therefore crucial to maintain stable operating conditions or to compare performance measured in different conditions. The talk presents the experimental setup which was used to study the dependence of triple-GEM gas gain on temperature and pressure. The results of the experimental study are shown alongside a results from simulation studies.

T 11.6 Mon 17:30 KH 01.014

**Characterisation of a multi-anode ACHINOS sensor for Spherical Proportional Counters** — •ITXASO BEATRIZ ANTOLÍN, KONSTANTINOS NIKOLOPOULOS, IOANNIS MANTHOS, ISABELLA OCEANO, and THEODOROS AVGITAS — University of Hamburg, Hamburg, Germany

The Spherical Proportional Counter (SPC) is a gaseous detector that combines intrinsic low capacitance with high gain, enabling energy detection thresholds down to the single ionization electron level. These features make the SPC a promising technology for searches for low-mass dark matter. In this talk the characterisation of a multi-anode ACHINOS sensor, consisting of 11 individually readout anodes, is presented. Moreover, the latest developments in SPC readout are discussed.

T 11.7 Mon 17:45 KH 01.014

**Research and Development of a micro-pixel capacitive sharing Micromegas detector** — •ESHITA KUMAR, OTMAR BIEBEL, VALERIO D'AMICO, RALF HERTENBERGER, NICK SCHNEIDER, LILLA SCHNEIDER, CHRYSOSTOMOS VALDERANIS, and FABIAN VOGEL — Ludwig Maximilians University, Munich

MICRO MESH Gaseous Structure (Micromegas) detectors are micro patterned gaseous detectors that have high rate capability due to the fast evacuation of positive ions and excellent spatial resolution due to a small scale readout strip pitch. However, large scale detectors need thousands of channels which leads to increased power consumption and significant heat generation, often requiring dedicated cooling systems. This talk explores a way to reduce the number of readout channels without compromising position measurement accuracy by encoding the precise position information of the particle's passage through the detector via capacitive sharing using multiple stacked layers of signal electrodes. A prototype of this detector was tested at CERN's SPS beam of 120 GeV muons and the results of the performance and efficiency of this detector will be presented. Comparison with the simulation results using ANSYS and Garfield++ will also be discussed.

T 11.8 Mon 18:00 KH 01.014

**Amplification properties of gaseous tetramethylsilane (TMS) for antineutrino-based nuclear safeguards** — •ADHITYA SEKHAR<sup>1</sup>, NICK THAMM<sup>2</sup>, SARAH FRIEDRICH<sup>1</sup>, ROBIN MENTEL<sup>1</sup>, STEFAN ROTH<sup>2</sup>, and YAN-JIE SCHNELLBACH<sup>1</sup> — <sup>1</sup>Technische Universität Darmstadt — <sup>2</sup>RWTH Aachen University

In recent years there has been growing interest in antineutrino-based nuclear safeguards for monitoring reactor operation and spent fuel containment through the low-MeV antineutrinos emitted in beta-decay of fission fragments. Following previous promising simulations, a prototype for a novel antineutrino detection concept utilising a liquid organic time projection chamber (LOr-TPC) is now being developed. This study presents the initial phase of this project, showcasing investigations into the amplification properties of gaseous tetramethylsilane (TMS).

NMR-grade liquid TMS was boiled and flushed through an experimental chamber using a simple gas circulation system, with the exhaust gas condensed and recollected for future repurification efforts. A first test was conducted using a single-wire proportional counter in a ~5mL cylindrical chamber and a <sup>55</sup>Fe source, with current amplification of up to three orders of magnitude observed at just under 4kV. Subsequently, a second test is being planned using a Thick Gaseous Electron Multiplier (THGEM). The results of these tests will be shown, along with comparisons made to previous measurements of amplification in other standard gases using the same setup.

## T 12: Silicon Detectors II

Time: Monday 16:15–18:15

Location: KH 01.022

T 12.1 Mon 16:15 KH 01.022

**Testing infrastructure for the quality control of ITk Pixelmodules** — •RUBEN FÖRSTER, JÖRN GROSSE-KNETTER, and ARNULF QUADT — II. Physikalisches Institut, Georg-August-Universität Göttingen

With the long shutdown of the Large Hadron Collider (LHC) and the subsequent upgrade to the High-Luminosity LHC (HL-LHC) starting soon, the ATLAS experiment will be undergoing extensive upgrades. A central element of this is

the new Inner Tracker (ITk), an all-Silicon detector designed to cope with the increased particle flux, radiation levels, and data rates expected at the HL-LHC.

One of the subdetectors is the ITk pixel detector, composed of roughly 8 000 pixel modules that are now in the critical phase of production. As part of the German production cluster, the University of Göttingen is responsible for many of the later production and quality control testing steps for several hundred of these modules.

The testing infrastructure in Göttingen, including setups, procedures, and software for electrical and thermal testing, gluing, and metrology, has been improved and upgraded. The experience gained during production has led to more streamlined workflows and an overall increase in achievable throughput.

A central aspect of this is a newly constructed radiation-compliant electrical test stand, designed for routine operation in a production environment. Together with clear procedures, training of laboratory staff and simplified operator interfaces, this infrastructure places Göttingen in a strong position for the remaining ITk pixel module production.

T 12.2 Mon 16:30 KH 01.022

**Electrical tests for the quality control of ITk Pixel modules** — RUBEN FÖRSTER, JÖRN GROSSE-KNETTER, •NIKLAS GRÜN, and ARNULF QUADT — II. Physikalisches Institut, Georg-August-Universität Göttingen

The Phase-II upgrade of the ATLAS experiment at the LHC includes a complete replacement of the current Inner Detector with the new all-Silicon Inner Tracker (ITk). The ITk is designed to operate at significantly higher luminosities, providing improved granularity, radiation hardness, and tracking performance for the HL-LHC environment. Its construction requires large-scale production, qualification, and integration of highly complex Silicon Strip and Pixel modules across several international sites.

The Pixel Detector modules feature a hybrid module design, meaning that the sensor is read out via frontend readout chips that are bump-bonded to the sensor. To secure high production standards and quality of the ITk Pixel modules, each of the Pixel modules faces multiple electrical QC check-ups between every major production step on top of non-electrical tests and metrology of the components.

In this contribution, work within the ITk Pixel module production chain is presented as carried out in Göttingen, which is one of the sites of the German production cluster. A focus will be placed on ensuring production quality, improving data-driven validation procedures, and contributing to the smooth operation of the module production workflow. In particular the electrical tests for the quality control of ITk Pixel modules are spotlighted.

T 12.3 Mon 16:45 KH 01.022

**Production and Quality Control of CMS Phase-2 Inner Tracker Pixel Modules** — •CHIN-CHIA KUO, MASSIMILIANO ANTONELLO, ERIKA GARUTTI, BIANCA RACITI, JÖRN SCHWANDT, and GEORG STEINBRÜCK — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

A quad module for the Phase-2 upgrade of the CMS Inner Tracker is a hybrid detector consisting of four ( $2 \times 2$ ) CMS readout chips manufactured in 65 nm CMOS technology (RD53B\_CMS) and a silicon pixel sensor. The sensor with  $100 \times 25 \mu\text{m}^2$  pixel size and  $150 \mu\text{m}$  thickness is coupled to the chips via fine-pitch flip-chip bump bonding. At the University of Hamburg, 500 quad modules for the CMS Tracker Endcap Pixel Detector will be assembled and qualified. Module production and quality control procedures are presented in this talk, including serial powering, threshold tuning, and data transmission tests of the readout chip, IV measurements for sensors, open bump bond identification, and thermal stress tests. The presentation will focus on grading criteria and the performance of pre-production modules.

T 12.4 Mon 17:00 KH 01.022

**Core column issue investigation on ATLAS ITk pixel detector modules in Siegen** — MARKUS CRISTINZIANI<sup>1</sup>, QADER DOROSTI<sup>1</sup>, OLIVIER FOX<sup>1</sup>, DANIEL GROTH<sup>1</sup>, •LUKE HAMMER<sup>1</sup>, STEFAN HEIDBRINK<sup>2</sup>, LASSE JÄDERBERG<sup>1</sup>, NILS KRENGEL<sup>1</sup>, LEONIE KRIPPENDORF<sup>1</sup>, DENISE MÜLLER<sup>1</sup>, JASON MÜLLER<sup>1</sup>, LINA REIFENBERG<sup>1</sup>, NOAH SIEGEMUND<sup>1</sup>, WALDEMAR STROH<sup>2</sup>, DARSHIL VAGADIYA<sup>1</sup>, WOLFGANG WALKOWIAK<sup>1</sup>, JENS WINTER<sup>2</sup>, MICHAEL ZIOLKOWSKI<sup>2</sup>, and ALESSIA ZUEV<sup>1</sup> — <sup>1</sup>Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — <sup>2</sup>Elektronikentwicklungslabor Physik, Universität Siegen

The High-Luminosity Large Hadron Collider (HL-LHC) upgrade will substantially increase the LHC's instantaneous luminosity, requiring a complete replacement of the ATLAS Inner Detector with the new all-silicon Inner Tracker (ITk). For the ITk pixel quad modules, a silicon sensor is connected to four front-end readout chips based on the ITkPix application-specific integrated circuit. During module production, characteristic inefficiencies in multiple columns of pixels, referred to as core column issues, were observed in ITkPix v1.1 and v2 quad modules. In this talk, results from dedicated investigations of these inefficiencies are presented. These studies in Siegen use and extend electrical testing tools developed by the collaboration. The observed response patterns are categorized and their impact on module performance is assessed. These investigations provide insight into the core column behavior observed during production and support quality assurance for reliable module operation in the future ATLAS ITk.

T 12.5 Mon 17:15 KH 01.022

**2S module assembly in Aachen for the CMS Phase-2 Outer Tracker upgrade** — MAX BECKERS<sup>2</sup>, CLARA EBISCH<sup>1</sup>, LUTZ FELD<sup>1</sup>, •NINA HÖFLICH<sup>2</sup>, KATJA KLEIN<sup>1</sup>, MARTIN LIPINSKI<sup>1</sup>, DANIEL LOUIS<sup>1</sup>, OLIVER POOTH<sup>2</sup>, VANESSA OPPENLÄNDER<sup>1</sup>, JOËLLE SAVELBERG<sup>1</sup>, MICHAEL WLOCHAL<sup>1</sup>, and WIOLETTA

WYSZKOWSKA<sup>2</sup> — <sup>1</sup>I. Physikalisches Institut B, RWTH Aachen University, D-52056 Aachen — <sup>2</sup>III. Physikalisches Institut B, RWTH Aachen University, D-52056 Aachen

In the context of the CMS Phase-2 upgrade, the complete Outer Tracker of the CMS detector will be replaced. The new Outer Tracker will contain two types of modules, 2S modules consisting of two silicon strip sensors and PS modules made from a silicon macro-pixel and a silicon strip sensor. In total, around 7600 2S and 6000 PS modules will be built and installed in the new outer tracker. These modules are currently under assembly in multiple assembly centers worldwide. At the Physics Institutes IB and IIIB at RWTH Aachen University, approximately 1000 2S modules will be assembled, with over 100 already completed. The module assembly consists of multiple gluing and wirebonding steps, which have to be performed with high precision. The assembly is accompanied by various QC measurements, especially module readout and sensor-sensor alignment tests, to ensure consistent module quality.

In this talk, the 2S module assembly at RWTH Aachen will be presented, including the current status and details on the different assembly steps.

T 12.6 Mon 17:30 KH 01.022

**2S module assembly progress and module test results for the CMS Phase-2 Tracker Upgrade** — •MAX BECKERS<sup>2</sup>, LUTZ FELD<sup>1</sup>, NINA HÖFLICH<sup>2</sup>, KATJA KLEIN<sup>1</sup>, MARTIN LIPINSKI<sup>1</sup>, VANESSA OPPENLÄNDER<sup>1</sup>, OLIVER POOTH<sup>2</sup>, and JOËLLE SAVELBERG<sup>1</sup> — <sup>1</sup>I. Physikalisches Institut B, RWTH Aachen University, D-52056 Aachen — <sup>2</sup>III. Physikalisches Institut B, RWTH Aachen University

For the CMS Phase-2 Outer Tracker upgrade, new silicon strip detector modules consisting of two silicon strip sensors, so-called 2S modules, are developed and produced. This process is distributed along multiple assembly centers worldwide.

RWTH Aachen University will build around 1000 2S modules. After each assembly step different QC measurements and tests are performed. Different kinds of specifications needs to be respected. The assembled modules are then shipped to DESY, where they are thermally cycled in the "Burn-in" setup. In addition, a multi module cold box is available in Aachen to perform thermal cycles for up to 4 modules.

With over 100 modules built in Aachen and shipped to DESY the assembly process is currently ongoing. As more and more modules become available, the QC and test results are continuously monitored and can be evaluated in relation to the overall statistical. These results can be used to implement a module grading concept.

This talk presents the current assembly progress of 2S modules at Aachen together with results from QC measurements, module tests and thermal cycling.

T 12.7 Mon 17:45 KH 01.022

**Petal Loading for the ITk Strip Endcap** — •MARIANA VIVAS ALBORNOZ — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The ATLAS detector will be upgraded for operation at the High Luminosity LHC. The upgrade of the detector includes the construction of a new all-silicon inner tracker (ITk) to effectively take data in an environment with increased pile-up and corresponding high occupancies. The ITk detector is composed of an outer silicon microstrip-based (strip) detector and an inner pixel detector. Both trackers are divided into a barrel region, around the interaction point, and two end-caps, extending into the forward regions. One strip endcap is being constructed at DESY. A strip endcap is composed of 192 petals holding 12 silicon module detectors in place. The assembly work for 96 petals is taking place at DESY. The silicon modules are loaded onto the petal cores via a multi-step procedure that requires careful handling and micrometer level precision. This contribution summarizes the steps and techniques involved in the loading task, and explains how precision during each step of the process is necessary for the overall functioning of the new ITk detector.

T 12.8 Mon 18:00 KH 01.022

**Segment Test on ATLAS ITk Strips End Cap** — •KONSTANTIN MAUER — Deutsches Elektronen-Synchrotron DESY, Hamburg

The upcoming High-Luminosity upgrade of the Large Hadron Collider (HL-LHC) will significantly increase its instantaneous luminosity. This will lead to a higher track density, a higher hit rate and an increased amount of radiation damage in the experiments. For this reason, the ATLAS experiment will be upgraded, and a new all-silicon inner tracking (ITk) detector has been designed, consisting of strip and pixel detector modules.

In the outer layers silicon strips modules are used and loaded onto local support structures. In the forward directions these are called petals. They are integrated into an End Cap (EC) mechanical structure at one of the two EC integration sites. After welding 16 petals to a cooling manifold, this segment will be fully powered and characterized using the final detector powering chain and readout devices.

With the production ramping up, petals are accumulating for fully populating the first segment. Thus, in summer 2026 the first segment test is scheduled. This talk presents ongoing preparations towards this milestone.

## T 13: Higgs Physics II

Time: Monday 16:15–18:15

Location: KH 02.013

T 13.1 Mon 16:15 KH 02.013

**Search for light pseudoscalar Higgs boson decays in the flavour-asymmetric  $\mu^+\mu^- c\bar{c}$  final state with the CMS detector** — KAI FABIAN ADAMOWICZ, DANYER PEREZ ADAN, LUTZ FELD, PHILIPP NATTLAND, and •KEITLIN SEJDARASI — 1. Physikalisches Institut B, RWTH Aachen

A search for exotic decays of the Standard Model (SM) Higgs boson into pairs of light pseudoscalar Higgs bosons  $a$  decaying in the flavour-asymmetric final state  $a \rightarrow \mu^+\mu^-$  and  $a \rightarrow c\bar{c}$  is presented. This channel exploits both the clean experimental signature provided by the excellent detector resolution for muons and the large branching fraction of the pseudoscalar decay into charm quarks, as predicted by the two-Higgs-doublet model extended by a singlet (2HDM+S). Pseudoscalar masses in the range 4–11 GeV are probed, corresponding to a kinematic regime where they exhibit a significant Lorentz boost. The resulting, highly collimated decay products lead to a distinctive topology: the dimuon invariant mass is used as the primary discriminating observable to extract any potential signal, while in the hadronic channel, the decay to charm quarks can be reconstructed using existing charm-jet identification techniques. In this talk, results obtained using the newly acquired Run 3 CMS data from 2024, at a center-of-mass energy of 13.6 TeV, are presented, aiming at improving the sensitivity through increased statistics. In addition, the performance and suitability of newly developed charm jet identification algorithms for Run 3 are investigated in the context of this search.

T 13.2 Mon 16:30 KH 02.013

**Search for light pseudoscalar bosons from Higgs boson decays in the four-kaon final state with the CMS detector** — NILS FALTERMANN<sup>1</sup>, JONAS FLOSSMANN<sup>1</sup>, •JOHANNES HORNING<sup>1</sup>, BENEDIKT MAIER<sup>2</sup>, and MARKUS KLUTE<sup>1</sup> — <sup>1</sup>Karlsruher Institut für Technologie, Karlsruhe, Germany — <sup>2</sup>Imperial College, London, United Kingdom

Since the discovery of the Higgs boson, extensive measurements of its properties have set upper limits on the branching ratio of its yet undetected decay modes. The branching ratio encompasses immediate decays into SM particles that are not detectable, as well as decays into BSM particles. This talk focuses on a search for Higgs boson decays into pairs of hypothetical pseudoscalar bosons  $a$ . These bosons can either be identified as pseudoscalar Axion-Like Particles (ALPs) or, more specifically, as additional Higgs Bosons, as suggested for example by the NMSSM. Specifically, the search strategy, focussing on the background estimation, and expected limits of an analysis targeting prompt decays  $H \rightarrow aa \rightarrow KKKK$  using data collected by the CMS detector during Run 2 of the LHC will be discussed.

T 13.3 Mon 16:45 KH 02.013

**Searches for rare Higgs boson decays to light hadronic resonances with CMS data** — KONSTANTINOS NIKOLOPOULOS, •MAHTAB JALAL VANDI, and ROBERT JAMES WARD — University of Hamburg, Hamburg, Germany

The current experimental constraints still allow for light, weakly coupled states in the Higgs sector. This motivates searches for rare Higgs boson decays such as  $H \rightarrow Za$ , where  $a$  is a hadronically decaying resonance with a mass between 0.5 and 3.5 GeV. While this mass range has been explored in previous searches, it remains experimentally challenging, and further investigation can benefit from improved experimental techniques. Studies on the development of such techniques and on the estimation of the expected sensitivity will be presented.

T 13.4 Mon 17:00 KH 02.013

**Interference effects of Beyond Standard Model Higgs to ditau production on Z pole** — •FRANK NOWAK, LUKA VOMBERG, PHILIP BECHTLE, CHRISTIAN GREFE, and KLAUS DESCH — Universität Bonn

The Higgs sector is still one of the most interesting areas of the Standard Model (SM), even more than 13 years after the discovery of the Higgs boson. There is a wide variety of motivation for expanded Higgs sectors in beyond-the-SM theories (BSM), both from theoretical considerations and from experimental hints. A particularly attractive addition would involve an additional light Higgs-boson below the mass of the SM-like Higgs boson at 125 GeV. It would be even more theoretically attractive to consider CP even  $H$ , CP odd  $A$  and mixed CP states  $\phi$  for this particle.

For this study the search for these BSM Higgs bosons in the decay of  $H/A \rightarrow \tau\tau$  covers the particularly challenging mass range around the  $Z$  peak. In this case, interference of the BSM Higgs boson production with  $Z$  boson production cannot be excluded for some contributions to the production. The possible inter-

ference effects of new particles are explored in truth level Monte Carlo samples in the  $pp \rightarrow \tau\tau + X$  channel. A special emphasis of this study is the influence of the CP-state of the new bosons on the interference between the BSM Higgs and  $Z$ .

T 13.5 Mon 17:15 KH 02.013

**The Importance of Being Kite** — •KARIM ELYAOUTI<sup>1</sup>, RAFAEL BOTO<sup>1</sup>, DUARTE FONTES<sup>1</sup>, MARIA GONÇALVES<sup>1</sup>, MILADA MARGARETE MÜHLEITNER<sup>1</sup>, JORGE C. ROMÃO<sup>3</sup>, RUI SANTOS<sup>2</sup>, and JOÃO P. SILVA<sup>3</sup> — <sup>1</sup>Karlsruher Institut für Technologie — <sup>2</sup>Universidade de Lisboa, Campo Grande — <sup>3</sup>Departamento de Física and CFTP, Instituto Superior Técnico, Universidade de Lisboa

The Complex Two-Higgs-Doublet Model (C2HDM) features an explicitly CP-violating scalar sector, making the electron electric dipole moment (eEDM) one of the most stringent probes of the model. The current limit of  $4.1 \times 10^{-30}$  e.cm already places strong constraints on CP-violating Higgs interactions, and future sensitivities are expected to improve by several orders of magnitude. This talk presents an updated analysis of the C2HDM parameter space under all current theoretical and experimental constraints. The calculation of the eEDM includes the contribution from the charm quark, which can be relevant in certain regions of the parameter space. Machine-learning techniques are employed to explore parameter regions that are difficult to access with traditional search strategies.

T 13.6 Mon 17:30 KH 02.013

**The cS2HDM as a unified framework for dark matter and electroweak baryogenesis** — THOMAS BIEKÖTTER<sup>1</sup>, •PEDRO GABRIEL<sup>2,3</sup>, MILADA MARGARETE MÜHLEITNER<sup>2</sup>, and RUI SANTOS<sup>3,4</sup> — <sup>1</sup>Instituto de Física Teórica UAM/CSIC, Madrid, Spain — <sup>2</sup>Institute for Theoretical Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>3</sup>Centro de Física Teórica e Computacional, Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal — <sup>4</sup>ISEL - Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Lisboa, Portugal

The discovery of the Higgs boson at the LHC confirms the Standard Model's (SM) mechanism for electroweak symmetry breaking, yet the SM fails to address key cosmological phenomena such as dark matter (DM) and the matter-antimatter asymmetry. Higgs-portal models with extended scalar sectors offer promising frameworks to bridge this gap. Among them, models incorporating a complex singlet scalar field can host pseudo-Nambu-Goldstone (pNG) DM, naturally suppressing direct-detection signals and making them ideal candidates for collider-based DM searches. However, minimal pNG DM models lack ingredients for electroweak baryogenesis. To overcome this, we look at the CP-violating singlet-extended two Higgs doublet model (cS2HDM) which contains both a pNG DM candidate and several sources of CP-violation and could serve as a benchmark for upcoming LHC searches

T 13.7 Mon 17:45 KH 02.013

**Machine learning in the 2HDM2S model for dark matter** — •RAFAEL BOTO<sup>1</sup>, TIAGO REBELO<sup>2</sup>, JORGE ROMÃO<sup>2</sup>, and JOÃO SILVA<sup>2</sup> — <sup>1</sup>Institute for Theoretical Physics, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — <sup>2</sup>CFTP, Instituto Superior Técnico, Universidade de Lisboa, Av Rovisco Pais, 1, P-1049-001 Lisboa, Portugal

In this work, we build a two real scalar singlet extension of the two Higgs doublet model to answer the dark matter problem. We study the vacuum structure, the bounded from below conditions, the restrictions from the oblique parameters  $S, T$  and  $U$ , as well as the unitarity constraints. We submit the model to collider and Dark Matter experimental constraints and explore its allowed parameter space. We compare randomly populated simulations, simulations starting near the alignment limit, and a Machine Learning based exploration to find viable solutions.

T 13.8 Mon 18:00 KH 02.013

**Dark Matter Aspects of the Composite Higgs Models** — •YU CHEN — Universität Würzburg

The nature of Dark Matter (DM) and the origin of small neutrino masses remain open questions in particle physics, motivating extensions of the Standard Model. In this talk, I explore Composite Higgs (CH) models that can simultaneously address both issues. As a concrete example, I will present a CH model based on the coset  $SU(6)/Sp(6)$ , which naturally provides potential DM candidates as a composite pseudo-Nambu Goldstone boson. I will discuss the phenomenological implications, focusing on explaining the DM relic density within this framework.

## T 14: Data, AI, Computing, Electronics II

Time: Monday 16:15–18:15

Location: KH 02.014

T 14.1 Mon 16:15 KH 02.014

**Towards a sustainable ET Computing Center** — •STEFAN KRISCHER and ACHIM STAHL — RWTH Aachen University, III. Physikalisches Institut B

For the Einstein Telescope, a dedicated computing center will be required to support detector control, low-latency data processing, and parts of the offline analysis. In preparation, the infrastructure is being explored with a strong focus on sustainability. To assess feasibility, a prototype computing facility is being developed with its own renewable energy system capable of supplying 100% locally generated power. In this setup, computing workloads and hardware adapt their power consumption to the instantaneous energy availability, reducing the required energy-storage capacity. We present the concept and initial insights from the prototype development as a basis for a more sustainable computing center for the Einstein Telescope.

T 14.2 Mon 16:30 KH 02.014

**Recent Developments in HEP Computing in Karlsruhe** — GIACOMO DE PIETRO, PATRICK ECKER, NILS FALTERMANN, EMELIE FUCHS, JOHANNES GAESSLER, MANUEL GIFFELS, ARTUR GOTTMANN, JAN KIESELER, MAX KÜHN, YANNIS KLUUGL, GÜNTER QUAST, RAQUEL QUISHPE, MATTHIAS SCHNEPF, NIKITA SHADSKIY, LARS SOWA, •TIM VOIGTLAENDER, and RALF FLORIAN VON CUBE — Karlsruhe Institute of Technology (KIT)

The computing contribution of the Karlsruhe Institute of Technology (KIT) to the WLCG pledge is provided through the Tier-1 center GridKa, together with opportunistic resources from the HoreKa HPC and the local Tier-3 cluster. These resources, together with the development activities of the Karlsruhe computing group, form a tightly integrated component that addresses a broad spectrum of high-energy physics (HEP) workloads and operational needs.

This talk outlines the current status and ongoing developments in HEP computing activities at KIT. This includes the status of the GPU integration into the WLCG from HoreKa and the Karlsruhe Tier-3 cluster, highlighting the first official workflows by LHC experiments on these systems. These early tests provide a baseline for future large-scale GPU-accelerated workflows. In addition, the ongoing effort to sustainably use legacy hardware during periods of renewable-energy surplus is presented as part of a broader move towards an energy-adaptive computing strategy. Finally, planned storage and compute extensions at GridKa Tier-1 center are presented, aimed at meeting future requirements and ensuring compliance with pledged resources.

T 14.3 Mon 16:45 KH 02.014

**Integration of NHR resources into the ATLAS computing workflow in Freiburg** — •DIRK SAMMEL, MICHAEL BÖHLER, and MARKUS SCHUMACHER — Albert-Ludwigs-Universität Freiburg

At many sites of the Worldwide LHC Computing Grid (WLCG), high-performance computing (HPC) resources are already integrated (or soon will be) into the computing workflows of various experiments. The WLCG Tier-2 cluster ATLAS-BFG in Freiburg has been extended by incorporating resources from the NHR cluster HoreKa at KIT.

To integrate these computing resources into the Freiburg Tier-2 cluster in a transparent and efficient manner, a container-based approach was adopted using the meta-scheduler COBald/TARDIS. TARDIS launches so-called drones on the HPC system, providing additional compute capacity to the Tier-2 cluster. To differentiate between these augmented resources and the WLCG resources in Freiburg, the AUDITOR accounting ecosystem is used.

This presentation provides an overview of the current status and initial experiences with integrating HPC resources into the Freiburg Tier-2 cluster ATLAS-BFG.

T 14.4 Mon 17:00 KH 02.014

**AUDITOR: Tackling HL-LHC accounting challenges and estimating environmental impact of jobs** — •RAGHUVAR VIJAYAKUMAR, MICHAEL BÖHLER, DIRK SAMMEL, and MARKUS SCHUMACHER — Universität Freiburg

Distributed computing infrastructures are shared by multiple research communities, particularly within High Energy Physics (HEP), where precise and transparent resource accounting is critical. To meet these demands, we developed AUDITOR (AccoUnting Datahandling Toolbox for Opportunistic Resources), a flexible, modular, and extensible accounting ecosystem designed for heterogeneous computing clusters.

AUDITOR captures, processes, and analyzes usage metrics through specialized collectors from HTCondor, Kubernetes, and Slurm batch systems, storing all data in a PostgreSQL database. Its plugin-based architecture allows integration with external tools with Rust and Python clients. Existing plugins include the APEL plugin, which publishes accounting data to the European Grid Initiative (EGI).

Recent developments include a Role-Based Access Control system and an archival subsystem that now periodically exports historical data to Parquet files.

The new utilization report plugin provides summaries of job counts, HEP-Score performance, power consumption, and estimated CO<sub>2</sub> footprint. Looking ahead, our accounting system is being designed to integrate environmental attributes directly into job-level analytics to measure the carbon impact of computing workloads. In this talk, we will present our new features and highlight how to meet the present and future challenges of HL-LHC accounting.

T 14.5 Mon 17:15 KH 02.014

**Theia - A General Photon Propagation Framework for GPUs** — •TOBIAS KERSCHER — Technical University of Munich

In neutrino telescopes, understanding how light produced by neutrino interactions via Cherenkov radiation propagates through the detector volume is essential. Due to its complexity this is usually done using Monte Carlo simulations. Using popular tools like GEANT4, however, this often turns out to be the most time consuming step in the overall simulation pipeline and thus becomes a bottleneck. Theia aims to solve this by not only running on GPUs, but also utilizing hardware accelerated ray tracing for fast and accurate intersections with the detector geometry. Since it uses an open standard GPU API, it is not limited to CUDA and NVIDIA hardware. Besides the classical photon tracking simulation, it can also solve for the radiance field producing the underlying expected signal distribution the tracking implicitly samples from. Theia was designed with expendability in mind, making minimal assumptions about the simulated environment. This allows it to be used in various scenarios not limited to neutrino telescopes.

T 14.6 Mon 17:30 KH 02.014

**Background Jobs for Efficient Resource Utilisation on HPC Systems** — INGA LAKOMIEC<sup>1</sup>, •UGHUR MAMMAZADA<sup>1</sup>, SAIDEV POLISETTY<sup>1</sup>, ARNULF QUADT<sup>1</sup>, RODNEY WALKER<sup>2</sup>, and SEBASTIAN WOZNIEWSKI<sup>1</sup> — <sup>1</sup>Georg August University of Göttingen — <sup>2</sup>Ludwig Maximilian University of Munich

The upcoming High Luminosity Large Hadron Collider (HL-LHC) era will greatly increase the computational and storage demands of high energy physics beyond what the current Worldwide LHC Computing Grid (WLCG) can provide. In Germany, university based Tier-2 sites are therefore transitioning their workloads to national HPC facilities at Nationales Hochleistungsrechnen (NHR). In this context, the GoeGrid Tier-2 site at the University of Göttingen is migrating its computing activities to the local NHR cluster EMMY.

To integrate HPC resources into the WLCG, virtual worker nodes are created. They must stop accepting WLCG jobs well before the time limit set by the HPC system, which prevents premature termination but leaves a significant fraction of the allocated CPU time unused near the end of the lifecycle. As the HL-LHC will increase the data volume by a factor of ten, such resource loss becomes increasingly inefficient. The heterogeneous WLCG-HPC environment also requires robust monitoring.

This work investigates opportunistic background jobs at GoeGrid and EMMY to recover this otherwise wasted capacity, and reviews the monitoring infrastructure and the concept of virtual worker nodes.

T 14.7 Mon 17:45 KH 02.014

**Assessing Power-Saving Potential Through ACPI Sleep States in Data Center Rack Servers at DESY** — •SANDRO GRIZZO, DWAYNE SPITERI, KILIAN SCHWARZ, MARTIN GASTHUBER, KONRAD KOCKLER, and JAN HARTMANN — DESY

This report evaluates the feasibility of using ACPI sleep states to reduce power consumption in rack servers at the DESY data center. It outlines the ACPI power-state model, with emphasis on the S5 \*soft\*off\* state and the Linux-specific suspend-to-idle mechanism, as these are the only sleep states typically supported on server-grade hardware. Measurements obtained via IPMI interfaces on several server models show potential power savings above 80% in S5 relative to idle mode. Suspend-to-idle provides a substantially lower reduction, but also lower wake-latencies in return. The findings indicate that using S5 for idle servers could offer considerable power-saving potential in data centers where low wake-latency is not a primary requirement.

T 14.8 Mon 18:00 KH 02.014

**Optimisation of GPU Accelerated Algorithms for Track Finding in Particle Physics** — •PETR FIEDLER, ANDRÉ SOPCZAK, and PAVEL TVRDIK — CTU in Prague

Track finding in particle physics has been an increasing challenge over the past decades because the intensities of collisions in state-of-the-art particle colliders have increased enormously. One of the track reconstruction steps is the track finding. For this, track seeds are determined and the tracks are successively reconstructed by adding more measurements. We explain the main ideas of the state-of-the-art GPU-accelerated implementation of the track finding algorithm and describe several optimisations focusing on an early elimination of fake tracks.



## T 15: Searches/BSM I

Time: Monday 16:15–18:15

Location: KH 02.018

T 15.1 Mon 16:15 KH 02.018

**Search for Di-lepton+X and Di-Photon Signatures with Forward Proton Scattering** — •VICTORIA LYSENKO and ANDRÉ SOPCZAK — CTU in Prague

The latest results are presented using combined data recorded with the central ATLAS detector and the ATLAS Forward Proton spectrometer. The focus is on two analyses, the search for a missing mass resonance in the channel  $pp \rightarrow p' p' \ell \ell X$ , and the search for an axion-like particle (ALP) in light-by-light scattering with the detection of a scattered forward proton.

T 15.2 Mon 16:30 KH 02.018

**Search for new phenomena in dilepton final states with associated  $b$ -jets at the ATLAS experiment** — •ANNA BINGHAM and FRANK ELLINGHAUS — Bergische Universität Wuppertal

An overview of a search for new phenomena in high-mass dilepton ( $ee, \mu\mu$ ) final states with associated  $b$ -jets is presented. The main analysis considers a  $Z'$  model as a candidate explanation for potential anomalies in  $B$  hadron decays, where the  $Z'$  boson couples to  $b$  and  $s$  quarks in the production. Non-resonant contact interactions and  $t$ -channel leptoquark production are taken in account as additional interpretations. The search is carried out using the dataset collected by the ATLAS detector in Run-2 of the LHC corresponding to an integrated luminosity of  $140 \text{ fb}^{-1}$ . Backgrounds are estimated from MC and also by data-driven methods. Control, signal and validation regions are defined, and these regions are fitted in a profile-likelihood fit. Exclusion limits are obtained based on the results of the fit.

T 15.3 Mon 16:45 KH 02.018

**Reconstruction of Heavy Neutral Leptons decaying into  $l + \rho$  with ATLAS using mass-constraint techniques** — •MAXIMILIAN RUHL — Institut für Physik, Humboldt-Universität zu Berlin

Heavy Neutral Leptons (HNLs) are well-motivated candidates for new physics in the GeV mass range and are investigated at the LHC, in particular with the ATLAS experiment, through displaced semileptonic decays. The channel  $N \rightarrow \ell \rho \rightarrow \ell \pi^\pm \pi^0$  might increase the search sensitivity at low HNL masses because its branching fraction is comparatively large and the visible decay products form a clean displaced-vertex signature. If the  $\pi^0$  is not explicitly reconstructed, essential kinematic information is missing. In this study, the three-momentum vector of the neutral pion is estimated using mass-constraint techniques. The photons from the  $\pi^0$  decay have a direction very close to the  $\pi^0$  momentum, hence  $\Delta R(\gamma, \pi_{\text{reco}}^0)$  is small. This characteristic pattern can help to reduce the background without requiring full reconstruction of the  $\pi^0$ . The analysis investigates these photon-based observables and evaluates their potential relevance for future searches for semileptonic HNL decays with ATLAS.

T 15.4 Mon 17:00 KH 02.018

**Anomaly detection for long-lived particles using CATHODE with CMS** — •JOVIN DREWS, LOUIS MOUREAUX, GREGOR KASIECZKA, KARIM EL MORABIT, CHITRAKSHEE YEDE, and TORE VON SCHWARTZ — University of Hamburg, Hamburg, Germany

In high-energy physics, numerous analyses search for phenomena beyond the Standard Model (BSM). Anomaly detection methods offer a model-independent way to probe such potential BSM signatures. We discuss CATHODE, an anomaly detection method combining density estimation and weak supervision, applied to signals from long-lived particles (LLP) embedded in multijet background from the CMS experiment. The work studies LLP scenarios with varying properties and different approaches to classification.

T 15.5 Mon 17:15 KH 02.018

**Search for Delayed Long-Lived Particles in Consecutive Bunch Crossings using the ATLAS Detector** — •TOBIAS HEINTZ — Kirchhoff Institute for Physics, Heidelberg, Germany

This contribution presents a novel strategy to detect long-lived particles (LLPs) that decay across two consecutive bunch crossings, combining missing transverse momentum from a slowly propagating LLP in one bunch crossing with a displaced jet that appears more than 25 ns later and is azimuthally correlated. Unconventional BSM scenarios would give rise to such a signature over multiple bunch crossings, but are not efficiently captured by conventional trigger and reconstruction approaches. The concept of a dedicated trigger and its implementa-

tion within the ATLAS detector are discussed, along with projected sensitivities for a benchmark scenario motivated by inelastic dipole dark matter.

T 15.6 Mon 17:30 KH 02.018

**Search for long-lived dark scalars at the LHCb experiment** — •PENELOPE HOFFMANN and CHRISTOPH LANGENBRUCH — Physikalisches Institut, Universität Heidelberg, Germany

In the minimal dark scalar portal model, a potential dark scalar sector is expected to couple to the Standard Model Higgs boson, with a dark scalar particle acting as a mediator for dark matter. At LHC energies, flavour-changing neutral current decays of  $K$  and  $B$  mesons are excellent probes for dark scalar particles in the  $\text{MeV}/c^2$  to  $\text{GeV}/c^2$  mass region.

This talk presents a search for a dark sector scalar particle  $\chi$ , produced via the decay  $B^0 \rightarrow K^{*0} \chi (\rightarrow \mu\mu)$ , in data recorded in late 2025 with the LHCb detector. Tracks from final state particles originating from long-lived scalar particles that decay outside the LHCb vertex detector (VELO) are reconstructed using only information from the LHCb upstream tracker (UT) and the downstream tracking system (SciFi). These tracks are referred to as downstream tracks.

Employing an improved downstream track reconstruction and a new dedicated trigger line, the preliminary expected limit presented in this talk showcases the promising potential of using downstream tracks in the search for a dark scalar particle at LHCb.

T 15.7 Mon 17:45 KH 02.018

**Search for Semivisible Jets with CMS Run 2 Scouting Data** — •MARCEL GAISDÖRFER<sup>1</sup>, JONAS JANIK<sup>1</sup>, BRENDAN REGNERY<sup>1</sup>, MARKUS KLUTE<sup>1</sup>, BENEDIKT MAIER<sup>2</sup>, CESARE TIZIANO CAZZANIGA<sup>3</sup>, ROBERTO SEIDITA<sup>3</sup>, ANNA PAOLA DE COSA<sup>3</sup>, AIMAR AGUADO BERASALUCE<sup>3</sup>, REBECCA NATALIA HAMP<sup>3</sup>, CELESTE HOLM<sup>3</sup>, and KEVIN PEDRO<sup>4</sup> — <sup>1</sup>Karlsruher Institut für Technologie (KIT) — <sup>2</sup>Imperial College London — <sup>3</sup>ETH Zürich — <sup>4</sup>Fermi National Accelerator Laboratory

Cosmological observations point towards the existence of Dark Matter (DM), a type of matter not described by the Standard Model (SM) that only interacts gravitationally and at most weakly with SM particles. This search looks for a signature called semivisible jets, which are jets containing invisible DM candidates. Semivisible jets could be caused by a QCD-like dark sector, coupled to the SM via a  $Z'$  mediator. To expand previous search efforts towards lower mediator masses, this search utilizes data scouting. Data scouting records the coarser HLT reconstruction instead of the full detector information to save on bandwidth, which allows lowering trigger thresholds, giving access to events that would typically have been discarded. This talk will give an overview of the search strategy, current status and expected limits of the search for semivisible jets with CMS Run 2 HLT scouting data.

T 15.8 Mon 18:00 KH 02.018

**Search for X17 particle at the BESIII** — •HANG ZHOU<sup>1,2</sup> and ACHIM DENIG<sup>1,2</sup> — <sup>1</sup>Johannes Gutenberg University Mainz, Germany — <sup>2</sup>Helmholtz Institute Mainz, Germany

The anomalous internal pair creation signals reported by the ATOMKI group suggest the emission of a new boson with an invariant mass of approximately 17 MeV, often referred to as X17. This hypothetical particle has been proposed as a mediator of a fifth force or as a portal between the Standard Model (SM) and a dark sector. Besides the ATOMKI measurements, several dedicated experiments, such as NA64, MEG II and PADME, have searched for X17-like signatures. So far, however, no independent experiment has conclusively confirmed the existence of X17. If X17 is a real boson, it should also be produced in processes beyond nuclear transitions. One suggested possibility is heavy meson decay, e.g. charmonium decay. Charmonium Dalitz decays, which are analogous to nuclear de-excitation with internal pair creation, offer an independent test of the X17 hypothesis and a unique environment to probe its couplings to second-generation quarks. Moreover, the available phase space in these decays is well suited for searches for MeV-scale dark photons that couple weakly to SM particles.

The BESIII experiment operating at the BEPCII  $e^+e^-$  accelerator, has collected world's largest data sample in the  $\tau$ -charm region. Using these data, a dedicated search for X17 in charmonium Dalitz decays is performed. This talk will present the analysis strategy and recent results from BESIII, providing a complementary and collider-based probe of the X17 scenario.

## T 16: Search for Dark Matter I

Time: Monday 16:15–18:15

Location: AM 00.014

T 16.1 Mon 16:15 AM 00.014

**XLZD: a next-generation multi-purpose liquid xenon observatory.** — •DANIEL WENZ for the XLZD-Collaboration — University of Münster

Owing to their excellent detection efficiency, scalability, and ultra-low background levels, dual-phase time projection chambers (TPCs) employing multi-tonne liquid xenon (LXe) targets provide a powerful tool for the discovery and study of a broad range of rare, low-energy phenomena. Key science channels include the search for dark matter, measurements of solar neutrinos and their properties, and searches for rare processes such as the neutrinoless double beta decay of Xe-136. In addition, LXe TPCs enable flavor-independent measurements of low-energy neutrino fluxes from supernovae, contributing to multi-messenger astronomy.

The proposed XLZD experiment is a next-generation, multi-purpose liquid xenon observatory that builds upon the technologies developed by the currently world-leading experiments XENONnT and LZ, as well as the R&D program of DARWIN. The nominal detector design foresees a 60-tonne LXe target mass, with a potential upgrade path to approximately 80 tonnes. In this talk, we present an overview of the XLZD concept and its projected sensitivities across the different science channels.

The author of this talk is supported by BMBF through the project numbers 05A23PM1 and the EU through the ERC AdG LowRad (101055063).

T 16.2 Mon 16:30 AM 00.014

**Design, Development and Characterization of Electrodes for XENONnT and towards XLZD** — •ALEXEY ELYKOV — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Dual-phase noble gas time projection chambers (TPCs) lie at the heart of detectors that perform a wide range of rare event searches, spanning from attempts to detect particle dark matter to studies of neutrino physics. High-voltage electrodes are instrumental for the generation and interpretation of signals produced in the TPC.

The XENON collaboration currently operates a state of the art, ~1.5 m-wide TPC, immersed in 8.9 t of liquid xenon. The XLZD (XENON, LZ, DARWIN) collaboration aims to construct and operate the ultimate xenon-based TPC, which will span ~3 m in diameter and will host 60 t of liquid xenon. With a keV-range threshold and an ultra-low radioactive background, XLZD will aim to probe the entire parameter space for WIMP dark matter down to the so-called neutrino fog, and will conduct searches for solar axions, axion-like particles, as well as measurements of the solar neutrino flux, and a probe of the Majorana nature of neutrinos.

In this talk, we will present the successful design, development and characterization of ~1.5 m-scale electrodes for the upgrade of the XENONnT detector and the R&D work towards electrodes for the XLZD detector [1]. This work has been supported in part by the Federal Ministry of Research, Technology and Space (BMFTR) through the grant 05A23VK3 within the ErUM-Pro funding line.

[1] arXiv:2511.16408

T 16.3 Mon 16:45 AM 00.014

**Modeling of signatures from charged leptonic products of dark matter annihilation** — •MILENA BRÜTTING<sup>1,2</sup>, ATHITHYA ARAVINTHAN<sup>1,2</sup>, JULIA BECKER TJUS<sup>1,2,3</sup>, JULIEN DÖRNER<sup>1,2</sup>, and JANNIS WAGNER<sup>1,2</sup> — <sup>1</sup>Theoretical Physics IV, Ruhr-University Bochum, Germany — <sup>2</sup>Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Bochum, Germany — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

The indirect search for Dark Matter (DM) has been challenging for decades due to the need for low-background environments and the ambiguity between potential DM signals and conventional astrophysical emission. A promising strategy is to model and compare signatures from different DM annihilation channels with astrophysical emission in a synthetic dwarf galaxy assuming the same total energy from both DM and astrophysical sources.

The prompt emission of DM annihilation and the secondary emission from interactions of charged products (such as electrons and positrons) with the ambient fields are modeled to help differentiate the DM and the astrophysical signal. Simulations are performed with the open-source code CRPropa 3.2, which provides a flexible and self-consistent modeling framework for particle propagation. Results reveal morphological differences between both sources. We test different DM annihilation channels, such as bottom quarks, top quarks and W gauge bosons, as well as DM density profiles, such as Einasto, Burkert and Navarro-Frenk-White.

T 16.4 Mon 17:00 AM 00.014

**Direct Detection of sub-GeV Dark Matter with the CRESST experiment** — •FEDERICO CASADEI for the CRESST-Collaboration — Max Planck Institut für Physik, Garching bei München, Deutschland

The Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) experiment is operating at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy, where it has been pursuing the direct detection of dark matter for almost three decades. Employing scintillating crystals instrumented with Transition Edge Sensors (TESs) and operated as cryogenic calorimeters at millikelvin temperatures, CRESST has achieved energy thresholds as low as 6.7 eV. Combined with the use of targets with light nuclei, this enables CRESST to be particularly sensitive to sub-GeV dark matter particles through nuclear-recoil interactions. In this talk, an overview of the CRESST experiment is presented, highlighting detector operation and recent dark-matter results. Ongoing work to improve sensitivity and advance detector design will also be discussed, together with prospects for future explorations of low-mass dark matter.

T 16.5 Mon 17:15 AM 00.014

**Illuminating the Invisible: Deep underground dark matter search with COSINUS** — •MUKUND BHARADWAJ for the COSINUS-Collaboration — Max Planck Institute for Physics, 85748 Garching - Germany

The COSINUS experiment (Cryogenic Observatory for Signatures seen in Next generation Underground Searches) is a cryogenic, low-background experiment being set up at Laboratori Nazionali del Gran Sasso, Italy. It aims to provide a model independent cross-check of the DAMA/LIBRA findings of a potential dark matter-like modulation signal. COSINUS utilizes a two-channel readout system based on transition edge sensors (TESs) that allows for particle discrimination. It consists of ultrapure scintillating sodium iodide (NaI) crystals, read out using a novel remoTES scheme to measure the phonon signal of a particle interaction. A silicon beaker surrounding the crystal is used to measure the light signal from the same particle interaction. Results from the latest measurements and updates on the setup will be presented in this contribution.

T 16.6 Mon 17:30 AM 00.014

**Towards DELight: First Results from a Prototype R&D Cell** — •ANNA BERTOLINI for the DELight-Collaboration — Kirchhoff-Institut für Physik, Universität Heidelberg

As direct detection experiments continue to push down the limits on heavy WIMPs, the low-mass dark matter (DM) regime remains comparatively unexplored. Probing this region requires detectors that combine sub-keV energy thresholds with large exposures. The Direct search Experiment for Light dark matter (DELight) aims to meet this challenge by using superfluid helium-4 as a target material and magnetic micromalorimeters (MMCs), enabling excellent energy resolution and detection thresholds of only a few eV. As a first step toward the full experiment, we have developed a dedicated R&D cell to study the MMC response to particle interactions in superfluid helium. In this setup, a 300-ml copper cell is cooled to ~10 mK, where an MMC fabricated on a silicon substrate and a resistive heater are fully submerged in the superfluid. This configuration allows us to characterize the detector response to both particle induced signals in helium and controlled heater pulses. In this contribution, we present the R&D setup, its operational performance, and the first experimental results that form the foundation for the DELight experiment. This work is supported through the Heidelberg Karlsruhe Strategic Partnership (HeiKA STAR).

T 16.7 Mon 17:45 AM 00.014

**Simulating DELight: the simulation framework of the DELight experiment** — •FRANCESCO TOSCHI for the DELight-Collaboration — Kirchhoff-Institut für Physik, Heidelberg University

The strong experimental constraints on well-motivated dark matter candidates for masses above 1 GeV/c<sup>2</sup> motivates the exploration of lighter alternative candidates. Probing the low-mass regime requires ultra-low energy thresholds: these are already achieved by solid-state cryogenic detectors thanks to their phonon signal and ultra-sensitive sensors. Combining this approach of ultra-low energy phonon detection with much lighter target nuclei will further enhance the low mass reach. The Direct search Experiment for Light dark matter (DELight) will use a superfluid helium-4 target instrumented with large area microcalorimeters (LAMCALS), combining the low threshold of phonon-based detection with the scalability of noble liquids. This allows DELight to explore masses below 100 MeV/c<sup>2</sup> with just 1 kg·d of exposure.

DELight is in its design phase, and detailed simulations play a central role in informing the design and construction of the final detector. This talk will present the DELight simulation framework, including the signal formation and propagation within the superfluid volume, as well as models of the relevant background sources.

T 16.8 Mon 18:00 AM 00.014

**ImpCresst - A versatile simulation tool focusing on cryogenic solid-state detectors at sub-MeV energies** — •HOLGER KLUCK for the CRESST-Collaboration — Marietta-Blau-Institut für Teilchenphysik der Österreichischen Akademie der Wissenschaften, 1010 Wien, Österreich

We present ImpCresst, a Geant4 based Monte Carlo tool to simulate radioactive and cosmogenic backgrounds in cryogenic solid-state detectors. It is tuned for a fast-evolving and heterogeneous detector environment with a focus on physics at the sub-MeV level. ImpCresst was developed for the CRESST experiment and

proved its suitability there. However, its flexibility and configurability makes it adaptable to any other experiment with a similar profile of requirements: dynamical creation of detector geometries, optionally directly from CAD files; ROOT based data persistency of the whole simulated event topology; automatic meta-data annotation for data provenance; and interfacing various particle generators specialized for radioactive and cosmogenic background sources. Especially for radioactive bulk and surface contaminations, we developed a new and convenient particle generator. Detector-specific energy and time resolutions are flexibly applied based on a user-provided data set of empirical parameterization.

## T 17: Neutrino Astronomy I

Time: Monday 16:15–18:15

Location: KS H C

T 17.1 Mon 16:15 KS H C

**Search for coincidences between IceCube sub-TeV neutrinos and sub-threshold Gravitational Wave events in the LIGO-Virgo-KAGRA third observing run** — •TISTA MUKHERJEE for the IceCube-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

Since the first direct detection of gravitational waves (GW) by the LIGO-Virgo-KAGRA detectors, the IceCube Neutrino Observatory has actively participated in identifying their neutrino counterparts. The sub-threshold GW alerts from the third observation run of LIGO-Virgo-KAGRA, identified by both template-based searches and minimally modelled pipelines, have also been examined in follow-up analyses with TeV-PeV neutrinos, but no correlations were found. This work presents a systematic search for lower-energy neutrino emission from the sub-threshold GWs, utilising the archival all-flavour, sub-TeV neutrino sample from the IceCube Neutrino Observatory. From the public GW catalogues, we identify 103 promising candidates, comprising a mixture of compact binary mergers and GW burst triggers. After conducting a catalogue search to identify correlated sub-TeV neutrinos within a 1000 s time window, employing an unbinned maximum likelihood method, no significant coincidences are found. Hence, we report neutrino flux upper limits from the sub-threshold GW sources followed up in this analysis within sub-TeV neutrino energy.

T 17.2 Mon 16:30 KS H C

**Improving Measurement of Astrophysical Neutrino Flux with Advanced Northern Tracks Selection in IceCube** — •SHUYANG DENG, LASSE DÜSER, SÖNKE SCHWIRN, PHILIPP SOLDIN, CHRISTOPHER WIEBUSCH, and MARCO ZIMMERMANN — III. Physikalisches Institut B RWTH Aachen University, Aachen, Germany

The IceCube Neutrino Observatory is a large neutrino detector at the South Pole. One of its main detection channels is via neutrino-induced muon tracks, which provide a large effective area and high angular resolution. The Advanced Northern Track Selection (ANTS) framework uses a graph convolutional neural network to improve the selection of these events, as well as to perform reconstructions of their physical parameters. Furthermore, these events show different topologies and signatures within the detector, which can be classified with ANTS, enabling dedicated handling of these topologies in analyses. In this talk, we will show the performance of ANTS and the improvement in sensitivity it provides for the measurement of the astrophysical neutrino flux.

T 17.3 Mon 16:45 KS H C

**Understanding Wind Related Background Radio Pulses at the Radio Neutrino Observatory in Greenland** — •PASCAL SCHRIEFER for the RNO-G-Collaboration — ECAP, Friedrich-Alexander-Universität Erlangen-Nürnberg

The Radio Neutrino Observatory in Greenland (RNO-G) aims to detect ultra-high energy ( $> 10$  PeV) neutrinos through pulsed radio signals generated by ice particle showers on the basis of the Askaryan effect. 35 independent detector stations are to be built on a grid with a spacing of  $\sim 1.2$  km, eight of which are already operational and equipped with antennas at shallow depths in the ice. Even though the detector is being constructed at the very remote summit of Greenland, approximately 3200 m above sea level, background radio signals of different origins are detectable. Especially during periods with high wind speeds ( $> 8 - 10$  m/s), an overwhelming number of radio pulses with signatures comparable to those of neutrino events are detected. This poses a significant issue for the identification of cosmic particles as high wind speeds are not only very common in Greenland, but during the polar winter, wind is the only power source available to keep the stations operational. In this contribution, RNO-G is being introduced and the current state of knowledge about wind-related backgrounds is discussed, including the theorized mechanism and origin of these signals as well as unexplained features and plans of how to further investigate them.

T 17.4 Mon 17:00 KS H C

**Downward ultra-high-energy neutrino detection in the atmosphere with radio antenna at the ground-based observatories** — •YUE BAOBIAO for the Pierre Auger-Collaboration — Bergische Universität Wuppertal

Ultra-high-energy (UHE) neutrinos are unique cosmic messengers offering direct insight into the most energetic processes in the universe. Radio detection promises significant advantages for detecting highly inclined air showers induced by UHE neutrinos, including a larger exposure range compared to particle detectors, which is due to minimal atmospheric attenuation of radio signals combined with good reconstruction precision. Furthermore, this technique improves the air shower longitudinal reconstruction, which can be used to identify neutrinos with their first interaction far below the top of the atmosphere. In this work, we present a method to reconstruct the radio emission maximum ( $X_{\text{max}}^{\text{radio}}$ ) and demonstrate its power in distinguishing deeply developing neutrino-induced showers from background cosmic rays. Using the Pierre Auger Observatory as a case study, we evaluate the detection efficiency of the  $\nu_e$ -CC, and the resulting effective area. Our results show that radio detection significantly enhances the sensitivity to very inclined showers above  $1$  EeV, complementing traditional particle detectors. This technique is highly scalable and applicable to future radio observatories such as GRAND. The proposed reconstruction and identification strategy provides a pathway toward achieving the sensitivity needed to detect UHE neutrinos. *\*Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

T 17.5 Mon 17:15 KS H C

**Modeling Gamma-Ray Bursts Using CRISP** — •THERESE PAULSEN, LEONEL MOREJÓN, and KARL-HEINZ KAMPERT — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

Astrophysical neutrinos are a clear identifier of photohadronic interactions in sources of Ultra-High-Energy Cosmic Rays (UHECRs). As the Pierre Auger Observatory has shown that UHECRs exhibit a composition heavier than protons at Earth, we expect that these heavy primaries undergo nuclear cascades due to photodisintegration in the dense source environments from which they originate.

In this talk, we will derive the neutrino spectra produced by these heavier primaries undergoing photohadronic interactions. This will be explored in the context of modeling the emission region of a gamma-ray burst. Photohadronic interactions will be modeled using the new framework for "Cosmic Ray Stochastic Interactions for Propagation" (CRISP), which employs an analytic approach to compute the underlying probabilistic description of UHECR interactions.

T 17.6 Mon 17:30 KS H C

**Prospects for Combined Hadronic Emission Analyses with KM3NeT and CTA** — •SHIVANI PADMA MOHAN for the KM3NET-ERLANGEN-Collaboration — ECAP, FAU Erlangen-Nürnberg, Erlangen, Germany

Multi-messenger analysis is becoming essential to probe the fundamental astrophysical processes in distant astrophysical sources. In particular, hadronic processes, where both neutrinos and high-energy gamma rays can be simultaneously produced, motivate the combined analysis of these two messengers. KM3NeT (cubic kilometre neutrino telescope) and CTA (Cherenkov Telescope Array) are next-generation instruments with increased sensitivities in neutrino and gamma-ray astronomy, respectively, making them ideal for such joint studies. A previous study demonstrated the feasibility of a combined CTA-KM3NeT analysis using GAMMAPY, an open source Python package widely used in gamma-ray astronomy. Due to its flexible framework, it can also incorporate neutrino data and was used in the study to determine the contribution of hadronic processes in well-known galactic gamma-ray sources. To facilitate future studies involving different messengers, source classes and detector configurations, the analysis pipeline has now been updated to the latest GAMMAPY 2.0 framework. Based on the current Monte-Carlo simulations, the updated Instrument Response Functions (IRFs) for KM3NeT will be presented in comparison with earlier results.

T 17.7 Mon 17:45 KS H C

**Framework for Gravitational-Wave and Neutrino stacking Analysis** — •CHLOE FISHER<sup>1,2</sup> and TISTA MUKHERJEE<sup>1,2</sup> for the IceCube-Collaboration — <sup>1</sup>Karlsruhe Institute of Technology — <sup>2</sup>Institute of Experimental Particle Physics (ETP)

Cosmic rays are charged particles whose trajectories are scrambled by magnetic fields, obscuring direct associations with their astrophysical origins. Identifying the engines capable of accelerating them therefore relies on neutral messengers such as neutrinos and gravitational waves. Compact binary coalescences, with or without neutron stars, are promising source candidates in this regard, as they may produce both gravitational-wave emission and hadronic outflows capable of generating high-energy neutrinos under suitable conditions. The joint interpretation of these signals within a multi-messenger framework enhances our ability to probe the physical conditions of their potential common source environments. However, no individual common source of gravitational waves and neutrinos has been identified with a global significance exceeding  $3\sigma$  after trial correction. This motivates a population-level analysis to search for correlated neutrino emission from the ensemble of observed compact binary coalescences.

T 17.8 Mon 18:00 KS H C

**Multi-Messenger Synergies at the Pierre Auger Observatory: Archive Expansion and Real-Time Neutrino Follow-Ups**<sup>\*,†</sup> — •SRIJAN SEHGAL for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Germany

## T 18: Methods in Astroparticle Physics I

Time: Monday 16:15–18:15

Location: KS 00.004

T 18.1 Mon 16:15 KS 00.004

**Large-scale TPB Vacuum Evaporation for the LEGEND-1000 Liquid Argon Veto** — •LORENZO PIETROPAOLI<sup>1</sup>, KONSTANTIN GUSEV<sup>1,2</sup>, LASZLO PAPP<sup>1</sup>, NADEZDA RUMYANTSEVA<sup>1,2</sup>, and STEFAN SCHÖNERT<sup>1</sup> — <sup>1</sup>Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany — <sup>2</sup>Dubna, Russia

LEGEND-1000 searches for  $0\nu\beta\beta$ -decay using HPGe detectors in instrumented LAr. A critical background suppression component is the LAr instrumentation, utilizing scintillating fibers coated with Tetraphenyl Butadiene (TPB) and read out by SiPMs. TPB acts as a wavelength shifter, converting 128 nm VUV scintillation light from LAr to  $\sim 430$  nm blue light, which is absorbed by green wavelength-shifting (and scintillating) fibers and guided to SiPMs for detection.

We present the design and status of the new LEGEND-1000 TPB evaporator. Building on the LEGEND-200 experience, the system features a 2.3 m tall vacuum chamber designed for the simultaneous, uniform coating of 9 fiber modules with lengths up to 1.6 m. The setup is under construction and assembly in a dedicated new clean room facility at TUM. This talk covers the technical design, the scaling of the evaporation process, and the current status of the commissioning.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS), through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 18.2 Mon 16:30 KS 00.004

**The detection principle and implementation of the Cryogenic Outer Veto for the NUCLEUS experiment** — •ALEXANDRA SCHRÖDER for the NUCLEUS-Collaboration — Technische Universität München

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) is predicted in the Standard Model to be a neutral current process with low recoil energies in the order of keV. Its experimental observation requires extremely sensitive detectors, enabling the study of neutrino properties and offering the potential to probe physics beyond the Standard Model. The NUCLEUS experiment is designed to observe CEvNS using cryogenic calorimeters with ultra-low energy thresholds of the order of a few 10 eV. The final experimental site will be at the Chooz nuclear power plant in France, featuring a relatively low overburden of 3 m water equivalent. As a result, a robust background mitigation strategy is required to achieve the desired sensitivity. The Cryogenic Outer Veto (COV), consisting of kilogram-scale high-purity germanium crystals, constitutes a key component of the NUCLEUS background suppression system. The realization of the COV was a collaboration-wide effort. Prior to the integration of the full COV configuration consisting of six crystals, a single COV crystal was tested and operated within the experiment. The complete six-crystal COV system was integrated in December 2024. In this talk, I will present the design and operating principle of the COV, along with an overview of the upscaling process from a single crystal to the final six-crystal configuration.

T 18.3 Mon 16:45 KS 00.004

**Overview of the Cryogenic Detector and Development of the Cryogenic Inner Veto for the Observation of Coherent Elastic Neutrino Nucleus Scattering (CEvNS) with NUCLEUS10g** — •MICHAEL HOCK — Technische Universität München

The Pierre Auger Observatory, the world's largest cosmic-ray detector, is designed to study the highest-energy particles in the universe and also has a remarkable capability to detect ultra-high-energy neutrinos. Operating continuously since 2004, it has made major contributions to cosmic-ray physics and to the growing field of multi-messenger astronomy. The Observatory is part of the Astrophysical Center for Multi-messenger in Europe (ACME), an infrastructure initiative aimed at facilitating data sharing among major observatories and improving the coordination of multi-messenger observations.

Within ACME, the Pierre Auger Observatory is expanding access to its extensive archive of data and preparing to provide real-time follow-ups by utilizing its sensitivity to neutrino-induced air showers. These efforts are intended to support the rapid identification and characterization of astrophysical sources. This talk will summarize the efforts undertaken within ACME, with particular emphasis on the planned expansion of the public data archive and the current status and development of Auger's real-time alert system.

<sup>\*</sup>Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)

<sup>†</sup>This work is supported by the EU Horizon Europe Research and Innovation Programme, Grant No. 101131928.

The study of Coherent Elastic Neutrino Nucleus Scattering (CEvNS) offers new opportunities to investigate fundamental neutrino properties and to probe physics beyond the Standard Model. The NUCLEUS experiment aims to precisely measure the CEvNS cross-section from electron antineutrinos produced at the reactors of the Chooz nuclear power plant in France.

NUCLEUS targets ultra-low recoil energies by employing gram-scale cryogenic calorimeters with energy thresholds on the order of  $\mathcal{O}(10\text{ eV})$ . In its first science phase, NUCLEUS 10g will deploy two detector modules, each comprising nine cryogenic target detectors embedded in a Cryogenic Inner Veto.

This contribution presents the current status of the NUCLEUS 10g detector components and reports on the ongoing development of the Cryogenic Inner Veto, which is expected to mitigate the Low Energy Excess (LEE) and therefore may be essential for achieving the required low-background conditions.

T 18.4 Mon 17:00 KS 00.004

**Digital broadband interferometry for mapping lightning at the Pierre Auger Observatory** — MARKUS CRISTINZIANI<sup>1</sup>, •ERIC-TEUNIS DE BOONE<sup>1</sup>, QADER DOROSTI<sup>1</sup>, STEFAN HEIDBRINK<sup>2</sup>, WALDEMAR STROH<sup>2</sup>, JENS WINTER<sup>2</sup>, and MICHAEL ZIOLKOWSKI<sup>2</sup> — <sup>1</sup>Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen — <sup>2</sup>Elektronikentwicklungslabor der Physik, Universität Siegen

Lightning-related phenomena are known to interact with and influence all detector systems of the Pierre Auger Observatory in Argentina. Notably, the Surface Detector has recorded unique signals linked to Terrestrial Gamma Flashes (TGFs) which are rare phenomena related to the initial processes of lightning. Interpreting these signals remains challenging due to the absence of a system capable of providing detailed 3D imaging of lightning propagation.

To address this gap, we are developing BOLT: Broadband Observatory for Lightning and TGFs, a state-of-the-art interferometric lightning mapping array that enhances the Observatory's unique capabilities for precision research including TGFs. It consists of radio detectors that have been previously developed for the Auger Engineering Radio Array (AERA), located at strategic positions within the Auger field.

This contribution highlights the recent hardware developments, progress towards selective triggering and precision timing, and first field data, illustrating the growing capability of the system for TGF and lightning studies.

T 18.5 Mon 17:15 KS 00.004

**Performance of a cryogenic heat pump demonstrator for future liquid xenon observatories** — •PHILIPP SCHULTE, LUTZ ALTHÜSER, ROBERT BRAUN, VOLKER HANNEN, CHRISTIAN HUHMANN, DAVID KOKE, YING-TING LIN, PATRICK UNKHOF, DANIEL WENZ, and CHRISTIAN WEINHEIMER — Institut für Kernphysik, Universität Münster

Future liquid xenon (LXe) dark-matter detectors require detector backgrounds about ten times below the solar neutrino-induced background level. Achieving this demands  $^{222}\text{Rn}$  concentrations in LXe  $< 0.1\text{ }^*\text{Bq/kg}$  (less than one  $^{222}\text{Rn}$  atom in 160 mol xenon). The ERC project \*LowRad\* develops high-throughput cryogenic distillation for radon removal, where xenon flow rates of  $\sim 1600\text{ kg/h}$  imply heating and cooling powers of  $\mathcal{O}(60)\text{ kW}$  at the column reboiler and condenser. To reduce the external cooling demand, a xenon-based cryogenic heat-

pump demonstrator has been built and operated. This contribution will present its design and performance, achieving up to ~130 W cooling/heating power at 3.3 bar and 4.3 bar with an electrical input of ~390 W (COP \*0.32). Implications for the design and integration of full-scale systems in future LXe observatories such as XLZD will be discussed. Acknowledging support of the ERC AdG \*LowRad\* (101055063).

T 18.6 Mon 17:30 KS 00.004

**Construction and Deployment of the Wavelength-Shifting Optical Module for the IceCube Upgrade** — •LEA SCHLICKMANN<sup>1</sup>, SEBASTIAN BÖSER<sup>1</sup>, ENRICO ELLINGER<sup>2</sup>, KLAUS HELBING<sup>2</sup>, KYRA MOSSEL<sup>1</sup>, ADAM RIFAIE<sup>2</sup>, and NICK SCHMEISSER<sup>2</sup> — <sup>1</sup>JGU Mainz University — <sup>2</sup>University of Wuppertal

The Wavelength-shifting Optical Module (WOM) is a novel optical sensor developed to enhance the sensitivity of neutrino detectors to ultraviolet (UV) Cherenkov light. It employs wavelength-shifting and light-guiding technology to efficiently detect UV photons that are otherwise difficult to capture with conventional sensors. Each WOM consists of a quartz tube coated with a wavelength-shifting paint, with a photomultiplier tube (PMT) coupled to each end. UV photons absorbed in the coating are re-emitted at longer wavelengths, captured by total internal reflection inside the tube, and guided to the PMTs for detection.

As part of the IceCube Upgrade, ten WOMs were produced, tested, and deployed in the Antarctic ice during the 2025/26 season. The IceCube Upgrade provides a unique opportunity to evaluate the performance of WOMs under real detector conditions, contributing to the development of future optical sensor technologies. This talk will present an overview of the WOM for the IceCube Upgrade.

T 18.7 Mon 17:45 KS 00.004

**Evaluating Dry Nitrogen Purging to Reduce Water Adsorption in Ultra-High-Vacuum Beam Tubes** — CHARLOTTE BENNING, •HSIANG-CHIEH HSU, TIM KUHLEBUSCH, ACHIM STAHL, and JOCHEN STEINMANN — III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope (ET) requires 120 km beam pipes with a diameter of one meter. Additionally, to achieve the design sensitivity of the ET, a residual pressure below  $10^{-10}$  mbar is required. Meeting both requirements will make the vacuum cost to about one-third of the total anticipated budget using current production and vacuum technologies. Continuous on-site manufacturing of the beam pipes in the tunnels can lower the cost while requiring novel cleaning method. Laser cleaning is proposed to be used to clean ferritic stainless steel surfaces and remove adsorbed water, eliminating the need for high-temperature and time-consuming bakeout. Therefore, controlling moisture re-adsorption is crucial. This work investigates how the dryness of the purging gas (nitrogen) influences the re-adsorption of water vapor on surfaces after cleaning, to identify the dryness level that keeps water contamination acceptably low.

T 18.8 Mon 18:00 KS 00.004

**Development of a High-Temperature Superconducting magnet** — •CHRISTIAN VON BYERN for the AMS-100 at RWTH Aachen-Collaboration — I. Physics Institute B, RWTH Aachen

While AMS-02 is currently operated on board of the International Space Station, the next generation of cosmic particle detector is already planned. AMS-100 is designed for operation at Lagrange Point 2 and will feature a geometric acceptance of  $100\text{m}^2\text{sr}$ . With this large acceptance and improved momentum resolution a measurement of cosmic rays up to the PeV scale will be possible and an improvement of a factor 1000 regarding the sensitivity of anti-matter measurements is expected. The magnetic field of the spectrometer will be generated by a High Temperature Superconducting (HTS) solenoid. This coil will include several layers of individual HTS tapes. During operation at 55K it will produce a field of 0.5T at 4.5kA current. To reduce the material budget in terms of mass and interaction length the HTS tapes will be stabilized using few millimetres of aluminium. As an intermediate step a small demonstrator coil is in preparation. In this R&D phase multiple samples, including straight cable samples, bent cable samples as well as coil samples with few windings are prepared and tested. In this talk the development of a soldering process for cable production and measurement results of the different samples will be presented and interpreted.

## T 19: Gravitational Waves I

Time: Monday 16:15–18:15

Location: KS 00.005

T 19.1 Mon 16:15 KS 00.005

**Integrating a Sagnac Interferometer into the Einstein Telescope** — •NIKLAS NIPPE and ACHIM STAHL — III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope (ET) aims to detect gravitational waves with unprecedented low-frequency sensitivity, where gravity gradients, so-called Newtonian Noise (NN), from seismic density fluctuations become a dominant limitation. While NN mitigation will most likely rely on arrays of seismometers measuring translational seismic motion to predict the resulting gravity perturbations, rotational motion carries complementary information that could improve NN prediction.

This talk explores the implementation of a Sagnac interferometer, a ring-laser system that would naturally provide high-precision rotational data in the low frequency regime, into one corner of the ET infrastructure. The area enclosed by the ring-laser setup would substantially increase compared to current state-of-the-art interferometers, hence an improvement in sensitivity by up to two orders of magnitude could be achieved. Finally, the potential contribution of such an integrated Sagnac interferometer to NN mitigation in the ET infrastructure is investigated.

T 19.2 Mon 16:30 KS 00.005

**Parameter Estimation for long duration Gravitational Wave signals at the Einstein Telescope using Deep Learning** — •TOBIAS REIKE<sup>1</sup>, JOHANNES ERDMANN<sup>1</sup>, and ACHIM STAHL<sup>2</sup> — <sup>1</sup>III. Physikalisches Institut A, RWTH Aachen University — <sup>2</sup>III. Physikalisches Institut B, RWTH Aachen University

The proposed Einstein Telescope will be a third-generation gravitational-wave detector, succeeding the current detectors LIGO, Virgo, and KAGRA. It aims to extend the sensitive frequency band toward both lower and higher frequencies and to improve the sensitivity of the current detectors by an order of magnitude. As a result, detected signals can be observed for much longer durations, ranging from minutes to hours, and the detection rate is expected to increase dramatically, reaching hundreds per day.

The analysis methods currently used to estimate source parameters from detected signals are extremely demanding in terms of computational resources, making them unsuitable for the substantially larger data volume anticipated for the Einstein Telescope. Consequently, new and more efficient methods are under development. We present a deep-learning-based approach to parameter estimation that relies on conditional normalizing flows, along with our ongoing work on the analysis of long-duration signals, which pose a particular challenge.

T 19.3 Mon 16:45 KS 00.005

**Prospects for Coincident Detection of Short Gamma-Ray Bursts with IceCube-Gen2 and the Einstein Telescope** — •RAJANVIR SINGH<sup>1</sup>, ANNA FRANCKOWIAK<sup>2</sup>, PHILIPP FÜRST<sup>1</sup>, CHRISTOPHER WIEBUSCH<sup>1</sup>, and ANGELA ZEGARELLI<sup>2</sup> — <sup>1</sup>III. Physikalisches Institut B, RWTH Aachen — <sup>2</sup>Astronomisches Institut, Ruhr-Universität Bochum

With the coincident observation of a short gamma-ray burst (sGRB) and gravitational waves from a neutron star binary merger (NSM) in 2017, these objects have become a primary target for multi-messenger astronomy. In this context, measuring also coincident neutrinos from these NSMs is decisive for probing hadronic processes in these violent environments. With enhanced sensitivity of next-generation neutrino and gravitational wave observatories, such as IceCube-Gen2 and the Einstein Telescope, the chances of observing coincidences improve. Based on previous work we will discuss simulated neutron star mergers with the goal of estimating detection rates of IceCube-Gen2 and the Einstein Telescope and a joint detection rate.

T 19.4 Mon 17:00 KS 00.005

**Probing binary black hole merger populations in AGN disks through future IceCube-Gen2 and Einstein Telescope observations** — •TISTA MUKHERJEE<sup>1</sup>, MAINAK MUKHOPADHYAY<sup>2</sup>, FOTEINI OIKONOMOU<sup>3</sup>, ANDREAS HAUNGS<sup>1</sup>, and RALPH ENGEL<sup>1</sup> — <sup>1</sup>Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — <sup>2</sup>Astrophysics Theory Department, Theory Division, Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA — <sup>3</sup>Institutt for fysikk, NTNU, Trondheim, Norway

The detection of astrophysical neutrinos and gravitational waves (GWs) has ushered in a new era of multi-messenger astroparticle physics. While coincident detections of GW and neutrinos alongside electromagnetic signals have already been achieved in separate instances, no common source of GW and neutrinos has yet been identified. To address the implications of non-detection, this work investigates the prospects for identifying binary black hole mergers embedded in AGN disks as common GW-neutrino sources with next-generation facilities, e.g., the Einstein Telescope and IceCube-Gen2. For sources located in the Northern Hemisphere, the detection significance is quantified for both individual mergers and their populations, to be seen by the Einstein Telescope. It is found that, even with improved sensitivity of next-generation detectors, catalogue searches have limited potential. In contrast, stacking offers a viable path to uncover a population of common GW-neutrino sources in the future.

T 19.5 Mon 17:15 KS 00.005

**Investigating the Visibility of Newtonian Noise in the Einstein Telescope Null Stream** — •JOSIE ALTENHÖVEL, JOHANNES ERDMANN, and PATRICK SCHILLINGS — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope (ET) is a planned third-generation gravitational-wave observatory designed to surpass the sensitivity of current detectors. Its triangular layout provides three interferometer signals with fixed geometric relations, enabling the construction of a null stream in which any gravitational-wave contribution is expected to cancel, while all non-gravitational disturbances are expected to remain with finite amplitude. Any event that appears in the null stream can therefore be identified as noise and is excluded from astrophysical interpretation. Among the relevant disturbances is Newtonian noise (NN), which originates from gravitational field fluctuations caused by seismic density variations in the surrounding rock and at surfaces. NN is expected to dominate the low-frequency regime that is critical for ET. To investigate its behavior, simulations are used to generate three-dimensional seismic fields and the corresponding NN forces acting on the ET test masses. A broad range of NN configurations is examined to determine under which conditions NN could produce signatures that disappear in the null-stream construction. The study thereby evaluates the diagnostic role of the ET null stream for an estimate of NN at future low-frequency gravitational-wave observatories.

T 19.6 Mon 17:30 KS 00.005

**Reducing Wind Turbine Vibrations for the Einstein Telescope in the EMR Region** — •TOM NIGGEMANN and ACHIM STAHL — III. Physikalisches Institut B RWTH Aachen University

The planned realization of the Einstein Telescope in the EMR region (Euregio Meuse-Rhine) requires a significant reduction of environmental disturbances, particularly those caused by seismic waves and the resulting Newtonian Noise. A significant contribution to these disturbances originates from the vibration modes of wind turbines, whose foundation and tower motions propagate through the ground and may compromise the sensitivity of the gravitational-wave detector. To mitigate these effects, several engineering measures are being investigated: the enlargement of foundations to lower eigenfrequencies and improve ground coupling, as well as the implementation of tuned mass dampers to suppress critical vibration modes. Complementary numerical simulations and studies are conducted to validate the effectiveness of these approaches. The overarching goal is to develop a robust vibration-reduction concept that reconciles the integration of renewable energy with the extreme requirements of gravitational-wave research.

T 19.7 Mon 17:45 KS 00.005

**Towards a more realistic Seismometer Position Optimization for Newtonian Noise Mitigation at the Einstein Telescope** — •PATRICK SCHILLINGS and JOHANNES ERDMANN — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope is a third-generation, underground gravitational wave detector that will allow us to measure gravitational waves with significantly improved precision. Its 'xylophone' arrangement is designed to extend the frequency range down to a few Hertz. To improve the sensitivity of the low-frequency interferometer, one needs to mitigate the gravitational effect of density fluctuations in the surrounding rock caused by seismic activity, which result in so-called Newtonian noise. To predict the Newtonian noise, an array of seismometers will be installed around the interferometer mirrors. Expensive boreholes will have to be drilled in order to place these seismometers, which will limit the total number of seismometers that can be placed for a given budget. Therefore, the available resources should be used optimally in terms of predicting the Newtonian noise from the seismometer data. Until now, optimizations were based on a simplified, analytical model of the seismic wave field. In this talk, I introduce a simulation of seismic waves that allows to lift several assumptions of this model. It provides a stepstone towards more complex site-specific geological models to be used for seismometer position optimization.

T 19.8 Mon 18:00 KS 00.005

**Stimulated Emission or Absorption of Gravitons by Light** — •RALF SCHÜTZHOLD — Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We study the exchange of energy between gravitational and electromagnetic waves in an extended Mach-Zehnder or Sagnac type geometry that is analogous to an optical Weber bar. In the presence of a gravitational wave (such as the ones measured by the Laser Interferometer Gravitational Wave Observatory), we find that it should be possible to observe (via interference or beating effects after a delay line) signatures of stimulated emission or absorption of gravitons with present-day technology. Apart from marking the transition from passively observing to actively manipulating such a natural phenomenon, this could also be used as a complementary detection scheme. Nonclassical photon states may improve the sensitivity and might even allow us to test certain quantum aspects of the gravitational field.

[1] R. Schützhold, *Stimulated Emission or Absorption of Gravitons by Light*, Phys. Rev. Lett. **135**, 171501 (2025)

## T 20: Cosmic Rays I

Time: Monday 16:15–17:45

Location: KS 00.006

T 20.1 Mon 16:15 KS 00.006

**The Roving Laser System for Absolute Energy Calibration of the Fluorescence Telescopes at the Pierre Auger Observatory\*** — •RUKIJE UZEIROSKA-GEYIK for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The Fluorescence Detector (FD) of the Pierre Auger Observatory provides energy measurements of primary cosmic rays that are largely independent of specific interaction models. The FD energy measurement is crucial for calibrating the energy reconstruction of the Surface Detector. Consequently, the accuracy of the FD energy calibration plays a significant role in the systematic uncertainties associated with nearly all scientific results of the Observatory. To this end, a laser with a well-defined energy output will be fired in the field of view of the FD telescopes. Unlike other calibration methods, the response of the telescopes to the laser closely simulates its reaction to an actual cosmic-ray air shower. The system was designed with special attention to the depolarization of the laser beam to ensure a consistent relationship between energy output and directional light yield.

This contribution presents the results of the laboratory test measurements of the laser system, which were performed to validate and optimize its performance before field deployment. In addition, we report on the preparations for the first in-field calibration campaign of the FD telescopes in Argentina.

T 20.2 Mon 16:30 KS 00.006

**Estimating the GZK Photon Flux from Extragalactic Cosmic Rays** — •CHIARA JANE PAPIOR, MARCUS NIECHCIOL, and MARKUS RISSE — Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Extragalactic cosmic-ray sources emit particles with energies beyond 100 EeV. At ultra-high energies, charged particles interact with the cosmic microwave background via photo-pion production, also referred to as the Greisen-Zatsepin-Kuzmin (GZK) effect, generating so-called GZK photons. The photon flux at Earth originating from this effect and other interactions depends on parameters of the cosmic-ray spectrum like the spectral index or potential cutoffs. Other

variables like the distance distribution of sources and the cosmic-ray mass composition have an impact on the expected photon flux as well. Simulations based on different input parameters have been performed with the CRPropa code and the expected GZK photon yields will be presented. The goal is to update the allowed range of the expected GZK photon flux based on current measurements of cosmic-ray observatories at ultra-high energies.

This work is supported by the German Research Foundation (DFG, Project No. 508269468).

T 20.3 Mon 16:45 KS 00.006

**Cosmic-Ray energy spectrum measurements with IceTop** — •FAHIM VARSİ for the IceCube-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

IceTop, the surface ice-Cherenkov array of the IceCube Neutrino Observatory, detects extensive air showers generated from the interaction of the cosmic rays with the atmosphere. It measures cosmic rays in the PeV-EeV energy range, targeting the transition region between galactic and extragalactic cosmic-ray origins, including spectral features such as the knee and the second knee. A novel two-component LDF method is used for event reconstruction, providing an energy estimator along with mass-dependent parameters. An unfolding procedure is then employed to derive the all-particle energy spectrum from the energy estimator parameter. The details of the analysis will be presented in the conference.

T 20.4 Mon 17:00 KS 00.006

**Neural Network-Based Estimation of Muon Content from Data Recorded by the SD-1500 of the Pierre Auger Observatory** — •STEFFEN HAHN for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

Ultra-high-energy cosmic rays (UHECRs) offer insights into the physics beyond the energies of human-made accelerators. However, to fully understand processes such as their acceleration, precise knowledge of their mass composition is crucial. Since the direct detection of UHECRs is infeasible, determining the mass

of the primary particles is challenging. One method of accessing this information is to estimate the number of muons produced in extensive air showers (EASs). The direct measurement of high-energy muons in an EAS can be achieved by using arrays of buried detectors, such as the Underground Muon Detector (UMD) at the Pierre Auger Observatory. However, the instrumentation area of the UMD is limited in size. One of the central components of the Pierre Auger Observatory is the Surface Detector (SD), which consists of multiple triangular grids of hybrid detector stations. These stations record the time signals of the secondary particles that are produced in EASs that reach the ground. In this contribution, we present a neural network (NN) that utilizes SD-1500 data, the main surface detector array of the Pierre Auger Observatory, to predict the muon content of EASs. This NN is calibrated indirectly to the UMD measurements using a calibrated NN designed for the SD-750, the second-largest surface detector array located near the UMD.

T 20.5 Mon 17:15 KS 00.006

**Observation of EarthCARE Laser Emissions with the Pierre Auger Observatory** — •THARA CABA PINEDA for the Pierre Auger-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — Observatorio Pierre Auger, Av. San Martín Norte 304, 5613 Malargüe, Argentina

The Atmospheric Lidar (ATLID) onboard the Earth Clouds, Aerosols and Radiation Explorer (EarthCARE) satellite has been repeatedly observed by the Fluorescence Detector of the Pierre Auger Observatory. Side-scattered ultraviolet light from ATLID laser pulses is recorded by the Auger fluorescence telescopes, which are primarily designed to measure the longitudinal development of extensive air showers initiated by ultra-high-energy cosmic rays. These measurements

enable a precise reconstruction of the atmospheric trajectory of the laser beam over the Observatory and provide a unique opportunity for systematic studies of the local atmospheric aerosol content. Furthermore, EarthCARE laser tracks can be observed at the Telescope Array Experiment in the USA within a few days during the same moon cycle, opening the possibility for a direct cross-calibration of the energy scales of the two cosmic-ray observatories. We present first reconstruction results from ATLID observations following EarthCARE's launch in 2024. These results highlight the potential of satellite-based lidar observations to support calibration and atmospheric characterization efforts at the Pierre Auger Observatory.

T 20.6 Mon 17:30 KS 00.006

**First results of the Auger Radio Infill SKALA Extension (ARISE)** — •CARMEN MERX<sup>1</sup>, STEF VERPOEST<sup>2</sup>, BEN FLAGGS<sup>2</sup>, and FRANK SCHRÖDER<sup>1,2</sup> for the Pierre Auger-Collaboration — <sup>1</sup>Karlsruhe Institute of Technology — <sup>2</sup>University of Delaware

Radio detection of extensive air showers has become a powerful technique for studying high-energy cosmic rays. To further enhance these measurements, the Pierre Auger Observatory in Argentina, one of the world's largest cosmic-ray experiments, has been upgraded with radio antenna stations. This upgrade aims to improve the precision of air-shower energy measurements in the energy range of several tens of PeV and above.

Within this framework, a new experiment, ARISE ("Auger Radio Infill SKALA Extension"), has been deployed at the Pierre Auger Observatory. ARISE consists of six stations, each comprising three SKALA antennas installed around a surface detector in the denser infill region.

This presentation will present first air-shower measurements from ARISE recorded in coincidence with the Auger surface detector array.

## T 21: Invited Overview Talks II

Time: Tuesday 11:00–12:30

Location: AudiMax

### Invited Overview Talk

T 21.1 Tue 11:00 AudiMax

**Three Decades of Dark Matter Annual Modulation Searches: Overview and Current Status** — •KAROLINE SCHAEFFNER — Max-Planck-Institut für Physik, München, Germany — Technische Universität München, München, Germany

A powerful method to discriminate potential dark matter signals from detector backgrounds is to search for an annual modulation in the event rate, induced by the seasonal variation of the Earth's velocity with respect to the Sun and, consequently, to the galactic dark matter halo.

The DAMA/LIBRA experiment pioneered this approach using sodium iodide (NaI(Tl)) detectors and has reported the observation of an annual modulation signal with very high statistical significance, exhibiting a period and phase consistent with expectations for dark matter interactions. The DAMA/LIBRA results remain in strong tension with the null results reported by most other direct dark matter detection experiments. Despite extensive experimental and theoretical efforts, a model-independent verification capable of resolving this long-standing discrepancy is still lacking.

In this talk, I will present an overview of the worldwide experimental program based on NaI detectors, summarize the current status of these experiments, discuss the key experimental challenges, and outline the open questions that continue to keep this enduring puzzle unresolved.

### Invited Overview Talk

T 21.2 Tue 11:30 AudiMax

**Status and meaning of current tensions in cosmology** — •JULIEN LESGOURGUES — RWTH Aachen University

After a decade of consensus around the standard cosmological model, LambdaCDM, more precise data have triggered the emergence of multiple tensions in cosmology. Tensions can hint either at misunderstood systematics or new physics. I will review the current status of the main ones: the Hubble tension, the lack of evidence for massive neutrinos, and recent indications for dynamical dark energy. I will also comment on the difficulty to find a working and plausible theoretical solution to these problems, at least according to our current understanding.

### Invited Overview Talk

T 21.3 Tue 12:00 AudiMax

**In search of the unknown: Pushing the boundaries in searches for new physics at the LHC** — •DANYER PEREZ ADAN — RWTH Aachen University, Sommerfeldstrasse 16, 52074 Aachen, Germany

Several fundamental aspects of particle physics lie beyond the predictive power of the Standard Model (SM), providing strong motivation for the search for new physics at the Large Hadron Collider (LHC). This presentation reviews the current landscape and prospects of searches for physics beyond the Standard Model (BSM) at the LHC experiments. Covered topics include investigations focused on well-motivated scenarios, such as supersymmetric and exotic particles, dark matter, heavy resonances, and extended Higgs sectors, as well as signature-driven strategies that transcend model specificity. Emphasis is placed on the relevance of balancing innovative exploration paradigms and the continued refinement of established methodologies. The growing effort of the experimental collaborations to expand the reach of BSM probes across multiple dimensions—including kinematic coverage, object topologies, and analysis approaches—is also highlighted.

## T 22: Neutrino Physics II

Time: Tuesday 16:15–18:30

Location: AudiMax

T 22.1 Tue 16:15 AudiMax

**Particle Identification in the Hybrid Opaque Scintillator Experiment NuDoubt++** — •KYRA MOSSEL for the NuDoubt-Collaboration — Johannes Gutenberg-Universität Mainz

Neutrinoless double beta decay is a hypothetical lepton-number-violating process whose observation would establish the Majorana nature of the neutrino. Detecting this extremely rare decay demands exceptionally low background levels and highly effective particle identification techniques.

The NuDoubt++ experiment investigates double beta plus decay modes using a novel hybrid opaque scintillator instrumented with a dense grid of optical

fibers coupled to SiPMs. This detector concept enables the reconstruction of energy-deposit topology while simultaneously exploiting the ratio of Cerenkov to scintillation light to enhance background rejection and particle identification.

In this presentation, event reconstruction and particle identification methods developed for NuDoubt++ are presented. Performance studies based on Monte-Carlo simulations are shown, demonstrating the potential of this approach for rare event searches.

T 22.2 Tue 16:30 AudiMax

**NuDoubt++: Search for Double Beta Plus Decays** — •VERONIKA PALUSOVA for the NuDoubt-Collaboration — Johannes Gutenberg-Universität Mainz



Double beta plus decay modes ( $\beta^+\beta^+$ ,  $\beta^+\text{EC}$ , and  $2\text{EC}$ ) are rare second-order weak processes converting two protons into two neutrons. Their observation is difficult due to extremely low probabilities, complex signatures, and the low natural abundance of suitable isotopes. Studying these decays offers insights into nuclear structure and fundamental symmetries. Decay rates depend on nuclear matrix elements (NMEs) and phase space factors (PSFs), crucial for interpreting data and refining theoretical models. We introduce NuDOUBT<sup>++</sup>, a novel detector concept for double beta plus decay searches with unprecedented sensitivity. It integrates hybrid and opaque scintillation technologies with advanced light readout to enhance positron detection. Preliminary estimates show that a 1-tonne-week exposure could reach sensitivity to  $2\nu\beta^+\beta^+$  and  $2\nu\beta^+\text{EC}$  decays in  $^{78}\text{Kr}$ . The design also improves background rejection and resolution, enabling exploration of  $0\nu\beta^+\beta^+$  decay beyond current limits.

T 22.3 Tue 16:45 AudiMax

**LEGEND-1000: Quasi Background-Free Search for Neutrinoless Double Beta Decay in  $^{76}\text{Ge}$  at the Ton-Scale** — •LORENZ GESSLER for the LEGEND-Collaboration — Eberhard Karls Universität, Tübingen, Germany

In pursuit of the observation of the first lepton-number violating process, the LEGEND collaboration is progressing towards a next-generation detector – LEGEND1000. The search for the neutrinoless double beta decay of  $^{76}\text{Ge}$  probes the Majorana nature of neutrinos as well as the absolute neutrino mass scale, directly accessing physics beyond the Standard Model. Lessons learned from GERDA, MAJORANA Demonstrator and LEGEND200 allow us to further improve background mitigation strategies and to bring state-of-the-art high-purity germanium detector technology to the ton-scale, enabling a quasi background-free regime at the design exposure. This will allow LEGEND1000 to probe the entire effective Majorana mass range of the inverted ordering, corresponding to a half-life sensitivity exceeding  $10^{28}$  yr. This overview talk summarizes the current status of LEGEND1000 and highlights recent progress in the experimental design, background rejection strategy, and overall detector concept.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFT Verbundprojekt 05A2023 (LEGEND).

T 22.4 Tue 17:00 AudiMax

**LEGEND-200: Recent results and experimental status** — •NADEZDA RUMYANTSEVA for the LEGEND-Collaboration — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

LEGEND is a staged program progressing from LEGEND-200 to the ton-scale LEGEND-1000, searching for neutrinoless double-beta decay ( $0\nu\beta\beta$ ) in  $^{76}\text{Ge}$ . Using enriched high-purity germanium detectors, LEGEND targets discovery sensitivity to half-lives beyond  $10^{28}$  years.

LEGEND builds on the GERDA and MAJORANA Demonstrator experiments and employs novel inverted-coaxial HPGe detectors operated in instrumented liquid argon, providing powerful signal identification and background rejection capabilities. The first LEGEND-200 physics results are based on an exposure of 61.0 kg yr and, in combination with GERDA and the MAJORANA Demonstrator, achieve a world-leading 90% confidence-level exclusion sensitivity of  $2.8 \times 10^{26}$  yr and set a lower limit of  $T_{1/2}^{0\nu} > 1.9 \times 10^{26}$  yr.

This talk summarizes the LEGEND-200 experimental concept, background-reduction strategy, and latest results.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We also acknowledge support from the BMFT Verbundprojekt 05A2023 (LEGEND).

T 22.5 Tue 17:15 AudiMax

**First observation of reactor antineutrinos by coherent scattering with CONUS+** — •NICOLA ACKERMANN for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The CONUS+ experiment measures coherent elastic reactor anti-neutrino nucleus scattering (CEvNS) on germanium nuclei. The detector is located at the KKL nuclear power plant in Leibstadt, Switzerland at a distance of 20.7 m from the reactor core. It uses four High Purity Germanium detectors with energy thresholds of  $\sim 160$  eV. In Run 1 of the experiment, which lasted from November 2023 to August 2024, the first observation of a CEvNS signal from a nuclear reactor was achieved. In 119 days of data taking (395+/-106) anti-neutrinos were measured, compared to a predicted number of (347+/-59) events. For improved sensitivity, the experiment is currently taking data in Run 2 using three new 2.4 kg germanium detectors.

T 22.6 Tue 17:30 AudiMax

**Beyond the Standard Model investigations at CONUS+** — •DARIO PIANI for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The detection of coherent elastic neutrino-nucleus scattering (CEvNS) opens up new opportunities for neutrino physics within and beyond the standard model (BSM) of elementary particles. The first detection of CEvNS at nuclear reactors by the CONUS+ experiment allows very valuable tests of BSM scenarios in a low momentum transfer regime. Among them, Non Standard Interactions (NSIs), light mediators (scalar and vector couplings) and electromagnetic properties were tested, setting very competitive limits in both the nuclear scattering interaction channel as well as the electron scattering channel. In particular, for vector NSIs a sensitivity to new physics of up to 145 GeV was achieved. Whereas, for the light mediators, couplings down to  $10^{-6}$  were probed.

T 22.7 Tue 17:45 AudiMax

**Exploring coherent elastic neutrino-nucleus scattering with NUCLEUS: Overview of the experiment** — •ALEXANDER WALLACH for the NUCLEUS-Collaboration — Technical University Munich, Munich, Germany

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) is a pure weak-neutral current interaction predicted within the Standard Model. The CEvNS cross section is several orders of magnitude larger than that of other low-energy neutrino interactions, enabling its study with small, highly sensitive detectors. Investigating CEvNS provides a pathway to probe neutrino properties, explore physics beyond the Standard Model, and address the CEvNS background in dark matter searches.

The NUCLEUS experiments aim to perform precision measurements of CEvNS properties using reactor antineutrinos at the Chooz nuclear power plant. In order to measure nuclear recoils below 100eV, NUCLEUS employs a multi-stage detection system, consisting of  $\text{CaWO}_4$  and  $\text{Al}_2\text{O}_3$  cryogenic calorimeters with an  $\mathcal{O}(10\text{ eV})$  energy threshold, surrounded by a twofold system of instrumented cryogenic vetoes, an external passive shielding and a muon veto to improve the identification and discrimination of backgrounds.

In this talk I will give an overview of the NUCLEUS experiment, focusing on the underlying physics motivation and the detection concept.

T 22.8 Tue 18:00 AudiMax

**Exploring coherent elastic neutrino-nucleus scattering: status of the NUCLEUS experiment** — •LARS WIENKE for the NUCLEUS-Collaboration — Technische Universität München, München, Deutschland

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) is a Standard Model process in which a neutrino scatters coherently off an entire nucleus via weak neutral current interactions. The CEvNS cross section is several orders of magnitude larger than that of other low-energy neutrino interactions, which makes this process a powerful tool to probe various physics scenarios, motivating a worldwide effort to detect the tiny nuclear recoils it produces.

The NUCLEUS experiment aims to perform precision measurements of CEvNS properties using reactor antineutrinos at the Chooz nuclear power plant. In order to measure nuclear recoils below 100eV, NUCLEUS employs a multi-target detection system, consisting of  $\text{CaWO}_4$  and  $\text{Al}_2\text{O}_3$  cryogenic calorimeters with an  $\mathcal{O}(10\text{ eV})$  energy threshold, surrounded by a twofold system of instrumented cryogenic vetoes, an external passive shielding and a muon veto to improve the identification and discrimination of backgrounds.

At present, the experiment is in the last steps of commissioning in the shallow underground laboratory at the Technical University of Munich (TUM), and the relocation to the Chooz-B nuclear power plant in the French Ardennes is underway. In this talk, I will provide an overview of the experiment's current status, focusing on the latest developments, milestones achieved and future plans.

T 22.9 Tue 18:15 AudiMax

**Development of a Novel Te-doped Liquid Scintillator with Slow Light Emission for  $0\nu\beta\beta$ -Decay Searches in a Hybrid Neutrino Detector** — •HANS TH. J. STEIGER<sup>1</sup>, M. BERETTA<sup>2</sup>, M. BÖHLES<sup>3</sup>, A. GARFAGNINI<sup>4</sup>, A. GAVRIKOV<sup>4</sup>, P. LOMBARDI<sup>2</sup>, K. LOO<sup>5</sup>, E. PASINI<sup>4</sup>, B. RASERA<sup>4</sup>, A. SERAFINI<sup>4</sup>, K. WALTER<sup>1</sup>, and M. WURM<sup>3</sup> — <sup>1</sup>Technical University of Munich, TUM School of Natural Sciences, Garching, Germany — <sup>2</sup>INFN, Sezione di Milano e Università degli Studi di Milano, Dipartimento di Fisica, Italy — <sup>3</sup>Institute for Physics, Johannes Gutenberg University Mainz, Mainz, Germany Mainz, Germany — <sup>4</sup>Dipartimento di Fisica e Astronomia dell'Università di Padova and INFN Sezione di Padova, Padova, Italy — <sup>5</sup>University of Jyväskylä, Department of Physics, Jyväskylä, Finland

It is a long-standing paradigm that organic scintillators allow excellent energy resolution but no directional reconstruction. Here we show the foundation for overcoming this by scintillators with slow light emission, paving the way for hybrid detectors that combine the advantages of Cherenkov and scintillation detectors. In such slow liquid scintillators, it is possible to reconstruct directional and topological information from Cherenkov light, while the high light yield of an organic scintillator ensures excellent energy resolution and low thresholds necessary for many applications in neutrino and particle physics such as the search for the  $0\nu\beta\beta$  decay. We also developed a novel loading technique for these scintillators with  $^{130}\text{Te}$  and show studies of fundamental properties of these scintillators and the novel dopant. This work is supported by the Clusters of Excellence PRISMA+ and ORIGINS.

## T 23: Top Physics I

Time: Tuesday 16:15–18:15

Location: KH 00.011

T 23.1 Tue 16:15 KH 00.011

**Measurement of differential cross sections in the process  $pp \rightarrow WWbb$  with the ATLAS experiment** — •JOHANNES HESSLER — Max-Planck-Institut für Physik, Boltzmannstr. 8, 85748 Garching

Precise measurements of differential cross sections in the process  $pp \rightarrow WWbb$  offer an outstandingly rich physics potential at highest precision. Although the process is theoretically and experimentally well defined, dedicated measurements of  $WWbb$  production cross sections were not (extensively) performed in the past at the LHC.

I will report on recently published measurements in the single-lepton channel with Run-II data taken by the ATLAS experiment. The analysis comprises three signal regions, focusing on the interference between  $t\bar{t}$  and  $tW$  processes, the explicit reconstruction of the kinematics of the  $WWbb$  system and on phase spaces motivated by BSM searches.

T 23.2 Tue 16:30 KH 00.011

**Extracting the Top Yukawa coupling from the  $t\bar{t}$  differential cross section in dilepton channel using ATLAS data** — •SADIA MARIUM — DESY, Zeuthen

Top quark, being the heaviest Standard Model fermion, has the highest value of Yukawa coupling with the Higgs field. This contribution presents an extraction of the top-quark Yukawa coupling, ( $Y_t$ ), from the  $t\bar{t}$  differential cross-section in the dilepton final state. Near the  $t\bar{t}$  production threshold, electroweak virtual corrections, including Higgs-boson exchange, modify the kinematic distributions of the invariant mass of the  $t\bar{t}$  system  $M_{t\bar{t}}$  and the top quark production angle  $\cos\theta_t^*$  in the  $t\bar{t}$  rest frame. These kinematic variables are therefore sensitive to  $Y_t$ , and hence, their distributions are used to extract its value. In the dilepton channel, the presence of two neutrinos prevents full event reconstruction, motivating the use of proxy observables that retain sensitivity to these effects. The analysis uses proton-proton collision data at  $\sqrt{s} = 13$  TeV corresponding to an integrated luminosity of  $140 \text{ fb}^{-1}$ , collected with the ATLAS detector at the Large Hadron Collider.

T 23.3 Tue 16:45 KH 00.011

**NNLO soft function for 0-jettiness in (associated)  $t\bar{t}$  production** — GUIDO BELL<sup>1</sup>, ALESSANDRO BROGGIO<sup>2</sup>, •SEBASTIAN EDELMANN<sup>1</sup>, MATTHEW A. LIM<sup>3</sup>, and RUDI RAHN<sup>2</sup> — <sup>1</sup>Theoretische Physik 1, Center for Particle Physics Siegen, Universität Siegen, Germany — <sup>2</sup>Faculty of Physics, University of Vienna, Austria — <sup>3</sup>Leonardo UK, Luton LU1 3PG, United Kingdom

Given the exceptional precision of LHC data, a detailed theoretical understanding of  $t\bar{t}$  and  $t\bar{t}X$  cross sections, where  $X = \gamma, W, Z, H$ , is required to better probe the top and the Higgs sectors of the Standard Model and search for new physics.

One promising method to achieve precise QCD calculations is N-jettiness slicing. It was shown that the  $t\bar{t}$  production cross section factorizes into hard, beam and soft functions at small values of the 0-jettiness variable. At NNLO only the relevant soft functions are currently missing for processes with two heavy quarks in the final state. By extending the SoftSERVE program to incorporate massive final-state partons, we were able to automate the numerical computation of the renormalized  $t\bar{t}$  soft function for various observables and verify its pole structure using the renormalization group equation.

The produced grids can be used to implement associated  $t\bar{t}$  production processes in the Monte-Carlo event generator GENEVA.

T 23.4 Tue 17:00 KH 00.011

**Studies of the  $t\bar{t}$ +heavy flavour jets using the ATLAS data** — •ABDERAHMANE MAIZA, MAHSANA HALEEM, and RAIMUND STRÖHMER — Universität Würzburg, Germany

The top-quark pair production in association with heavy-flavour jets provides an essential test of quantum chromodynamics (QCD) predictions. These processes are challenging to model and constitute large irreducible background to rare SM processes such as  $t\bar{t}H$  and  $tH$  productions as well as to the processes predicted by several extensions of the Standard Model.

The fiducial and differential cross-sections of  $t\bar{t}$ +b-jets have been measured using the ATLAS Run-2 data with precision ranging from 8.5% – 20%. Inclusive cross-section of  $t\bar{t}$ +c-jets has been measured with the precision of 15% – 20% in given phase space. Further improvements in these measurements are expected through exploitation of the full ATLAS Run-2 and Run-3 datasets, improved MC simulations, advanced background estimation techniques and enhanced b-/c-jet origin classification leading to better event construction.

This talk will present the ongoing developments on the b-jets classifications in  $t\bar{t}bb$  events using a transformer network. Furthermore, the method for the simultaneous estimation of flavour composition of additional jets in  $t\bar{t}$ +jets events will be presented.

T 23.5 Tue 17:15 KH 00.011

**First measurement of the CKM matrix element  $|V_{cb}|$  in  $t\bar{t}$  decays with the ATLAS detector** — DIPTAPARNA BISWAS, CAROLINA COSTA, MARKUS CRISTINZIANI, CARMEN DIEZ PARDOS, IVOR FLECK, GABRIEL GOMES, JAN JOACHIM HAHN, NIKOLAOS KAMARAS, VADIM KOSTYUKHIN, NILS BENEDIKT KRENGEL, AUSTIN OLSON, INÊS PINTO, SEBASTIAN RENTSCHLER, ELISABETH SCHOPF, KATHARINA VOSS, WOLFGANG WALKOWIAK, and •ADAM WARNERBRING — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The CKM matrix element  $|V_{cb}|$  is one of the free parameters of the Standard Model. Until now, all determinations of  $|V_{cb}|$  have relied on  $B$ -hadron decays, using either inclusive measurements, which include all possible final states, or exclusive measurements that focus on specific decay channels. Between these methods, a tension of about  $3\sigma$  is observed. However,  $|V_{cb}|$  can also be determined from on-shell  $W$  boson decays, as the branching ratio of  $W \rightarrow cb$  is proportional to  $|V_{cb}|^2$ . This talk presents the first ATLAS measurement to determine  $|V_{cb}|$  from hadronic  $W$  boson decays in  $t\bar{t}$  production, targeting events in which one  $W$  boson decays leptonically and the other hadronically. The talk will cover the data analysis strategy, including the multivariate classifier used to separate signal from background and the use of flavour tagging, along with the dominant systematic uncertainties. The measurement is the first determination of this CKM matrix element at the electroweak scale and provides an orthogonal determination of  $|V_{cb}|$  compared to previous measurements.

T 23.6 Tue 17:30 KH 00.011

**Flavour Changing Neutral Current decays of the top quark to a Higgs boson and a charm or up quark with the ATLAS experiment** — DIPTAPARNA BISWAS, CAROLINA COSTA, MARKUS CRISTINZIANI, CARMEN DIEZ PARDOS, IVOR FLECK, GABRIEL GOMES, JAN JOACHIM HAHN, NIKOLAOS KAMARAS, VADIM KOSTYUKHIN, NILS BENEDIKT KRENGEL, AUSTIN OLSON, •INÊS PINTO, SEBASTIAN RENTSCHLER, ELISABETH SCHOPF, KATHARINA VOSS, WOLFGANG WALKOWIAK, and ADAM WARNERBRING — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Top-quarks can decay to lighter quarks with the same charge by emitting a neutral boson in processes called Flavour Changing Neutral Current (FCNC). These are forbidden at the lowest order, and highly suppressed at higher orders, by the Glashow-Iliopoulos-Maiani mechanism.

We aim to search for FCNC decays of a top quark to a Higgs boson, and either a charm or an up quark, with data collected by the ATLAS detector during Run 2 and the ongoing Run 3 of the LHC. These decay modes are extremely rare, with expected branching ratios of about  $10^{-15}$  for  $t \rightarrow Hc$  and  $10^{-17}$  for  $t \rightarrow Hu$ , far beyond the sensitivity of current detectors. As such, observing these decays at a significant rate would be a clear indication of New Physics. The search will aim to exploit the highest branching ratio decay mode of the Higgs boson,  $H \rightarrow b\bar{b}$ , taking advantage of the latest machine learning developments in jet flavour tagging in the ATLAS experiment.

T 23.7 Tue 17:45 KH 00.011

**FCNC in the Top Sector** — •MAURICE SCHÜSSLER<sup>1</sup>, PEDRO MIGUEL FERREIRA<sup>2</sup>, and MILADA MARGARETE MÜHLEITNER<sup>1</sup> — <sup>1</sup>Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>2</sup>Universidade de Lisboa, Lisboa, Portugal

Several observations give access to physics beyond the Standard Model. Among these are flavor-changing neutral currents, which are suppressed within the Standard Model. While flavor-changing neutral current processes in the bottom sector are strongly constrained experimentally even in beyond Standard Model theories, those involving the top quark remain less explored due to its short lifetime. In our work, we extend the Standard Model by an additional Higgs doublet and study the flavor-changing neutral currents of these Higgs bosons, focusing on the top sector. Within this framework a scan of the possible parameter space is done after taking into account experimental constraints. Then the cross section of flavor violating final states originating from gluon fusion is calculated and discussed.

T 23.8 Tue 18:00 KH 00.011

**Measurement prospects for the top-antitop energy asymmetry in the production with an additional jet in the resolved topology with ATLAS** — •JESSICA HÖFNER, ANNIKA STEIN, FREDERIC FISCHER, and LUCIA MASETTI — University Mainz, Institute for physics

The top quark is the heaviest particle in the Standard Model (SM) of particle physics and the only quark which decays before hadronization can happen. The top quark is suitable for the search of physics beyond the SM of particle physics (BSM). There could be even heavier particles and they might become observable at higher center-of-mass energies, and the top quark could potentially interact with them. At the currently reachable center-of-mass energies, however, the impact of BSM physics might only be indirectly observable via the variation

of properties of the production or decay of SM particles. In the production of a top-antitop pair with an additional jet at the LHC the energy asymmetry, complementary to the rapidity asymmetry, can be measured. The energy asymmetry is expected in the SM, but also sensitive to physics beyond the SM and therefore it is of high interest to measure this observable. The measurement is performed

in the single lepton and jets resolved topology, in which the quarks are reconstructed separately in small-R jets. The challenge in the event reconstruction is to assign the jets to the correct mother particle, which is done using a neural network. This presentation will show the performance of the neural network and the impact of the event reconstruction on the energy asymmetry measurement.

## T 24: Standard Model Physics II

Time: Tuesday 16:15–18:15

Location: KH 00.014

T 24.1 Tue 16:15 KH 00.014

**Hadronic Recoil in future high  $\mu$  measurements** — FABRICE BALLI<sup>1</sup>, •TIM FREDERIK BEUMKER<sup>2</sup>, and FRANK ELLINGHAUS<sup>2</sup> — <sup>1</sup>Université Paris-Saclay — <sup>2</sup>Bergische Universität Wuppertal

A precise calculation of the missing transverse momentum ( $E_T^{\text{miss}}$ ) is crucial for many Standard Model measurements. In addition, the recently published measurement of charged-current Drell-Yan cross-sections at high transverse masses showed that uncertainties arising from the  $E_T^{\text{miss}}$  calculation dominate, in particular when determining fake lepton contributions.

The Hadronic Recoil provides an alternative method of calculating the  $E_T^{\text{miss}}$  by using the recoil of the vector boson. It has been successfully used in low- $\mu$  precision  $W$  measurements so far and an implementation of the Hadronic Recoil was moved to the central ATLAS reconstruction software, to make it accessible for future high- $\mu$  ( $\hat{=}$  #interactions per bunch crossing) analyses. This talk presents the general procedure for calculating the Hadronic Recoil and its validation at high  $\mu$ .

T 24.2 Tue 16:30 KH 00.014

**Measuring the  $W$  Mass with the ATLAS low- $\langle\mu\rangle$  Dataset** — •MATHIAS BACKES — Heidelberg University

The measurement of the mass of the  $W$ -boson is one of the fundamental tests of the Standard Model. ATLAS (2024) and CMS (2024) published measurements presenting results for the  $W$ -mass which are in agreement with the Standard Model. These measurements are in more than  $5\sigma$  tension with the value obtained by the CDF collaboration (2022). In order to investigate this tension ATLAS is currently performing an additional measurement.

The  $W$  mass is most accurately measured using the leptonic decay channel  $W \rightarrow l\nu_l$  with  $l \in (e, \mu)$ . The low-pileup dataset of ATLAS (taken in Run-2) is especially useful because a central aspect of this analysis is the precise estimation of the hadronic recoil to infer the energy and direction of the neutrino. Since the  $W$  mass cannot be measured directly it has to be inferred through comparisons with Monte Carlo simulations in a Profile Likelihood Fit.

In this talk the current status of the analysis including the details of the Profile Likelihood Fit is presented.

T 24.3 Tue 16:45 KH 00.014

**Impact of measuring the  $W$  boson mass in a combined analysis at several collision energies with the ATLAS experiment** — PHILIP BECHTLE<sup>1</sup>, •OLIVER BUT<sup>1</sup>, MATTHIAS SCHOTT<sup>1</sup>, and CHEN WANG<sup>2</sup> — <sup>1</sup>Physikalisches Institut, Universität Bonn — <sup>2</sup>Deutsches Elektronen Synchrotron, Hamburg

The precision measurement of the  $W$  boson mass is an important consistency test of the standard model. To match the standard model fit uncertainty of the  $W$  boson mass of less than 10 MeV all sources of uncertainties have to be carefully controlled. One strategy is to include data taken at multiple proton proton collision energies and fit them simultaneously. As a consequence, systematic effects which act differently for different collision energies decorrelate from the parameter of interest and reduce their impact on the uncertainty.

In this talk, I introduce the concept of correlated parameters and demonstrate how combining a 5 TeV and 13 TeV dataset in the  $W$  mass measurement at the ATLAS experiment can help reduce the uncertainty coming from systematics.

T 24.4 Tue 17:00 KH 00.014

**Study of electroweak production of  $W(\ell\nu)\gamma\gamma$  events in the Run-2 and Run-3 proton-proton collision data of the ATLAS detector.** — •SINA AKTAS, GIA KHORIAULI, RAIMUND STRÖHMER, and THOMAS TREFZGER — Julius-Maximilians-Universität Würzburg, Würzburg, Germany

Production of electroweak vector bosons provides a sensitive probe of the gauge interactions of the Standard Model, especially through the study of heavy gauge boson polarisation. The longitudinal polarisation of the  $W$  and  $Z$  bosons is of particular interest. The electroweak production of the  $W\gamma\gamma$  events in proton-proton collisions at the LHC is sensitive to triple and quartic electroweak gauge couplings and its study provides an opportunity to test the predictions of the electroweak theory.

We work on the development of analysis methods to measure differential cross sections and polarisation fractions of the  $W$  boson in the electroweak produc-

tion of  $W(\ell\nu)\gamma\gamma$  in the ATLAS detector. The analysis will use the full datasets of proton-proton collisions at the LHC at  $\sqrt{s} = 13\text{TeV}$  (Run-2) and  $\sqrt{s} = 13.6\text{TeV}$  (Run-3).

In this work, we discuss the current status of the study. The methods and preliminary results of the analysis based on Monte Carlo simulations are presented.

T 24.5 Tue 17:15 KH 00.014

**Machine Learning Based Tagging of Vector Boson Polarization** — •LENA AL-SHUT, ERIK BACHMANN, MAREEN HOPPE, and FRANK SIEGERT — Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Germany

The longitudinal polarization of massive vector bosons (MVBs) is a direct consequence of electroweak symmetry breaking and serves as a sensitive probe of the Higgs mechanism and potential new physics. Because longitudinally polarized MVBs are rare, previous studies at the LHC have relied on neural-network classifiers trained to distinguish polarization states. However, this formulation depends on nonphysical quantities with unknown distribution and assumes classes of purely longitudinal or transverse polarized MVBs.

In this work, the alternative strategy of polarization fraction regression is explored. These fractions at phase-space point level are physical observables with well-defined distributions. This enables a direct comparisons of model predictions and MC truth values, providing the opportunity for systematic improvement of polarization tagging.

We develop a Machine Learning-based tagger that predicts event level polarization fractions using the four-momenta of final-state particles. A MLP and a Transformer are trained on Standard Model expectations. In this talk, we present results for  $Z$ +jets in the leptonic decay channel at LO, LO+PS, and higher perturbative orders as an exemplary test case. The approach can directly be translated to the analysis of LHC pp collision data, where it allows for a more physical interpretation of polarization measurements.

T 24.6 Tue 17:30 KH 00.014

**Probing vacuum dispersion with electron-laser interactions** — •ANTHONY HARTIN — LMU, Munich, Germany

Particle physics processes occurring in the strong field of an intense laser can only be fully described by a quantum field theory that is non-perturbative with respect to the strong field. Such a theory is provided by the Furry interaction picture where the strong field is included in exact solutions of the Dirac equation. These solutions describe a new particle, the bound fermion, which sees a structured space-time depending on where it is in relation to the kinematics and phase of the strong field. This theory predicts novel phenomenology, including a shift in rest mass of the bound fermion, a dispersive vacuum and consequently, novel resonances in the bound fermion propagator. We review the theory and phenomenology and propose an experiment which can detect these novel non-perturbative resonances.

T 24.7 Tue 17:45 KH 00.014

**The gradient flow coupling of three- and four-dimensional QED** — •LARS GEORG, ROBERT HARLANDER, and ROBERT MASON — RWTH Aachen University

Connecting low-energy lattice results to high-energy continuum calculations is highly nontrivial, as they rely on fundamentally different regularizations. The gradient flow offers an elegant way to bridge this gap, since it can be implemented both on the lattice and in the continuum and naturally defines renormalized couplings and observables.

While the GF up to now has found most of its applications in QCD, I consider its implementations in other theories such as scalar QCD, or theories with  $U(1)$  gauge factor. I present explicit results for the perturbative gradient-flow coupling for QED in  $(3+1)$  and  $(2+1)$  dimensions. QED<sub>4</sub> serves as a clean Abelian testing ground and limiting case of QCD, while QED<sub>3</sub> shares important qualitative features with QCD such as chiral symmetry breaking and the presence of an infrared fixed point in the large- $N_f$  expansion.

T 24.8 Tue 18:00 KH 00.014

**Nonrelativistic reduction of relativistic effective field theories** — •TOBIAS ASANO<sup>1</sup>, FABIO DI PUMPO<sup>2</sup>, ENNO GIESE<sup>3</sup>, and MOTOAKI BAMBA<sup>1,4</sup> —

<sup>1</sup>Department of Physics, Graduate School of Engineering Science, Yokohama National University, Japan — <sup>2</sup>Institut für Quantenphysik, Universität Ulm, Ger-

many — <sup>3</sup>Technische Universität Darmstadt, Institut für Angewandte Physik, Germany — <sup>4</sup>Institute for Multidisciplinary Sciences, Yokohama National University, Japan

The applications of effective field theories (EFTs) range from Standard Model EFT to nonrelativistic (NR) EFTs like NR quantum chromodynamics. A symmetry-based construction of relativistic EFTs, like Standard Model EFT is straightforward. In contrast, Lorentz invariance is not trivial in NR EFTs, making a construction more complicated. While construction rules are well understood for, e.g., NR quantum chromodynamics, there is no simple extension when one includes more fields, such as gravity.

In this work, we present an approach starting from the construction of a relativistic EFT, conceptually close to Standard Model EFT, and perform an NR reduction, centered on an extended Foldy-Wouthuysen transformation, leading to NR quantum chromodynamics, for instance. Such a treatment is highly suited for theories where NR construction rules are not straightforward, such as an EFT on curved spacetime.

This work is supported by the Japan Society for the Promotion of Science (JSPS) (Grant Nos. JP25KJ1313, JP24K21526, JP25K00012, JP25K01691, JP25K01694, JPJSJRP20221202) and the Research Foundation for Opto-Science and Technology.

## T 25: Higgs Physics III

Time: Tuesday 16:15–18:15

Location: KH 00.016

T 25.1 Tue 16:15 KH 00.016

**Measurement of differential cross-sections in the  $H \rightarrow ZZ^* \rightarrow 4\ell$  decay channel with the ATLAS Run 3 data** — •ELENA CUPPINI<sup>1</sup>, SANDRA KORTNER<sup>1</sup>, OLIVER KORTNER<sup>1</sup>, LUCA SPITZAUER<sup>1</sup>, ALICE REED<sup>2</sup>, and TAE HYOUN PARK<sup>1</sup> — <sup>1</sup>Max Planck Institute for Physics — <sup>2</sup>University of Glasgow

The decay of the Higgs boson into a pair of Z bosons, which subsequently decay to four leptons ( $H \rightarrow ZZ^* \rightarrow 4\ell$ ), provides a clean signature and high signal-to-background ratio for studying the properties of the Higgs boson. This allows for precise differential fiducial cross-section measurements of this decay channel.

The measurement is performed using 165 fb<sup>-1</sup> of proton-proton collision data at  $\sqrt{s} = 13.6$  TeV recorded with the ATLAS detector between 2022 and 2024. This data set, for the first time, surpasses the size of the full Run 2 sample, enabling further improvement in measurement precision. The analysis minimises model dependence by employing fiducial phase-space selections that closely match the experimental acceptance, together with corrections for detector effects. The results will be compared to Standard Model predictions, with emphasis on key differential observables.

T 25.2 Tue 16:30 KH 00.016

**Higgs boson production cross-section measurements in the  $H \rightarrow ZZ^* \rightarrow 4\ell$  decay channel with the ATLAS Run 3 data** — •LUCA MATTHIAS SPITZAUER<sup>1</sup>, ELENA CUPPINI<sup>1</sup>, SANDRA KORTNER<sup>1</sup>, OLIVER KORTNER<sup>1</sup>, TAE HYOUN PARK<sup>1</sup>, and ALICE REED<sup>2</sup> — <sup>1</sup>Max-Planck-Institut für Physik, Garching — <sup>2</sup>University of Glasgow, Glasgow

Cross-section measurements of various Higgs boson production processes are crucial for exploring Higgs boson properties and are highly sensitive to potential physics beyond the Standard Model. The decay of the Higgs boson into a pair of Z bosons, each subsequently decaying into two leptons ( $H \rightarrow ZZ^* \rightarrow 4\ell$ ), is particularly important for these measurements due to its exceptionally clean signature.

Within the framework of Simplified Template Cross Sections (STXS), exclusive regions of phase space are defined for the different Higgs boson production modes. Accurate classification of reconstructed events into the appropriate STXS Higgs production regions is essential to enhance signal sensitivity and reduce uncertainties. The latest cross-section measurements in each STXS production region are based on 165 fb<sup>-1</sup> of Run 3 ATLAS data. The analysis results are presented together with improvements achieved through an optimized classification employing a new Set Transformer machine learning model, replacing the baseline Recurrent Neural Network method.

T 25.3 Tue 16:45 KH 00.016

**Measurement of  $H \rightarrow \gamma\gamma$  fiducial cross sections with 13.6 TeV CMS data** — •CAIO DAUMANN, JOHANNES ERDMANN, LINUS ERDMANN, JAN LUKAS SPÄH, and MAXIMILIAN WRABETZ — RWTH Aachen, Physikalisches Institut III A

The Higgs boson is of fundamental importance for the understanding of particle physics. Since its discovery in 2012, it has been studied extensively by the ATLAS and CMS collaborations. The measurement of Higgs boson production cross sections is crucial for studying deviations from the Standard Model (SM) in the scalar sector.

In this presentation, the developments and current status of the Run 3  $H \rightarrow \gamma\gamma$  fiducial cross-section measurement are presented. With the increasing amount of data collected by the CMS experiment, these measurements are able to precisely test the SM and set constraints on scenarios beyond the SM. Effective Field Theory (EFT) and light-quark Yukawa coupling interpretations of these measurements are presented.

Special emphasis is placed on the statistical analysis, interpretations, and the new methods employed. In particular, the implementation and impact of the main systematic uncertainties are discussed, which become increasingly relevant with the unprecedented amount of data provided by the LHC during Run 3.

T 25.4 Tue 17:00 KH 00.016

**STXS Measurements of  $H \rightarrow \gamma\gamma$  Cross Sections with 13.6 TeV CMS Data** — JOHANNES ERDMANN and •MAXIMILIAN WRABETZ — III. Physikalisches Institut A, RWTH Aachen University

The discovery of the Higgs boson opened the way to test the standard model through precise measurements of its production and decay properties. As the experimental precision increases with the large Run 3 datasets, a key challenge is to design measurements that remain interpretable in the presence of potential physics beyond the standard model (BSM), while maintaining minimal dependence on theoretical assumptions.

This contribution discusses the ongoing efforts within the CMS experiment to perform Higgs boson cross-section measurements in the simplified template cross section (STXS) framework, using events in which the Higgs boson decays into a pair of photons. The analysis makes use of proton-proton collision data recorded at a centre-of-mass energy of  $\sqrt{s} = 13.6$  TeV.

The STXS framework partitions Higgs production into a set of well-defined particle-level bins, characterised by the production mode and key kinematic variables. This granular binning reduces the dependence on detailed SM modelling and isolates specific regions of phase space that are particularly sensitive to potential BSM contributions. The talk will outline the analysis strategy and highlight selected methodological components, with a focus on ongoing developments.

T 25.5 Tue 17:15 KH 00.016

**Combined analysis of  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^* \rightarrow 4\ell$  cross sections using partial Run-3 CMS data** — •LINUS ERDMANN, JOHANNES ERDMANN, JAN LUKAS SPÄH, and MAXIMILIAN WRABETZ — III. Physikalisches Institut A, RWTH Aachen University

Measurements of the Higgs boson production cross sections and decay channels are extensively studied and essential to probe possible deviations from the standard model in the scalar sector.

This presentation outlines studies towards a combined measurement of the Higgs boson production cross section in the diphoton and four-lepton decay channels with the CMS experiment. The dataset used comprises proton-proton collisions at  $\sqrt{s} = 13.6$  TeV recorded during Run-3, corresponding to an integrated luminosity of 171.4 fb<sup>-1</sup>. Both decay channels provide clean signatures and well-understood event topologies, which contribute to a precise determination of Higgs boson properties. Their combination increases the overall statistical precision and enables the simultaneous constraint of several Higgs boson properties. For each channel, the cross sections are measured in a fiducial phase space at particle level, which enhances model independence and minimises extrapolation uncertainties, before being extrapolated to the total phase space for the combined measurement.

These studies highlight the potential of combining different Higgs boson decay channels for a more precise determination of its production cross sections and discuss prospects for simultaneously constraining Higgs boson couplings through the joint analysis of the two channels.

T 25.6 Tue 17:30 KH 00.016

**Quantum tomography using machine learning to infer incomplete information in  $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$**  — CARSTEN BURGARD<sup>1</sup>, VINCE CROFT<sup>2</sup>, ANDRÉ SOPČZAK<sup>3</sup>, •ANDRII VAK<sup>3</sup>, and LENNART VÖLZ<sup>1</sup> — <sup>1</sup>TU Dortmund University — <sup>2</sup>Leiden University — <sup>3</sup>CTU in Prague

We present a novel experimental strategy for testing quantum entanglement in Higgs boson decays to W boson pairs at the Large Hadron Collider. Unlike theoretical approaches that rely on expectation values of Bell operators, which are highly sensitive to outliers and detector effects, we introduce a continuous formulation of the CGLMP inequality that enables standard hypothesis testing between entangled and separable states. To overcome the fundamental challenge of reconstructing invisible neutrino momenta in the  $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$  channel, we employ conditional denoising diffusion probabilistic models (cD-

DPM), which provide unbiased, multidimensional unfolding applicable to the full measured dataset including backgrounds. We compare the performance of diffusion-based reconstruction against neural network regression and analytical methods, evaluating each through profile likelihood hypothesis tests implemented in RooFit. Our results demonstrate that the diffusion-based approach enables robust hypothesis testing of quantum entanglement in a realistic collider environment, achieving sensitivity to Bell inequality violation with existing LHC datasets.

T 25.7 Tue 17:45 KH 00.016

**Constraining Effective Field Theory operators in the HZZ4 channel with CMS** — •CHRISTIAN-MAX SAMMORAY, MATTEO BONANOMI, JOHANNES HALLER, and MATTHIAS SCHRÖDER — Institut für Experimentalphysik, Universität Hamburg

The discovery of the Higgs boson in 2012 by the CMS and ATLAS collaborations at the CERN Large Hadron Collider (LHC) set a major milestone in confirming the predictive power of the Standard Model (SM) of particle physics. However, despite its remarkable success, it leaves several unanswered questions, and direct searches for new physics have fallen short in observing new particles that could answer them, thus hinting at the existence of new physics beyond the energy scale reachable at the LHC.

The Standard Model Effective Field Theory (SMEFT) provides a powerful framework to probe such effects indirectly by expanding the SM Lagrangian with higher order operators. In this work, we use simulated CMS data corresponding to data-taking conditions at 13.6 TeV center-of-mass energy to study SMEFT

effects in the Higgs to four-lepton channel. Differential cross section measurements are used to constrain new physics within the SMEFT framework.

This talk details the derivation of the parameterization of EFT effects on both the production and decay of the Higgs boson in the four-lepton final state, and how these measurements can be used to obtain constraints on new physics through a maximum likelihood fit.

T 25.8 Tue 18:00 KH 00.016

**Combined measurements of the Higgs boson at ATLAS** — •AHMED MARKHOOS, BENEDICT WINTER, and KARL JAKOBS — University of Freiburg, Freiburg im Breisgau, Germany

Statistical combinations provide the cutting edge results for processes that can be studied through different signatures. Notable examples at the LHC have been measurements of Higgs boson production and decays. In this talk, I present the status of the latest combination of the Higgs boson measurements, performed by the ATLAS experiment with the Run 2 dataset spanning two main subjects. The first are measurements of the overall products of the Higgs-boson cross-sections and branching ratios, as well as a measurement performed in the Simplified Template Cross-section scheme, showcasing sensitivity gains in challenging parts of the phase space that may feature first hints of physics beyond the Standard Model. The second are interpretations of these measurements with the Kappa framework, which compares the measured coupling properties with those predicted by the Standard Model, and via Effective Field theory exploring possible couplings beyond the Standard Model.

## T 26: Methods in Particle Physics II

Time: Tuesday 16:15–17:30

Location: KH 00.020

T 26.1 Tue 16:15 KH 00.020

**Luminosity Calibration in the 2025 Oxygen Runs for the ATLAS Experiment using van der Meer Scans** — •JON HOXHA, CIGDEM ISSEVER, and CLARA ELISABETH LEITGEB — Humboldt-Universität zu Berlin

The ATLAS experiment is a general-purpose detector at the Large Hadron Collider (LHC) at CERN, which conducts precise measurements for a wide range of physics phenomena. To obtain precise cross-section measurements, it is crucial to properly calibrate the luminosity detectors. ATLAS employs dedicated van der Meer (vdM) scan sessions to calibrate them, during which interaction rates are measured in certain beam conditions. Most importantly, during these scans, the beams are transversely separated in a controlled manner to understand changes in the interaction rate with separation, which is ultimately used for the luminosity calibration.

This presentation will outline the methodology, the analysis workflow, and the specific challenges for the luminosity calibration of the oxygen collision runs, which were conducted in July 2025. These runs represent the first time such collisions happened at the LHC, providing unique information into the dynamics of light-ion collisions, as well as the potential for improving of the modeling of the high energy cosmic ray air showers. Particular attention will be given to the data analysis procedure.

T 26.2 Tue 16:30 KH 00.020

**Precision Luminosity Measurement with Standard Candles using HLT Scouting Data** — •TATIANA SELEZNEVA — Karlsruher Institut für Technologie, Karlsruhe, Deutschland

Precise determination of instantaneous and integrated luminosity at the LHC becomes increasingly challenging as collision rates rise and radiation damage accumulates in the CMS detector. Alongside the baseline luminosity determination, Standard Candle processes offer valuable complementary constraints. Although an absolute calibration below the 1% level is limited by theoretical cross-section uncertainties, such measurements are essential for validating long-term stability and linearity.

CMS has extensive experience with Z counting, benefiting from the clean  $Z \rightarrow \mu\mu$  signature and efficient high- $p_T$  muon reconstruction. A complementary approach is based on  $J/\psi$  production, which features a much larger cross section and thus higher event rates, including during van der Meer scans. By recording most reconstructed muons in a reduced data format, the HLT Scouting stream enables rates up to 30 kHz without degrading reconstruction performance, compensating for the suppression of low- $p_T$  muons by standard triggers.

While the statistical gain for Z counting is moderate, the rapid availability of Scouting data enables near real-time luminosity monitoring using both Z and  $J/\psi$ . In addition, first results on W counting are presented, providing an orthogonal observable that can further constrain Z-based luminosity through its dependence on the electroweak mixing angle.

T 26.3 Tue 16:45 KH 00.020

**Position monitoring system for the LHCb Upgrade II downstream tracker** — •TODOR TODOROV<sup>1</sup>, MARCO GERSABECK<sup>1</sup>, FLO REISS<sup>1</sup>, and PASCAL SAINVITU<sup>2</sup> — <sup>1</sup>Albert-Ludwigs-Universität Freiburg — <sup>2</sup>CERN

The LHCb Upgrade 2 has the ambitious goal of increasing the instantaneous luminosity in the detector by a factor of 5. Due to the increase in detector occupancy and pileup, upgrades of many detector systems will be required, including the tracker. A new hybrid tracker will be installed downstream from the magnet, the Mighty Tracker, that will consist of silicon pixel sensors in the most occupied regions near the beam pipe and improved scintillating fibres in the remaining areas. The detector alignment and physics results will benefit from a real-time position monitoring system, but any such system will have to adhere to the strict material budget and space constraints. Frequency sweeping interferometry is chosen as a technique capable of fulfilling all requirements. A study on its use for effective position monitoring in the Mighty Tracker is presented.

T 26.4 Tue 17:00 KH 00.020

**Proof of Concept for a Brute-Force Alignment Approach for the CBM STS Detector** — •NORA BLUHME<sup>1</sup>, SERGEY GORBUNOV<sup>2</sup>, and VOLKER LINDENSTRUTH<sup>1,2</sup> for the CBM-Collaboration — <sup>1</sup>Goethe-University Frankfurt, Frankfurt am Main, Germany — <sup>2</sup>GSI, Darmstadt, Germany

The Compressed Baryonic Matter experiment (CBM) at FAIR will study heavy-ion collisions at interaction rates of up to  $10^7$  events per second. For this purpose, accurate alignment of the detector systems is essential to exploit the high resolution of the sensors. This is typically achieved through track-based software alignment, which minimises a global  $\chi^2$  over a set of high-quality tracks.

To complement existing alignment tools, we investigate a brute-force  $\chi^2$  minimisation approach that can be applied with minimal analytical prerequisites. The method allows individual alignment parameters to be treated independently and enables the straightforward inclusion of various constraint types.

In this contribution, we present a proof-of-concept study demonstrating that this brute-force optimisation strategy is viable for the CBM Silicon Tracking System (STS) under idealised conditions. Using MC events with randomized sensor shifts and rotations, we evaluate the method's ability to recover the imposed misalignments. We show that the approach converges stably across a range of test configurations and discuss its potential and limitations as a part of the alignment strategy within CBM.

This work is supported by BMFTR (05P24RF3).

T 26.5 Tue 17:15 KH 00.020

**Track Based Software Alignment Using the General Triplet Track Fit** — •DAVID FRITZ, TAMASI KAR, and ANDRÉ SCHÖNING for the Mu3e-Collaboration — Physikalisches Institut, Universität Heidelberg, Germany

The Mu3e experiment aims to observe the charged-lepton-flavour-violating decay  $\mu^+ \rightarrow e^+ e^- e^+$  at the Paul Scherrer Institut with a signal sensitivity of 1 in  $10^{16}$  muon decays. To reach the physics goals and tracking performance of Mu3e, precise alignment of the tracking detector is crucial. Whereas optical surveillance

systems provide an initial reference, track-based software alignment is required to achieve the resolution required.

A new alignment procedure based on the General Triplet Track Fit (GTTF) [1] enables the simultaneous determination of track and alignment parameters. The GTTF is a non-iterative triplet-based track fit that incorporates hit uncertainties and multiple scattering. It is highly parallelizable and suitable for implementation on, for example, GPUs or FPGAs.

This talk introduces the Mu3e experiment and places the GTTF-based alignment in the context of standard track based alignment approaches. Results from simulation studies and first applications to Mu3e commissioning data collected in June 2025 are presented, thereby demonstrating the potential of the GTTF-based alignment for the experiment.

[1] A. Schöning, 2025, A General Triplet Track Fit based on Triplets, <https://doi.org/10.1016/j.nima.2025.170391>

## T 27: Muon Detectors

Time: Tuesday 16:15–18:15

Location: KH 00.023

T 27.1 Tue 16:15 KH 00.023

**Development of a test bench for the MDT front-end electronics and L0 MDT Trigger Processor full-slice tests at the expected HL-LHC rates** — •GEORGIOS LAMPRINOUDIS, GIA KHORIAULI, RAIMUND STRÖHMER, and THOMAS TREFZGER — Julius-Maximilians-Universität Würzburg

The new electronic readout of the Muon Drift Tube (MDT) chambers is a key component of the ATLAS Phase 2 upgrade for HL-LHC. The system will incorporate new mezzanine boards and chamber service modules of the MDT front-end electronics in conjunction with the new L0 MDT Trigger Processor. The development of this electronic chain requires continuous quality control and assessment. The test bench is being designed to fulfil both of these tasks by using simulated muon samples to emulate the operation and performance of the full-slice MDT readout and to optimize the muon L0 trigger.

T 27.2 Tue 16:30 KH 00.023

**Small-Diameter Muon Drift Tube Detector Chambers for the ATLAS Phase-II Upgrade: Performance and Certification with Final Readout Electronics** — •ELENA VOEVODINA, OLIVER KORTNER, HUBERT KROHA, NICK MEIER, and DAVID WEBER — Max Planck Institut für Physik - Werner Heisenberg Institute Boltzmannstr. 8 - 85748 Garching, Germany

To meet the High-Luminosity LHC (HL-LHC) requirements, the Muon Drift Tube (MDT) chambers in the ATLAS Muon Spectrometer's inner barrel layer (BIS) are being replaced by small-diameter MDT (sMDT) chambers. The new sMDT stations will be integrated with triplets of thin-gap Resistive Plate Chambers (RPCs) to increase geometric acceptance and strengthen the barrel muon trigger. Between January 2021 and September 2023, 102 sMDT chambers were produced at two sites; 50% with some spares were built at the Max Planck Institute for Physics (MPI), Munich. All detectors from both production sites have been shipped to CERN for final validation. Following the production of ~3,600 stacked readout mezzanine cards and their QC/QA testing at the University of Würzburg, the cards were installed on the BIS1-6 sMDT chambers at CERN in 2025. In this contribution, we present the certification methodology and performance results for detectors equipped with the final electronics at the CERN BB5 facility\*covering gas tightness, electronic noise, muon detection efficiency, and spatial resolution\*and compare them with the outcomes of the initial quality-assurance campaign conducted at MPI.

T 27.3 Tue 16:45 KH 00.023

**Integration of an SiPM-Based Scintillation Detector into the Readout Chain of a Cosmic Muon Test Stand with a CMS Drift Tube Chamber** — ERIK EHLERT, DMITRY ELISEEV, •NILS JONATHAN ESPEL, THOMAS HEBBEKER, KERSTIN HOEPFNER, MARKUS MERSCHMEYER, CARSTEN PRESSER, and ALEXANDER SCHMIDT — III. Physikalisches Institut A, RWTH Aachen University

The III. Physics Institute A at RWTH Aachen University operates a cosmic test stand with a fully functional Drift Tube (DT) chamber and all necessary peripherals, which is similar to the chambers used in the Compact Muon Solenoid (CMS) experiment. Recently, the chamber was equipped and recommissioned with the readout electronics that will be used in the Phase-2 upgrade of CMS. In addition, a scintillation detector with Silicon Photomultiplier (SiPM) readout has been constructed at our institute. With the goal of integrating the readout of the scintillator into the chamber backend system, new electronics and corresponding firmware have been developed. These electronics feature the Low Power Gigabit Transceiver (lpGBT) chip, a serializer-deserializer device developed at CERN. It allows to inject the detector data into the backend system, and maintains synchronization with the global clock. This talk presents the newly developed scintillator readout chain and first recorded data. The data is compared to the independently reconstructed tracks from the DT chamber.

T 27.4 Tue 17:00 KH 00.023

**Integration of Upgraded MDT Readout Electronics in the LMU Cosmic Ray Facility** — •LILLA SCHNEIDER, OTMAR BIEBEL, VALERIO D'AMICO, RALF HERTENBERGER, ESHITA KUMAR, NICK SCHNEIDER, CHRYSOSTOMOS VALDERANIS, and FABIAN VOGEL — LMU München

The Phase-II upgrade of the ATLAS Muon Spectrometer for the High Luminosity LHC (HL-LHC) involves the implementation of a more advanced trigger and

readout system for the Monitored Drift Tube (MDT) chambers. The Cosmic Ray Facility (CRF) at Ludwig-Maximilians University Munich, equipped with two fully operational ATLAS series production, 8 m<sup>2</sup> sized MDT chambers enclosed by a scintillator hodoscope for triggering, is an optimal location for the testing and evaluation of these systems. Integrating the new readout electronics into the existing reconstruction chain in the CRF is a crucial step in this evaluation process. It allows for detailed studies of any differences between the legacy electronics and the upgraded system. This talk will present the current status of this project and show a comparison between the performance of the old system and the new Phase-II electronics.

T 27.5 Tue 17:15 KH 00.023

**Simulation of a calorimetric muon detector using liquid organic media for imaging of nuclear materials** — •NICOLAS ANDREAS SCHWARZ, YAN-JIE SCHNELLBACH, and SARAH FRIEDRICH — Technische Universität Darmstadt, Darmstadt, Germany

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) aims to ensure the exclusively peaceful civilian use of nuclear technology in energy generation and disarmament. Nuclear safeguards are technical measures to support non-proliferation. This contribution presents a conceptual muon detector that could prove itself useful as a safeguard for the purpose of (re-)verification. The energy loss of cosmic muons as charged particles is described by the Bethe-Bloch formula. They belong to minimally ionizing particles (MIPs) and thus the mean energy loss is a function of the momentum alone for given material charge densities in the Bethe region. The proposed detector concept studied in this work is a two-sided hybrid muon detector, that uses a PVT scintillator hodoscope for muon track reconstruction, and a liquid organic TPC for calorimetric energy loss measurement since the muon ionizes the medium, producing drift electrons proportional to the deposited energy. Multiple Coulomb Scattering implies a near Gaussian distribution of scattering angles. Combining both information, simulation-based feasibility studies have been conducted to yield density images and show that a differentiation of heterogeneous materials is possible. The insights gained from this analysis will be further developed to apply them to the context of Spent Nuclear Fuels.

T 27.6 Tue 17:30 KH 00.023

**Simulations regarding the water tank instrumentation for LEGEND-1000** — •ERIC ESCH — University Tübingen

In order to reach the challenging background goal of less than 10<sup>-5</sup> cts/(keV\*kg\*yr) targeted by the next phase of the Large Enriched Germanium Experiment for Neutrinoless  $\beta\beta$  Decay (LEGEND), new detector systems have to be planned and optimized. Previous Monte Carlo studies have revealed that the in-situ production and delayed decays of <sup>77</sup>Ge and its metastable state <sup>77m</sup>Ge constitute a significant cosmogenic background. This talk will present recent simulations exploring the instrumentation of the water tank, aimed at mitigating these contributions. Specifically, the instrumentation seeks to identify and veto events produced by neutron-showering muons, the key source of <sup>77(m)</sup>Ge background.

T 27.7 Tue 17:45 KH 00.023

**Development of new measurement methods of particle track  $dE/dx$  and time slew corrections to drift times for the ATLAS MDT detectors** — •JENS LEDERMANN, THOMAS TREFZGER, RAIMUND STRÖHMER, GIA KHORIAULI, and GEORGIOS LAMPRINOUDIS — Julius-Maximilians-Universität Würzburg

The Monitored Drift Tube detectors (MDT) of the ATLAS Muon Spectrometer will be equipped with a new front-end electronics system after the ATLAS Phase-2 upgrade for an operation at the HL-LHC. The new 24-channel front-end mezzanine cards are designed for a precise time measurement of MDT hits at the expected HL-LHC particle rates. Comprehensive quality assessment and control tests of the mezzanine cards are performed using the tester hardware tool developed at the University of Würzburg. The test data of the mezzanine cards can be used for a calibration of a measurement of MDT ionisation charge and hence,  $dE/dx$  of charged tracks for a particle identification. Besides that, the time slew corrections for measurements of MDT hit drift times can be derived using the test data. Corresponding new methods are currently being developed.

The development progress and the application of the new methods using cosmic data collected at the MDT Cosmic Ray Facility at the LMU Munich are presented in this work.

T 27.8 Tue 18:00 KH 00.023

**Activities towards Phase-II upgrade of the CMS Drift Tube detector** — •DMITRY ELISEEV, NILS ESPER, CARSTEN PRESSER, MARKUS MERSCHMEYER, ALEXANDER SCHMIDT, and THOMAS HEBBEKER — III. Physikalisches Institut A, RWTH Aachen University

The Compact Muon Solenoid (CMS) experiment is currently preparing for its Phase-2 Upgrade, which includes major improvements to the electronics of the Drift Tube (DT) muon detectors. A central part of this upgrade is the replace-

ment of the legacy on-chamber minicrates with newly developed and recently produced units.

Large-scale production of the new components has been completed, and the project has now entered the assembly and quality-assurance phase. Our group has played a significant role not only in the development and production of the new electronics but also in establishing of the quality assurance of the new DT electronics. Together with the CMS DT collaboration, the group has developed and deployed a software framework designed for testing and validating the new electronics, enabling consistent operation at multiple collaboration sites.

This talk reviews the ongoing CMS DT upgrade activities, and also summarizes the latest results from the current validation program. The upcoming steps on the path toward the CMS DT Upgrade are discussed as well.

## T 28: Data, AI, Computing, Electronics III

Time: Tuesday 16:15–18:45

Location: KH 00.024

T 28.1 Tue 16:15 KH 00.024

**Multi-Modal track reconstruction using Graph Neural Networks at Belle II** — •TRISTAN BRANDES<sup>1</sup>, TORBEN FERBER<sup>1</sup>, GIACOMO DE PIETRO<sup>1,2</sup>, and LEA REUTER<sup>1</sup> — <sup>1</sup>Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>2</sup>Scientific Computing Center, Karlsruhe Institute of Technology, Karlsruhe, Germany

Large backgrounds and detector aging impact the track finding in the Belle II central drift chamber, reducing both purity and efficiency in events. This necessitates the development of new track algorithms to mitigate detector performance degradation. Building on our previous success with an end-to-end multi-track reconstruction algorithm for the Belle II experiment at the SuperKEKB collider (arXiv:2411.13596), we have extended the algorithm to incorporate inputs from both the drift chamber and the silicon vertex tracking detector, creating a multi-modal network. We employ graph neural networks to handle the irregular detector structure and object condensation to address the unknown, varying number of particles in each event. This approach simultaneously identifies all tracks in an event and determines their respective parameters.

We have fully integrated this algorithm into the Belle II analysis software framework. Utilizing a realistic full detector simulation, which includes beam-induced backgrounds and detector noise derived from actual collision data, we report the performance of our track-finding algorithm across various event topologies compared to the existing baseline algorithm used in Belle II.

T 28.2 Tue 16:30 KH 00.024

**Graph Neural Networks for multi-hypothesis clustering in the Belle II Electromagnetic Calorimeter to improve hadron clustering** — •JONAS EPELT and TORBEN FERBER — Karlsruhe Institute of Technology

The Belle II experiment at the SuperKEKB collider in Tsukuba, Japan, studies the products of  $e^+e^-$  collisions to probe the Standard Model and search for new physics. Many of these processes involve  $\pi^0$ , which almost always decay into two  $\gamma$ , and reconstructing these correctly is important for many analyses. The currently used clustering algorithm is optimized towards the reconstruction of photon clusters, which form regular, mostly round clusters. However, the  $e^+e^-$  collisions also produce hadronic particles, which also interact in the calorimeter. As their energy depositions are more irregularly shaped and can produce split-off particles, which create disconnected, additional clusters, they pose a significant challenge for any clustering optimized for electromagnetic clusters. Improving upon their reconstruction would not only improve their identification, but also help constrain the energy in the calorimeter to the collision energy. I will show an implementation of a graph neural network, optimized for both photon and hadron reconstruction. Not only does it improve the photon energy resolution, but it also improves the hadron position reconstruction. Further, I will demonstrate the improved constraints on the energy in the calorimeter on the collision energy.

T 28.3 Tue 16:45 KH 00.024

**Point Cloud Segmentation for the Belle II GNN-Based Tracking** — •DANIEL GROSSMANN, TRISTAN BRANDES, GIACOMO DE PIETRO, TORBEN FERBER, and LEA REUTER — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Our implementation of an end-to-end multi-track based reconstruction algorithm for the Belle II experiment at the SuperKEKB collider improves the tracking performance compared to the baseline algorithm (arXiv:2411.13596). It combines the Object Condensation algorithm with a Graph Neural Network that simultaneously identifies all tracks in an event and determines their respective parameters. However, our current algorithm is based on a segmentation step during the model post-processing, which fails to capture specific signatures for more complex track topologies.

This work improves the segmentation by employing a pointcloud-based model in the post-processing step for the track and hit assignment. We report the per-

formance of our improved track-segmentation algorithm across various event topologies compared to the existing segmentation method and to the baseline tracking algorithm used in Belle II.

T 28.4 Tue 17:00 KH 00.024

**Graph Neural Network based inclusive flavour tagger at the LHCb experiment** — •YUKAI ZHAO<sup>1</sup>, SARA CELANI<sup>2</sup>, STEPHANIE HANSMANN-MENZEMER<sup>1</sup>, and PELIAN LI<sup>3</sup> — <sup>1</sup>Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Germany — <sup>2</sup>CERN, Switzerland — <sup>3</sup>University of Chinese Academy of Sciences, China

The study of CP violation at the LHCb experiment is essential for understanding the observed matter\*antimatter asymmetry in the universe. A key component of many such measurements is the decay-time-dependent analysis of oscillating neutral B mesons, which requires knowledge of the b-hadron flavour at production. This initial flavour information can not be determined directly from the decay products of the signal candidate. Instead, it is inferred using flavour tagging algorithms which exploit correlations with other particles produced in the same proton\*proton collision. This talk presents a novel flavour-tagging method based on Graph Neural Networks (GNNs). The approach leverages the Deep Full Event Interpretation framework, which performs inclusive reconstruction of heavy hadrons in the event. By modelling the relationships between particles identified through inclusive reconstruction, the GNN-based tagger is expected to enhance the usage of kinematic and topological information, leading to a significant improvement in the estimated flavour-tagging performance. The results represent a promising advancement for time-dependent CP violation measurements at LHCb.

T 28.5 Tue 17:15 KH 00.024

**Machine-Learning based Energy Regression of Muon Detector Showers in CMS** — •MASCHA HACKMANN, AYSE ASU GUVENLI, KARIM EL MORABIT, and GREGOR KASIECZKA — University of Hamburg, Hamburg, Germany

Exotic Long-Lived Particles (LLPs), predicted by many extensions of the Standard Model, can travel macroscopic distances before decaying. Decays inside the muon system of the CMS detector produce hadronic showers instead of isolated muon tracks, leading to unconventional signatures beyond the scope of standard muon reconstruction.

This talk presents a machine learning approach to analyze Muon Detector Showers (MDS) originating from LLP decays in the CMS experiment. For the analysis of the MDS, the Cathode Strip Chambers are interpreted as a sampling calorimeter. Low-level hit information is used as input to train a ParticleNet based Dynamic Graph Convolutional Neural Network (DGCNN) to regress the energy of the LLP. These studies provide insight to improve future searches for LLPs that decay in the muon system of the CMS.

T 28.6 Tue 17:30 KH 00.024

**Machine-Learning Based Reconstruction of Muon Detector Showers in CMS** — •AYSE ASU GUVENLI, KARIM EL MORABIT, GREGOR KASIECZKA, and MASCHA HACKMANN — University of Hamburg, Hamburg, Germany

Long-lived particles (LLPs) appear in many extensions of the Standard Model and can travel measurable distances before decaying. When such decays occur in or near the CMS muon system, they can produce atypical showers of hits rather than standard muon signatures. These muon detector showers (MDS) offer a promising handle for LLP searches but remain difficult to reconstruct with algorithms optimized for muons.

This work explores machine-learning based reconstruction of shower-like hit patterns in the CMS Cathode Strip Chambers, aiming to improve the identification and characterization of MDS from LLP decays. We present ongoing developments toward low-level hit reconstruction with ML methods and discuss their potential to enhance the sensitivity of Run-3 LLP searches.



T 28.7 Tue 17:45 KH 00.024

**Reconstructing missing transverse momentum for electroweak precision measurements at the ATLAS experiment** — •GABRIEL SANCHEZ SHESTAKOVA, MATTHIAS SCHOTT, TIMO SAALA, and PHILIP BECHTLE — Physikalisches Institut, Bonn, Germany

We present first studies of a supervised Machine Learning (ML) approach for reconstructing missing transverse energy (MET) using Particle Flow (PF) information acquired from open Large Hadron Collider (LHC) data. Using simulated  $W^+ \rightarrow \mu^+ \nu$  events at  $\sqrt{s} = 8$  TeV, we compute an event-level MET observable directly from PF objects by explicitly reconstructing transverse momentum components and forming an analytically calculated MET, which serves as a controlled regression target for the ML approach.

A fully connected multilayer perceptron (MLP) is trained on per-event PF momentum components, with variable-length PF collections handled via zero-padding to a fixed input dimension. We also develop a graph neural network (GNN) approach that operates on variable-size PF representation. Quantile-based selections on the number of PF objects and on the calculated MET are applied prior to training in order to mitigate outliers and reduce input distribution mismatches.

T 28.8 Tue 18:00 KH 00.024

**Secondary Particle Tracking with Graph Neural Networks for the ATLAS Experiment** — •HANNAH SCHLENKER, SEBASTIAN DITTMEIER, and ANDRÉ SCHÖNING — Physikalisches Institut, Universität Heidelberg, Germany

The increased number of simultaneous proton-proton collisions in the upcoming High Luminosity LHC will increase the computational demands for charged particle track reconstruction in the new Inner Tracker (ITk) of the ATLAS Experiment. To reduce computing resources, the usage of parallel architectures like GPUs are investigated, and new track reconstruction algorithms based on machine learning are in development. Track finding on the basis of Graph Neural Networks (GNNs) has been shown to be promising [1]. This method constructs a graph based on all hits of an event using a module map, assigns a score to each edge and finds track candidates based on these scores.

Previous work focused on particle tracks originating near the interaction region [1]. Secondary particle tracks, which are produced all over the detector,

have not been targeted. A good track finding efficiency for these particles is important for enhanced energy measurements, characterisations of material interactions and potential searches of long-lived particle decays.

This talk discusses the secondary tracking performance of current models and of new models developed specifically for this task.

[1] ATLAS Collaboration, Optimizations of the ATLAS ITk GNN reconstruction pipeline, tech. rep., CERN, 2025, URL: <https://cds.cern.ch/record/2948192>

T 28.9 Tue 18:15 KH 00.024

**Keeping Track of Graphs: 4D Tracking with Graph Neural Networks at Muon Colliders** — •LUKAS BAUCKHAGE — Deutsches Elektronen-Synchrotron DESY — Physikalisches Institut, Universität Bonn

This talk explores the application of Graph Neural Networks (GNNs) to track reconstruction at a future muon collider experiment utilising precise timing information. We highlight the challenges posed by high beam-induced backgrounds, making robust and efficient tracking exceptionally difficult. We demonstrate how GNNs can effectively model the 4D relationships among detector hits to identify and group related hits by leveraging spatial and timing information to distinguish true particle trajectories from background activity. Our results on the performance of reconstruction algorithms aided by GNNs compared to established algorithms purely based on Kalman-Filters are presented.

T 28.10 Tue 18:30 KH 00.024

**Machine Learning Models for Separating Signal and Background Events in LHC pp Collisions** — OLEKSANDR SHEKHOVTSOV, ANDRÉ SOPCZAK, and •LUKAS VICENIK — CTU in Prague

We investigate machine-learning-based signal-background discrimination for measuring Higgs boson production in association with top quarks (tH) in multi-lepton final states at  $\sqrt{s} = 14$  TeV. We simulated a dataset for a generic detector that mimics a realistic analysis. Low low-level features are used. A range of methods from standard Machine Learning models to advanced approaches inspired by geometric deep learning are benchmarked. The study evaluates these approaches, highlighting their performance and identifying directions for improving symmetry-aware machine learning in collider measurements.

## T 29: Flavour Physics II

Time: Tuesday 16:15–18:15

Location: KH 01.011

T 29.1 Tue 16:15 KH 01.011

**Branching fraction measurement of the  $\Lambda_b^0 \rightarrow p\pi\mu^+\mu^-$  decay with Run 1 + Run 2 data at LHCb** — •PIERA BATTISTA<sup>1,2</sup> and MARIE-HELENE SCHUNE<sup>1</sup> — <sup>1</sup>IJCLab, Orsay — <sup>2</sup>TU Dortmund

Rare decay transitions are powerful tools to search for New Physics. Flavour physics experiments have extensively studied  $b \rightarrow s\ell^+\ell^-$  transitions in a multitude of various modes and have found tensions with the Standard Model. To further the study of Flavour Changing Neutral Currents,  $b \rightarrow d\ell^+\ell^-$  transitions are the next object of study, as they are additionally Cabibbo suppressed. The baryonic  $\Lambda_b^0 \rightarrow p\pi\mu^+\mu^-$  transition is part of this family of decays. This mode was first observed in LHCb using  $pp$ -collision Run 1 data with  $3\text{ fb}^{-1}$  luminosity, and its branching fraction was measured to be  $(6.9 \pm 1.9 \pm 1.1^{+1.3}_{-1.0}) \times 10^{-8}$ . This talk will present the ongoing efforts to update the branching fraction measurement, incorporating Run 2 data and achieving a  $9\text{ fb}^{-1}$  luminosity, in order to reduce the uncertainties. In addition, a study of the differential branching fraction in bins of di-muon momentum  $q^2$  is presented, representing the first measurement of this type in this mode.

T 29.2 Tue 16:30 KH 01.011

**Electromagnetic corrections to leptonic charm decays** — •ARITRA BISWAS<sup>1</sup>, MAX FERRE<sup>2</sup>, JACK JENKINS<sup>1</sup>, and IPSITA RAY<sup>3</sup> — <sup>1</sup>University of Siegen, Siegen, Germany — <sup>2</sup>Johannes Gutenberg University, Mainz, Germany — <sup>3</sup>University of Montreal, Montreal, Canada

We investigate the soft photon energy spectrum of leptonic charm decays  $D_{(s)} \rightarrow l\nu(\gamma)$ ,  $l = \mu, \tau$  at fixed order in the electromagnetic coupling, including hadronic substructure effects that are the dominant sources of theoretical uncertainty. We address the different scales involved in the problem with respect to the heavy and light leptonic final states. We find that the leading electromagnetic corrections are comparable to the experimental precision at BESIII in general. We also incorporate the effect of these corrections on model dependent/independent constraints in BSM scenarios and comment on the shift in the corresponding parameter space resulting from the inclusion of these corrections in the Standard Model estimate.

T 29.3 Tue 16:45 KH 01.011

**Measurement of the  $\pi^0 \rightarrow e^+e^-\gamma$  decay at NA62** — •CELIA POLIVKA — Mainz Universitaet

The current value for the  $\pi_D^0 \rightarrow e^+e^-\gamma$  Dalitz decay is  $\mathcal{B}r(\pi_D^0) = (1.174 \pm 0.035) \cdot 10^{-2}$  and has a large uncertainty. This is a limiting factor for other measurements that use the Dalitz decay as normalisation channel. This analysis aims to improve the precision on this measurement using data from the NA62 experiment at CERN. The  $\pi^0$  mesons are tagged by  $K^+ \rightarrow \pi^+\pi^0$  decays. The  $\pi_D^0$  is then identified by reconstruction of the three track vertex of  $e^+, e^-$  and  $\pi^+$ . Presented are the status of the analysis and an outlook on the precision of the measurement.

T 29.4 Tue 17:00 KH 01.011

**Search for  $B^+ \rightarrow K^{*+}\tau^+\tau^-$  with Hadronic Tagging at the Belle II Experiment** — •LENNARD DAMER, TORBEN FERBER, and PABLO GOLDENZWEIG — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

In recent years, hints for violation of lepton flavor universality have been observed in semileptonic  $B$  decays by various experiments. The flavor-changing neutral current process  $b \rightarrow s\tau^+\tau^-$  is particularly sensitive to models which feature large couplings to third generation leptons or couplings proportional to the particle mass. Some theoretical models allow for an increase in the branching fraction of up to three orders of magnitude compared to the Standard Model prediction, which is within the observable range of the Belle II experiment. In this analysis, hadronic tagging is employed where the corresponding  $B$  meson partner in  $Y(4S)$  decays is reconstructed in a variety of hadronic decay chains to increase the selection purity. This talk presents the status of the first search for  $B^+ \rightarrow K^{*+}\tau^+\tau^-$  decays along with an estimate on the signal sensitivity.

T 29.5 Tue 17:15 KH 01.011

**Early measurement of  $r_{J/\psi}^{K,K^*}$  with 2024 data** — JOHANNES ALBRECHT<sup>1</sup>, MICHELE ATZENI<sup>2</sup>, LUKAS CALEFICE<sup>3</sup>, ANGEL FERNANDO CAMPOVERDE QUEZADA<sup>4</sup>, JAMES GOODING<sup>1</sup>, CARLA MARIN BENITO<sup>5,3</sup>, •LORENZO NISI<sup>1</sup>, RENATO QUAGLIANI<sup>5</sup>, ALESSANDRO SCARABOTTO<sup>1</sup>, ELUNED SMITH<sup>2</sup>, and POL VIDRIER VILLALBA<sup>3</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>Massachusetts Institute of Technology, Cambridge, United States — <sup>3</sup>Universitat de Barcelona, Barcelona, Spain — <sup>4</sup>University of Chinese Academy of Sciences, Beijing, China — <sup>5</sup>CERN, Geneva, Switzerland

During 2024, the LHCb experiment collected more than  $9\text{ fb}^{-1}$  of integrated luminosity for  $pp$  collisions, recording approximately as many collisions as be-

tween 2011 and 2018. The performance of the upgraded LHCb detector in Run 3 of the LHC must be fully understood to perform precise measurements with this new dataset.

Measurements of ratios between  $B$  meson decays to final states containing different lepton pairs can be used to study lepton flavour universality, e.g.,  $R_{K,K^*}$  between  $B^{+(0)} \rightarrow K^{+(0*)} \mu^+ \mu^-$  and  $B^{+(0)} \rightarrow K^{+(0*)} e^+ e^-$  decays. The  $J/\psi \rightarrow \ell\ell$  resonant modes are commonly used as control channels and their ratio  $r_{J/\psi}^{K,K^*}$  is well-understood to be consistent with unity. As such  $r_{J/\psi}^{K,K^*}$  can be used to validate detector performance and data-MC corrections.

This contribution presents the progress towards a measurement of  $r_{J/\psi}^{K,K^*}$  using 2024 data.

T 29.6 Tue 17:30 KH 01.011

**Search for  $B_c^+ \rightarrow B_s^0 \mu^+ \nu_\mu$  decays at LHCb** — •MIKHAIL CHEKAL and MARCO GERSABECK — Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany

Semileptonic decays are useful for probing new physics as they can be used to test lepton flavour universality. To date,  $B_c^+ \rightarrow J/\psi \ell^+ \nu_\ell$  remains the only semileptonic  $B_c^+$  decay channel to be observed. A search for the semileptonic decay  $B_c^+ \rightarrow B_s^0 \mu^+ \nu$  using the LHCb Run 3 data collected in 2024–2025 is presented. The strategy is to extract the  $B_c^+ \rightarrow B_s^0 \pi^+$  yield, which serves as the normalization channel, as well as the combined  $B_c^+ \rightarrow B_s^0 \mu^+ \nu$  and  $B_c^+ \rightarrow B_s^{*0} \mu^+ \nu$ , and compute their ratio of branching fractions. The  $B_s^0$  candidates are reconstructed as  $B_s^0 \rightarrow D_s^-(K^+ K^- \pi^-) \pi^+$  and the results will later be combined with those of the second group working on the  $B_s^0 \rightarrow J/\psi \phi$  channel. Methods, used for  $B_s^0$  and  $B_c^+$  candidates selection for the normalization and signal channels are presented.

T 29.7 Tue 17:45 KH 01.011

**Update of the SM prediction for  $\bar{B} \rightarrow X_s \gamma$**  — •TOBIAS HUBER<sup>1</sup>, MIKOLAJ MISIAK<sup>2</sup>, MATTHIAS STEINHAUSER<sup>3</sup>, MATEUSZ CZAJA<sup>3</sup>, MICHAŁ CZAKON<sup>4</sup>, KAY SCHÖNWALD<sup>5</sup>, ABDUR REHMAN<sup>6</sup>, and MARCO NIGGETT<sup>7</sup> — <sup>1</sup>Theoretische

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We will provide an update of the SM theory prediction for  $\mathcal{B}(\bar{B} \rightarrow X_s \gamma)$ , including, in particular, NNLO  $Q_{1,2} - Q_7$  interferences with exact charm-quark mass dependence. Also phenomenological implications such as constraints on the charged-Higgs mass in two-Higgs-doublet models will be given.

T 29.8 Tue 18:00 KH 01.011

**B-meson decay width up to  $1/m_b^3$  corrections within and beyond the Standard Model** — •ALI MOHAMED<sup>1</sup>, ALEXANDER LENZ<sup>1</sup>, MARTIN LANG<sup>1</sup>, MARIA LAURA PISCOPO<sup>2,3</sup>, and ALEXEY RUSOV<sup>4</sup> — <sup>1</sup>Siegen University, Siegen, Germany — <sup>2</sup>Nikhef, Amsterdam, Netherlands — <sup>3</sup>Vrije Universiteit Amsterdam, Amsterdam, Netherlands — <sup>4</sup>Technische Universität München, München, Germany

We determine subleading power corrections to heavy-hadron decay rates within and beyond the Standard Model. In the SM, we compute previously unknown penguin-induced contributions to the chromomagnetic ( $1/m_Q^2$ ) and Darwin ( $1/m_Q^3$ ) operators in the Heavy Quark Expansion, improving predictions for  $B$ -hadron lifetimes.

Motivated by tensions in colour-allowed non-leptonic decays, we extend the analysis to a general BSM framework and provide complete contributions to the Wilson coefficients of the chromomagnetic and Darwin operators, including the calculation of BSM Weak Annihilation contributions. This completes the dimension-six BSM operator basis for non-leptonic decays.

Our results enable precise global SM analyses and model-independent new physics searches using lifetime observables such as  $\tau(B_s)/\tau(B_d)$ , closing a critical gap in the theoretical description of these quantities.

## T 30: Silicon Detectors III

Time: Tuesday 16:15–18:30

Location: KH 01.012

T 30.1 Tue 16:15 KH 01.012

**Current and low-field carrier mobility in silicon sensors irradiated to extreme fluences** — CHRISTIAN SCHARF<sup>1</sup>, PEILIN LI<sup>1</sup>, •HEIKO MARKUS LACKER<sup>1</sup>, INGO BLOCH<sup>2</sup>, and BEN BRUERS<sup>2</sup> — <sup>1</sup>Humboldt-Universität zu Berlin — <sup>2</sup>Deutsches Elektronen-Synchrotron (DESY)

We present a study of the forward and reverse currents in silicon pad diodes irradiated to extreme neutron fluences up to  $1 \times 10^{18} n_{eq}/cm^2$ , similar to the expected fluences of tracking detectors at a future circular hadron collider.

At such fluences, the silicon bulk and the implant no longer behave like a typical pn diode. Excess free carriers are trapped at radiation-induced deep defects, compensating ionized shallow defects in the bulk. Consequently, carrier concentrations in the bulk decrease and become similar to those in intrinsic silicon, increasing the resistivity of the bulk. The interaction between ionized defects and free carriers leads to increased Coulomb scattering, causing a decrease in the low-field carrier mobilities with fluence.

To quantify the mobility degradation as a function of fluence and to obtain a qualitative understanding of the diode's electrical performance, current-voltage characteristics were measured at various temperatures. These measurements are compared to TCAD simulations using different radiation-damage models.

T 30.2 Tue 16:30 KH 01.012

**The Production Database of the High-Granularity Timing Detector for the ATLAS Phase-II Upgrade** — •ANNIKA STEIN<sup>1</sup>, LUCA CADAMURO<sup>2</sup>, MARTIN CHRISTIANSEN<sup>1</sup>, FREDERIC FISCHER<sup>1</sup>, JESSICA HÖFNER<sup>1</sup>, YUN-JU LU<sup>3</sup>, LUCIA MASETTI<sup>1</sup>, YUAN-YEN PENG<sup>4</sup>, HENDRIK SMITMANN<sup>1</sup>, and SONG-MING WANG<sup>3</sup> — <sup>1</sup>Institut für Physik, Johannes Gutenberg-Universität Mainz — <sup>2</sup>IJCLab, Frankreich — <sup>3</sup>Academia Sinica, Taiwan — <sup>4</sup>NTHU, Taiwan

The High-Granularity Timing Detector is being built as part of the Phase-II upgrade of ATLAS. It is based on Low-Gain-Avalanche-Detector sensors and provides the time of tracks in the forward region. Assembly and testing sites use the Production Database (ProdDB) to track components and their properties like measurements and part-to-part relations. To leverage dynamic updates of the ProdDB and local data, a python API client has been developed that ensures proper data structure and minimizes backend server load by running consistency checks on the client side before uploading. With the new user interface, we model the module assembly, module loading onto support units, and detector assembly processes. The tools integrate seamlessly into existing frameworks for quality control of modules (consisting of module PCB and two hybrids) as well as flexible PCB cables (flex tails). Applying module hybrid clustering algorithms on current-voltage curves to find matching components is possible. Furthermore,

by running automated continuous integration pipelines, we also perform nightly reporting of part yields. In this presentation, the DB infrastructure, focusing on novel interface methods, will be explained.

T 30.3 Tue 16:45 KH 01.012

**Radiation damage studies of the ATLAS ID Pixel detector at LHC** — ARNULF QUADT, STEFFEN KORN, and •MARCELLO BINDI — II. Physikalisches Institut, Georg-August-Universität, Göttingen

By the end of 2025, the ATLAS ID Pixel detector, including its inner Insertable B-Layer (IBL), have integrated up to  $2 \times 10^{15} n_{eq} cm^{-2}$  substantially increasing sensor leakage currents. Since leakage current is a key indicator of detector health and a proxy for particle fluence, its accurate monitoring is essential. Because it is strongly temperature-dependent, simultaneous current and temperature measurements are needed to disentangle thermal effects from true radiation-induced bulk damage. I-V scans provide this information and allow early identification of abnormal currents or breakdown behaviour, which is critical for detector safety. Rising leakage currents affect operations through higher power dissipation, increased noise, and potential power-supply limitations.

This work presents leakage current data for the ATLAS Pixel detector, including results from IBL planar and 3D sensor technologies, before and after normalization to sensor volume and temperature correction. Temperature measurements from NTC thermistors on the hybrid flex are also discussed. All scans were recorded over multiple years in stable detector conditions, either without beam (e.g., winter shutdowns and technical stops) or during collisions alongside charge-collection measurements. A summary of the full Run-3 dataset will be shown, emphasizing the effects of radiation fluence and temperature inhomogeneities across detector layers, staves, and modules.

T 30.4 Tue 17:00 KH 01.012

**Analysis of de-tuning behaviour of the ATLAS Insertable B-Layer during LHC Run 2 and Run 3** — •JOHANNES KLAS<sup>1</sup>, KERSTIN LANTZSCH<sup>1</sup>, and SERGI RODRIGUEZ BOSCA<sup>2</sup> — <sup>1</sup>Universität Bonn — <sup>2</sup>CERN

Over time the ATLAS pixel detector has been re-tuned many times. Either due to a change of the tuning set-points, routine retuning after a shutdown, or, in the case of the 2014 installed Insertable B-Layer (IBL), due to de-tuning because of irradiation. Effects like the TID had a severe impact on the tuning of IBL at the start of LHC Run 2. While this concrete behaviour of the de-tuning was studied systematically during the start of Run 2 for IBL, it has not been done in such detail thereafter. Tuning data for the full Run 2 and partial Run 3 was collected and analysed to gain a better understanding of the de-tuning behaviour on a larger timeline and document the overall evolution of the relevant parameters.

T 30.5 Tue 17:15 KH 01.012

**Luminosity measurements using the ATLAS Forward Proton (AFP) detector** — JAN BROULIM, PETR FIEDLER, •DANIIL KHEMELNYTSKYI, and ANDRÉ SOPCZAK — CTU in Prague

The latest results of luminosity measurements using the ATLAS Forward Proton (AFP) detector are presented.

T 30.6 Tue 17:30 KH 01.012

**ATLAS Forward Proton (AFP) detector operation challenges and ToF Run-3 performance** — •VIKTORIA LYSENKO and ANDRÉ SOPCZAK — CTU in Prague

Operational and data quality challenges for the ATLAS Forward Proton (AFP) detector in 2025 are presented together with performance studies of the Time-of-Flight (ToF) detector during LHC Run-3 data-taking.

T 30.7 Tue 17:45 KH 01.012

**Towards ultra-thin hybrid pixel detectors via wafer-to-wafer bonding** — FABIAN HÜGGING<sup>1</sup>, JANNA VISCHER<sup>2</sup>, JENS WEINGARTEN<sup>2</sup>, MATTHIAS SCHÜSSLER<sup>1</sup>, •MAXIMILIAN MUCHA<sup>1</sup>, THOMAS FRITZSCH<sup>3</sup>, YANNICK DIETER<sup>1</sup>, and JOCHEN DINGFELDER<sup>1</sup> — <sup>1</sup>Physikalisches Institut, Universität Bonn, Deutschland — <sup>2</sup>Technische Universität Dortmund, Deutschland — <sup>3</sup>Fraunhofer Institute IZM, Berlin, Deutschland

Hybrid pixel detectors are a key technology for precise particle tracking in high energy physics in high rate and high radiation environments. Conventional hybrid detector assemblies rely on die-level bump bonding techniques, which impose limitations on the achievable detector area and the overall material budget. Wafer-to-wafer bonding provides an alternative by interconnecting sensor and readout wafers prior to dicing, enabling large-area devices and aggressive thinning of the bonded stack, while keeping the advantage of a separate development and optimization of both the sensor and readout wafer. This contribution presents ongoing work towards the realization of ultra-thin hybrid pixel detectors based on wafer-to-wafer bonding. An overview of the project and current progress is given. Particular emphasis is placed on the electrical characterization of silicon sensor wafers prior to bonding. Current-voltage (IV) measurements at wafer level are discussed to evaluate leakage current behavior and breakdown performance. The talk concludes with an outlook on the transition to bonded wafer stacks, including the preparations for wafer-level studies.

T 30.8 Tue 18:00 KH 01.012

**Investigation of bond qualities in daisy chain wafers for Wafer-to-wafer bonded hybrid pixel detectors** — •JANNA VISCHER<sup>1</sup>, YANNICK DIETER<sup>2</sup>, FABIAN HÜGGING<sup>1</sup>, KEVIN KRÖNINGER<sup>2</sup>, MAXIMILIAN MUCHA<sup>2</sup>, MATTHIAS SCHÜSSLER<sup>2</sup>, and JENS WEINGARTEN<sup>1</sup> — <sup>1</sup>Technische Universität Dortmund, Dortmund, Germany — <sup>2</sup>Universität Bonn, Bonn, Germany

Semiconductor pixel detectors allow for precisely tracking ionizing particles in high-energy physics experiments and medical applications. Previously, during the manufacturing of hybrid pixel detectors, a common practice to combine the separately manufactured sensor and its readout chip is to bump-bond two single dies together. Wafer-to-wafer bonding is a new method in development for manufacturing hybrid pixel detectors, where whole detector wafers and chip wafers are bonded before being diced to their definite size. This promises detectors to have larger sensitive areas and a reduced thickness through thinning of the wafers after bonding.

To refine the Wafer-to-wafer bonding procedure low-cost non-detector daisy chain wafer stacks have been produced for proof of principle. This talk discusses recent results of measurements on one of those bonded wafer stacks. The resistivity of single bonds as well as bonds connected in daisy chains have been measured on wafer level to investigate spatial dependent deviances in preparation for the first Wafer-to-wafer bonded detectors.

T 30.9 Tue 18:15 KH 01.012

**All-Silicon Modules - RDL development in FTD Cleanroom** — •ANDREAS ULM, MARCO VOGT, HANS KRÜGER, and JOCHEN DINGFELDER — Physikalisches Institut der Universität Bonn, Bonn, Germany

Silicon Pixel Detectors are an essential part of most modern tracking systems for high energy physics as they can fulfill requirements of high spatial and time resolution, feasible power consumption and relatively low material budget. To cover large areas in the detector volume individual chips are glued together to create modules. These modules are easier to assemble to full tracking systems than what would be possible if all chips had to be installed individually, however gluing, additional flex PCBs, cooling and support structures and also structural silicon can introduce significant amounts of material.

To reduce the material budget of tracking detectors as far as possible, a new concept of module-building is investigated. By post-processing monolithic chip wafers, redistribution layers (RDL) can be built on top of the chips for electrical connections to several chips in a row. By using low power monolithic chips air cooling is feasible and mechanical support is not necessary for thin ladder structures of up to 15 cm in length with thicknesses around 200 micron.

This talk will discuss concepts, look into prototype production, and discuss early measurements and simulations of high speed differential lines for module-sized RDL.

## T 31: Scintillator Detectors I

Time: Tuesday 16:15–18:15

Location: KH 01.014

T 31.1 Tue 16:15 KH 01.014

**Commissioning of the Mu3e Tile Detector** — •ERIK STEINKAMP for the Mu3e-Collaboration — Kirchhoff-Institut für Physik, Heidelberg, Germany

The Mu3e experiment has been designed with the objective of detecting the charged lepton flavour violating decay  $\mu \rightarrow eee$  with an ultimate branching ratio of  $10^{-16}$ . To achieve this sensitivity, the Mu3e experiment needs precise vertexing and tracking as well as very precise timing.

The Mu3e tile detector is a scintillator-based timing detector with SiPM readout that aims at a timing resolution of less than 100 ps. The final detector modules are currently being assembled and installed in the Mu3e experiment. A first commissioning beamtime of the Mu3e detector with three out of a total of 14 tile modules took place in mid-2025. In preparation for the first physics beamtime in late 2026, this data is being used to improve the performance of the tile detector through a comprehensive offline calibration procedure, as well as a robust clustering algorithm to combine individual channel hits into clusters for track matching. This talk will present the current status of the commissioning of the Mu3e tile detector, focusing on results from the 2025 beamtime, the qualification of existing modules and further developments.

T 31.2 Tue 16:30 KH 01.014

**Timing performance of multiple prototypes of the Surrounding Background Tagger of the SHiP experiment** — •ALESSIA BRIGNOLI for the SHiP-SBT-Collaboration — Humboldt-Universität zu Berlin

SHiP (Searching for Hidden Particles) is a beam-dump experiment that will be built at CERN, to search for new feebly interacting particles. A crucial component of the SHiP experiment is the Surrounding Background Tagger (SBT), a liquid scintillator based detector designed to suppress background arising from muons entering the helium-filled decay volume, as well as from muon/neutrino inelastic interactions occurring within the decay volume and its surroundings.

The SBT consists of about 900 cells filled with liquid scintillator (LAB+PPO). Light collection is achieved through two PMMA wavelength-shifting optical modules (WOMs) per cell, each optically coupled to an array of 40 SiPMs. This work presents a collection of results from timing performance studies of SBT prototypes developed and tested between 2022 and 2025 at the CERN PS and at DESY Hamburg. The prototypes differ in the cell construction material as well as in the materials used to enhance the reflectivity of the inner walls, which is a crucial factor for light collection. In addition to the timing performance, the detector's capability of reconstruct particle crossing point and direction was studied. Finally, the experimental results were compared with Geant4-based photon transport simulations, providing further insight into the detector response and the overall quality of the constructed prototypes.

T 31.3 Tue 16:45 KH 01.014

**Results from the November 2025 Test Beam measurements of SHiP's Surrounding Background Tagger prototypes** — •HANNES BRAUNE for the SHiP-SBT-Collaboration — Humboldt-Universität zu Berlin

The SHiP (Search for Hidden Particles) experiment, scheduled to start operation in 2032 at the CERN SPS Beam Dump Facility, aims to search for as-yet undiscovered feebly interacting long-lived particles. A large  $\mathcal{O}(50\text{ m})$  long decay volume filled with helium together with a spectrometer allows the reconstruction of their decay products. The decay volume is surrounded by the Surrounding Background Tagger (SBT) to tag muons entering from outside and muon or neutrino inelastic interactions in helium. The SBT consists of  $\mathcal{O}(900)$  cells forming a continuous 20 cm thick layer of LAB+PPO liquid scintillator around the entire volume, and is read out with wavelength-shifting optical modules (WOMs) coupled to SiPM arrays. In November 2025, the long-term performance as well as different cell sizes and WOM configurations were tested in dedicated test beam measurements at the CERN PS.

T 31.4 Tue 17:00 KH 01.014

**Large liquid scintillator detectors in SHiP - Hardware and electronics** — •TILMAN ROCK for the SHiP-SBT-Collaboration — Albert-Ludwigs-Universität, Freiburg, Germany

In the search for particles in the hidden sector, the SHiP (Search for Hidden Particles) experiment, a high-intensity, general-purpose beam-dump experiment, is in preparation. The primary objective is to search for weakly interacting particles within the GeV mass range, which requires a zero-background level. To this end, SHiP's large, helium-filled decay volume is encircled by the Surrounding Background Tagger (SBT), which is essentially a large array of about 900 individual mirror-polished aluminum cells filled with liquid organic scintillator. The SBT is designed to identify particles entering the decay volume and neutrino-induced reactions within it. To efficiently collect light, the cells have UV-reflective walls and wavelength-shifting optical modules (WOMs) for light collection. The collected light is detected by 40 silicon photomultipliers arranged in a circle, which are optically coupled to each of the WOMs. In this presentation, different types of optical coupling will be compared. Additionally, temperature-dependent gain variations will be compensated by changing the operating voltages. To measure the temperature-dependent breakdown voltages of the SiPMs, a dedicated test setup has been developed that measures the dark currents of entire arrays of 40 SiPMs for varying bias voltages and temperatures. The setup will be explained and first results will be presented.

T 31.5 Tue 17:15 KH 01.014

**Data-based studies on the single hit efficiencies of the LHCb Scintillating Fibre Tracker** — BLAKE LEVERINGTON, ULRICH UWER, •TOM WOLF, CHISHUAI WANG, MIGUEL RUIZ DIAZ, GIULIA TUCI, SEBASTIAN BACHMANN, XIAOXUE HAN, and YA ZHAO — Physikalisches Institut Universität Heidelberg

During 2019-2022 the LHCb detector was upgraded to allow operation at higher luminosity and full-detector read-out at 40 MHz. As core part of this upgrade, the Scintillating Fibre Tracker (SciFi) has been installed as the new main tracker. To detect charged tracks it makes use of 12 layers, constructed from 250  $\mu\text{m}$  diameter scintillating fibres that are readout by silicon photomultipliers.

A principle performance parameter for the SciFi is the single hit efficiency, its ability to detect a hit when a particle track passes through one of its layers. To measure this value from data, charged particle tracks are reconstructed while excluding the layer under study, in which matching hits are then searched for. The efficiency is studied over the entire detector area, as well as over time and as a function of occupancy, to gauge the impact of the ionising radiation and luminosity delivered during Run 3 of the LHC.

T 31.6 Tue 17:30 KH 01.014

**Optical simulations of plastic and CeBr<sub>3</sub> scintillator modules read out by SiPMs for the scintLaCharm Compton camera** — •KAVEH KOOSHJALALI, ALEXANDER DEISTING, THERESA HAHN, and UWE OBERLACK — Institute of Physics and Excellence Cluster PRISMA++

Within the framework of the ScintLaCHARM (Localization and CHAracterization of Radioactive Material) Compton Camera Project, which aims at the development of scintillation-based Compton cameras for applications such as nuclear power plant decommissioning, we present a Geant4-based optical simulation developed to study scintillation and Cherenkov light production and transport in plastic and CeBr<sub>3</sub> scintillators with silicon photomultiplier (SiPM) readout.

The detector geometry models two types of scintillation medium, reflective boundaries, and segmented top and bottom SiPM planes. Wavelength-dependent optical material properties and surface models are implemented to describe refraction, absorption, and reflection at all interfaces. Optical photon transport is tracked in detail, including absorption in the crystal, escape into the surrounding volume, and multiple reflections prior to detection. A SiPM sensitive detector records photon boundary crossings and classifies hits by detector plane, timing, and reflection history.

We study the impact of geometry and optical properties on detector performance, simulating light-collection efficiency, timing response, and detector position and energy resolution.

T 31.7 Tue 17:45 KH 01.014

**Opaque Scintillators for Neutrino Physics** — CHRISTIAN BUCK<sup>1</sup>, BENJAMIN GRAMLICH<sup>1</sup>, and •STEFAN SCHOPPMANN<sup>2</sup> — <sup>1</sup>Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — <sup>2</sup>Johannes Gutenberg-Universität Mainz, Exzellenzcluster PRISMA+, Detektorlabor, Staudingerweg 9, 55128 Mainz, Germany

A new scintillator system was developed based on admixtures of wax in organic scintillators. The opacity and viscosity of this gel-like material can be tuned by temperature adjustment, wax concentration, and wax type. Whereas it is a colourless transparent liquid at high temperatures, it has a milky wax structure below.

Due to its light confinement, the scintillator system is expected to exhibit unprecedented particle ID via the morphology of energy depositions. Moreover, a high degree of isotope loading is feasible, e.g. in the context of searches for double beta decays or neutron capture.

In this presentation, the production and properties of various opaque scintillators as well as their advantages compared to transparent scintillators are described.

T 31.8 Tue 18:00 KH 01.014

**Opaque liquid scintillator prototype for Light Dark Matter Searches** — •JONAS PÄTSCHKE for the MAGIX-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg-University Mainz, Germany

In the ongoing search for light dark matter, the DarkMESA and NuDoubt<sup>++</sup> collaborations have joined forces to explore a new region of parameter space. DarkMESA is an upcoming electron beam dump experiment at the new MESA accelerator facility in Mainz, designed to search for light dark matter particles mediated by a hypothetical dark photon  $\gamma'$ , using a crystal calorimeter for detection. The NuDoubt<sup>++</sup> experiment will employ an opaque liquid scintillator detector to investigate double beta decay ( $2\beta\beta$ ) and the beyond Standard Model neutrinoless double beta decay ( $0\nu\beta\beta$ ), two processes that have yet to be discovered.

This contribution will focus on the ongoing investigation into the use of opaque liquid scintillators as an additional or alternative detector medium to the DarkMESA crystal calorimeter. Such a detector would be able to reject events based on the topological signature. For this purpose, a prototype detector was designed, simulated and tested at the MAMI accelerator at energies around 10 MeV. This detector uses a 22-litre cubic volume of linear alkylbenzene (LAB) scintillator and 255 wavelength-shifting fibres attached to SiPMs arranged in a triangular grid with 10 mm pitch near a beam entrance window. A comparative analysis will be presented, evaluating the simulation and expected performance against the results of this first prototype.

## T 32: Higgs Physics IV

Time: Tuesday 16:15–18:30

Location: KH 01.019

T 32.1 Tue 16:15 KH 01.019

**Preparation of Higgs boson STXS measurements in the  $H \rightarrow \tau\tau$  decay, based on LHC Run-3 data taken with the CMS Experiment** — •SOFIA GIAPPICHINI, ROGER WOLF, MARKUS KLUTE, and GÜNTER QUAST — Karlsruher Institut für Technologie, Institut für Experimentelle Teilchenphysik, Karlsruhe, Deutschland

This analysis presents measurements of Higgs boson production in the  $\tau\tau$  decay channel. The study uses proton-proton collision events collected by the CMS experiment at the CERN LHC between 2022 and 2025, at a center-of-mass energy of 13.6 TeV, with a total integrated luminosity of 287  $\text{fb}^{-1}$ . Focusing on both gluon fusion and vector boson fusion production modes, measurements of the signal strengths and cross-sections times branching fraction within the simplified template cross-section scheme are presented. These results provide precise sensitivity to Higgs boson production at high transverse momentum and to event topologies featuring jets.

T 32.2 Tue 16:30 KH 01.019

**Newest developments and validation of the  $\tau$ -embedding method for the estimation of genuine  $\tau\tau$  backgrounds for  $H \rightarrow \tau\tau$  analyses of CMS** — •SEBASTIAN KAISER, CHRISTIAN WINTER, ROGER WOLF, GÜNTER QUAST, and MARKUS KLUTE — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

The  $\tau$ -embedding method, used to estimate all backgrounds with genuine  $\tau$  lepton pairs in an event, is one of the main pillars for a number of precision measurements in the  $H \rightarrow \tau\tau$  decay channel, of CMS. For this method events with two muons are selected, in data. All energy deposits associated to these muons during reconstruction, are removed from the event record and replaced by the energy deposits of simulated  $\tau$  lepton decays with the same kinematic properties. The presentation will summarize the method itself and report on the steps undertaken to validate it for the upcoming LHC Run-3 analyses.

T 32.3 Tue 16:45 KH 01.019

**Re-analysis of the LHC Run-2 data taken with the CMS Experiment in view of a combined LHC Run-2 + Run-3 measurement of Higgs boson STXS measurements in the  $H \rightarrow \tau\tau$  decay channel** — •TAMARA APP, ARTUR MONSCH, MARKUS KLUTE, GÜNTER QUAST, and ROGER WOLF — KIT, Karlsruhe, Germany

A re-analysis of LHC Run-2 data of the year 2018, after a complete re-reconstruction performed by the CMS Collaboration, in view of an anticipated combined Run-2 + Run-3 measurement of Higgs boson STXS measurements in the  $H \rightarrow \tau\tau$  decay channel is presented. The level of data understanding is demonstrated indicating the transition towards high precision measurements and the perspective of a future measurement based on a systematic uncertainty aware neural network training is given.

T 32.4 Tue 17:00 KH 01.019

**ML-driven Di-Tau Mass and Momentum Reconstruction at the ATLAS Detector** — •JONATHAN PAMPEL, TATJANA LENZ, and JOCHEN DINGFELDER — University of Bonn

A common process in particle physics analyses is the decay of a neutral particle into two tau leptons. Each tau lepton decay contains at least one neutrino, making the reconstruction of the 4-momentum – and in particular, the mass – of the neutral particle an underdetermined problem.

In this work, a neural network has been trained on ATLAS  $\gamma^*$  Monte Carlo samples at  $\sqrt{s} = 13.6$  TeV to estimate the di-tau system's 4-momentum, using the reconstructed visible tau 4-momenta and the missing transverse momentum as input features.

This talk presents the development of the neural network and its performance in comparison to the Missing Mass Calculator (MMC), the previously established tool for di-tau 4-momentum reconstruction.

T 32.5 Tue 17:15 KH 01.019

**Higgs Boson Mass Reconstruction in the Analysis of  $tH(\tau\tau)$  Production with ATLAS Run-2 Data** — JIRI JAVORA<sup>1</sup>, •CHRISTIAN B. HUGHES<sup>1</sup>, CHALAKA FERNANDO<sup>2</sup>, and ANDRÉ SOPCZAK<sup>1</sup> — <sup>1</sup>CTU in Prague — <sup>2</sup>CERN

The latest results on the mass reconstruction in the analysis  $tH(\tau\tau)$  are presented with focus on machine learning using ATLAS Run-2 data.

T 32.6 Tue 17:30 KH 01.019

**Estimate of the contribution from jets misidentified as hadronic tau decays using normalizing flows** — •MATTHIAS MOSER, TAMARA APP, NIKITA SHADSKIY, ARTUR MONSCH, MARKUS KLUTE, GÜNTER QUAST, and ROGER WOLF — KIT, Karlsruhe, Germany

For  $H \rightarrow \tau\tau$  analyses, the most accurate estimation of the background originating from falsely identified hadronic  $\tau$  decays remains a major challenge. To estimate this background from data, we employ the fake-factor method, in which the rate of misidentified  $\tau$  candidates is obtained from a Determination Region, which is maximally pure in a given background process, and then applied in an Application Region to determine the rate of misidentified tau candidates in the desired Signal Region.

The resulting  $F_F$  transfer function exhibits non-trivial dependencies on several variables, which are difficult to model using conventional techniques. It can be shown that these dependencies are determined by the probability density functions (p.d.f.) of events in the Application and Signal Regions. These p.d.f.s can be learned with neural-networks, like e.g., normalizing flows. While the training procedure may be computationally intensive, the evaluation of the p.d.f.s after training is fast. This approach provides an efficient and scalable description of the multi-variable dependence of the  $F_F$  transfer function.

T 32.7 Tue 17:45 KH 01.019

**Construction and investigation of optimal observables for testing CP invariance in the decay  $H \rightarrow \tau^+\tau^-$  at the LHC** — •YANN STOLL, HEIDI RZEHA, and MARKUS SCHUMACHER — Albert-Ludwigs-Universität, Freiburg

Since the Higgs boson's discovery, a central objective in particle physics has been the precise determination of its properties. Beyond its key role in electroweak symmetry breaking, the Higgs sector may also provide clues to physics beyond the Standard Model.

In particular, extended models that aim to support electroweak baryogenesis require additional sources of CP violation, which could arise if the Higgs boson is not a CP eigenstate but a CP-mixed state. In the Higgs-tau-tau vertex the strength of CP violation can be parameterized by a single parameter  $\phi_{CP}$ . This talk examines whether the CP-sensitivity in the decay  $h \rightarrow \tau^+\tau^-$  at the LHC can be enhanced through the use of optimal observables. The tau-lepton decay modes  $\tau^\pm \rightarrow (\pi^\pm \nu)$ ,  $(\pi^\pm \pi^0 \nu)$  and  $(l^\pm \nu \nu)$  are considered. We will outline the construction of these observables and present a sensitivity study based on simulated signal samples. This study is based on the past analysis by the ATLAS collaboration using the Run-2 data set collected at a centre-of-mass energy of 13 TeV, in the sense that we use a comparable event selection and categorization.

T 32.8 Tue 18:00 KH 01.019

**Test of CP invariance of the Higgs-strahlungs process  $pp \rightarrow V \rightarrow VH$  exploiting the  $H \rightarrow \tau\tau$  and  $V \rightarrow jj$  decay mode with the ATLAS detector** — •FREDERIK SCHULZ, LORENZO ROSSINI, and MARKUS SCHUMACHER — Albert-Ludwigs-Universität, Freiburg, Deutschland

One open question in cosmology is the origin of the observed baryon asymmetry in our universe. This asymmetry can be explained if the three Sakharov conditions are fulfilled. One of these conditions includes the violation of the invariance under combined charge (C) and parity (P) conjugation. However, the magnitude of CP effects predicted in the Standard Model (SM) is not large enough to explain the size of the observations. The Higgs boson is a promising candidate for investigating possible CP-violating interactions, particularly in the coupling vertex with vector bosons (HVV).

In this talk, the focus will be on the Higgs-strahlung production mode (VH), with a subsequent decay of the Higgs boson into two hadronically decaying tau-leptons, and the V boson also decaying hadronically. Preliminary studies for an analysis based on the proton-proton data collected by the ATLAS experiments at a center of mass energy of  $\sqrt{s} = 13.6$  TeV during Run 3 will be presented. The analysis is based on the measurement of the CP-odd optimal observable. A profile-likelihood fit is performed to extract the expected sensitivity to CP-sensitive EFT models, such as SMEFT.

T 32.9 Tue 18:15 KH 01.019

**Machine Learning to search for the CP violation of the Higgs boson in  $H \rightarrow \tau\tau$  decays at ATLAS** — •LANEY KLIPPAHN, PHILIP BECHTLE, KLAUS DESCH, CHRISTIAN GREFE, and TIMO SAALA — University of Bonn

Reconstruction at ATLAS has been evolving throughout the past decades. Especially machine learning (ML) techniques have been implemented to support and replace individual steps in the reconstruction chain. With these powerful methods, the question arises, to what extent Machine learning models can learn and reproduce the complex calculations that map detector signals to high-level physics observables?

A particularly interesting challenge for ML is the study of CP violation of the Higgs boson in  $H \rightarrow \tau\tau$  decays. The CP property of the Higgs is closely linked to one of the unsolved questions in physics, namely the matter and anti-matter asymmetry observed in the universe today. While the pure CP-odd state has been excluded by measurements, the CP-even or CP-mixed property of the Higgs has yet to be confirmed experimentally. In the Higgs-Yukawa coupling the CP-violation is accessible from the angular correlations of the decay products, which depend on the decay mode of the  $\tau$  leptons in the  $H \rightarrow \tau\tau$  decay. The CP-property is then obtained by a non-trivial combination of multiple observables in the final state. In this talk I will present the studies on ML for the CP violation of the Higgs boson to assess whether ML models can reach similar or better accuracy than traditional reconstruction algorithms.

## T 33: Silicon Detectors IV

Time: Tuesday 16:15–18:15

Location: KH 01.022

T 33.1 Tue 16:15 KH 01.022

**Production of Outer Barrel pixel detector modules for the ATLAS ITk pixel detector at the FTD in Bonn** — •MATTHIAS SCHÜSSLER, YANNICK DIETER, JOCHEN DINGFELDER, FLORIAN HINTERKEUSER, FABIAN HÜGGING, HANS KRÜGER, MATTHIAS HAMER, and MAXIMILIAN MUCHA — Physikalisches Institut der Universität Bonn, Bonn, Germany

With the upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC (HL-LHC), the instantaneous luminosity will increase by a factor of 5 with respect to its design value from 2030 onward. This results in unprecedented hit

rates and radiation levels which require major upgrades of the detectors at the HL-LHC.

For the upgrade of the ATLAS detector, a new all-silicon inner tracking detector (ITk detector) consisting of silicon strip and pixel modules will be installed to replace the currently operated Inner Detector. In total, approximately 10.000 new pixel detector modules have to be built and carefully tested to ensure that only functional detector modules are installed. During the currently ongoing 2-year production of the ATLAS ITk pixel detector, at least 1600 pixel detector modules are being built and tested at the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn.

This large-scale production requires a dedicated quality control (QC) effort to assure the functionality of the final detector. This talk provides an overview of the assembly and testing procedures that are ongoing at the FTD in Bonn, including an overview of the production so far.

T 33.2 Tue 16:30 KH 01.022

**Experience with the production of ATLAS ITk pixel detector modules for the HL-LHC upgrade in Siegen** — MARKUS CRISTINZIANI<sup>1</sup>, QADER DOROSTI<sup>1</sup>, OLIVIER FOX<sup>1</sup>, DANIEL GROTH<sup>1</sup>, LUKE HAMMER<sup>1</sup>, STEFAN HEIDBRINK<sup>2</sup>, LASSE JÄDERBERG<sup>1</sup>, NILS KRENGEL<sup>1</sup>, LEONIE KRIPPENDORF<sup>1</sup>, DENISE MÜLLER<sup>1</sup>, JASON MÜLLER<sup>1</sup>, LINA REIFENBERG<sup>1</sup>, •NOAH SIEGEMUND<sup>1</sup>, WALDEMAR STROH<sup>2</sup>, DARSHIL VAGADIYA<sup>1</sup>, WOLFGANG WALKOWIAK<sup>1</sup>, JENS WINTER<sup>2</sup>, MICHAEL ZIOLKOWSKI<sup>2</sup>, and ALESSIA ZUEV<sup>1</sup> — <sup>1</sup>Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen — <sup>2</sup>Elektronikentwicklungslabor Physik, Universität Siegen

With the High-Luminosity upgrade of the Large Hadron Collider (HL-LHC), the innermost layer of the ATLAS detector will be replaced by a new Inner Tracker (ITk) pixel detector. The University of Siegen contributes to this upgrade by producing quad modules for the outer barrel region of the pixel detector. A quad module is designed as a hybrid structure consisting of a flexible printed circuit board (PCB) glued onto a bare module in a cleanroom environment. That bare module is composed of a silicon-based sensor and four front-end readout chips (FEs). Electrical connection between the FEs and the PCB is provided by about 700 wirebonds. Extensive quality control (QC) procedures are performed before and after assembly, including metrology, visual inspections, and electrical characterization. In this contribution, the production chain of quad modules at the University of Siegen will be presented, with focus on the non-electrical aspects of the QC workflow.

T 33.3 Tue 16:45 KH 01.022

**The ATLAS ITk cell integration site in Bonn** — •ALEXANDRA WALD, KLAUS DESCH, MATTHIAS HAMER, FLORIAN HINTERKEUSER, JOCHEN DINGFELDER, NICO KLEIN, and DOMINIK HAUNER — Physikalisches Institut, Universität Bonn, Deutschland

In conjunction with the high luminosity upgrade of the Large Hadron Collider at CERN, the current tracking system of the ATLAS experiment will be replaced by the Inner Tracker (ITk), an all-silicon detector consisting of 5 layers of pixel detectors and 4 layers of strip detectors. More than 8000 modules will be installed in the pixel layers, which together have an active area of approximately 13m<sup>2</sup> and cover a pseudorapidity of up to 4. In order to build such a large detector in time, the integration of the ITk Pixel modules on their local support structures (longerons or inlind half-rings (IHR)), as well as the quality control of individual loaded local supports will be distributed over many institutes. One of the assembly lines will be setup at the University of Bonn, with technicians from other German locations also helping with cell integration. Due to the serial powering scheme of the ITk Pixel Detector, the quality control of a loaded local support is challenging in several aspects, as the simultaneous operation of multiple modules is necessary for any tests. A large number of different components must hence be integrated into the quality control setup, such as an optical readout system, an interlocks system, industrial power supplies and a scalable DCS. In this presentation, the loaded local support assembly line and the QC setup in Bonn are presented, with particular attention to recent operational developments and the latest tests.

T 33.4 Tue 17:00 KH 01.022

**Integration Test with 2S Modules for the CMS Phase-2 Outer Tracker Upgrade** — MAX BECKERS<sup>2</sup>, LUTZ FELD<sup>1</sup>, NINA HÖFLICH<sup>2</sup>, KATJA KLEIN<sup>1</sup>, MARTIN LIPINSKI<sup>1</sup>, •VANESSA OPPENLÄNDER<sup>1</sup>, and OLIVER POOTH<sup>2</sup> — <sup>1</sup>Physikalisches Institut B, RWTH Aachen — <sup>2</sup>Physikalisches Institut B, RWTH Aachen

The new operating conditions of the future HL-LHC require a replacement of the complete silicon tracking system of the CMS experiment as part of the CMS Phase-2 Upgrade. For the Phase-2 Outer Tracker new silicon strip modules, so-called 2S modules, have been developed that consist of two silicon sensors stacked on top of each other. By correlating the measured hits of both sensors, this module design enables the inclusion of tracking information in the Level-1 trigger at CMS for the first time. For the new Phase-2 tracker the endcap region is known as the Tracker Endcap Double-Disks (TEDD) and is composed of five double-disks on each detector side that feature PS modules at smaller radii as well as 2S modules at larger radii. Each disk will be composed of two half disks that are called dee. After the careful assembly of the modules they are integrated onto the dees, which serve as the cooling and support structure for the modules. In this talk measurements and results from a dee integration test at DESY with 8 of the first pre-production 2S Modules built at RWTH Aachen will be shown.

T 33.5 Tue 17:15 KH 01.022

**CMS Outer Tracker Beam Test at CHARM** — ALEXANDER DIERLAMM<sup>1</sup>, ANDROMACHI TSIROU<sup>2</sup>, ASHLING CLARE QUINN<sup>3</sup>, GUIDO MAGAZZU<sup>4</sup>, •IVAN SHVETSOV<sup>1</sup>, JOHN STEVEN LAWLESS<sup>5</sup>, PIERO GIORGIO VERDINI<sup>4</sup>, PRAFULLA SAHA<sup>6</sup>, YURI GERSHTEIN<sup>6</sup>, and GARVITA AGARWAL<sup>7</sup> — <sup>1</sup>Institute of Experimen-

tal Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — <sup>2</sup>National and Kapodistrian University of Athens — <sup>3</sup>Princeton University — <sup>4</sup>University of Pisa — <sup>5</sup>University of Tennessee — <sup>6</sup>Rutgers State University of New Jersey — <sup>7</sup>University of Notre Dame

In the scope of the HL-LHC upgrade the new CMS Tracker will be built. The future tracker will consist of two module types: strip-strip (2S) and pixel-strip (PS) modules. In order to stress the operation of these modules a test beam at the CERN Highly-Accelerated Mixed Field Facility (CHARM) was performed. The facility provides a mixed particle spectrum, which allows to operate the modules in an environment close to realistic conditions of the future detector. The modules were irradiated with a flux of up to  $\sim 10^7/\text{cm}^2 \cdot \text{s}$ . The data was successfully collected with a prototype of the final data acquisition chain. Technical details of the test beam operation as well as results of the studies performed during the test beam are presented.

T 33.6 Tue 17:30 KH 01.022

**Characterization of the bPOL48V DC-DC converter and Integration Tests with a CMS Phase-2 Strip Module** — LUTZ FELD, KATJA KLEIN, MARTIN LIPINSKI, and •JOËLLE SAVELBERG — 1. Physikalisches Institut B, RWTH Aachen

The bPOL48V is a newly developed DC-DC Point-of-Load (POL) buck converter designed at CERN and characterized at RWTH Aachen University within the DRD7 program, which supports R&D for future electronic systems and technologies for particle-physics experiments. It converts a 48 V input to an adjustable low-voltage output (5-24 V), enabling power delivery at higher distribution voltages and lower cable currents, thereby improving overall system efficiency by reducing Ohmic losses.

The converter features a radiation-hard controller designed at CERN, capable of continuous operation up to 50 Mrad and in magnetic fields above 4 T. It is paired with a EPC2152 GaN power stage. This combination provides performance in harsh radiation and magnetic-field environments, making the bPOL48V a strong candidate for power distribution in future high-energy physics experiments.

At RWTH Aachen, the bPOL48V has been characterized in multiple setups, evaluating its efficiency, stability, temperature dependence, and radiated and conducted noise. This presentation focuses on reducing conducted noise using a pi filter, demonstrating clear improvements consistent with simulation. Additionally, we present results in which the bPOL48V powers a CMS Phase-2 silicon strip module as a proof of principle, confirming its suitability for detector integration.

T 33.7 Tue 17:45 KH 01.022

**Verification of a cell isolation test for loaded cells of the ATLAS ITk Pixel detector** — •NICO KLEIN, KLAUS DESCH, MATTHIAS HAMER, FLORIAN HINTERKEUSER, ALEXANDRA WALD, and DOMINIK HAUNER — Physikalisches Institut, Universität Bonn, Deutschland

The high luminosity upgrade for the Large Hadron Collider at CERN requires a complete redesign of the current tracking detector of the ATLAS experiment. The new Inner Tracker, the ITk Detector, will consist of a silicon pixel detector and a silicon strip detector. The ITk Pixel Detector is divided into three subsystems, the Outer Barrel (OB), Outer Endcaps and Inner System. In the OB, modules are loaded on thermally conductive bare module cells (now called loaded cells) before they are mounted on the local supports (so-called longerons and half-rings). The serial powering scheme of the ITk Pixel Detector requires a good electrical isolation of the readout ASICs from the (grounded) local support structures. For the loaded cells a test was developed to verify this isolation and the results obtained, using pre-production cells, are shown in this presentation.

T 33.8 Tue 18:00 KH 01.022

**Development of an automated ATLAS pixel detector monitoring website** — MARCELLO BINDI, ARNULF QUADT, and •TIM SCHLÖMER — II. Physikalisches Institut, Georg-August-Universität Göttingen

The ATLAS Pixel Detector records charged particles through the ionisation charge they deposit as they traverse the sensor. A hit is recorded when the collected charge exceeds a programmable threshold, and the corresponding time-over-threshold (TOT) provides an estimate of the deposited charge. The threshold and TOT response are periodically re-tuned to maintain their target values, which drift with accumulated luminosity due to radiation-induced degradation. It is therefore essential to continuously monitor the key operational parameters like charge threshold, TOT, digital-to-analogue converter settings, the number of masked pixels, and the number of disabled columns. Tracking their evolution as a function of time and integrated luminosity is crucial both for ensuring optimal detector performance and contributing to radiation-damage studies.

A dedicated web-based framework presents these operational parameters through a set of automatically updated plots and summary metrics. Following each detector tuning, an automated pipeline refreshes the displayed results while preserving previous versions for reference. The framework also enables users to visualise long-term trends in critical parameters and to compare tunings from different periods of the detector's operational lifetime.

## T 34: Data, AI, Computing, Electronics IV

Time: Tuesday 16:15–18:45

Location: KH 02.014

T 34.1 Tue 16:15 KH 02.014

**SysVar: A new tool for enhancing consistency in the treatment of systematic** — •AGRIM AGGARWAL<sup>1</sup>, GEORGIOS ALEXANDRIS<sup>1</sup>, FLORIAN BERNLOCHNER<sup>1</sup>, STEFANIE MEINERT<sup>1</sup>, FELIX METZNER<sup>1</sup>, GIACOMO DE PIETRO<sup>2</sup>, MARKUS PRIM<sup>1</sup>, SLAVOMIRA STEFKOVA<sup>1</sup>, and ILIAS TSAKLIDIS<sup>1</sup> — <sup>1</sup>Universität Bonn — <sup>2</sup>Karlsruhe Institute of Technology

SysVar provides an end-to-end, consistent machinery to build template histograms and their systematic variations with correlations preserved. To account for effects such as detector acceptance and calibration, physics reweighting, event-by-event correction weights are applied to the Monte-Carlo templates which have systematic uncertainties. For a typical template fit spanning multiple channels, multiple templates and multiple observables keeping book of all correlations becomes non-trivial.

In this talk, we present SysVar - A python package that streamlines the treatment of systematic uncertainties for collider-physics analyses that rely on Monte-Carlo template fits. SysVar produces outputs compatible with popular HEP template-fitting libraries such as cabinetry and pyhf. It was originally developed within the Belle II context, but its design and interfaces are experiment-agnostic.

By having consistency across systematics and preserving correlations, this also enables the combination of a measurement from different analysis based on orthogonal selections

T 34.2 Tue 16:30 KH 02.014

**MC-Run: Monte Carlo Workflows for Precision Phenomenology** — MAXIMILIAN HORZELA<sup>1</sup> and •CEDRIC VERSTEGE<sup>2</sup> — <sup>1</sup>Georg-August-Universität Göttingen, Germany — <sup>2</sup>Karlsruhe Institute of Technology, Germany

Reliable Monte Carlo (MC) predictions are a key ingredient for precision phenomenology in high-energy physics, in particular for the derivation of non-perturbative and electroweak correction factors. We present MC-Run, a lightweight framework that enables reproducible end-to-end MC studies, from event generation to Rivet-based analyses and further processing.

Originally developed for the determination of non-perturbative corrections, MC-Run has been successfully applied in phenomenological analyses and HEP publications, supporting large-scale production campaigns at the level of O(100k) CPU hours. More recently, the framework has been extended to studies of electroweak corrections and can be readily adapted to different physics processes and observables.

This talk will give an overview of MC-Run, its modular workflow design, built-in support for grid computing, how to extend it to other MC generators and adapt it for further physics analyses.

T 34.3 Tue 16:45 KH 02.014

**FeynGraph - A Modern High-Performance Feynman Diagram Generator** — •JENS BRAUN — Institute for Theoretical Physics, Karlsruhe Institute of Technology

We present FeynGraph, a modern high-performance Feynman diagram generator designed to integrate seamlessly with modern computational workflows to calculate scattering amplitudes. FeynGraph is designed as a high-performance Rust library with easy-to-use Python bindings, allowing it to be readily used in other tools. With additional features like arbitrary custom diagram selection filters and automatic diagram drawing, FeynGraph strives to be a fully-featured Feynman diagram toolkit at any loop order.

T 34.4 Tue 17:00 KH 02.014

**Differentiable Setup for a Top-Higgs Analysis** — •FELIX ZINN<sup>1</sup>, PETER FACKELDEY<sup>2</sup>, BENJAMIN FISCHER<sup>1</sup>, NINA HERFORT<sup>1</sup>, and MARTIN ERDMANN<sup>1</sup> — <sup>1</sup>RWTH Aachen University — <sup>2</sup>Princeton University

In high energy physics (HEP), the measurement of physical quantities often involves intricate data analysis workflows that include the application of kinematic cuts, event categorization, machine learning techniques, and data binning, followed by the setup of a statistical model. Each step in this process requires careful selection of parameters to optimize the outcome for statistical interpretation.

This presentation introduces a differentiable approach to the data analysis workflow utilizing the python package evermore for statistical model building. Built on top of JAX, the models created in evermore benefit from automatic differentiation. By leveraging this feature alongside neural networks, we can apply optimization across all stages of the analysis. This method allows for a more systematic selection of parameter values while also ensuring that the optimization process accounts for systematic uncertainties included in the analysis.

We apply this approach to a CMS analysis targeting the production of a Higgs boson in association with one or two top quarks and demonstrate how each individual step can be implemented in a differentiable manner. A setup for a differentiable analysis workflow is presented.

T 34.5 Tue 17:15 KH 02.014

**Exploring future Monte-Carlo generators: MC Validation in ATLAS with PAVER** — •DOMINIC HIRSCHBÜHL, JOHANNA KRAUS, ANNA BINGHAM, FRANK ELLINGHAUS, and TIM BEUMKER — Bergische Universität Wuppertal, Wuppertal, Germany

Monte-Carlo (MC) simulations play a key role in high energy physics, for example at the ATLAS experiment. MC generators evolve continuously, so a periodic validation is indispensable for obtaining reliable and reproducible physics simulations. For that purpose, an automated and central validation system was developed: PMG Architecture for Validating Evgen with Rivet (PAVER). It provides an MC event generator validation procedure that allows a regular evaluation of new revisions and updates for commonly used MC generators in ATLAS as well as comparisons to measured data. The result is a robust, fast, and easily accessible MC validation setup that is constantly developed further. This way, issues in simulated samples can be detected before generating large samples for the collaboration, which is crucial for a sustainable and low-cost MC production procedure in ATLAS.

T 34.6 Tue 17:30 KH 02.014

**Implementation of a reliable ML model life cycle for the CMS Phase-2 L1 Trigger Upgrade** — •LEON JOEL KERNER<sup>1,2</sup> and ALEXANDER SCHMIDT<sup>1</sup> — <sup>1</sup>Physics Institute IIIA, RWTH Aachen University, (DE) — <sup>2</sup>CERN, (CH)

To achieve the ambitious goals of the High-Luminosity LHC upgrade, a new Level-1 trigger must be developed for the CMS experiment. Machine Learning based models will be deployed in the trigger system, which introduces a range of new challenges. The development of such models involves many individual steps. Any change in the configuration or the data can require repeating the entire workflow, and these steps are currently carried out manually by the model developers. In addition, the deployment of trained models in the trigger requires robust procedures that ensure long-term quality and stability. To address these issues, methods from machine learning operations (MLOps) must be integrated into the workflow.

To address this problem, a GitLab CI/CD pipeline and a training infrastructure consisting of a MLflow server and a WebEOS instance was created to log and manage model training sessions.

T 34.7 Tue 17:45 KH 02.014

**A Common Language for Complex Particle Decays: demonstrated on  $B^+ \rightarrow D^{*+} D^+ K^+$**  — •ALEXANDER KAZATSKY, MIKHAIL MIKHASENKO, and MARIAN STAHL — Experimental Physics I, Ruhr-University Bochum, Germany

The Amplitude Model Serialization (AMS) project of the DEMOS (DEMocratizing MODELS) consortium aims to provide a standardized format for the description of particle decay processes of varying complexity. This enables more straightforward reproduction of existing analyses, offers a framework for performing new amplitude studies, and facilitates the integration of complex decay chains into external systems such as Monte Carlo generators. In this work, the translation of a partial-wave analysis from the TensorFlow Partial Wave Analysis (TF-PWA) framework, which is widely used in experiments like LHCb and BESIII, is demonstrated. While the AMS format has so far been applied to singular three-body decays, the present analysis of  $B^+ \rightarrow D^{*+} D^+ K^+$  features a more complex topology. Namely, the decay of  $D^{*+} \rightarrow D^0 \pi^+$  needs to be accounted for. The branching structure of two-body decays inherent to TF-PWA is translated into a system of three- and two-body decays in the AMS format. This coupled-channel analysis, which previously revealed new tetraquark candidates (PRL 133 (2024) 13, 131902), was reproduced using TF-PWA, translated, and repeated in the AMS framework. A standardized workflow for translating models from TF-PWA into the AMS system is presented.

T 34.8 Tue 18:00 KH 02.014

**Python framework for the topological track reconstruction in JUNO** — •MIKHAIL SMIRNOV, DANIEL BICK, MILO CHARAVET, and CAREN HAGNER — Institute of Experimental Physics, University of Hamburg, Hamburg, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a new-generation kiloton-scale neutrino detector based on liquid scintillator (LSc). With a target mass of 20 kilotons, it is the largest LSc detector in the world. Utilizing the antineutrino flux from two nuclear power plants at a baseline of approximately 53 km, JUNO aims to determine the neutrino mass ordering with high statistical significance and to perform precision measurements of neutrino oscillation parameters. JUNO has successfully started to operate in August 2025. Topological Track Reconstruction (TTR) was originally developed to reconstruct energetic muon events in large unsegmented LSc detectors. The algorithm exploits the time and spatial distributions of PMT first-hit times to reconstruct a three-dimensional photon-emission density inside the detector. In the original C++ implementation, this density is obtained via deterministic kernel summation, which provides a heuristic estimate but lacks a well-defined statistical interpre-



tation. This talk presents pyTTR, a Python-based reimplementation and conceptual extension of the TTR. The new framework reformulates TTR as a likelihood-based inverse problem, naturally separating detector geometry, photon propagation, PMT response, and statistical inference, and provides increased flexibility for future physics analyses

T 34.9 Tue 18:15 KH 02.014

**LEGEND Analysis with the JuLeAna Software Stack** — •ANDREAS GIEB<sup>1</sup>, FLORIAN HENKES<sup>2</sup>, SUSANNE MERTENS<sup>1</sup>, JONAS SCHLEGEL<sup>1</sup>, OLIVER SCHULZ<sup>3</sup>, and CHRISTOPH WIESINGER<sup>1</sup> for the LEGEND-Collaboration — <sup>1</sup>Max-Planck-Institut für Kernphysik, Heidelberg, Germany — <sup>2</sup>Technische Universität München, Munich, Germany — <sup>3</sup>Max-Planck-Institut für Physik, Munich, Germany

The Large Enriched Germanium Experiment for Neutrinoless  $\beta\beta$  Decay (LEGEND) is a staged experimental program searching for the neutrinoless double-beta ( $0\nu\beta\beta$ ) decay of  $^{76}\text{Ge}$ . The first stage of the experiment LEGEND-200 is currently taking data at the Gran Sasso Underground Laboratory. Data analysis within LEGEND-200 is carried out using two dedicated software stacks. This talk will focus on the structure and analysis workflows of the JuLeAna software stack.

## T 35: Searches/BSM II

Time: Tuesday 16:15–18:30

Location: KH 02.018

T 35.1 Tue 16:15 KH 02.018

**The current status of the Mu2e experiment at Fermilab** — •STEFAN E. MÜLLER, ANNA FERRARI, OLIVER KNODEL, and REUVEN RACHAMIN for the Mu2e-Collaboration — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany  
The Mu2e experiment, which is currently under construction at the Fermi National Accelerator Laboratory near Chicago, will search for the neutrinoless direct conversion of a muon to an electron in the field of an aluminum nucleus, aiming at a sensitivity four orders of magnitude better than previous experiments. The observation would imply the violation of charged lepton flavor, and hint at physics beyond the Standard Model.

With the arrival of the large superconducting solenoid magnets at Fermilab, and the installation of the main detector subsystems at their final locations inside the Mu2e hall, the experiment has entered an exciting phase of its construction towards data taking.

The design and status of the Mu2e experiment and its detector subsystems will be presented, highlighting the large progress made over the last year.

T 35.2 Tue 16:30 KH 02.018

**Probing hidden sectors with the SHiP experiment at CERN** — •JAMES WEBB for the SHiP-D-Collaboration — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, 79104 Freiburg, Germany

SHiP (Search for Hidden Particles) is a general purpose fixed target experiment. Approved in 2024 by the CERN research board, SHiP will be CERN's flagship experiment in the search for GeV-scale Feebly Interacting Particles (FIPs) and accelerator neutrino physics.

A 400 GeV/c proton beam extracted from the Super Proton Synchrotron (SPS) will be dumped on a heavy target, producing an expected  $6 \times 10^{20}$  proton-target collisions over 15 years of operation. A dedicated detector, based on a long helium decay volume, surrounded by veto detectors, and then followed by a spectrometer and particle identification detectors, will allow for a variety of new physics models with light long-lived exotic particles to be probed in a near-zero background environment. This detector will increase the discovery sensitivity for many new physics models by orders of magnitude. A second detector dedicated to the study of neutrino cross-sections of all three flavours, will incorporate tracking and calorimetry detectors interwoven between five tonnes of tungsten and iron plates. The large neutrino flux produced during the beam dump coupled with the mass of the detector will yield a significant number of neutrino interactions that will become available for measurement.

In this talk a brief discussion on the physics potential and an overview of the detector layout, with an emphasis on the contributions from the German community, will be presented.

T 35.3 Tue 16:45 KH 02.018

**Search for exotic particles at NA62** — •DANIEL GREWE<sup>1</sup>, BABETTE DÖBRICH<sup>1</sup>, OTMAR BIEBEL<sup>3</sup>, TOMMASO SPADARO<sup>2</sup>, JAN JERHOT<sup>1</sup>, LO CHIATTO PRISCO<sup>1</sup>, JONATHAN SCHUBERT<sup>1</sup>, and MARCZIKA ANDRÁS<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Physik, Munich, Germany — <sup>2</sup>INFN e Laboratori Nazionali di Frascati, Frascati, Italy — <sup>3</sup>LMU, Munich, Germany

The NA62 experiment at the CERN SPS primarily aims to measure rare kaon decays. In addition, the experiment has the capability to collect data in a beam dump mode, where the 400 GeV protons are dumped on an absorber. In this configuration, exotic particles might be produced and reach the fiducial volume.

T 34.10 Tue 18:30 KH 02.014

**Data- and Metadata Management at HZDR** — •STEFAN E. MÜLLER, THOMAS GRUBER, OLIVER KNODEL, DAVID PAPE, and MARTIN VOIGT — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The integrity and utility of research output critically depends on both data and metadata. While data comprise the primary outputs of experiments, simulations or analyses, metadata describe the origin, structure, semantics, and context of the data, enabling the interpretation, discovery, and reuse. Metadata are essential for ensuring compliance with the FAIR principles (Findable, Accessible, Interoperable, and Reusable), and failure to adequately define or manage metadata leads to poor reproducibility and limited interoperability.

At HZDR, the Helmholtz-Zentrum Dresden-Rossendorf, researchers profit from the "Rossendorf Data Repository" RODARE, which allows them to publish their research data. Especially for large data sets, which can contain up to several Terabyte of data, a good description of the metadata is required to allow a practical reuse of the data sets. The SciCat metadata catalog is used at HZDR to provide the corresponding metadata together with a RODARE data publication.

The presentation will describe how SciCat and RODARE are used together to make a large data set FAIR.

Previous searches have focused on exotic particles with charged particle final states. In this talk, the first steps toward an analysis of a  $\gamma \gamma$  final state decay are presented, including the development of new methods for vertex reconstruction for such decays.

T 35.4 Tue 17:00 KH 02.018

**Event Selection for the Search of Sub-Relativistic Magnetic Monopoles with the IceCube Neutrino Observatory** — •JONAS HÄUSSLER<sup>1</sup>, BRYNDIS KERN<sup>1</sup>, NICK SCHMEISSER<sup>2</sup>, and CHRISTOPHER WIEBUSCH<sup>1</sup> — <sup>1</sup>RWTH Aachen, Aachen, Deutschland — <sup>2</sup>Bergische Universität Wuppertal, Wuppertal, Deutschland

Grand-Unified-Theories predict the existence of magnetic monopoles to be created during transitions from one gauge group to a smaller sub-group. For most GUTs, magnetic monopoles can reach masses above  $10^{14}$  GeV resulting in sub-relativistic speeds. These magnetic monopoles can catalyze nucleon decays via the Rubakov-Callan effect, resulting in a unique signature of small particle cascades along the trajectory of a slow moving particle. To search for this signature, a dedicated slow particle trigger has been implemented in the IceCube Neutrino Observatory since 2012. The low, if existent, flux of magnetic monopoles requires an exceptional classification, with high background rejection and signal efficiency. In this talk, a multi-level boosted decision tree for the event selection and the sensitivity of IceCube for the detection of sub-relativistic magnetic monopoles, is shown. This talk presents an event selection using a multi-level boosted decision tree, the sensitivity for the detection of sub-relativistic magnetic monopoles, and potential applications to other slow exotic particle searches in IceCube.

T 35.5 Tue 17:15 KH 02.018

**Luminescence Simulation for the Search of Sub-Relativistic Magnetic Monopoles in IceCube** — •BRYNDIS KERN, JONAS HÄUSSLER, and CHRISTOPHER WIEBUSCH — III. Physikalisches Institut B, RWTH Aachen University

Magnetic monopoles are hypothetical particles predicted by various Grand Unified Theories, typically expected to have masses exceeding  $10^{14}$  GeV. Such monopoles, as relics from the Big Bang, would propagate with sub-relativistic velocities, characterized by  $\beta < 10^{-2}$ . In ice they can emit light through two mechanisms: the catalyzation of nucleon decays via the Rubakov-Callan effect and luminescence. This results in a distinct signature of a slow light-emitting track in the IceCube Neutrino Observatory. Dedicated simulations of sub-relativistic monopole propagation and detector response are employed to model these signatures and to provide training data for Boosted Decision Trees (BDTs) used in event selection. This talk shows results from the inclusion of a new luminescence model into the monopole simulation framework.

T 35.6 Tue 17:30 KH 02.018

**Search for Nuclearites with IceCube** — •NICK JANNIS SCHMEISSER<sup>1</sup> and JONAS HÄUSSLER<sup>2</sup> for the IceCube-Collaboration — <sup>1</sup>Bergische Universität Wuppertal — <sup>2</sup>RWTH Aachen

Nuclearites are lumps of strange quark matter that were first proposed in the 1980s. Strange quark matter consists of roughly equal amounts of up-, down-, and strange-quarks and could appear in the Standard model at high densities as well as in BSM theories. They are candidates for the cold dark matter observed in the Universe. We are presenting the first search for nuclearites with IceCube.

The IceCube Neutrino Observatory is expected to have the best sensitivity to nuclearites due to its size and lower noise rate in comparison to other neutrino telescopes.

This presentation gives a short motivation for nuclearites and discusses their properties and the signature they are expected to produce in the IceCube detector, which are thermal shocks produced by atomic collisions in the Antarctic ice. The analysis chain used to search for nuclearites is discussed, leading to the first sensitivities of the IceCube detector for different nuclearite masses.

T 35.7 Tue 17:45 KH 02.018

**Design Studies and Detector Simulation for the proposed Dark Photon Search Experiment Lohengrin** — •CEDRIC BREUNING for the Lohengrin-Collaboration — Physikalisches Institut, University of Bonn, Bonn, Germany

The proposed Lohengrin experiment will search for light dark matter at the Electron Stretcher Accelerator (ELSA) in Bonn. It employs the fixed-target missing momentum based technique for searching for dark-sector particles. A beam of electrons is extracted from ELSA and is shot onto a thin target to produce mainly Standard Model bremsstrahlung and – in rare occasions – possibly new particles, like the dark photon, coupling feebly to the electron. In the current phase, detector layouts and designs are studied and optimized to reach the highest sensitivity. This requires an accurate simulation of the interactions in the target and the detector response. In this talk, we present one of the ongoing design studies for the target and electromagnetic calorimeter of the experiment, including a full detector simulation in the DD4hep framework.

T 35.8 Tue 18:00 KH 02.018

**Light Dark Matter simulation studies with GEANT4 for the DarkMESA experiment** — •SASKIA PLURA for the MAGIX-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

Dark Matter searches are an integral part of physics beyond the Standard Model. However, Dark Matter has yet to be observed directly. Theoretical models pro-

vide a large parameter space for Dark Matter and allow for different particle properties. Models incorporating so-called portal interactions, which allow Dark Matter to interact with Standard Model matter, are of special interest. Examples for these are Dark Photons and Axion-like particles (ALPs), which can be studied at low energy accelerator facilities.

The DarkMESA experiment is a beam dump experiment located at the upcoming accelerator MESA at the JGU Mainz, set to start operation in 2026. The accelerator provides an electron beam of 155 MeV and 150  $\mu$ A in extracted beam mode, which, alongside the beam dump of the P2 experiment, provides an ideal environment for Light Dark Matter (LDM) searches.

To predict the potential signal yield of the separate phases of the DarkMESA experiment in relation to different Dark Matter models, a GEANT4 simulation is used. The simulation incorporates different production channels for Dark Matter through Dark Photons, ALPs, pseudoscalar or scalar mediators and offers both invisible (e.g. DM decays) or visible (e.g. SM decays) decay options. Here, the current status of the simulations is discussed.

T 35.9 Tue 18:15 KH 02.018

**Search for Dark Matter with metastable nuclear isomer  $^{180m}\text{Ta}$**  — •JANNIS ENDER, BJÖRN LEHNERT, and KAI ZUBER — IKTP TU Dresden

Due to extremely suppressed transitions, the nuclear isomer  $^{180m}\text{Ta}$  is stable on cosmological time scales. It is the longest lived isomer and its decay has not yet been observed with half-live limits at  $T_{1/2} > 0.29 \times 10^{18} \text{ y}$  over all decay channels. Recently it has been proposed to use such isomers as detectors for Dark Matter particles, in which the DM particles would deexcite the isomer by scattering with the nucleus. A measurable signal could then be obtained through the decay chain of the isomer or the exited DM particle rescattering in a conventional DM detector setup. In this talk, different methods of implementing these possibilities into DM detectors are discussed to further probe the parameter space of various DM models currently unavailable.

## T 36: Search for Dark Matter II

Time: Tuesday 16:15–18:30

Location: AM 00.014

T 36.1 Tue 16:15 AM 00.014

**A large-diameter, dual-phase liquid xenon TPC in the unshielded PANCAKE facility** — •SEBASTIAN LINDEMANN — University of Freiburg, Germany

Future liquid xenon (LXe) based observatories searching for rare processes, such as XLZD, require testing of large components and sub-assemblies in cryogenic liquid or gaseous xenon environments. In this talk, I will present results from operating a 1.5 m diameter, 3 cm deep, dual-phase LXe time projection chamber (TPC) in the unshielded PANCAKE platform without underground suppression of cosmic ray backgrounds.

Measurements of various detector- and LXe-specific quantities, such as the electron lifetime dependent on purity and the electron drift velocity dependent on electric field, demonstrate that operating a large-diameter TPC is feasible in a high-background environment.

T 36.2 Tue 16:30 AM 00.014

**Radon removal by cryogenic distillation for future liquid xenon detectors** — •ROBERT BRAUN, LUTZ ALTHUESER, DAVID KOKE, VOLKER HANNEN, CHRISTIAN HUHMANN, YING-TING LIN, PHILIPP SCHULTE, PATRICK UNKHOFF, DANIEL WENZ, and CHRISTIAN WEINHEIMER — Universität Münster

Radon emanation from detector materials is a dominant background source in liquid xenon (LXe) detectors used for rare event searches including dark matter and neutrinoless double beta decay. Because of the continuous emanation of radon it is necessary to remove radon faster than its half-life of 3.8 days in order to effectively reduce the radon concentration of the detector itself. For the large detector masses of next generation LXe experiments (e.g. XLZD) this requirement corresponds to a total xenon flow of up to 1600 kg/h, which is more than an order of magnitude higher than those achieved by current systems of about 80 kg/h.

In the LowRAD project a cryogenic distillation setup is developed for reducing the concentration of radon to unprecedented levels. To investigate the scalability of the system, the required heating and cooling power is provided by an hermetically separated heat pump cycle, for which a first demonstrator with about 10 slpm is now scaled to a "XENONnT-sized" heat pump with 300 slpm. This talk will present the design and commissioning of the radon distillation column and its subsystems, with a particular emphasis on the integrated radon-decay detector enabling continuous online monitoring of radon concentrations. Supported by the ERC Advanced Grant "LowRad" (101055063).

T 36.3 Tue 16:45 AM 00.014

**Beyond standard model physics with electronic recoil data of XENONnT** — •SEBASTIAN VETTER — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

The XENONnT detector is among the world leading experiments in the direct search for Weakly Interacting Massive Particles (WIMPs), one of the prime candidates to form particle Dark Matter (DM). XENONnT uses liquid Xe in a dual-phase time projection chamber (TPC) as a detector target. One of the great advantages of a TPC is the ability to discriminate between energy deposits from incoming particles on the target nuclei, nuclear recoils (NRs), or on the electron clouds of the atoms, electron recoils (ERs). While WIMPs are expected to interact via NRs, many signals of scientific interest can occur as ERs. The ER data allows us to explore the flux of solar neutrinos from the pp chain, and look beyond the standard model for other than WIMP DM candidates like Dark Photons or Axion Like Particles.

In this talk, I will highlight challenges and opportunities, as well as the latest status, in the analysis of XENONnT ER data in a wide energy range from keV to MeV scale.

This work is supported in part through the Helmholtz Initiative and Networking Fund (grant agreement no.~W2/W3-118) and through the grant 05A23VK3 within the ErUM-Pro funding line by the German Federal Ministry of Research, Technology and Space. In addition, support by the KIT graduate school KSETA is gratefully acknowledged.

T 36.4 Tue 17:00 AM 00.014

**Characterization of anomalous electron backgrounds in XENONnT** — •ALEXIS MICHEL for the XENON-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Dual-phase xenon time projection chambers like XENONnT are widely used in searches for rare events. These detectors have a layer of gaseous xenon (GXe) above a target of liquid xenon (LXe). Interactions in the LXe produce scintillation light and ionization electrons. With electric fields generated by electrodes, clouds of such ionization electrons are drifted upwards in the liquid and then extracted into the gas, where they produce a secondary proportional scintillation light signal.

Such xenon-based TPCs commonly see various forms of spurious emission that are associated with electrical fields and electrode operation. One such emission type are so-called  $e^-$ -bursts that were observed in XENONnT and other detectors. These  $e^-$ -bursts are large and clustered delayed electron signals observed where the extraction of the initial electron cloud at the LXe-GXe interface was incomplete and electrons got trapped at the LXe surface. Another such spurious

emission type is from so-called hot-spots, which are spatially localized sources of continuous and intermittent single electron emission.

In this talk I will present the recent results on the studies of spurious electron emission phenomena in XENONnT and their implications for the next generation of xenon-based detectors such as XLZD.

This work has been supported in part by the Federal Ministry of Research, Technology and Space (BMFTR) through the grant 05A23VK3 within the ErUM-Pro funding line.

T 36.5 Tue 17:15 AM 00.014

**Development of Cryogenic Single-Photon Detectors to Study the Light Output of Sodium Iodide Crystals for Rare Event Searches** — •LUTZ ZIEGELE for the COSINUS-Collaboration — Max-Planck-Institut für Physik, 85748 Garching, Germany

The Cryogenic Observatory for Signatures seen in Next-generation Underground Searches (COSINUS) is a dark matter direct detection experiment located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. It employs sodium iodide (NaI) crystals operated as cryogenic calorimeters. Particle interactions in the crystal produce phonons, which are detected by a remote Transition Edge Sensor (remoTES), while the accompanying scintillation light is absorbed by silicon absorbers equipped with Transition Edge Sensors. This dual-readout scheme enables particle discrimination and allows for an in-situ determination of energy-dependent quenching factors.

This contribution presents the development of a detector module with enhanced scintillation light sensitivity, enabling photon-number-resolved measurements. Rather than using a single large light detector, multiple smaller light absorbers are arranged around the NaI crystal. Their reduced heat capacity improves the overall sensitivity. The main goal is a precise characterization of the scintillation light yield of ultrapure NaI crystals, which is crucial for the analysis of upcoming COSINUS data. In addition, this development establishes the basis for future studies of dark matter-electron interactions within the OνDES project, funded by the Klaus Tschira Foundation.

T 36.6 Tue 17:30 AM 00.014

**Tracking down the Low-Energy Excess: First results from CRESST Double-TES Modules** — •MARCO ZANIRATO for the CRESST-Collaboration — Max Planck Institut für Physik, München, Deutschland

The Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) is a forefront experiment in the direct detection of dark matter, located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. By employing cryogenic calorimeters based primarily on scintillating crystals equipped with Transition Edge Sensors (TESs), CRESST achieves energy thresholds of the order of 30 eV with a 24 g detector. However, the development of such a cutting-edge experiment presents several challenges. One of the most pressing is the unexplained rise in the number of events observed below 200 eV, commonly referred to as the Low-Energy Excess (LEE).

To investigate the origin of this excess, the current data-taking campaign utilises detector modules with two sensors per crystal, allowing the collaboration to disentangle whether the LEE is linked to the crystal or to the sensors themselves. This talk will provide an overview of the concept behind these new modules, the results obtained in above-ground tests, and the first preliminary findings from the ongoing underground run.

T 36.7 Tue 17:45 AM 00.014

**The Projected Sensitivity of the DELight Experiment** — •ELEANOR FASCIONE for the DELight-Collaboration — Kirchhoff-Institut für Physik

In the search for dark matter, there is vast unexplored parameter space for masses below a few GeV, and the field of direct dark matter detection is constantly expanding to new frontiers. Low mass dark matter candidates necessitate novel detector designs with lower thresholds and alternative target materials compared to experiments currently providing the strongest overall constraints on many thermal dark matter models. The Direct search Experiment for Light dark matter (DELight) will deploy a target of superfluid  $^4\text{He}$  instrumented with large area microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology in a setup optimized for light dark matter searches. In this talk an overview of this upcoming experiment will be presented along with the expected dark matter sensitivity.

T 36.8 Tue 18:00 AM 00.014

**Aboveground Studies of the Low-Energy Excess in CRESST** — •ELEONORA REBECCA CIPELLI for the CRESST-Collaboration — Max Planck Institut für Physik, Garching bei München, Deutschland

The CRESST experiment, located at the Laboratori Nazionali del Gran Sasso (LNGS), is a leading direct dark matter detection experiment. It employs cryogenic calorimeters operated at millikelvin temperatures and instrumented with Transition Edge Sensors (TESs), achieving extremely low energy thresholds ( $\sim 10$  eV) and high sensitivity to sub-GeV dark matter particles. However, the experiment's sensitivity is currently limited by an unexplained increase in background events below  $\sim 200$  eV, known as the Low-Energy Excess (LEE).

This talk will present new investigations into possible origins of the LEE based on dedicated above-ground R&D studies. In particular, it will focus on the impact of thermal cycles on the LEE decay, as well as the influence of aluminium phonon collectors. These studies provide new insights into the nature and mechanisms of the LEE.

T 36.9 Tue 18:15 AM 00.014

**Status of the MainzTPC Upgrade for Precision Low-Energy Recoil Measurements in Liquid Xenon** — •CONSTANTIN SZYSZKA, ALEXANDER DEISTING, CHRISTOPHER HILS, PETER GYÖRGY, JOHANNES MERZ, and UWE OBERLACK — Institut für Physik & Exzellenzcluster PRISMA<sup>+</sup>, Johannes Gutenberg-Universität Mainz

The MainzTPC is an experimental dual-phase xenon time projection chamber (TPC) dedicated to the study of scintillation and ionization processes in liquid xenon (LXe) for low-energy electronic and nuclear recoils. Its design has been optimized for use as the primary target in Compton and neutron scattering experiments to measure recoil energies in LXe down to 1 keV.

To improve position resolution in  $x$  and  $y$  the MainzTPC was redesigned to accommodate an array of silicon photomultipliers (SiPMs) in place of its monolithic top photomultiplier tube (PMT) and eight avalanche photodiodes. The goal of this upgrade is to enable the MainzTPC to perform a measurement of the Migdal effect in LXe. For this purpose, a cryogenic amplifier board housing the SiPM array was developed. To address known instabilities in the liquid level of the MainzTPC, we rebuilt the level meters and level control based on camera observations of the liquid-gas interface. We report on the status of this work.

## T 37: Neutrino Astronomy II

Time: Tuesday 16:15–18:30

Location: KS H C

T 37.1 Tue 16:15 KS H C

**Title: Characterization and calibration of photomultiplier tubes for the Pacific Ocean Neutrino Experiment** — •JOSEF PFLANZ for the P-ONE-Collaboration — Technische Universität München, Germany

The Pacific Ocean Neutrino Experiment (P-ONE) is a planned cubic-kilometer scale neutrino telescope, designed for high-precision neutrino source searches and long-baseline astrophysical observations. The first detector line is currently under development and will consist of 20 modules, equipped with photomultiplier tubes (PMTs). The Hamamatsu R14374 PMT was selected for this first deployment due to its low transit-time spread, high stability, and overall performance quality. In this talk, I will present the characterization and validation procedures carried out on these PMTs. In particular, I will focus on measurements of quantum efficiency, photon detection efficiency, and the linearity of the PMT response when coupled to P-ONE's dedicated front-end electronics. These results provide essential input for the detector's Monte Carlo simulations and establish a robust framework for future large-scale PMT characterization for the full P-ONE array. The talk will highlight the measurement techniques, calibration methods, and results obtained from a subset of the PMTs.

T 37.2 Tue 16:30 KS H C

**Construction and testing of the first string for the Pacific Ocean Neutrino Experiment** — •LAURA WINTER for the P-ONE-Collaboration — Technical University of Munich, TUM School of Natural Sciences, Department of Physics, James-Frank-Straße 1, D-85748 Garching bei München, Germany

The Pacific Ocean Neutrino Experiment (P-ONE) is a next-generation multi-cubic-kilometer neutrino telescope under construction in the Northeast Pacific Ocean off the coast of Vancouver Island, Canada. The first construction phase comprises the initial detector string, which is currently under construction and testing, with deployment planned for summer 2026. The line consists of 20 optical and calibration modules designed for the detection of Cherenkov light. Each module features a modular multi-photomultiplier tube (PMT) design with 16 PMTs per module, optically and mechanically coupled to the glass using individual silicone gel pads. The first line will also be used to test biofouling mitigation strategies using both polished glass hemispheres and hemispheres treated with a special anti-biofouling coating. Module integration onto the detector line is currently being performed at TRIUMF (Tri-University Meson Facility) in Vancouver. This contribution presents the optical module production process, the line integration process, and first results from system-level testing of the full string.

T 37.3 Tue 16:45 KS H C

**Development of a High-Resolution Muon Calibration Sample for the IceCube Upgrade** — •SIMON PICK — DESY, Zeuthen

The IceCube Upgrade will deploy nearly 800 new optical sensors in a closely spaced region within the IceCube DeepCore volume, enabling an unprecedented view of atmospheric muons and neutrinos. This dense instrumentation may offer the opportunity to identify muon tracks with exceptionally high angular precision through direct detection. Such events could serve as powerful calibration sources for detector response and angular reconstruction algorithms.

In this contribution, I will present ongoing work toward the development of a high-resolution muon calibration sample. This includes progress on characterizing muon-induced sensor responses through laboratory measurements and simulation, with a particular focus on the development of a new dedicated calibration stand. More broadly, I will provide an overview of the current status and outline the next steps toward the sample development and studies of potential improvements in reconstruction performance.

T 37.4 Tue 17:00 KS H C

**Wavelength Division Multiplexing for the Pacific Ocean Neutrino Experiment** — •LEA GINZKEY for the P-ONE-Collaboration — Technical University of Munich

The Pacific Ocean Neutrino Experiment (P-ONE) aims to detect high-energy astrophysical neutrinos by instrumenting more than one cubic kilometer of deep ocean water in the Northeast Pacific, off the coast of Vancouver Island (Canada). With the first detector line nearing deployment, planning for the next stages of P-ONE is already underway.

To decrease both cable production complexity and overall cost, we aim to reduce the number of fibers per module while maintaining DAQ redundancy. Wavelength Division Multiplexing (WDM) enables the simultaneous transmission of multiple independent optical channels through a single fiber, offering a promising path towards more efficient deep-sea readout architectures.

The current status of WDM tests for P-ONE will be presented, providing an outlook on how WDM could support the next generation of large-volume oceanic neutrino detectors.

T 37.5 Tue 17:15 KS H C

**Production, Installation & Detector Operations of a Calibration Device for the IceCube Upgrade** — •LEONHARD EIDENSCHINK, ANDRII TERLIUK, and PATRICK SCHAILE for the IceCube-Collaboration — Technical University of Munich

The Precision Optical Calibration Module (POCAM) is an isotropic, multi-wavelength, self-monitoring optical calibration device. The IceCube Upgrade, an extension of the IceCube detector located at the geographic South Pole, includes seven new strings equipped with more than 700 modules, 22 of which are POCAM devices. All produced POCAMs underwent extensive calibration of their optical properties at our testing facility at Technical University of Munich (TUM). The purpose of POCAM is to emit a well-characterized isotropic light pulse that allows for calibration of both the optical medium and the detector modules. In addition to the routine calibration operations planned after full deployment, a series of special operations were carried out during the installation. This talk provides an overview of the device production, installation in the IceCube Upgrade, and the special calibration operations performed, along with their first data.

T 37.6 Tue 17:30 KS H C

**Calculation of the neutrino flavour ratios for astrophysical dense environments** — •TILMAN ECKSTEIN<sup>1,2</sup>, VLADIMIR KISELEV<sup>1,2</sup>, JONAS HELLRUNG<sup>1,2</sup>, and JULIA BECKER TJUS<sup>1,2,3</sup> — <sup>1</sup>Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — <sup>2</sup>Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Neutrinos are elementary particles that are characterised in particular by their weak interaction. This allows them to travel enormous distances almost unhindered and still be detected on Earth. Dense astrophysical environments, such as compact obscured nuclei (CONs), are potential sites where high-energy neutrinos may be produced.

In this work, the event generator SIBYLL 2.3d was used to simulate pp collisions under extreme astrophysical conditions, as they might occur in such dense environments. A special feature of the resulting particle showers is that different decay channels lead to characteristically different neutrino flavour compositions. These flavour ratios were calculated using the numerical tool MCEq.

After their creation, neutrinos are subject to the quantum mechanical phenomenon of neutrino oscillation, which causes their flavour composition to change as they propagate over distance. Finally, the numerical tool NuSQuIDS was used to determine the theoretical flavour ratios after propagation from these potential astrophysical source regions to Earth.

T 37.7 Tue 17:45 KS H C

**Tau neutrino appearance with KM3NeT/ORCA** — •SEBASTIAN WEISSBROD for the KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP, Erlangen, Germany

KM3NeT/ORCA is a water-Cherenkov neutrino telescope currently under construction in the Mediterranean Sea. Due to its modular design, based on strings of Digital Optical Modules (DOMs), data taking is possible already during the construction phase. In the last year, the KM3NeT collaboration has presented a multitude of physics results obtained with a 433 kt-yr data-set recorded with the six-string ORCA6 sub-array. Among these results is the analysis of tau neutrino appearance in the atmospheric neutrino flux through neutrino oscillations, providing insight into the tau neutrino cross section, as well as probing non-unitary neutrino mixing.

The analysis is based on the minimization of a binned log-likelihood ratio comparing model predictions with observed event counts. The detector response is estimated using detailed Monte Carlo simulations that are specific to the present detector geometry.

A new analysis is currently in preparation, harnessing the further deployment of more strings, providing an expanded detector sub-array and increasing the exposure to up to 1.7 Mt-yr. This update introduces new challenges, such as the characterization of the larger data-set and the transition to a new software framework for the statistical calculations. In my talk I will be presenting preliminary insights on atmospheric tau neutrino appearance using the expanded data-set.

T 37.8 Tue 18:00 KS H C

**Integration of the NEUT Neutrino Interaction Model into the KM3NeT/ORCA Simulation Framework and Evaluation of Its Impact on Oscillation Analyses** — •FREDERIK ANDERSEN, THOMAS EBERL, and RODRIGO GRACIA-RUIZ for the KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

The KM3NeT/ORCA neutrino telescope is currently under construction in the Mediterranean Sea. It is optimised to detect atmospheric neutrinos with energies up to 100 GeV. To this end a three dimensional grid of photomultiplier tubes detects Cherenkov radiation induced by particles that result from neutrino interactions with seawater. The data recorded by the experiment is analysed by comparing to detailed Monte-Carlo simulations which implement state-of-the-art knowledge on secondary particle production and detection processes. As a first step, so-called neutrino event generator codes employ different approximations to simulate the distribution of final-state particles produced in neutrino interactions. Differences in neutrino generators can introduce biases in the interpretation of the experimental data, and lead to tensions in measurements performed by different experiments. In this talk we will present our results how using different neutrino event generators impacts KM3NeT/ORCA's scientific results by implementing an alternative simulation pipeline using NEUT, the neutrino event generator developed by Super-Kamiokande, and compare its results to the default KM3NeT pipeline employing GENIE as event generator.

T 37.9 Tue 18:15 KS H C

**KM3NeT/ARCA All-Sky Diffuse Analysis using PyForwardFolding** — •ANKE MOSBRUGGER and OLIVER JANIK — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

KM3NeT/ARCA is a cubic-kilometer water-Cherenkov neutrino detector under construction in the Mediterranean Sea. Its primary goal is to detect high-energy neutrinos from both galactic and extragalactic sources. This talk presents methods to improve the search for the astrophysical neutrino flux using ARCA21, the construction phase with 21 detection lines in operation.

Studies of the astrophysical neutrino flux commonly use a binned, forward-folding likelihood method. Our analysis is carried out with the new open-source tool PyForwardFolding (PyFF). PyFF supports the full analysis chain following event selection, including flux weighting, binning, and handling of systematics. PyFF also enables combined analyses across different detector configurations and between experiments, such as KM3NeT and IceCube. This is especially relevant for searches along the Galactic Plane and for identifying potential Galactic neutrino sources.

## T 38: Methods in Astroparticle Physics II

Time: Tuesday 16:15–18:30

Location: KS 00.004

T 38.1 Tue 16:15 KS 00.004

**The Super-SANDI nylon vessel: Compatibility with Water-based Liquid Scintillator** — •NOAH GOEHLKE, AMALA AUGUSTHY, JOHANN MARTYN, PHILIPP KERN, MICHAEL WURM, DAVID MAKSIMOVIC, and OLIVER PILARCZYK — Johannes Gutenberg-Universität Mainz

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a neutrino detector at the Booster Neutrino Beam at Fermilab, designed for measuring the neutron multiplicity in neutrino-nucleus interactions. ANNIE has a strong focus on testing new detector technologies, among which is Water-based Liquid Scintillator (WbLS). WbLS is a novel detection medium, consisting of liquid scintillator dissolved in water with the help of a surfactant. It allows for the simultaneous observation of Cherenkov and scintillation light. To test the reconstruction of extended event topologies in WbLS, ANNIE is going to deploy a nylon vessel containing 8 m<sup>3</sup> of WbLS (dubbed Super-SANDI) this summer. In preparation for Super-SANDI, the chemical compatibility between WbLS and different types of Nylon was investigated. UVvis spectroscopy was used to study the effects on the transparency and on the organic components of the WbLS after exposure to Nylon for an extended period of time. While the transparency is unaffected, an adsorption of PPO into nylon was found, creating slightly scintillating nylon.

T 38.2 Tue 16:30 KS 00.004

**Developing a Cryogenic SiPM Characterization Setup** — •NICOLAS KRIEGER, ANDREAS LEONHARDT, STEFAN SCHÖNERT, and MARIO SCHWARZ — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

Silicon photomultipliers (SiPMs) are promising photodetectors for liquid noble gas detectors, which impose challenging cryogenic and vacuum-ultraviolet conditions. Understanding SiPM behavior in this environment is crucial, given the strong temperature dependence of key performance parameters, such as the dark count rate (DCR), breakdown voltage ( $V_{bd}$ ), gain, photon detection efficiency (PDE), crosstalk, and afterpulsing. We developed a dedicated SiPM characterization setup inside a temperature-controlled vacuum chamber (300–40K) and present the main challenges in achieving stable SiPM operation and readout. The vacuum environment enables systematic measurements over a wide temperature range and rapid sample turnaround, both of which are not accessible in liquid noble gas setups. Finally, we present temperature-dependent SiPM performance measurements, which will support ongoing studies of SiPM behavior for the LEGEND experiment. We acknowledge support from the Deutsche Forschungsgemeinschaft and through the Sonderforschungsbereich SFB 1258.

T 38.3 Tue 16:45 KS 00.004

**Innovative Production Approach to Vacuum Beam Pipes of the Einstein Telescope** — •CHARLOTTE BENNING, ROBERT JOPPE, OLIVER POOTH, and ACHIM STAHL — RWTH Aachen University, Physics Institute 3B

The Einstein Telescope (ET), Europe's next-generation gravitational-wave detector, requires 120 km of underground vacuum tubes with a diameter of 1 m to achieve the design sensitivity. The current design foresees the production of the beam pipes in sections of 15 m, which results in high efforts for transportation, welding, and cleaning. BeamPipes4ET proposes an innovative production approach in which the vacuum pipes are manufactured directly on-site inside the tunnels through a continuous forming process using sheet-metal coils. It offers potential reductions in time, cost, installation effort, and environmental impact. In this talk, the current project status, key technological developments, and a comparison between the current ET design and the BeamPipes4ET approach are discussed.

T 38.4 Tue 17:00 KS 00.004

**Commissioning of a vacuum-insulated liquid argon purifier for removing trace amounts N<sub>2</sub> featuring a novel Li-FAU molecular sieve for LEGEND** — •GEORGIA PAVLIDAKI<sup>1</sup>, CHRISTOPH VOGL<sup>1</sup>, LASZLO PAPP<sup>1</sup>, MARIO SCHWARZ<sup>1</sup>, GRZEGORZ ZUZEL<sup>2</sup>, and STEFAN SCHÖNERT<sup>1</sup> — <sup>1</sup>Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany — <sup>2</sup>M. Smoluchowski Institute of Physics, Jagiellonian University, Cracow, 30-348, Poland

LEGEND-1000 will search for neutrinoless double-beta decay of <sup>76</sup>Ge with up to 1000 kg of enriched high-purity germanium detectors. The detectors are operated bare in liquid argon (LAr) which acts as a coolant, shield, and particle detector. To effectively detect background radiation, LAr has to be kept clean. Impurities such as oxygen, nitrogen or water deteriorate its scintillation properties. A recently identified Li-FAU molecular sieve effectively removes nitrogen from LAr. We construct a LAr purification system featuring Li-FAU and a copper catalyst and report on the current status. The system is able to purify in batch and loop mode, and is vacuum insulated, minimizing LAr losses. The purifier

will provide high-purity LAr for a future investigation of the scintillation properties of xenon-doped liquid argon, and offers excellent windows of opportunity to gain operational experience with Li-FAU for LEGEND-1000. We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFT Verbundprojekt 05A2023 (LEGEND).

T 38.5 Tue 17:15 KS 00.004

**Low-Background Gamma Spectrometry for LEGEND** — HANNES BONET<sup>1</sup>, •PATRICK BONGRATZ<sup>1</sup>, BENJAMIN GRAMLICH<sup>1</sup>, MANUEL HUBER<sup>2</sup>, MATTHIAS LAUBENSTEIN<sup>3</sup>, SUSANNE MERTENS<sup>1</sup>, HARDY SIMGEN<sup>1</sup>, HERBERT STRECKER<sup>1</sup>, and EDGAR SANCHEZ GARCIA<sup>1</sup> for the LEGEND-Collaboration — <sup>1</sup>Max Planck Institut für Kernphysik, Heidelberg — <sup>2</sup>Technische Universität München, Garching — <sup>3</sup>Laboratori Nazionali del Gran Sasso (LNGS)

Low-background experiments depend on minimizing radioactive contamination in detector materials. For example, in the Large Enriched Germanium Experiment for Neutrinoless  $\beta\beta$  Decay (LEGEND), all materials are screened for radioisotopes to achieve this high radiopurity. This is commonly done by gamma spectroscopy using low-background, high-purity Germanium (HPGe) spectrometers. Operating these spectrometers in an underground laboratory reduces the cosmic background for the measurement. In this talk, I present on HPGe-spectrometers operated at 15 m.w.e. in Heidelberg (Germany) and at 3800 m.w.e. at LNGS (Italy). I describe how measurements from these detectors are used to derive the total background budget for the LEGEND-1000 experiment and to fix radiopurity requirements for its components. Sample-specific detection efficiencies are determined using the Geant4-based simulation framework remage.

T 38.6 Tue 17:30 KS 00.004

**Characterizing infrared scintillation light in xenon** — •ROBERT HAMMANN, KAI BÖSE, STEFFEN FORM, LUISA HÖTZSCH, and TERESA MARRODÁN UNDAOITIA — Max-Planck-Institut für Kernphysik

Xenon in gaseous and liquid form is a widely used target material for rare-event searches, including the direct detection of dark matter. Its scintillation properties in the ultraviolet (UV) spectrum are well-known and extensively used. However, the potential of infrared (IR) scintillation light remains largely unexplored. Characterizing this IR component is important for evaluating possible improvements in the physics output of future astroparticle detectors.

This contribution presents studies of xenon gas scintillation at room temperature using a dedicated setup equipped with an alpha particle source, as well as one IR- and two UV-sensitive photomultiplier tubes. This allowed the first time-resolved measurement of the IR scintillation response, revealing both a fast nanosecond-scale and a slow microsecond-scale decay component. Remarkably, our measurements showed that the IR light yield is comparable to the UV yield. We also investigated the effects of gas pressure and impurity levels on the IR signal.

Initial results with a dual-phase detector possessing broadband wavelength sensitivity are consistent with IR emission from the liquid xenon target and electroluminescence in the gas phase, indicating the potential of xenon-based detectors with multi-wavelength readout.

T 38.7 Tue 17:45 KS 00.004

**Methods to measure the ice stratigraphy in the IceCube Upgrade** — •ANNA EIMER for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

A precise understanding of the optical properties of the instrumented Antarctic ice sheet is crucial to the performance of the IceCube Neutrino Observatory and its planned successors.

The ice optical properties are driven by impurities deposited with the snow that formed the ice and thus layers of constant optical properties form a stratigraphy. Due to the underlying bedrock, these layers undulate over the large lateral footprints of these detectors.

Within IceCube, the layer undulations have originally been mapped using stratigraphy measurements by a stand-alone laser dust logger. It required a dedicated deployment setup, as it was not located on the main sensor cables. This resulted in significantly increased costs.

New methods to replace the stand-alone dust logger as have been employed during the deployment of the IceCube Upgrade will be shown in this talk. One approach consists of a light source that was co-deployed with the photosensor modules and operated during the deployment of the detector. Another approach uses a camera to record the stratigraphy. Initial data from both approaches, in particular sampling 150m below the depth instrumented by IceCube, will be shown and discussed.

T 38.8 Tue 18:00 KS 00.004

**Deployment of the Acoustic Module for the IceCube Upgrade** — •ANDREAS NÖLL, JAN AUDEHM, JÜRGEN BOROWKA, MIA GIANG DO, CHRISTOPH GÜNTHER, DIRK HEINEN, CHRISTOPHER WIEBUSCH, and SIMON ZIERKE — III. Physikalisches Institut B, RWTH Aachen University

The IceCube Neutrino Observatory is a cubic kilometer-sized detector located at the geographic South Pole, consisting of 5160 Digital Optical Modules (DOMs). In the Antarctic summer 2025/26 more than 700 new modules will be installed as part of the IceCube Upgrade. These include ten Acoustic Modules (AMs), capable of transmitting and receiving acoustic signals between 5 and 30kHz. Additionally, up to 30 acoustic receivers will be located in new DOMs. The goal of these devices is to improve the geometry calibration based on multilateration of the measured acoustic propagation times, as well as enhance our understanding of the acoustic properties of the ice. This talk presents the current state of the project after the deployment of the IceCube Upgrade.

T 38.9 Tue 18:15 KS 00.004

**Experimental progress of the Munich Electrostatic Storage Ring (ESR)** — •ADIL W. MUGGO, CHIARA BRANDENSTEIN, NILS DOLL, PETER FIERLINGER, DARIO RÜCKWARTH, WOLFGANG SCHOTT, VITUS SCHUSTER, HANS TH. J. STEIGER, KONSTANTIN WALTER, and FLORIAN ZÖTL — School of Natural Sciences, Physics-Department, Technical University of Munich, 85748 Garching, Germany

Stored ions or ionic molecules in a non-relativistic electrostatic storage ring can serve as a versatile platform for various fundamental experiments. Through precise control of beam dynamics and polarization, searches for electric dipole moments (EDMs) or axion-like particles (ALPs) become feasible in a rather unique and novel setting. Recent progress on the implementation of such a device is being discussed. Our experimental demonstrator comprises three subsystems: a laser ablation source for ion generation and acceleration, an injection beamline for beam focusing and transport, and the storage ring itself, where electrostatic elements confine the ions on stable trajectories. The current commissioning status of the setup is presented, as well as experimental challenges and first performance benchmarks.

## T 39: Gravitational Waves II

Time: Tuesday 16:15–17:45

Location: KS 00.005

T 39.1 Tue 16:15 KS 00.005

**Cavity-Based High-Frequency Gravitational-Wave Detection at GravNet** — •STEFAN HORODENSKI, KRISTOF SCHMIEDEN, MATTHIAS SCHOTT, and SWARANGEE SARAF — University of Bonn, Physikalisches Institut, Bonn, Germany

The GravNet collaboration aims to perform the first detection of high-frequency gravitational waves (HFGWs) in the GHz range (1-10 GHz), which could provide sensitivity to primordial black holes, one candidate for dark matter.

GravNet is a network of high-frequency gravitational-wave detectors currently under construction. One detector concept exploits the inverse Gertsenshtein effect, in which gravitational waves induce electromagnetic signals in small, strongly magnetized radio-frequency (RF) cavities.

The experimental setup comprises a cryogenic cylindrical RF cavity mounted inside a 12 T superconducting magnet and coupled to an ultra-low-noise read-out chain, whose first amplification stage is a traveling-wave parametric amplifier (TWPA), enabling near-quantum-limited noise performance. We discuss the prospects of RF-based gravitational-wave searches and present the development of a new experimental setup at Bonn, including optimization of the prototype cavity and characterization of the TWPA.

T 39.2 Tue 16:30 KS 00.005

**Challenge of High-Frequency Gravitational Waves Detection** — •GUDRID MOORTGAT-PICK Z. HD. LIPPS<sup>1,2</sup>, GUDRID MOORTGAT-PICK Z. HD. LIPPS<sup>1</sup>, GUDRID MOORTGAT-PICK Z. HD. LIPPS<sup>1</sup>, GUDRID MOORTGAT-PICK Z. HD. LIPPS<sup>1</sup>, GUDRID MOORTGAT-PICK Z. HD. LIPPS<sup>2</sup>, and GUDRID MOORTGAT-PICK Z. HD. LIPPS<sup>2</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>Am alten Tor 11

High frequency gravitational waves (GWs) remain unexplored messengers of new physics. Proposed sources in the MHz - GHz band include primordial black hole mergers, black hole superradiance and several stochastic backgrounds. Our collaboration is working on tapping into this source by employing superconducting microwave cavities for high precision measurements of harmonic displacements.

The talk give an actual status report on the experimental as well as the theoretical new developments including the measurements as well as background considerations.

T 39.3 Tue 16:45 KS 00.005

**ML based detection strategies for high frequency GWs.** — •SWARANGEE SARAF<sup>1</sup>, MATTHIAS SCHOTT<sup>2</sup>, KRISTOF SCHMIEDEN<sup>2</sup>, STEFAN HORODENSKI<sup>2</sup>, and CHRISTIAN GOTTSCHLICH<sup>2</sup> — <sup>1</sup>University of Bonn, Germany — <sup>2</sup>Physikalisches Institute, University of Bonn, Germany

The Gravitational Wave Network (GravNet) is a network of high frequency gravitational wave detectors currently under construction. The detector concept relies on the resonant conversion of gravitational wave energy into electromagnetic energy, using the inverse Gertsenshtein effect. In this talk we will discuss challenges in detecting high frequency GWs and explore solutions by using machine learning techniques.

T 39.4 Tue 17:00 KS 00.005

**Newtonian Noise in non-spherical caverns for the Einstein Telescope** — •VALENTIN TEMPEL, JÖRG PRETZ, and ACHIM STAHL — III. Physikalisches Institut, RWTH Aachen

The Einstein Telescope (ET), a proposed third-generation gravitational-wave detector, aims to exceed the sensitivity of current interferometers, enabling the observation of significantly fainter signals. Achieving the desired performance re-

quires a precise understanding and likely also mitigation of Newtonian Noise (NN), which is expected to be a significant contribution to the ET noise budget in the 1-10 Hz region. One important NN component originates from seismic-induced density fluctuations in the surrounding rock, as well as from the motion of cavern walls, producing fluctuating gravitational forces on the interferometer test masses. In the past, simplified models with spherical caverns have often been used as a theoretical order-of-magnitude estimation for NN, but those models are not generally representative of realistic underground environments. We present how cavern geometry affects the coupling of NN from seismic waves to the ET mirrors. Using analytical and numerical methods, we quantify how deviations from spherical symmetry and variations in cavern size modify the NN coupling transfer functions. The results highlight the limitations of simplified models and emphasize the importance of accurate models for reliable NN predictions in the Einstein Telescope.

T 39.5 Tue 17:15 KS 00.005

**Newtonian Noise mitigation for the Einstein Telescope using Deep Learning** — •JONATHAN KUCKERT, JAN KELLETER, PATRICK SCHILLINGS, and JOHANNES ERDMANN — III. Physikalisches Institut A, RWTH Aachen University

In the past, gravitational wave interferometers were not able to measure low frequency gravitational waves. The Einstein-Telescope (ET) is a proposed third-generation underground gravitational wave interferometer. For the first time, ET will enable measurements in the 1-10 Hz region. In this region, Newtonian Noise (NN), perturbations in the gravitational field due to density fluctuations in the underground, is the predicted dominant noise source. As a gravitational phenomenon NN, cannot be shielded. Therefore, the most promising mitigation strategy is based on seismometer arrays. The seismometers surround the interferometer mirrors and the gravitational noise on the mirrors is predicted using the seismometer data. For this kind of prediction, Wiener Filters (WFs) were deployed as a standard solution in the past. Based on simulations of simplified seismic events, it has been shown that Deep Learning methods, specifically Graph Neural Networks (GNNs) can match and outperform WFs. In this talk we present further improvements in mitigation and first steps towards optimising seismometer positions using Machine Learning.

T 39.6 Tue 17:30 KS 00.005

**Testing Noise Mitigation Techniques for Future Gravitational Wave Detectors**

— MARKUS BACHLECHNER, JOHANNES ERDMANN, •TIM J. KUHLEBUSCH, ACHIM STAHL, and JOCHEN STEINMANN — III. Physikalisches Institut, RWTH Aachen

Future gravitational wave (GW) detectors like the Einstein Telescope aim to decrease the detector noise to increase the precision of measurements and to detect weaker signals. To measure the minuscule length changes induced by GWs, extremely low vibration levels for the test masses are required. New noise sources become relevant in reducing the residual vibrations of the test masses. Gravitational couplings from density fluctuations of the surrounding material, called gravity gradient noise, can not be shielded. Therefore, predicting the coupled noise from inertial sensors is essential to reduce the impact in the 1 to 10 Hz range.

Wiener filters are a simple and robust approach to predicting coupled noise. However, the classic Wiener filter can not adapt to variations in the amplitude of the coupled noise. As variations in the amplitude over time are expected for the ambient noise sources in GW detectors, an adaptive filter is required for optimal performance. This talk discusses adaptive filtering options and presents the evaluation in a small-scale interferometer.

## T 40: Cosmic Rays II

Time: Tuesday 16:15–18:30

Location: KS 00.006

T 40.1 Tue 16:15 KS 00.006

**The triboelectric effect at the Pierre Auger Observatory** — •JULIAN RAUTENBERG for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

With the AugerPrime extension of the Pierre Auger Observatory all surface detector stations have been equipped with radio antennas to measure extensive air showers in the 30-80 MHz region. For the data acquisition using a trigger based on radio pulses, the triboelectric effect has been reported to be responsible for an increased background rate at high wind-speeds for ice-based radio experiments. With the self-triggered data of the Auger Engineering Radio Array (AERA) we estimate the correlation between trigger rate and wind speed.

T 40.2 Tue 16:30 KS 00.006

**Transferability of 3D-Wave Reconstruction with ML Models\*** — •SVEN QUERCHFELD for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

Within the ErUM-Wave project, a Machine Learning (ML) model is developed to reconstruct three-dimensional wave fields. The goal is to predict the propagation of seismic waves on the basis of only a few measurements. To test the transferability of this method to other fields, it will be applied to the propagation of radio waves in the atmosphere. These waves are produced by cosmic-ray-induced extensive air showers and are measured by the Pierre Auger Observatory. First events have already been recorded by its radio detector, which finished deployment on the full array in November 2024. Training and validation are based on CORSIKA 7 simulations using the CoREAS extension. To obtain more realistic traces, a noise library was created using in-field measurements, utilising the small radio footprint of vertical showers to supplement the simulated events. Due to the CPU-intensive simulations, a preliminary test of the developed ML models for reconstructing 3D wave propagation is presented, using a limited set of showers.

\*Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1) and ErUM-Wave

T 40.3 Tue 16:45 KS 00.006

**Measurement of air-showers by the radio antennas of the IceCube Surface Array Enhancement** — •MEGHA VENUGOPAL for the IceCube-Collaboration — Institute of Astroparticle Physics (IAP), Karlsruhe Institute of Technology, Germany

In a cubic km of ice at the South Pole, strings of Digital Optical Modules of the IceCube observatory measure neutrinos from astrophysical phenomena. IceTop, located on the surface of this detector, comprising 81 pairs of ice Cherenkov detectors measure the electromagnetic and muonic parts of air showers induced by cosmic rays. Challenges arising from the accumulation of snow over these detectors over time led to a planned enhancement of these detectors. Since early 2025, the Surface Array Enhancement has three stations each equipped with 3 antennas and 8 scintillators deployed on the IceTop footprint. The data from the new stations were checked and the first radio data triggered by scintillators measured in all three stations have been reconstructed and verified. Estimation of Xmax with the previous dataset with a single station is also discussed.

T 40.4 Tue 17:00 KS 00.006

**Absolute Energy Calibration of the Auger Engineering Radio Array** — •ASIL MEADOW for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology

The Pierre Auger Observatory detects ultra-high-energy cosmic rays over a surface area of more than 3000 km<sup>2</sup>, requiring a precise and stable energy-scale calibration. Traditionally, this calibration relied solely on fluorescence detectors (FD). In recent years, radio detection has become an increasingly valuable technique, offering complementary insights through an independent reconstruction. Previous comparisons revealed that the energy scales determined with the FD and the Auger Engineering Array (AERA) are consistent within systematic uncertainties, with energies reconstructed with AERA being 12% higher. We present how the AERA standard event reconstruction has been adapted to provide electromagnetic and cosmic-ray energies consistent with the energy scale determined with AERA. We also outline how this approach will be extended to inclined air showers in future work.

T 40.5 Tue 17:15 KS 00.006

**A bayesian method for radio-based air shower reconstruction** — •KAREN TERVEER<sup>1</sup> and ANNA NELLES<sup>1,2</sup> — <sup>1</sup>ECAP, FAU Erlangen-Nürnberg, Germany — <sup>2</sup>Deutsches Elektronen-Synchrotron (DESY) Zeuthen, Germany

Over the past decade, radio detection of cosmic-ray air showers has established itself as a standalone technique. Observatories such as the Low-Frequency Array (LOFAR) have successfully constrained the mass composition in the 10<sup>16.5</sup> - 10<sup>18</sup> eV range, capturing the transition region from galactic to extragalactic

sources. Although standard reconstruction methods based on CoREAS simulations achieve a state-of-the-art  $X_{\max}$  precision of 19 g/cm<sup>2</sup>, they are computationally expensive and do not use all available signal information. We present a new reconstruction method based on Information Field Theory (IFT) that simultaneously uses particle and radio data. The Bayesian framework of IFT ensures rigorous uncertainty quantification and reconstruction of the full posterior distribution. Using JAX for automatic differentiation, the method enables efficient gradient-based inference in high-dimensional parameter spaces. We present the first results of this technique applied to LOFAR data, representing the first approach to exploit a more complete information content of these datasets.

T 40.6 Tue 17:30 KS 00.006

**Bayesian Inference to Reconstruct Current Densities from Radio Emission of Extensive Air Showers** — •STEFANIE GIROD, MAXIMILIAN STRAUB, and MARTIN ERDMANN — RWTH Aachen University, Physics Institute 3A, Otto-Blumenthal-Str., 52074 Aachen, Germany

We are developing an approach to image extensive air showers based on Bayesian Inference. This approach aims to reconstruct the atmospheric current densities that induce radio emissions. The reconstruction requires a forward model with a generator capable of producing current densities in extensive air showers. To ensure differentiability and computational efficiency, we employ Gaussian processes to generate the current densities. We extract the current densities from air showers simulated by the Monte Carlo code CORSIKA to tune the generator's hyperparameters. With a tuned generator capable of sampling the parameter space of realistic air showers, we can apply the reconstruction on realistic scenarios.

T 40.7 Tue 17:45 KS 00.006

**The Auger Radio Infill SKALA Extension (ARISE)** — •CARMEN MERX<sup>1</sup>, BEN FLAGGS<sup>2</sup>, ALEXANDER NOVIKOV<sup>2</sup>, FREDERIK SCHMITT<sup>1</sup>, MEGHA VENUGOPAL<sup>1</sup>, STEF VERPOEST<sup>2</sup>, ANDREAS WEINDL<sup>1</sup>, and FRANK SCHRÖDER<sup>1,2</sup> — <sup>1</sup>Institute for Astroparticle Physics, Karlsruhe Institute of Technology, University of Delaware

Radio detection of extensive air showers has become a powerful technique for studying high-energy cosmic rays. To further enhance the measurement of ultra-high-energy cosmic rays, the Pierre Auger Observatory in Argentina, the world's largest cosmic-ray experiment, has been upgraded with radio antennas for inclined air showers. In 2025, we have installed an additional pathfinder radio array, ARISE ("Auger Radio Infill SKALA Extension"), aiming at the demonstration of full detection efficiency for vertical air showers in the energy range of 100 PeV and above.

The ARISE setup is based on the radio component of the IceCube Surface Array Enhancement. It consists of six stations, each comprising three SKALA antennas installed around a surface detector in the denser infill region of the Pierre Auger Observatory.

This talk will give an overview of ARISE and present first radio measurements triggered by the Auger surface detector.

T 40.8 Tue 18:00 KS 00.006

**A Near-Field Interferometry of Cosmic Ray Air Showers with the Square Kilometre Array** — •KEITO WATANABE<sup>1</sup>, TIM HUEGE<sup>1,2</sup>, TORSTEN ENSSLIN<sup>3,4,5</sup>, and VINCENT EBERLE<sup>3,4</sup> for the SKA HECP SWG-Collaboration — <sup>1</sup>Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>2</sup>Inter-University Institute For High Energies, Vrije Universiteit Brussel, Brussels, Belgium — <sup>3</sup>Max-Planck Institut für Astrophysik, Garching, Germany — <sup>4</sup>Ludwig-Maximilians-Universität München, München, Germany — <sup>5</sup>Deutsches Zentrum für Astrophysik, Görlitz, Germany

With the advent of the low-frequency component of the Square Kilometre Array (SKA-Low), its high antenna density and large frequency bandwidth will allow radio measurements of cosmic ray air showers to be performed with unprecedented accuracy. Current analysis techniques can already reconstruct shower properties with high precision, but are limited by their high computational cost and limited use of the information within the signal. In this work, we showcase that SKA-Low has the potential to perform near-field interferometry by reconstructing the spatial and temporal evolution of the shower with Information Field Theory, a novel Bayesian reconstruction framework that retrieves distributions of field-like quantities from observed signals. We validate our approach with realistic simulated datasets, showing that, through the reconstruction of the shower evolution, we can not only improve our understanding of the mass composition of cosmic rays but also probe the underlying hadronic physics within the shower.



T 40.9 Tue 18:15 KS 00.006

**Development of Radio-Interferometric Lightning Reconstruction for BOLT Using AERA Measurements\*** — •MELANIE JOAN WEITZ for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The Pierre Auger Observatory has detected downward terrestrial gamma-ray flashes (TGFs) with its water-Cherenkov detectors. A key to understanding this high-energy radiation in thunderstorms is to combine such measurements with those of lightning processes in their earliest stages. The Broadband Observatory of Lightning and TGFs (BOLT) is a detector currently under construction for imaging lightning propagation in three dimensions using radio interferometry. With eleven modified Auger Engineering Radio Array (AERA) stations and their

bandwidth range from 30-80 MHz, the necessary spatial and temporal resolution can be provided.

To prepare for BOLT measurements, we characterize lightning signals in existing AERA data to validate the instrument design, particularly concerning the signal amplitude and dynamic range. We will present the reconstructed location and emission time of lightning candidates observed with AERA stations using external lightning information. Furthermore, we present the development of a radio-interferometric analysis suitable for application to the first BOLT signal traces.

\*Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)

## T 41: Invited Overview Talks III

Time: Wednesday 11:00–12:30

Location: AudiMax

T 41.1 Wed 11:00 AudiMax

**Invited Overview Talk**  
**One of a kind: the Higgs boson** — •MATTEO BONANOMI — Universität Hamburg

Discovered by the ATLAS and CMS experiments nearly 60 years after its prediction, the Higgs boson is a cornerstone of the Standard Model of particle physics.

What began as the challenge of discovering a rare particle has now become a vast program of precision measurements which have enabled a deep understanding of the origin of particle masses, the observation of rare Higgs couplings, and a highly granular characterization of the Higgs boson properties with unprecedented precision. This has only been possible thanks to sophisticated detector technologies and great advances in analyses techniques.

Today, experimental efforts are increasingly focused on the simultaneous production of multiple Higgs bosons. The observation of this process would provide direct insight into the Higgs self-interaction and could shed light on fundamental open questions about the origin and evolution of the Universe.

In this talk, I will provide an experimental overview of the field and highlight recent progress of the ATLAS and CMS Collaborations to understand and characterize this one-of-a-kind particle. In the final part of the talk, I will also discuss the experimental prospects for the ongoing Run III and the upcoming High-Luminosity phases of the LHC.

T 41.2 Wed 11:30 AudiMax

**Invited Overview Talk**  
**Higgs Physics at the LHC and Beyond: Connecting Colliders and the Early Universe** — •THOMAS BIEKÖTTER — Instituto de Física Teórica UAM/CSIC, Madrid, Spain

The discovery of the Higgs boson was a landmark achievement, confirming the mechanism of electroweak symmetry breaking that gives mass to elementary particles. At the same time, it marked the beginning of a deeper quest: to under-

stand the underlying dynamics responsible for this mechanism, and to determine whether the Higgs sector is truly minimal, as predicted by the Standard Model (SM), or part of a richer structure predicting additional Higgs bosons.

I will present a theory overview of Higgs physics at the LHC and how precision measurements of the Higgs boson, together with searches for additional scalar particles, provide powerful probes of physics beyond the SM. Many well-motivated extensions of the Higgs sector link collider phenomenology directly to the early Universe. Extended Higgs sectors can accommodate viable Higgs-portal dark matter scenarios that can be probed at the LHC. Moreover, by altering the nature of the electroweak phase transition, a non-minimal Higgs sector can provide the conditions to dynamically generate the matter-antimatter asymmetry of the universe and leave observable imprints in the form of primordial gravitational waves. I will discuss how incorporating the full wealth of current and future LHC data is essential to obtain realistic, data-driven predictions for complementary observations at space-based gravitational-wave observatories like LISA.

T 41.3 Wed 12:00 AudiMax

**Invited Overview Talk**  
**Gravitational waves from cosmological phase transitions.** — •THOMAS KONSTANDIN — Notkestraße 85, 22607 Hamburg, Germany

First-order cosmological phase transitions are an intriguing source of gravitational waves. Depending on the temperature of the phase transition, the gravitational wave spectrum can be observed by pulsar timing arrays, space-based interferometers or ground-based experiments. Quantifying the produced power spectrum is however quite challenging, and non-linear hydrodynamics and turbulence are essential for robust predictions. The aim of the presentation is to summarize the history of the field and also discuss some recent developments.

## T 42: Annual Meeting of Young Scientists in High Energy Physics (yHEP)

Time: Wednesday 12:40–13:40

Location: KS H C

T 42.1 Wed 12:40 KS H C

**10th Annual Meeting of Young Scientists in High Energy Physics (yHEP)** — •SIMRAN GURDASANI<sup>1</sup>, MICHAEL LUPBERGER<sup>2</sup>, SRIJAN SEGHAL<sup>3</sup>, LEONEL MOREJON<sup>3</sup>, FARAH AFZAL<sup>4</sup>, JUDITA BEINORTAITE<sup>1</sup>, and JULIAN GETHMANN<sup>5</sup> — <sup>1</sup>DESY — <sup>2</sup>Albert-Ludwigs-Universität Freiburg — <sup>3</sup>Bergische Universität Wuppertal — <sup>4</sup>Ruhr-Universität Bochum — <sup>5</sup>Karlsruher Institut für Technologie

In this year's yHEP meeting, we will give a brief overview of our activities from the past year and present a retrospective on the development of yHEP since its founding in 2015.

This talk will be structured as a snapshot of current and old activities — including the European Strategy process, ECR representation in national and European committees, sustainability initiatives, the WissZeitVG and residence permit issues, and our efforts to strengthen ECR visibility and connectivity across Germany. Finally, we would like to hear from you: What should yHEP focus on in the coming year?

Food and light refreshments will be provided. All students, doctoral candidates, post-docs and scientists on temporary contracts are warmly invited. Please register to our mailing list (via [yhep.desy.de](mailto:yhep.desy.de)) to receive details on the meeting.

## T 43: Invited Topical Talks I

Time: Wednesday 13:45–15:45

Location: AudiMax

T 43.1 Wed 13:45 AudiMax

**Invited Topical Talk**  
**Upgrade of the ATLAS tracker for HL-LHC: production status and challenges** — •ROLAND KOPPENHOFER — Albert-Ludwigs-Universität, Freiburg, Germany

In 2030, the High-Luminosity Large Hadron Collider (HL-LHC) at CERN is planned to start its operation. An integrated luminosity of up to 4000 fb<sup>-1</sup> is expected over a runtime of up to twelve years. This results in significantly increased particle densities and radiation levels in all HL-LHC experiments

compared to the LHC phase. The ATLAS experiment replaces its inner detector by a completely new all-silicon tracking detector within the Phase-II Upgrade.

The new ATLAS Inner Tracker (ITk) consists of pixel modules in the innermost layers and strip modules in the outer layers. To assemble the required number of detector modules with highest quality and install them in larger detector structures ready for installation in the ATLAS detector in time, a production scheme has been developed with shared responsibilities between ITk institutes

all over the world. After an overview of the scope of the ATLAS ITk Upgrade, this contribution will mainly focus on the production plan of the ITk strip detector. Besides discussing the current production status, a selection of technical challenges that needed to be overcome on the way is presented.

**Invited Topical Talk** T 43.2 Wed 14:15 AudiMax  
**Entering the high-granularity calorimetry era: the CMS HGCal upgrade** — •ANTOINE LAUDRAIN — Deutsches Elektronen-Synchrotron, Hamburg, Germany

The LHC has seen a successful data taking over the last 15 years. However, 90% of the planned dataset will be recorded in the upcoming High-Luminosity phase of the LHC (HL-LHC). While this enormous dataset will enable the high-precision measurements on a range of topics, the LHC experiments will come under a high stress: radiation damage, detector occupancy, data rate, etc. To cope with these challenging conditions, the CMS experiment is upgrading most of its subsystems, including its end-cap calorimeters: they will be completely removed and replaced by the High-Granularity Calorimeter. The HGCal uses a mixture of silicon sensors in the high-radiation areas, and plastic scintillator tiles readout by SiPMs in the lower radiation areas. It totals more than 6 million channels, 2 orders of magnitude more than the current calorimeter system. The scintillator section alone is composed of 4000 modules hosting more than 270'000 individual channels which poses challenges for the production scalability, especially automating the assembly and quality control. This contribution will present the HGCal upgrade and the German contributions to its construction: DESY, one of the two assembly centres worldwide for the scintillator section, will build and test half of these modules, while KIT is involved in the readout electronics in.

**Invited Topical Talk** T 43.3 Wed 14:45 AudiMax  
**Searching for New Physics in Otherwise Lost LHC Data** — •FALK BARTELS — CERN

The search for physics beyond the Standard Model at the LHC is often limited by trigger requirements that prioritise high-energy signatures. As a consequence, potential signals at lower energies may evade conventional analyses altogether. Extending the experimental sensitivity into this previously inaccessible phase

space is therefore a key challenge for current and future searches at both ATLAS and CMS.

This talk will discuss several innovative ideas that aim to overcome these limitations and open up new regions of parameter space for LHC searches. A central example is trigger-level analysis, which makes use of event information reconstructed online during data taking. By recording reduced event content at high rates, this strategy relaxes bandwidth constraints and allows searches to probe significantly lower mass scales. Beyond this, further developments are addressing the hardware-based Level-1 trigger, including the use of anomaly detection techniques to increase sensitivity to unconventional or unexpected signatures. Together, these approaches demonstrate how novel trigger concepts can substantially expand the discovery potential of the LHC.

**Invited Topical Talk** T 43.4 Wed 15:15 AudiMax  
**Federated Computing Infrastructures** — •INGA LAKOMIEC — II. Institute of Physics, Georg-August-University, Göttingen, Germany

Federated computing infrastructures are established to address the rapidly growing data volumes and computational demands of high energy physics (HEP) research. The transition from self-sufficient data and computing centres towards federated resources requires a dedicated approach to ensure interoperability across heterogeneous architectures, research organisations, and geographically distributed sites. Such changes cannot be introduced without significant financial support. The ErUM-Data, ErUM-Pro and NFDI projects are an essential part of this transformation in Germany.

An important step in this process is a transition of storage and computing contributions of the German university-based WLCG Tier-2 centres to the Helmholtz Centres and National High Performance Computing (NHR) sites, respectively. The technologies developed within the dedicated projects are crucial to meeting the computing and storage needs of the WLCG and HEP research in general. The solutions offered by the involved communities are designed in a sustainable way, taking into account scalability as well as efficient resource provisioning and utilisation.

This talk presents recent strategies for federated computing infrastructures and technologies being developed within the R&D projects in Germany. It focuses on the WLCG and the challenges posed by the High-Luminosity LHC.

## T 44: Invited Topical Talks II

Time: Wednesday 13:45–15:45

Location: MED 00.915

**Invited Topical Talk** T 44.1 Wed 13:45 MED 00.915  
**Probing Heavy New Physics at the Precision Frontier with Effective Field Theory** — •PETER STANGL — Johannes Gutenberg-Universität Mainz

The Standard Model of particle physics successfully describes all known elementary particles, yet it leaves fundamental questions unanswered, from the origin of neutrino masses and the Higgs hierarchy problem to the puzzling patterns in particle masses and mixings. With direct searches at the LHC having reached their energy limit without discovering particles beyond the Standard Model, precision measurements offer a powerful complementary approach: heavy new particles, even if beyond direct reach, modify the interactions of known particles in measurable ways. I will discuss how Effective Field Theory methods combined with precision data from flavour physics, electroweak measurements, and collider observables can be used to systematically search for these subtle signatures of physics beyond the Standard Model.

**Invited Topical Talk** T 44.2 Wed 14:15 MED 00.915  
**Hadron Spectroscopy at Belle (II)** — •STEFAN WALLNER — Max Planck Institute for Physics, Garching, Germany

The Belle and Belle II experiments recorded the world's largest dataset of  $e^+e^-$  collisions at center-of-mass energies at and around the  $\Upsilon(nS)$  resonances. This dataset provides diverse opportunities to study the excitation spectrum of mesons and baryons with unparalleled precision. We present measurements of hadrons composed of heavy quarks, searches for exotic states beyond the quark model, and studies of the light-meson spectrum.

**Invited Topical Talk** T 44.3 Wed 14:45 MED 00.915  
**Rare B meson decays at Belle II: indirect searches for new physics at the luminosity frontier** — •ANA LUISA MOREIRA DE CARVALHO — DESY, Hamburg, Germany

There is a lot we still do not understand about the Universe and its evolution. A striking example is the observed asymmetry in the quantity of matter and antimatter, which, together with other experimental evidence, points to physical processes and/or particles not contemplated in our current theoretical framework (the Standard Model).

Despite extensive searches at the LHC, the highest energy particle collider available, no evidence of physics beyond the Standard Model has been observed, indicating that new physical phenomena may lie beyond the energy reach of current experiments.

In this context, indirect searches - based on precision measurements and the study of rare Standard Model processes - provide a powerful and complementary approach. These studies require very large data samples, such as those produced in high-luminosity electron-positron collisions at the SuperKEKB accelerator, where the Belle II detector operates. At Belle II, rare electroweak transitions of a b-quark into an s-quark can be studied as sensitive probes of physics beyond the Standard Model. Additionally, precise measurement of the differences in the transition properties of a b-quark and an anti-b-quark may shed light on the mechanisms responsible for the matter-antimatter asymmetry in the present Universe.

**Invited Topical Talk** T 44.4 Wed 15:15 MED 00.915  
**Search for CP violation in  $D^0 \rightarrow K_S^0 K_S^0$  decays at the LHCb experiment** — •GIULIA TUCI — Heidelberg University

The study of CP violation in charm mesons provides a complementary probe of possible physics beyond the Standard Model with respect to beauty mesons, and allows the exploration of very high energy scales. The LHCb experiment has collected the largest sample of charm hadrons ever and in 2019 reported the first observation of CP violation analysing  $D^0 \rightarrow K^+ K^-$  and  $D^0 \rightarrow \pi^+ \pi^-$  decays, marking a milestone in flavour physics. However, the interpretation of this observation within the Standard Model is still under debate, making complementary experimental results essential to clarify the picture. In this presentation, a new measurement of the time-integrated CP asymmetry in the  $D^0 \rightarrow K_S^0 K_S^0$  decay will be presented. The analysis uses data collected by LHCb in 2024, inaugurating a new era enabled by the upgraded detector, which provides improved tracking, vertex resolution, and a fully software-based trigger, allowing unprecedented precision in charm physics.

## T 45: Neutrino Physics III

Time: Wednesday 16:15–18:30

Location: AudiMax

T 45.1 Wed 16:15 AudiMax

**Upgrading the ECHo-1k experimental setup** — •MARGARETA CHILL for the ECHo-Collaboration — Kirchhoff-Institute for Physics

With the ECHo experiment, the effective electron neutrino mass can be determined via the high energy resolution measurement of the  $^{163}\text{Ho}$  electron capture spectrum. In ECHo, large arrays of metallic magnetic calorimeters hosting  $^{163}\text{Ho}$  are operated at millikelvin. For the ECHo-1k phase, two MMC arrays have been used for acquiring 200 million  $^{163}\text{Ho}$  events with an energy resolution of about 7 eV FWHM at 1800 eV. For that experiment, only about one half of the channels could be read out due to failures in several SQUID channels. We present the upgrade of the ECHo-1k set-ups by the exchange of the SQUID read-out. We discuss the performance achieved with one of those set-ups and the implication for a coming small scale experiment aiming to reach a sensitivity on the effective neutrino mass below 5 eV/e<sup>2</sup>.

T 45.2 Wed 16:30 AudiMax

**Principal Component Analysis for Pile-up Event Detection in the ECHo Experiment** — •DOMENIC KLUMPP for the ECHo-Collaboration — Kirchhof Institut of Physics, Heidelberg, Germany

The ECHo (Electron Capture in Holmium-163) experiment uses metallic magnetic calorimeter (MMC) detectors to calorimetrically measure the electron capture spectrum of Ho-163 with the goal of determining the effective electron neutrino mass via the analysis of the endpoint region. In the data analysis, a significant challenge is the identification and rejection of pile-up events for which the time interval is of the order or smaller than the rise time of the pulse signal. Those events represent an intrinsic background distorting the spectrum and therefore affecting the accuracy of neutrino mass determination. We present an approach using Principal Component Analysis (PCA) to identify pile-up events. Simulated events preserving the shape and noise of real events have been generated according to the shape of the Ho-163 spectrum, including pile-up events to test the developed algorithms. For the ECHo-LE experiment the unresolved pile up fraction, given as product of the pixel activity times the time resolution, should be kept below  $10^{-6}$ , which for an activity of 10 Bq per pixel, implies a time resolution of 100 ns. We present the preliminary results obtained with the simulated data and discuss the implication of then in respect to the requirements for ECHo-LE.

T 45.3 Wed 16:45 AudiMax

**Sterile-neutrino search based on 259 days of KATRIN data** — •XAVIER STRIBL and SUSANNE MERTENS for the KATRIN-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

Light sterile neutrinos with a mass on the eV-scale could explain several anomalies observed in short-baseline oscillation experiments. The Karlsruhe Tritium Neutrino (KATRIN) experiment is designed to directly determine the effective electron anti-neutrino mass by measuring the tritium beta decay spectrum. The measured spectrum can also be investigated for the signature of light sterile neutrinos.

In this talk we present the result of the light sterile neutrino analysis of the first five KATRIN measurement campaigns. To handle the computational challenge, a neural network is used. The obtained result is compared to results from other experiments and anomalies in the field of light sterile neutrinos.

T 45.4 Wed 17:00 AudiMax

**Qualification Measurements Toward a New KATRIN Rear Wall** — •KERSTIN TROST<sup>1</sup>, DOMINIC BATZLER<sup>1</sup>, MARCO RÖLLIG<sup>1</sup>, MARIUS SCHAUFELBERGER<sup>1</sup>, MARIE SCHÄFER<sup>1</sup>, MICHAEL STURM<sup>1</sup>, and MART VAN DEN BOSCH<sup>2</sup> for the KATRIN-Collaboration — <sup>1</sup>Karlsruhe Institute of Technology, Germany — <sup>2</sup>Eindhoven University of Technology, Netherlands

Starting this year, the KATRIN experiment is undergoing a major upgrade to enable the search for sterile neutrinos in the keV mass range. This upgrade introduces a significant systematic uncertainty arising from electron backscattering at the upstream end of the tritium source, the Rear Wall (RW). To mitigate this effect, two new RW candidates, beryllium and microstructured silicon, are currently under investigation as they are expected to reduce the backscattering probability significantly.

This presentation discusses the ongoing qualification program for these Rear Wall candidates, including systematic studies of tritium accumulation as well as an ozone-based decontamination procedure. The stability of both materials under ozone exposure is assessed to ensure long-term compatibility with routine decontamination cycles. Furthermore, charge-up effects and potential surface modifications induced by ozone treatments are analyzed using Auger Electron Spectroscopy (AES). These characterization measurements form a crucial step toward implementing an optimized Rear Wall for the upcoming KATRIN keV sterile neutrino measurement phase.

T 45.5 Wed 17:15 AudiMax

**Electron Backscattering at the Focal Plane Detector of KATRIN** — •PHILIPP LINGNAU for the KATRIN-Collaboration — Tritium Laboratory Karlsruhe (TLK), Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), 76344 Eggenstein-Leopoldshafen, Germany

The KATRIN experiment has put the most stringent model-independent upper limit on the electron antineutrino mass. The goal is to limit it to  $< 0.3$  eV. To achieve this, a large amount of tritium beta-electrons need to be spectroscopied using a MAC-E-filter type spectrometer.

One systematic effect on the neutrino mass measurement is the detector backscattering. In the past we performed an in-situ measurement using time-of-flight spectroscopy. With it, the structure in electron energy loss due to plasmon excitations inside the detector can be resolved.

I will present the analysis of the measurement, featuring various improvements, including a rigorous investigation of the impact of fluctuations of the electrical potentials, improved electric and magnetic field simulations using Kasiopeia, as well as more in-depth ToF simulations.

In the future, this measurement principle and the analysis framework can be adapted for the TRISTAN phase of KATRIN, where understanding the escape spectrum from backscattered electrons is of greater importance than for KATRIN.

T 45.6 Wed 17:30 AudiMax

**Detection of neutrons produced in neutrino-nucleus interactions with T2K** — •ASIT SRIVASTAVA — Johannes Gutenberg - Universität Mainz

T2K is a long-baseline experiment which measures parameters of neutrino oscillations. This can be done by analysing the interaction of neutrinos closer to the point of beam production and 295 km downstream. The detector located near the source of beam production, called ND280, primarily includes the interactions of neutrinos with carbon nuclei. The particles produced as a result of the interactions deposit energy in ND280 which is used to characterise the incoming neutrino flux and neutrino cross sections before oscillation occurs.

Out of all the particles produced in typical neutrino interactions, neutrons are by far the most challenging to detect since they are electrically neutral and do not leave a visible track in the detector. As a result, they provide uncertainties in identifying the interactions happening in the detector and measuring cross sections. ND280 has a newly installed Super Fine-Grained Detector (SFGD) made of plastic scintillator cubes. The upgraded detector capable of better position resolution and 3D reconstruction opens up the possibilities of improving the efficiency of neutron detection. Presence of a neutron is established using cuts on energy deposits and hence, possible neutron candidates, such as based on time of flight, kinetic energy of the candidate and the separation of energy deposit from the interaction vertex. This talk will go through neutron selection and how neutrons can help in understanding nuclear effects better.

T 45.7 Wed 17:45 AudiMax

**Reconstruction of neutrino interactions with silicon strip detectors at the SHiP experiment** — •JAMES WEBB, CHRISTIAN WEISER, YANNIKA MATT, and ELIAS BAUKNECHT — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, 79104 Freiburg, Germany

SHiP (Search for Hidden Particles) is a general purpose fixed target facility, currently in the design phase, and to be installed at CERN at the beginning of the next decade. A 400 GeV/c proton beam will be dumped on a heavy target, yielding an expected  $6 \times 10^{20}$  proton-target collisions over 15 years of operation. The beam dump will produce a huge neutrino flux of all three flavours, making this environment ideally suited for performing neutrino physics studies: a key component of the SHiP physics programme.

A proposed detector design for the measurement of neutrino interactions consists of a passive tungsten plane, followed by a pair of silicon strip detectors, oriented such that the pair of strips are directed perpendicularly. Many such layers are envisioned to be stacked-up along the beam axis to maximise the detector mass.

This talk will discuss the potential of such a detector in terms of a tracking detector (track and vertex reconstruction) and a high-granularity calorimeter, with an emphasis on the study of tau neutrino interactions.

T 45.8 Wed 18:00 AudiMax

**Data-driven pile-up systematic estimation for neutrons in T2K ND280Upgrade detector** — •GIOELE REINA — JGU Mainz

The T2K experiment is a long baseline neutrino experiment, located in Japan. It studies neutrino oscillations by detecting accelerator neutrinos with a complex of near detectors and a far detector. ND280, one of the near detectors, provides a reduction of the neutrino flux and cross section uncertainties and performs cross

section measurement. The new features of the upgraded ND280 detector allow to improve reduction these capabilities. In particular, the newly installed target, the Super Fine-Grained Detector, which consists of small plastic scintillator cubes read out by three WLS fibers in the three orthogonal directions, offers high granularity and 3D reconstruction. This new detector design unlocks the sensitivity to neutrons produced in charge-current interactions by measuring their time of flight in the detector.

In order to develop a selection of neutron events it is crucial to estimate the relevant systematic uncertainties. An important systematic uncertainty is related to the background contribution of the pile-up, which consists of simultaneous interactions that mimic the presence of a neutron in the signal sample. By creating a hybrid sample composed of signal events and enhanced background estimated in data, it is possible to evaluate the pile-up contribution using a data-driven approach. Here, this approach is described, along with the effects of this systematic on the signal sample selection.

## T 46: Top Physics II

Time: Wednesday 16:15–18:00

Location: KH 00.011

T 46.1 Wed 16:15 KH 00.011

**Measurement of the differential t-channel production cross-section of single top quarks and top antiquarks in proton-proton collisions at 13 TeV using the full Run 2 dataset recorded with the ATLAS detector** — DOMINIC HIRSCHBÜHL, LUKAS KRETSCHMANN, •MAREN STRATMANN, and WOLFGANG WAGNER — Bergische Universität Wuppertal

The t-channel production is the dominant process for single top quark and single top antiquark production at the LHC. The measurement of the differential cross section can contribute to constraining proton PDFs and has not been measured with the full Run 2 dataset up to date. This measurement uses the full Run 2 dataset recorded with the ATLAS detector in the years 2015–2018. The differential production cross-sections of the top-quark and top-antiquark as well as their ratio are measured as a function of their transverse momentum  $p_T$  and rapidity  $|\eta|$ .

T 46.2 Wed 16:30 KH 00.011

**Investigating systematic uncertainties in the search for single-top s-channel production** — •ALFREDO MANENTE and ANDREA KNUE — TU Dortmund, Otto-Hahn Str. 4a, 44227 Dortmund

An analysis of single top-quark production in the s-channel at a centre-of-mass energy of 13 TeV will be presented, using simulated proton-proton collision data corresponding to the Run 2 dataset recorded by the ATLAS detector at the Large Hadron Collider. The single top quark s-channel production mode is characterised by a relatively small production cross section and large backgrounds. To enhance the separation between signal and background processes, a Deep Neural Network (DNN) classifier is employed and used as the discriminant in a binned profile likelihood fit. The analysis focuses on the leptonic decay mode of the top quark, resulting in a final state consisting of one charged lepton, missing transverse momentum and two b-tagged jets. The signal strength of the single top-quark s-channel process is measured using an Asimov dataset and a detailed investigation of the statistical and systematic uncertainties will be shown.

T 46.3 Wed 16:45 KH 00.011

**Using Machine Learning Techniques for a Search for Single Top Quark Production** — •NIKLAS DÜSER and ANDREA KNUE — TU Dortmund

The search for single-top-quark production in the s-channel is experimentally challenging due to its small cross-section and similarity to dominant background processes. This analysis investigates two machine-learning approaches to enhance signal discrimination: a deep neural network (DNN) using high-level kinematic variables, and a graph neural network (GNN) encoding event topology through particle-object correlations. Both models were trained and evaluated on simulated proton-proton collisions at a center-of-mass energy of 13 TeV, corresponding to the Run 2 dataset at ATLAS with an integrated luminosity of 140 fb<sup>-1</sup>. The performance of the DNN and GNN is compared with a focus on signal and background modelling uncertainties.

T 46.4 Wed 17:00 KH 00.011

**Measurement of differential cross-sections of single-top-quark production in association with a photon at the ATLAS experiment with  $\sqrt{s} = 13$  TeV** — •LUCAS CREMER<sup>1</sup>, NILS JULIUS ABICHT<sup>1</sup>, ANDREA HELEN KNUE<sup>1</sup>, TOMAS DADO<sup>2</sup>, and MARINA ANDRESS<sup>3</sup> — <sup>1</sup>TU Dortmund — <sup>2</sup>CERN — <sup>3</sup>Bergische Universität Wuppertal

The inclusive measurement of single-top-quark production in association with a photon at the ATLAS experiment yielded an increased cross-section compared to the Standard Model prediction. As the analysis was not statistically limited,

T 45.9 Wed 18:15 AudiMax

**Towards a High-Rate Active Neutrino Detector at FASER: Performance Studies with Deep Learning** — FLORIAN BERNLOCHNER, TOBIAS BOECKH, DHRUV CHOUHAN, JÖRN MAHLSTEDT, •FELIX ANTONIO JUNJIRO OBANDO MOLINA, MATTHIAS SCHOTT, and KONSTANTINOS SPYROU — Universität Bonn, Regina-Pacis-Weg 3, D-53113 Bonn, Germany

The FASER experiment at the LHC is a forward detector designed to study light, weakly interacting particles and has successfully established a dedicated neutrino program to measure high-energy collider neutrinos. During LHC Run-4, however, the expected increase in muon background rates will exceed the tolerable limits of the current emulsion-based neutrino detector, motivating the exploration of alternative technologies. We investigate the feasibility of an active neutrino detector concept based on multilayer active pixel sensors capable of operating at high rates. In this talk, we present a detailed study of neutrino reconstruction performance in such a detector using modern deep learning approaches, including deep neural networks (DNNs) and convolutional neural networks (CNNs), with a focus on efficient neutrino event classification in a challenging high-background environment.

a measurement of differential cross-sections is performed to further investigate the excess.

A signal region enriched with  $tq\gamma$  events is defined using machine learning techniques to separate signal and background events. Corresponding distributions sensitive to physics beyond the Standard Model are unfolded to particle level utilising a profile likelihood unfolding approach. An approach for the optimisation of the binning as well as the stability of the unfolding is investigated. The results estimated on the complete ATLAS Run-2 dataset, corresponding to an integrated luminosity of 140 fb<sup>-1</sup>, are presented.

T 46.5 Wed 17:15 KH 00.011

**Using Neural Networks to Identify Pure Signal Regions for  $tq\gamma$  Production at the ATLAS Experiment** — •MARINA ANDRESS<sup>1</sup>, ANDREA KNUE<sup>2</sup>, and LUCAS CREMER<sup>2</sup> — <sup>1</sup>Bergische Universität Wuppertal — <sup>2</sup>TU Dortmund

Following the observation of single-top production in association with a photon at the ATLAS experiment, a differential cross-section measurement is performed. An event classification strategy for  $tq\gamma$  events is developed, with the goal of defining a pure signal region suitable for a subsequent unfolding measurement. Such a region is essential to enable differential studies of this rare process, which directly probe the electroweak coupling of the top quark. Therefore, two machine learning approaches are investigated: a deep neural network with a conventional feed-forward structure and a graph neural network that incorporates event topology. The results are estimated using the full ATLAS Run-2 dataset, corresponding to an integrated luminosity of 140 fb<sup>-1</sup>.

T 46.6 Wed 17:30 KH 00.011

**Search for tWZ in proton-proton collisions at  $\sqrt{s} = 13$  and  $13.6$  TeV with the ATLAS Experiment** — DIPTAPARNA BISWAS, •CAROLINA COSTA, MARKUS CRISTINZIANI, CARMEN DIEZ PARDOS, IVOR FLECK, GABRIEL GOMES, JAN JOACHIM HAHN, NIKOLAOS KAMARAS, VADIM KOSTYUKHIN, NILS BENEDIKT KRENGEL, AUSTIN OLSON, INÊS PINTO, SEBASTIAN RENTSCHLER, ELISABETH SCHOPF, KATHARINA VOSS, WOLFGANG WALKOWIAK, and ADAM WARNERBRING — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The production of top quarks in association with bosons are important Standard Model processes that allow tests of the electroweak couplings of the top quark to bosons. Any deviations of these couplings from Standard Model expectations could indicate the presence of new physics, which could be probed in the context of, e.g. Effective Field Theory interpretations. The associated production of a single top quark together with a W and a Z boson (tWZ) is one of the rarest processes accessible at the LHC, benefiting from the large proton-proton collision datasets collected at centre-of-mass energies of 13 TeV and 13.6 TeV. In this contribution, the ongoing effort to measure tWZ with the ATLAS detector using Run 2 and Run 3 data is presented. The measurement focuses on multilepton final states, where the Z boson and at least one of the two W bosons decay to leptons, yielding a final state with three or four leptons.

T 46.7 Wed 17:45 KH 00.011

**Measurement of tWZ production with full Run 2 and 3 data at CMS** — •FLORENT PRÉAU, ROMAN KOGLER, ALBERTO BELVEDERE, and DENNIS SCHWARZ — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

The production of a single top quark in association with a W boson and a Z boson, also referred to as tWZ production, is a very rare process of high en-

ergy proton-proton collisions. It presents unique and important features when it comes to probing the Standard Model of particle physics and looking for physics beyond this model. This process offers the possibility to probe the electroweak couplings of the top quark, as well as its coupling to the Higgs field.

In this talk I will present the current state-of-the-art of the CMS tWZ analy-

sis and will discuss some of the important extensions that I will explore during my PhD project. These extensions include performing an analysis with the full Run 2 and Run 3 datasets of CMS, performing a differential measurement of the process, and extracting top quark couplings using the Standard Model Effective Field Theory (SMEFT) framework.

## T 47: Higgs Physics V

Time: Wednesday 16:15–18:15

Location: KH 00.014

T 47.1 Wed 16:15 KH 00.014

**Top-Yukawa- and Light-Quark-Induced Electroweak Corrections in Higgs Pair Production** — ARUNIMA BHATTACHARYA<sup>1</sup>, FRANCISCO CAMPANARIO<sup>1</sup>, •SAURO CARLOTTI<sup>2</sup>, JAMIE CHANG<sup>3</sup>, JAVIER MAZZITELLI<sup>3</sup>, MILADA MARGARETE MÜHLEITNER<sup>2</sup>, JONATHAN RONCA<sup>4</sup>, and MICHAEL SPIRA<sup>3</sup> — <sup>1</sup>University of Valencia-CSIC, Spain — <sup>2</sup>Karlsruher Institut für Technologie, Germany — <sup>3</sup>Paul Scherrer Institut, Switzerland — <sup>4</sup>University of Padua, Italy  
Since the discovery of the Higgs boson in 2012, the measurements of the Higgs self coupling remains a major challenge for current and future experiments in particle physics. Current projections for the trilinear coupling measurements at HL-LHC, and next generation of colliders, require the experimental precision to be matched by theory predictions. This necessitates besides the QCD corrections, which are found to be large, also the electroweak corrections (EW). The NLO corrections involve evaluation of two-loop Feynman diagrams. The EW corrections are a true challenge for the numerical solution of the two-loop integrals due to the presence of many different mass scales, such as the gauge boson, bottom, top quark, and Higgs boson masses. Additional challenges arise from numerical instabilities near virtual thresholds, which require a careful treatment. In my talk, I will present results for the EW corrections induced by the top Yukawa coupling, including contributions from light-quark loops, without using any reduction techniques to master integrals. All calculations are performed with fully symbolic masses while maintaining a manageable code size, enabling future studies of parametric and mass-scheme/scale uncertainties.

T 47.2 Wed 16:30 KH 00.014

**Search for non-resonant Higgs boson pair production in  $bb\tau\tau$  final states with the CMS experiment** — •SIMON DAIGLER, JAN VOSS, NIKITA SHADSKYI, ARTUR GOTTMANN, ROGER WOLF, and MARKUS KLUTE — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)  
Our preparation of a search for non-resonant Higgs boson pair production in  $bb\tau\tau$  final states is presented. A first setup of the analysis is based on the well-understood data of the LHC Run-2, of the year 2018, which have been completely re-reconstructed by the CMS Collaboration. The  $e\tau_h$ ,  $\mu\tau_h$ , and  $\tau_h\tau_h$  final states are analysed. Event classification is based on neural network multi-class classification. The sensitivity is compared to a previous publication of CMS.

T 47.3 Wed 16:45 KH 00.014

**Status of the  $HH \rightarrow \bar{b}b\tau^-\tau^+$  analysis with the CMS experiment with Run 3 data** — •ANA ANDRADE, BOGDAN WIEDERSPAN, NATHAN PROUVOST, MARCEL RIEGER, MORITZ WOLF, TOBIAS KRAMER, QUINTUS DIEPHOLZ, BENJAMIN LE, JONAH FISCHER, and PETER SCHLEPER — University of Hamburg  
The shape of the Higgs potential plays a crucial role in our understanding of vacuum stability. The potential is directly dependent on the Higgs boson self-coupling which, despite continuous efforts, has yet to be experimentally determined. One way to probe its existence is through double Higgs boson production, where one Higgs boson can directly decay into two Higgs bosons. The predicted cross-section of such a decay depends on the self-coupling strength and can therefore be probed with experimental data. The  $\bar{b}b\tau^-\tau^+$  final state is a promising candidate to perform such a search, as it offers a good compromise between sufficient statistics and reasonably low background contamination.

This talk summarizes the current status of the  $HH \rightarrow \bar{b}b\tau^-\tau^+$  analysis with Run 3 data recorded by the CMS experiment at a center-of-mass energy of  $\sqrt{s} = 13.6$  TeV. The techniques employed in background estimation, signal extraction, and statistical inference will be discussed, amongst other developments. Particularly, we will present recent work in the discriminator network which enhances the search sensitivity.

T 47.4 Wed 17:00 KH 00.014

**Statistical analysis for the  $HH \rightarrow \bar{b}b\tau^+\tau^-$  analysis with the ATLAS detector** — •PIM BIJL, KARL JAKOBS, BRIAN MOSER, BENEDICT WINTER, and YINGJIE WEI — University of Freiburg, Freiburg im Breisgau, Germany  
Di-Higgs production at the Large Hadron Collider (LHC) allows to directly measure the Higgs boson self-coupling and, in turn, the shape of the Higgs potential. This talk will present studies performed for the statistical analysis used to measure or establish limits on the di-Higgs signal strength in the  $HH \rightarrow \bar{b}b\tau^+\tau^-$  decay channel, using the combined LHC Run 2 and partial Run 3 datasets of up to  $191 \text{ fb}^{-1}$  collected by the ATLAS experiment. This decay channel has one of

the largest branching ratios of di-Higgs decays and provides a clean decay signature. Because di-Higgs production is expected to be a very small signal, the statistical analysis makes use of pseudo-experiments which serve to validate results of the analysis.

T 47.5 Wed 17:15 KH 00.014

**Neural network classifier strategy for optimal Higgs boson self-coupling sensitivity in the CMS  $HH \rightarrow bb\tau\tau$  analysis** — ANA ANDRADE, •BENJAMIN LE, BOGDAN WIEDERSPAN, MARCEL RIEGER, MORITZ JONAS WOLF, NATHAN PROUVOST, PETER SCLEPER, and TOBIAS KRAMER — University of Hamburg  
The Standard Model (SM) of particle physics remains one of the most accurate theories describing the universe's matter and its fundamental interactions at the smallest scales. One prediction that is yet to be fully tested is the self-interaction of the Higgs boson, characterized by the trilinear coupling strength  $\lambda$ , which gives rise to the shape of the Higgs potential. Typical analysis strategies involve neural networks for signal-background classification, often trained with simulated signal events following the SM prediction for  $\lambda$ . However, in case the actual value of  $\lambda$  deviates from the SM expectation, kinematic properties are subject to change and therefore, rendering the choice of  $\lambda$  used during training suboptimal. This talk summarizes a study that addresses this challenge by exploring different neural network strategies, enhancing the sensitivity to a wide range of hypothetical self-coupling values.

T 47.6 Wed 17:30 KH 00.014

**Searching for Higgs boson pair production in the  $HH \rightarrow bb\tau\tau$  channel with the ATLAS experiment** — •KATHARINA HÄUSSLER, KARL JAKOBS, BRIAN MOSER, YINGJIE WEI, CHRISTIAN WEISER, and BENEDICT WINTER — University of Freiburg

The Standard Model (SM) predicts final states with multiple Higgs bosons, which have yet to be observed experimentally, to occur in proton-proton collisions at the LHC. The production of Higgs boson pairs is interesting especially because it provides a direct test of triple Higgs boson self-interactions. The  $bb\tau\tau$  final state presents a good compromise between expected signal yields and background contamination, making it one of the golden channels to explore this phenomenon.

This talk presents the current ATLAS  $HH \rightarrow bb\tau\tau$  analysis with a focus on the estimation of the background stemming from  $Z$  bosons produced in association with heavy flavour jets, which is a major background for the analysis.

T 47.7 Wed 17:45 KH 00.014

**Estimation of the Background from  $i\bar{i}$  Events with Misidentified Tau Leptons in the Search for Di-Higgs Production in the  $bb\tau_{\text{had}}\tau_{\text{had}}$  Channel with the ATLAS Detector** — •BAKTASH AMINI, BRIAN MOSER, YINGJIE WEI, CHRISTIAN WEISER, BENEDICT TOBIAS WINTER, and KARL JAKOBS — Albert-Ludwigs-Universität Freiburg

Interactions involving multiple Higgs bosons in the final state are yet to be observed. Higgs boson pair production via gluon-gluon fusion or vector-boson fusion involves tri-linear couplings of Higgs bosons providing a unique opportunity to observe the self-coupling at the LHC and to test the Standard Model. Thanks to a good balance of signal yields and signal purity, di-Higgs boson production with one Higgs boson decaying into two  $b$ -quarks and the other into two tau leptons is one of the best channels to observe this process. The second-largest background in the  $HH \rightarrow bb\tau\tau$  analysis is top pair production, where at least one quark- or gluon-initiated jet is misidentified as a hadronic tau decay. This background is estimated via a data-driven scale-factor method. The talk presents this method for the analysis of the ATLAS Run 2 and partial Run 3 datasets.

T 47.8 Wed 18:00 KH 00.014

**Studies for validating the CMS Run-3  $HH \rightarrow b\bar{b}\gamma\gamma$  analysis with  $ZZ \rightarrow b\bar{b}e^+e^-$  events** — JOHANNES ERDMANN, •LEA JAKUBOWSKI, and NITISH KUMAR — III. Physikalisches Institut A, RWTH Aachen University

Since its discovery, the properties of the Higgs boson have been the subject of extensive study. Of particular interest is the structure of the Higgs potential, which can be constrained by measuring the trilinear Higgs self-coupling. This coupling can be accessed via Higgs boson pair production. However, owing to the small predicted production cross-section relative to the background processes, it has yet to be observed experimentally.

A particularly promising channel for probing this interaction is the  $HH \rightarrow b\bar{b}\gamma\gamma$  decay. Its sensitivity arises from the large branching fraction of  $H \rightarrow b\bar{b}$ , combined with the low background rates and excellent mass resolution achievable in the  $H \rightarrow \gamma\gamma$  final state.

This talk presents studies for validating the CMS Run-3 non-resonant  $HH \rightarrow b\bar{b}\gamma\gamma$  analysis via a well-understood Standard Model process with a similar final-state topology. The validation channel,  $ZZ \rightarrow b\bar{b}e^+e^-$ , is chosen due to its sig-

nificantly higher cross-section compared to di-Higgs production and the similar detector signatures of electrons and photons, which yield a final-state signature closely mirroring  $HH \rightarrow b\bar{b}\gamma\gamma$ . By employing an analysis strategy analogous to that of the  $HH \rightarrow b\bar{b}\gamma\gamma$  search, we perform studies toward a cross-section measurement of  $ZZ \rightarrow b\bar{b}e^+e^-$  that aims to provide a robust validation and benchmark for the di-Higgs analysis.

## T 48: Methods in Particle Physics III

Time: Wednesday 16:15–18:15

Location: KH 00.020

T 48.1 Wed 16:15 KH 00.020

**Muon flux measurements at SND@LHC for the LHC p+O run** — •JANNIS THIENEL, HEIKO LACKER, and EDUARD URSOV — Humboldt-Universität zu Berlin

The Scattering and Neutrino Detector at LHC (SND@LHC) has collected data from various runs of proton-proton (pp) collisions at the ATLAS interaction point (IP1) of the LHC in a previously unexplored pseudo-rapidity range of  $7.2 < \eta < 8.4$ . The analyses of these runs have successfully demonstrated the detection of (high-energy) neutrinos, including the first detection of muon-neutrino charged-current interactions. Muon flux measurements are essential to quantify one of the backgrounds to neutrino measurements and to verify Monte Carlo simulations. A dedicated investigation of the muon flux in the very forward direction from the p+O collisions at SND@LHC might be of interest for testing hadronic interaction models relevant for cosmic airshower physics. First preliminary results of these muon flux measurements will be presented.

T 48.2 Wed 16:30 KH 00.020

**Suppressing muon-induced background in SHiP with the Surrounding Background Tagger** — •JASMIN WEISS — Humboldt-Universität zu Berlin

SHiP (Search for Hidden Particles) will be a fixed-target experiment at CERN's SPS designed to search for feebly interacting particles (FIPs) in the GeV range. Installed in a dedicated beam-dump facility in the ECN3 cavern, SHiP will use 400 GeV/c SPS protons to reach  $6 \cdot 10^{20}$  on-target collisions over 15 years of data taking, while suppressing backgrounds from the intense muon and neutrino flux emerging from the beam dump. A key element is the Surrounding Background Tagger (SBT), which encloses the 50 m helium-filled decay volume and tags charged particles entering from the sides as well as inelastic interactions occurring inside the decay volume.

The contribution focuses on simulation studies evaluating muon-induced backgrounds and the performance of the SBT in rejecting these events, highlighting their impact on the overall background-suppression strategy.

T 48.3 Wed 16:45 KH 00.020

**Muon Momentum Scale and Resolution Calibration for CMS in Run 3** — •DORIAN GUTHMANN<sup>1</sup>, MARKUS KLUTE<sup>1</sup>, FILIPPO ERRICO<sup>2</sup>, and JOST VON DEN DRIESCH<sup>1</sup> — <sup>1</sup>Karlsruhe Institute of Technology — <sup>2</sup>INFN

Precise muon momentum calibration is essential for many analyses at the LHC, as detector misalignment and magnetic field uncertainties lead to systematic differences between data and simulation. Within the CMS experiment, updated scale and resolution corrections for Run 3 data were derived over the past year using the ScaReKIT framework, which was also optimized with a focus on performance and stability. These improvements streamline the calibration workflow and reduce the computational cost of producing accurate calibration factors. This presentation highlights the motivation, methodology, and recent progress in refining the CMS muon momentum calibration, as well as the outlook for further improvements in upcoming datasets.

T 48.4 Wed 17:00 KH 00.020

**Calibrating Charm Jet Tagging in ATLAS** — DIPTAPARNA BISWAS, CAROLINA COSTA, MARKUS CRISTINZIANI, CARMEN DIEZ PARDOS, IVOR FLECK, GABRIEL GOMES, JAN JOACHIM HAHN, NIKOLAOS KAMARAS, VADIM KOSTYUKHIN, NILS BENEDIKT KRENGEL, AUSTIN OLSON, •INÊS PINTO, SEBASTIAN RENTSCHLER, ELISABETH SCHOPF, KATHARINA VOSS, WOLFGANG WALKOWIAK, and ADAM WARNERBRING — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Classifying jets according to the flavour of the initiating parton is essential for many ATLAS analyses involving  $b$ - and  $c$ -quarks. Recent developments employ end-to-end transformer architectures to improve jet flavour identification. In this talk, we present an alternative data-driven calibration of the  $c$ -jet tagging efficiency using the  $W + c$  method, which selects  $W + c$  events through a soft muon from the semi-leptonic decay of a charmed hadron. The charge correlation between the  $W$  boson and the charm quark strongly suppresses backgrounds, allowing a clean determination of the  $c$ -jet content. Unlike the standard  $t\bar{t}$ -based calibration, which is not suitable for Beyond the Standard Model top-quark studies, this method provides an independent and complementary handle on  $c$ -jet performance. We present current measurements of the  $c$ -jet efficiency, and the

$c$ -jet mis-identification efficiency in the case of  $b$ -jet identification, in data and simulation, and derive the corresponding scale factors.

T 48.5 Wed 17:15 KH 00.020

**Finding Photon Fusion processes with a track veto** — •DANIEL WERNER — DESY, Hamburg

Photon Fusion processes offer the possibility of studying QED production modes in the otherwise QCD dominated environment of the LHC. A key difference between the production of leptons via photo fusion or the Drell-Yan process is the presence of underlying events. To exploit this difference, a veto on any tracks near the primary vertex can be used.

This talk aims to introduce both photon fusion processes and the reconstruction of tracks in the ATLAS detector. A focus is put on tracks with a low transverse momentum that can boost the discrimination power of the veto. Reconstruction efficiencies are shown for low momentum tracks in Run 4.

T 48.6 Wed 17:30 KH 00.020

**Calibration of the Photon Identification Efficiency in ATLAS** — •LEONOR SANTOS PEREIRA TRIGO — Deutsches Elektronen-Synchrotron (DESY), Zeuthen, Germany

The accurate measurement of photon efficiency remains an essential ingredient of many physics analyses at the LHC and with the ATLAS detector. Considering the reliance of said analyses on simulation samples, the calculation of scale factors quantifying the differences in how accurately the ATLAS detector identifies real photons and fake photons between simulation and real data is an important task. One of the methods used to obtain these scale factors is the matrix method, which provides a data-driven estimate for the efficiency of the ATLAS detector in distinguishing photons of interest from other particles misidentified as photons. With the use of data regions enriched in either true or misidentified photons, it is possible to estimate the photon identification efficiency within ATLAS with minimal reliance on background simulation.

T 48.7 Wed 17:45 KH 00.020

**Determining the  $\tau$ -Lepton Efficiency in a Global Approach at the ATLAS Experiment** — •HARILAL BHATTARAI, PHILIP BETCHLER, and CHRISTIAN GREFE — Physikalisches Institut, Universität Bonn

The measurement of the hadronic  $\tau$ -lepton identification efficiency at ATLAS is important for the proper modeling of signal and background processes, which directly impacts the sensitivity to Standard Model (SM) and BSM phenomena. In this approach, we will measure tau ID at a centre of mass energy  $\sqrt{s} = 13$  TeV, across multiple channels such as  $Z \rightarrow \tau\tau$  and  $W \rightarrow \tau\nu$ .

In this analysis, we use Run 2 data corresponding to an integrated luminosity of  $139 \text{ fb}^{-1}$  and applying optimized selections on lepton isolation, tau  $p_T$ ,  $\eta$ , and charge requirements to suppress backgrounds. We perform a global measurement of tau ID efficiencies and the corresponding Data-to-MC scale factors at ATLAS for 1-prong and 3-prong  $\tau$  candidates using the HAPPY and ROOT frameworks. In this talk, we will present the efficiencies and scale factors.

T 48.8 Wed 18:00 KH 00.020

**Determination of Universal Tau Fake Factors for the Run 3 Data Taking Period of ATLAS** — •CHRISTIAN SCHMIDT, ARNO STRAESSNER, and ASMA HADEF — Institut für Kern- und Teilchenphysik, Technische Universität Dresden

Tau leptons are an important product in collision events at the LHC; they primarily decay into a hadronic final state. Hadronic jets can easily produce similar signatures inside the ATLAS detector, leading to misidentified or "fake" taus, so it becomes necessary to estimate the fake tau background. The Fake Factor (FF) method estimates this background from data events with non-isolated tau candidates using a correction factor which depends on the transverse momentum of the tau candidate. In addition, the FF depends on the origin of the fake-producing jets, such as quark or gluon jets. Instead of measuring the FFs in a separate control region for each physics analysis, the Universal Fake Factor (UFF) method uses an estimate of the jet composition to linearly interpolate the FFs.

This talk will present the general principles of the UFF method, the process and data preparation being used to determine the UFF parameters in ATLAS Run 3 data, and current results.

## T 49: Electronics, Trigger, DAQ II

Time: Wednesday 16:15–18:15

Location: KH 00.023

T 49.1 Wed 16:15 KH 00.023

**Readout Electronics for the ECHo-LE Experiment** — •TIMO MUSCHEID, ROBERT GARTMANN, DANIEL CROVO, MATTHIAS BALZER, and LUIS ARDILA-PEREZ for the ECHo-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

Precise knowledge of the neutrino mass is crucial for solving fundamental questions in the Standard Model of Particle Physics. The ECHo collaboration aims to further limit the electron neutrino mass by analyzing the electron-capture spectrum of Holmium-163. ECHo-100k employs 10,000 detectors with a total activity of 100 kBq to improve energy resolution through increased measurement statistics. For operation of these microwave-SQUID-multiplexed pixels a custom Software-defined radio (SDR) system has been developed. This system is responsible for stimulating the resonators in the 4-8 GHz band, frequency demultiplexing and flux-ramp demodulation of the carrier tones as well as online data rate reduction. The next phase, ECHo-LE, will further increase the pixel count to 20,000 across 25 cryogenic readout lines. The room-temperature readout system will be based on the existing SDR electronics from ECHo-100k, completed by 10 additional modules. Firmware development will continue, focusing on enhanced capabilities such as tone-tracking, which promises to reduce distortion and intermodulation. In this contribution, we will present the proposed hardware architecture and firmware concept of the ECHo-LE room-temperature readout electronics. We discuss potential hardware upgrades and new firmware features of the SDR, highlighting their importance for meeting the high demands of the experiment.

T 49.2 Wed 16:30 KH 00.023

**Compact and fast ADCs for pixel detectors** — •KENNEDY CAISLEY, HANS KRÜGER, and JOCHEN DINGFELDER — University of Bonn, Germany

This work investigates improving analog to digital converters (ADCs) in the context of CMOS pixel detectors; a discipline with perhaps the most stringent silicon area constraints. We assembled a custom flow built on open source chip design tools, which enabled comparisons between circuit topologies and process nodes including 180, 65, and 28 nm. We then fabricated a prototype ASIC in 65 nm using this methodology, aiming for a state-of-the-art  $2500 \mu\text{m}^2$  area and 100  $\mu\text{W}$  power budget, while sustaining a performance of 12-bit resolution at 10 Ms/s. Initial validation of this prototype and our on-going developments will be presented.

T 49.3 Wed 16:45 KH 00.023

**Readout Electronics for the IceCube Surface Array Enhancement** — •FREDERIK SCHMITT<sup>1</sup>, MEGHA VENUGOPAL<sup>1</sup>, ANDREAS WEINDL<sup>1</sup>, ALEXANDER NOVIKOV<sup>2</sup>, FRANK SCHRÖDER<sup>1,2</sup>, ANDREAS HAUNGS<sup>1</sup>, and MATTHIAS KLEIFGES<sup>3</sup> for the IceCube-Collaboration — <sup>1</sup>Institute of Astroparticle Physics (IAP), Karlsruhe Institute of Technology, Germany — <sup>2</sup>University of Delaware, Newark, USA — <sup>3</sup>Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology, Germany

The IceCube Neutrino Observatory consists of a cubic-kilometer in-ice neutrino detector and the IceTop surface detector. IceTop comprises 81 pairs of ice-Cherenkov tanks for air-shower detection. As part of the upgrades, IceTop will be equipped with new surface stations, each consisting of eight scintillator panels and three radio antennas. Three of these stations are already in operation at the South Pole, and more are to be installed in the coming years in the area of the current IceCube experiment. The design is also the baseline for the surface instrumentation of IceCube-Gen2.

In this contribution, we focus on improvements to the current readout electronics deployed in prototype stations at IceCube, Pierre Auger, and the Telescope Array. Additionally, we present the development status of a new generation of the electronics capable of being implemented in the future IceCube and IceCube-Gen2 readout system. This design is based on a multi-FPGA board and provides GSa/s radio readout capabilities along with extensive onboard memory for signal buffering.

T 49.4 Wed 17:00 KH 00.023

**Upgrade of the KlauS6 ASIC** — •YUNG-WEI CHANG — Im Neuenheimer Feld 227, 69120 Heidelberg

In this talk, we share recent work on the KLauS ASIC, which was designed for the prototype of CALICE collaboration's Analog Hadron CALorimeter (AHCAL) and now is undergoing significant enhancements to its digital blocks and I/Os to better meet the needs of future experimental applications in particle physics. The next generation of the KlauS6 ASIC will emphasize improvements in its digital interface robustness, aim at achieving higher measurement data rate and increased adaptability in experimental settings. As in previous versions, the new design incorporates strategies for low power consumption with the requirements of high-density channel applications, ensuring that the KLauS ASIC remains a

cutting-edge solution for scintillator-based calorimetry in future collider experiments.

Key features of the upgraded KlauS6c include dual-configurable interfaces via both I2C and SPI, which will facilitate integration with various systems and enhance operational flexibility. Furthermore, the ASIC will support numerous speed options of LVDS readout exceeding 160 Mbps, ensuring rapid data transmission to accommodate the demands of future circular collider (FCC) experiments. Improved packaging options, compatible with QFN84 and QFN100, will provide greater reliability and ease of integration. The upgraded KlauS6c will maintain its core functionalities still on high precision charge measurement and a wide dynamic range, allowing for comprehensive and precise silicon photo-multiplier (SiPM) readout behavior.

T 49.5 Wed 17:15 KH 00.023

**Validation of the SiPM-on-Tile Readout Chain for the CMS High Granularity Calorimeter** — •FABIAN HUMMER — Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

For the upcoming high-luminosity LHC, the endcap calorimeters of the CMS experiment will be replaced by the high-granularity calorimeter (HGCAL), a sampling calorimeter using silicon sensors in the front and plastic scintillators read out by SiPMs in the back. We have built and tested a complete horizontal slice of scintillator tile modules and readout electronics under realistic installation, grounding and powering conditions. Using this system, we validated the powering scheme, assessed the system stability and demonstrated data readout with the Serenity back-end hardware. The successful validation of the SiPM-on-Tile front-end as a complete system is an important milestone towards the construction and operation of HGCAL. In this contribution, we will describe our system validation setup and showcase results from bench-top tests.

T 49.6 Wed 17:30 KH 00.023

**Enabling lpGBT Interface Prototyping with a New FPGA Mezzanine Card**

— •DMITRY ELISEEV, NILS ESPER, CARSTEN PRESSER, MARKUS MERSCHMEYER, ALEXANDER SCHMIDT, and THOMAS HEBBEKER — III. Physikalisches Institut A, RWTH Aachen University

The lpGBT (Low Power GigaBit Transceiver) is a radiation-tolerant ASIC developed to provide robust, high-speed, bidirectional optical links for the next generation of high-energy physics experiments. It is dedicated to communicate via optical links and supports transfer rates up to 10 Gb/s. The chip integrates Timing and Trigger Control (TTC), Data Acquisition (DAQ), and Slow Control (SC) data streams into a single constant-latency link. This unified architecture enables reliable transmission of timing, trigger, control, and monitoring information between the counting room and on-detector electronics, even in the harsh radiation environment of the LHC.

This talk introduces a newly developed FMC mezzanine board that provides an accessible and flexible platform for working with the lpGBT ASIC. It gives engineers and researchers a practical way to explore, test, and integrate the lpGBT into their detector readout and control systems. With the ready to use electrical and firmware interfaces, the board supports early development without requiring a full custom electronic and firmware design.

The talk gives an overview of the board's design features, from the optical SFP link to the on-board switches for selecting lpGBT working modes. It also presents a brief overview of the IP cores for interfacing.

T 49.7 Wed 17:45 KH 00.023

**ITkPix Read-out Chip Software Emulator for the ITk Pixel Online DAQ Software**

— MATTHIAS DRESCHER, JÖRN GROSSE-KNETTER, •TIMO POSPIECH, ARNULF QUADT, and ALI SKAF — II. Physikalisches Institut, Georg-August-Universität Göttingen

During the approaching ATLAS HL-LHC phase 2 upgrade, the current Inner Detector will be replaced by the all-silicon Inner Tracker (ITk). In particular, the ITk pixel part will be composed of around 9k detector modules built with about 30k ITkPix read-out chips. The data acquisition (DAQ) read-out system needs to deal with the tremendous challenges it faces and, of course, be validated before the commissioning of the new ITk. With the read-out software as the head of the chain, it needs to be running reliably to acquire data and test other components of the DAQ chain, ideally at a large-scale system level.

To help with the development and debugging of the read-out software, a software model of the on-detector hardware is needed. As such, this project focuses on developing a standalone C++ software emulator of the ITkPix front-end, which can be used for that purpose. The software emulator faithfully replicates the behaviour of the ITkPix-V2 chip, which is the final production read-out chip. With that, the behaviour of the emulator is as close to the real conditions



as possible. The emulator is validated against already existing read-out chain tools and will be integrated in the online DAQ software, allowing system-level development and debugging, but could also be used during actual data taking for validation purposes.

T 49.8 Wed 18:00 KH 00.023

**Front-End Readout for the LHCb Mighty SciFi Tracker** — CARLOS GARCIA ARGOS, MARCO GERSABECK, •MICHAEL LUPBERGER, SANTIAGO OCHOA, KSENIA SOLOVIEVA, and JAN SOROKOVSKI — Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany

During CERN's Long Shutdown 4, several sub-detectors of the LHCb experiment will be replaced. This upgrade is required to cope with the further increase

in instantaneous luminosity and with the radiation that will accumulate until the end of the experiment's lifetime.

One of these is the tracker located downstream of the spectrometer magnet. The current tracking detector is based on Scintillating Fibres (SciFi). It will be replaced by a hybrid detector, called Mighty Tracker, that combines HV-CMOS MAPS in the central region near the beam pipe and new SciFi modules in the outer part. The latter will be read out using Silicon Photomultipliers operated at cryogenic temperatures. Their signals will be processed by a front-end chip, which is controlled and read out by IpGBT chips. The readout board is housed in a metal box that serves cooling and shielding.

This contribution presents the current status of the front-end readout. It focuses on the key requirements and on how the design aims to satisfy them.

## T 50: Data, AI, Computing, Electronics V

Time: Wednesday 16:15–18:00

Location: KH 00.024

T 50.1 Wed 16:15 KH 00.024

**NEEDLE - A modern orchestration framework for Neural Simulation Based Inference tools** — •KYLIAN SCHMIDT<sup>1</sup>, ULRICH HUSEMANN<sup>2</sup>, NICOLÒ TREVISANI<sup>1</sup>, STEPHEN JIGGINS<sup>2</sup>, LEVI EVANS<sup>2</sup>, JUDITH KATZY<sup>2</sup>, STEFAN KATSAROV<sup>2</sup>, FELIX KAHLHÖFER<sup>3</sup>, NINO KOVAČIĆ<sup>4</sup>, LENA RATHMANN<sup>3</sup>, and NIKLAS REUS<sup>3</sup> — <sup>1</sup>ETP, KIT, Karlsruhe — <sup>2</sup>DESY, Hamburg — <sup>3</sup>IAP, KIT, Karlsruhe — <sup>4</sup>Department of Physics, U. of Zagreb

Neural Simulation Based Inference (NSBI) is a new machine learning (ML) paradigm for statistical data analysis in high energy physics (HEP). These tools learn the underlying statistical distribution of the data using surrogate neural networks and show clear improvements over classical likelihood estimation methods. However, these methods require the training of a large number of networks in order to achieve this increase in performance while retaining robustness towards biases. It is therefore crucial to address the challenges of orchestrating many neural network trainings, alongside efficient utilization of computational resources.

The NEEDLE project aims to provide a flexible framework for distributed training together with a library of NSBI tools for deployment on High Performance Computing clusters. NEEDLE combines modern ML libraries together with commonly-used HEP data analysis tools and formats. In this talk, we present the design of the NEEDLE framework, how it handles large data streams and our integration with pytorch lightning.

T 50.2 Wed 16:30 KH 00.024

**Search for keV-Scale Sterile Neutrinos with TRISTAN at KATRIN Using Neural Simulation-Based Inference** — •LUCA FALLBÖHMER for the KATRIN-Collaboration — Max-Planck-Institute for Nuclear Physics

Following the completion of its neutrino mass measurement program at the end of 2025, the KATRIN experiment aims to probe keV-scale sterile neutrinos by analyzing the full tritium beta decay spectrum with a novel detector system, TRISTAN. Leveraging KATRIN's high source activity, this search is sensitive to mixing amplitudes at the parts-per-million level. However, extracting a potential sterile neutrino signature is challenging, as it relies on detailed modeling of the observed tritium spectrum and requires computationally intensive Monte Carlo simulations. To address this challenge, we implement neural simulation-based inference using normalizing flows to approximate the underlying probability density of the physics simulation. We demonstrate that continuous normalizing flows trained via conditional flow-matching enable highly efficient modeling of experimental spectra. This approach opens up the possibility of a fast surrogate model for rapid sampling and generates a continuous, unbinned representation of the KATRIN beamline response, accelerating and enabling the analysis pipeline.

T 50.3 Wed 16:45 KH 00.024

**Unbinned, High-dimensional Precision Measurements through the Lens of Deep Learning** — •JINGJING PAN — Karlsruhe Institute of Technology, Karlsruhe, Germany

Unbinned, high-dimensional machine learning-based unfolding has rapidly progressed from a conceptual method to a practical analysis tool now deployed across multiple experiments, including but not limited to ATLAS, CMS, H1, LHCb, STAR and T2K. Building on the classifier-based framework of OmniFold, recent work has consolidated best practices for validation, calibration, uncertainty quantification, and data-release format, enabling robust unbinned measurements in the natural high-dimensional phase space of experimental data. Two recent analyses that highlight this progress are presented in this talk.

The recent H1 measurement performs the first OmniFold unfolding of all final-state particles in high- $Q^2$  events using a point-edge transformer to process variable-length event topologies. This full-phase-space result enables both re-measurements of classic DIS observables and new projections, such as simultaneous jet measurements in the laboratory and Breit frames from a single unfolded

dataset. Meanwhile at the LHC, ATLAS has applied ML-assisted unfolding to extract jet track-function moments while circumventing binning artifacts that affect non-linear QCD evolution studies. These results demonstrate that modern ML-based unfolding delivers systematically controlled, fully differential data products that are broadly reusable for downstream physics.

T 50.4 Wed 17:00 KH 00.024

**Unbinned Unfolding of the WWbb Analysis with OmniFold** — •JOSEF MURNAUER, DANIEL BRITZGER, and STEFAN KLUTH — Max-Planck-Institute for Physics

We revisit the recently published ATLAS measurement of WWbb production and explore an alternative unfolding strategy based on OmniFold. The newly published single- and di-lepton WWbb cross-section measurements have demonstrated that this process constitutes a major new avenue for precision studies in top-quark physics at the LHC. New paradigms in data analysis for Run-III and beyond are emerging rapidly, with traditional techniques (such as cut-and-count or matrix-based unfolding) increasingly being superseded by more flexible and powerful machine-learning algorithms. We present initial results from applying an unbinned unfolding technique to the WWbb analysis in the lepton+jets channel, highlight its potential advantages over standard unfolding methods, and discuss its implications for Run-III data analyses.

T 50.5 Wed 17:15 KH 00.024

**Binary Black Hole Parameter Estimation using a Conditioned Normalizing Flow** — •MARKUS BACHLECHNER and ACHIM STAHL — III. Physikalisches Institut B, RWTH Aachen

The proposed Einstein Telescope is the first of the third-generation gravitational wave detectors. It is expected to reach a noise level at least one order of magnitude lower than current interferometers like LIGO and Virgo. Thus, the improved sensitivity increases the observable volume and extends the time window in which the inspiral phase of binary systems is measurable. To analyze the resulting vast amounts of data efficiently, Neural Networks (NNs) can be utilized. This talk presents a fast Binary Black Hole parameter reconstruction using a conventional convolutional NN, which conditions a subsequent Normalizing Flow (NF). Using the NF, an approximate posterior parameter distribution is obtained on an event-by-event basis, allowing for the estimation of uncertainties.

T 50.6 Wed 17:30 KH 00.024

**Normalizing-Flow-Based Reweighting of Detector Systematics in Neutrino Telescopes** — •OLIVER JANIK — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Accurate measurements of the astrophysical neutrino flux require reliable predictions of the detector response in neutrino telescopes. Because this response is highly non-analytical, such predictions rely on Monte Carlo (MC) simulations and a forward-folding approach. A key limitation is that MC simulations must assume specific detector properties. Evaluating detector systematic uncertainties therefore requires either simulating multiple MC sets with fixed detector parameters or using approaches such as SnowStorm, which sample detector parameters continuously on an event-by-event basis. In both cases, reweighting typically relies on interpolation between MC expectations, introducing an implicit dependence on an assumed flux model. We present a normalizing-flow-based approach that factorizes detector systematics into shape and yield components. A conditional normalizing flow is used to model changes in the distribution of reconstructed observables, while the overall event yield is modeled separately as a function of the relevant detector parameters. This separation enables consistent reweighting for both discrete MC sets and SnowStorm simulations, without relying on flux-dependent interpolation. In this talk, we demonstrate the application of this method to detector-systematics modeling in astrophysical neutrino flux measurements.

T 50.7 Wed 17:45 KH 00.024

**Covering Unknown Correlations in Bayesian Priors by Inflating Uncertainties** — •LUKAS KOCH — JGU Mainz

Bayesian analyses require that all variable model parameters are given a prior probability distribution. This can pose a challenge for analyses where multiple experiments are combined if these experiments use different parametrisations for their nuisance parameters. If the parameters in the two models describe exactly the same physics, they should be 100% correlated in the prior. If the parameters describe independent physics, they should be uncorrelated. But if they describe

related or overlapping physics, it is not trivial to determine what the joint prior distribution should look like. Even if the priors for each experiment are well motivated, the unknown correlations between them can have unintended consequences for the posterior probability of the parameters of interest, potentially leading to underestimated uncertainties. In this presentation I will show that it is possible to choose a prior parametrisation that ensures conservative posterior uncertainties for the parameters of interest under some very general assumptions.

**T 51: Flavour Physics III**

Time: Wednesday 16:15–18:45

Location: KH 01.011

T 51.1 Wed 16:15 KH 01.011

**Angular analysis technique for systems of two identical vector mesons and its applications in the LHCb experiment** — •ILYA SEGAL, MIKHAIL MIKHASENKO, and MARIAN STAHL — Ruhr-University Bochum, Bochum, Germany

The angular analysis of systems composed of two identical vector mesons offers a powerful framework for probing a wide range of physical phenomena. Notable examples include searches for all-charm tetraquarks  $T_{cc\bar{c}\bar{c}}$  in the  $J/\psi J/\psi$  system, investigations of glueball candidate in the central exclusive production of  $\phi\phi$ , and studies of the internal structure of charmonia through their decays to  $\phi\phi$ . A dedicated technique for constructing reaction amplitudes for the production of resonances decaying into pairs of identical vector particles is presented. The method accounts for the full symmetry properties of the system and provides a consistent framework for amplitude modeling and angular analysis. Applications of this technique to LHCb data are presented.

T 51.2 Wed 16:30 KH 01.011

**Dalitz analysis of B to D pi pi decays** — •MELISA-MELEK AKDAG — University of Bonn, Bonn, Germany

Recent studies have provided strong evidence that the  $D_0^*$  meson is better described by an amplitude modeled using unitarized chiral perturbation theory rather than a traditional Breit-Wigner distribution. This finding underscores the importance of a more nuanced approach to modeling these states. The  $D^+\pi^-\pi^-$  decay is dominated by a loop diagram that includes the  $\rho$  meson, resulting in significant theoretical uncertainties. To mitigate these uncertainties, we directly access the  $\rho$  meson in the analysis by incorporating the isospin conjugated modes which include the  $\pi^0$  via the decay chain  $\bar{B}^0 \rightarrow D^+\rho^-$  into our considerations.

To achieve these goals, it is crucial to analyze not only the  $B^- \rightarrow D^+\pi^-\pi^-$  final state, which the LHCb experiment can measure with high precision, but also decays involving neutral pions, emerging from  $\bar{B}^0 \rightarrow D^+\pi^-\pi^0$ , where the Belle II experiment can uniquely contribute. This allows us to study the orbitally excited charmed mesons, the  $D_0^*$  and the  $D_2^*$  in the  $D\pi\pi$  final state, and the  $D_1$ ,  $D_1'$  and  $D_2^*$  in the  $D^*\pi\pi$  final state. By studying both processes we can test heavy quark spin symmetry in these final states.

T 51.3 Wed 16:45 KH 01.011

**Pole Search for  $\Xi^*(1620)$  and  $\Xi^*(1690)$  Resonances in the  $\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$  Decay at LHCb** — •ANNA LENA ZIMMER, MIKHAIL MIKHASENKO, and MARIAN STAHL — Ruhr-Universität Bochum, Germany

Understanding the excitation spectrum of strange baryon resonances remains a challenge. In particular, many excited  $\Xi$  baryon states are poorly established and their properties vary widely between models. Pole positions characterize hadronic states in a reaction-independent manner, but are rarely determined with rigor. This project aims to extract the pole positions of  $\Xi^*(1620)^0$  and  $\Xi^*(1690)^0$  using parameters from an amplitude model of the decay  $\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$ . The model is based on an analysis of the proton\*proton collision data obtained by the LHCb detector at  $\sqrt{s} = 13$  TeV. The resonance poles are determined directly from the parameterized K-matrix model, coupling the  $\Xi\pi$ ,  $\Lambda\bar{K}$ ,  $\Sigma\bar{K}$  and  $\Xi\eta$  scattering channels. The extracted pole parameters aid in accurate reaction-independent quantification of the excitation spectrum and evaluation of coupled channel effects.

T 51.4 Wed 17:00 KH 01.011

**Angular analysis of  $\Omega_b^- \rightarrow \Xi_c^+K^-\pi^-$  using LHCb Run3 data** — •DHURUVANSHU PARMAR, MIKHAIL MIKHASENKO, and MARIAN STAHL — Ruhr-Universität Bochum, Bochum, Germany

Using Run2 data, five excited states of  $\Omega_c^0$  were observed decaying into  $\Xi_c^+K^-$  in prompt inclusive production. From exclusive  $\Omega_b^-$  decays, reconstructed with LHCb Run2 data, spin and parity of four out of the five previously observed states were studied. However, the results were inconclusive due to the limited statistics of Run2 dataset. To address this, the study of process  $\Omega_b^- \rightarrow \Xi_c^+K^-\pi^-$  is motivated using Run3 data of LHCb experiment, enabling precise measurement of these quantum numbers of excited  $\Omega_c^0$  states. Additional sensitivity in helicity

amplitude of  $\Omega_c^0$  is achieved by accounting for the spin and parity dependencies arising from  $\Xi_c^+$  decay. Selection techniques implemented to filter  $\Omega_b^-$  events from Run3 data will be highlighted in the presentation, which are crucial to get necessary statistical precision for the angular analysis.

T 51.5 Wed 17:15 KH 01.011

**Lineshape study of the  $\chi_{c1}(3872)$  state with LHCb** — •ROBERT HENTGES<sup>1</sup>, MIKHAIL MIKHASENKO<sup>1</sup>, VANYA BELYAEV<sup>2</sup>, and MATTHEW NEEDHAM<sup>3</sup> — <sup>1</sup>Ruhr-University Bochum — <sup>2</sup>Sapienza Università INFN, Roma — <sup>3</sup>University of Edinburgh

After its discovery in 2003, the  $\chi_{c1}(3872)$  state, also known as  $X(3872)$ , has been established as an exotic hadron. However, its exact nature as meson-anti-meson molecule, compact tetraquark, conventional charmonium or a mixture thereof is still being investigated. Using the full LHCb Run 1&2 data set of the inclusive  $b \rightarrow (X(3872) \rightarrow J/\psi\pi^+\pi^-) + Any$  and exclusive  $B^+ \rightarrow (X(3872) \rightarrow J/\psi\pi^+\pi^-)K^+$  decays, this analysis probes different lineshapes in their ability to describe the recorded data. The probed lineshapes arise from diverse theoretical models, taking into account the proximity of the  $\chi_{c1}(3872)$  state to the  $D^0\bar{D}^{*0}$  threshold. From these lineshapes, this analysis aims at precise determination of the physical parameters mass  $m$  and width  $\Gamma$ , as well as the scattering parameters. Especially knowledge of its position relative to the  $D^0\bar{D}^{*0}$  threshold is required to advance our understanding of the state. Thus, a special focus is set on the systematic uncertainty stemming from background interference.

T 51.6 Wed 17:30 KH 01.011

**Implementation of a generic three-body decay model in EvtGen for a  $\Xi_c^+$  polarimetry analysis** — •HENRY VAN DER SMAGT, ILYA SEGAL, MIKHAIL MIKHASENKO, and MARIAN STAHL — Ruhr-University Bochum, Bochum, Germany

The amplitude-serialization project of the LHCb Bochum group as part of the BMFTR-funded Democratizing-Models (DEMOS) consortium provides a generic and well-structured format that facilitates reproducibility and exchange within the high-energy physics community. This work presents a C++ implementation of the helicity formalism using the Dalitz-plot decomposition method. The framework is integrated into a new decay model EvtThreeBodyDecays for EvtGen, the main b-physics event generator, which constructs amplitude models from JSON descriptions. The model enables the inclusion of the recently published  $\Xi_c^+ \rightarrow pK^-\pi^+$  decay variables in hadronic amplitude analyses involving the  $\Xi_c^+$  baryon. Furthermore, it provides access to the polarimetry vector field of this decay, allowing studies of  $\Xi_c^+$  polarization and improved handling of model-dependent uncertainties by describing all 31 alternative models.

T 51.7 Wed 17:45 KH 01.011

**Event Selection for  $Y(5S)$  Entanglement Studies** — •KILIAN BRÜCKNER, HANS-GÜNTHER MOSER, VANESSA GEIER, LOUISE BERIET, and CELIA ÁLVAREZ — Max Planck Institut für Physik, Boltzmannstraße 8, 85748 Garching

The entanglement of  $B^0\bar{B}^0$  meson pairs from  $Y(4S)$  decays is an important resource for many analyses, especially for time dependent  $CP$  violation analyses. At the  $Y(5S)$ , however, more features of the entanglement itself can be studied. Due to the higher energy of the  $Y(5S)$ , excited  $B^{0*}$  mesons can be produced from its decay. These spin 1 excited  $B^{0*}$  states decay via the emission of a photon, so that  $C = +1$  and  $C = -1$  entangled  $B^0\bar{B}^0$  states are produced. In comparison, The  $Y(4S)$  only provides a state entangled with a  $C = -1$  wave function.

The challenge for an analysis at the  $Y(5S)$  arises from the low amount of  $121\text{ fb}^{-1}$  of data, so far taken only by Belle. This requires an efficient event selection with many decay channels to keep statistics high enough. In this talk, the full event selection for the analysis is described. This includes choosing the decay channels of the  $B$  mesons, as well as handling all occurring backgrounds. For the main background source of  $q\bar{q}$  continuum, a gradient boosted decision tree is utilized.

T 51.8 Wed 18:00 KH 01.011

**Entanglement studies with Belle Y(5S) data** — •LOUISE BERIET, VANESSA GEIER, and HANS-GÜNTHER MOSER — Max Planck Institute for Physics, Garching, Germany

Compared to the Y(4S), the Y(5S) can decay into excited  $B^{0*}$ , giving rise to  $B^0/\bar{B}^0$  pairs in different quantum states. Directly after the Y(5S) decay, the produced  $B^{0(*)}\bar{B}^{0(*)}$  pairs are expected to be in a  $J^{PC} = 1^{--}$  state. Following the radiative transition  $B^{0*} \rightarrow B^0 \gamma$ , the system evolves into states with  $J^{PC} = 1^{--}$ . Depending on the C-parity, the  $B^0/\bar{B}^0$  can be in a symmetric (triplet) or anti-symmetric (singlet) wave function, leading to different time evolutions of the entangled states. By mixing the two C-parity states  $C = -1$  and  $C = +1$ , one can create a mixed state that is physically indistinguishable from a disentangled system.

We aim to study these effects using the Y(5S) data available from Belle. The analysis includes the reconstruction of the signal  $B^{0(*)}$  meson pairs through the decay chain  $B^0 \rightarrow D^- (\rightarrow K^+ \pi^- \pi^-) \pi^+$ , as well as obtaining the vertex and flavor information of the other B-meson inclusively. In addition, the  $B^0/\bar{B}^0$  quantum states are separated using the variables  $M_{bc}$  and  $\Delta E$ .

We analyze the quantum coherence using the Partial Spontaneous Disentanglement model, which quantifies the entanglement via a number  $\zeta \in [0, 1]$ . This parameter can be extracted by performing a likelihood fit on time-dependent parameters, which themselves can be computed from the spatial separation of the  $B^0$  pair. First results using Monte Carlo data are presented.

T 51.9 Wed 18:15 KH 01.011

**Separation of different quantum states of  $B^0 \bar{B}^0$  meson pairs at the Upsilon 5S** — •CELIA ÁLVAREZ ÁLVAREZ, KILIAN BRÜCKNER, VANESSA GEIER, and HANS-GÜNTHER MOSER — Max Planck Institut für Physik, Boltzmannstr. 8 85748 Garching.

At the Upsilon 5S the energy is high enough that  $B^0$  can be produced in excited states such as  $Y(5S) \rightarrow B^0 \bar{B}^0$ ,  $Y(5S) \rightarrow B^{0*} \bar{B}^0 + c.c.$  and  $Y(5S) \rightarrow B^{0*} \bar{B}^{0*}$ . The  $B^{0*}$  decays via the emission of a photon and  $B^0/\bar{B}^0$  pairs can be observed in different quantum states. Those pairs which stem from  $B^0 \bar{B}^0$  and  $B^{0*} \bar{B}^{0*}$  have a  $C = -1$  antisymmetric wave function, while the ones that decay from  $B^{0*} \bar{B}^0 + c.c.$  have a  $C = +1$  symmetric wave function. The different states show different forms of entanglement.

Using data of the Belle experiment, these three decay modes are reconstructed through the three hadronic decay chains:  $B^0 \rightarrow D^- \pi^+$  with  $D^- \rightarrow K^+ \pi^- \pi^-$ ,  $B^0 \rightarrow D^{*-} \pi^+$  with  $D^{*-} \rightarrow \bar{D}^0 \pi_s^-$  and  $\bar{D}^0 \rightarrow K^+ \pi^-$  or  $\bar{D}^0 \rightarrow K^+ \pi^- \pi^+ \pi^-$ . Using  $M_{bc}$ , the three decay modes are separated and signal and background is fitted using  $\Delta E$ . Using the S-weight technique the  $\Delta t$  signal is extracted and a signal fit is performed with the weighted data.

T 51.10 Wed 18:30 KH 01.011

**Study of Quantum Disentanglement in the  $B^0 \bar{B}^0$  System at Belle II** — •ABHIJITH RAJAGOPALAN, MAXIMILIAN KEI HATTENBACH, SAGAR HAZRA, and HANS-GÜNTHER MOSER — Max-Planck-Institute for Physics, Munich, Germany

Quantum entanglement has been extensively tested in systems of photons and atoms. Its investigation in the context of heavy, unstable particles such as B mesons remains an active and compelling area of research. Quantum entanglement is a crucial assumption for time dependent CP violation studies at Belle II. However, a fraction of these  $B^0 \bar{B}^0$  pairs that are disentangled would introduce systematic uncertainties in these studies, which are currently not accounted for. We present simulation-based studies of quantum entanglement in the  $B^0 \bar{B}^0$  system using the hadronic  $B^0 \rightarrow D^{(*)-} \pi^+$  and  $D^- \pi^+$  decay channels. We test the model of partial spontaneous disentanglement, in which a fraction of the  $B^0 \bar{B}^0$  pairs lose their entanglement and subsequently evolve independently.

## T 52: Silicon Detectors V

Time: Wednesday 16:15–18:15

Location: KH 01.012

T 52.1 Wed 16:15 KH 01.012

**Performance of FBK Trench-Isolated LGAD coupled to Timpix3 Chip** — •CHIN-CHIA KUO, ERIKA GARUTTI, JÖRN SCHWANDT, ANNIKA VAUTH, and CONSTANZE WAIS — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

The widely used instrumentation telescope operated at the DESY-II beam lines consists of six sensor planes using MIMOSA 26 monolithic active pixel devices for track reconstruction. However, the readout time of the current telescope is around 115  $\mu s$ . As a result, a time reference layer is necessary to properly associate telescope tracks with the hits in the device under test. Additionally, a layer with high time resolution would provide a reference for the characterization of timing detectors. The low-gain avalanche diode (LGAD) with a good time resolution at the picosecond level is a good candidate for this purpose. LGAD with an isolated trench design is chosen for the study. With the trench design, the multiplication layer is extended, resulting in a better fill factor. In this presentation, the performance of FBK TI-LGAD bump-bonded to the Timpix3 chip is presented, including the gain factor, efficiency, and time resolution. Modules are tested at the DESY testbeam facility, using electrons with an energy of 3 GeV.

T 52.2 Wed 16:30 KH 01.012

**Characterization of CASSIA 1, an LGAD design in a commercial CMOS imaging process** — •SILAS MÜLLER, CHRISTIAN BESPIN, HANS KRÜGER, LARS SCHALL, SINOUE ZHANG, ALEXANDER WALSEMANN, RASMUS PARTZSCH, FABIAN HÜGGING, and JOCHEN DINGFELDER — Physikalisches Institut der Universität Bonn, Nußallee 12, 53115 Bonn

Next-generation detector technologies have to cope with high rate environments, where precise time-tagging is needed. Sensors with internal gain may offer several advantages for these applications. They can achieve higher signal amplitudes, which can simplify the design of in-pixel electronics, and their superior timing performance may be beneficial for future 4D tracking or time-tagging applications. The CASSIA project (CMOS Active SenSor with Internal Amplification) seeks to develop monolithic active pixel sensors (MAPS) with internal signal gain and low noise, implemented within the Tower Semiconductor 180 nm process. This talk presents first characterization results from CASSIA 1, a prototype designed to test the feasibility of integrating a gain layer in a 180 nm commercial CMOS imaging Tower Semiconductor process. Different gain layer configurations are examined and results from electrical tests as well as measurements with radioactive sources are shown. Gain measurements obtained with pulsed lasers of different wavelength and initial test beam results are presented.

T 52.3 Wed 16:45 KH 01.012

**Test beam studies of Resistive Silicon Detectors** — •NIYATHIKRISHNA MEENAMTHURUTHIL RADHAKRISHNAN<sup>3</sup>, ROBERTA ARCIDIACONO<sup>1</sup>, NICOLO CARTIGLIA<sup>2</sup>, ALEXANDER DIERLAMM<sup>3</sup>, LING LEANDER GRIMM<sup>3</sup>, LORENA HAHN<sup>3</sup>, MARKUS KLUTE<sup>3</sup>, AURORA LOSANA<sup>4</sup>, BRENDAN REGNER<sup>3</sup>, and LUCA MENZIO<sup>5</sup> — <sup>1</sup>Univesita di Piemonte Orientale — <sup>2</sup>Istituto Nazionale di Fisica Nucleare — <sup>3</sup>Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>4</sup>University of Turin — <sup>5</sup>CERN

Resistive Silicon Detectors (RSDs) are among the most promising candidates for 4D tracking for future colliders where precise position and timing information will be quintessential for tracking. RSDs are based on the Low Gain Avalanche Diode technology with an additional resistive layer which enables spread of signal so that a single particle hit induces signal on multiple readout pads, and the reconstruction results in a higher resolution compared to traditional pixelated or strip detectors. The talk will give a summary of the results obtained from the data collected during the test beam measurements at the H6B beam line of the CERN SPS North Area with 120 GeV pions in October 2025. The setup consisted of two DC coupled RSD sensors and one AC coupled RSD sensor. This talk will emphasize the efforts to improve track reconstruction and analysis of test beam data with the software framework, Corryvreckan.

T 52.4 Wed 17:00 KH 01.012

**A novel Low Gain Avalanche Diode design: MARTHA** — •E. C. WAIS<sup>1</sup>, A. BAEHR<sup>2</sup>, J. DAMORE<sup>2</sup>, E. GARUTTI<sup>1</sup>, C. KOFFMANE<sup>2</sup>, J. NINKOVIC<sup>2</sup>, E. PRINKER<sup>2</sup>, R. H. RICHTER<sup>2</sup>, G. SCHALLER<sup>2</sup>, F. SCHOPPER<sup>2</sup>, J. SCHWANDT<sup>1</sup>, and J. TRIES<sup>2</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>Semiconductor Laboratory of the MPG

To cope with the high interaction rates of new colliders, detectors with time resolution in the range of 10 ps are required to disentangle pileups. LGADs are a promising candidate for this task. LGADs feature a low amplification gain, which enables good timing resolution in thin sensors. However, due to the strong electrical field in the gain region, LGADs tend to break down at the pixel edges. In order to overcome this, the sensors have to be equipped with complex separation structures, which usually result in dead areas without gain between pixels. The Monolithic Array of Reach THrough Avalanche diodes design aims to tackle this problem, by combining a deeply implanted gain layer followed by an additional n-doped Field Drop Layer. This reduces the electric field at the n+-edges, thereby preventing them from breaking down. Since the gain region is not segmented, there are no dead spaces in the inter-pixel regions. A first prototype batch with test structures is being investigated. The sensors are optimized for photon detection without any specific timing requirements and are expected to have a fill factor of 100%. Future R&D aims to optimize this design for fast timing applications. In this talk, the MARTHA concept, characterization measurements and first test beam data from the DESY 2 test beam facility, are presented.

T 52.5 Wed 17:15 KH 01.012

**Probing the Acceptor Removal Effect in Silicon Test Diodes Mimicking LGAD Gain Layers** — •P. ERBERK, E. GARUTTI, J. SCHWANDT, and E. FRETWURST — Universität Hamburg

P-type low gain avalanche diodes are silicon sensors with an intrinsic charge multiplication gain layer. They offer high temporal resolution and are foreseen to be used in HL-LHC timing detectors but are susceptible to radiation damage. Especially in the highly boron doped gain layer the acceptor removal effect occurs, leading to boron defect formation. This process not only deactivates the boron atoms as dopants but also leads to the formation of BiOi defects. These defects are detrimental to the gain layer as they counteract the local electric field by providing positive space charge, eventually removing the gain layer. Carbon co-doping has shown promising results in mitigating gain loss, as the implantation of carbon atoms is believed to influence the boron defect formation kinetically. The study of radiation-induced defects in the gain layer using microscopic defect spectroscopy techniques is challenging as it is difficult to distinguish between bulk and gain layer. To enable more precise investigation of defect kinetics, silicon diodes on highly doped p-type substrates mimicking the gain layer were produced, a total of 25 wafers with test structures covering various doses of carbon implantation, phosphorous co-doping, and oxygenation. This extensive set of samples allows to systematically investigate and thereby parametrize the acceptor removal effect. In this talk the analysis of the samples before and after irradiation including DLTS, TSC and IV/CV measurements is presented.

T 52.6 Wed 17:30 KH 01.012

**Characterisation of an Enhanced Lateral Drift (ELAD) Sensor Prototype** — •JUDITH SCHLAADT, NAOMI DAVIS, DORIS ECKSTEIN, MORITZ GUTHOFF, SIMON SPANNAGEL, ANASTASIIA VELYKA, and GIANPIERO VIGNOLA — DESY, Hamburg, Germany

The development of vertex and tracking detectors for future lepton colliders faces various challenges regarding time and position resolution while maintaining a low material budget and the capability to process high particle rates. In this context, one approach to improve the spatial resolution is to utilise the effect of charge sharing. Here, the ratio of the signal amplitudes measured by neighbouring readout electrodes gives information about the hit position of the traversing particle. By applying a magnetic field and exploiting the Lorentz drift of the generated charge carriers in the sensor volume, charge sharing can be observed. Also, tilting the sensor results in the same effect. However, neither approach is suitable for vertex detectors, since the effect is not sufficient in the case of thin sensors.

The enhanced lateral drift (ELAD) sensor prototype addresses these requirements by featuring a multiple-layer design including buried doping implants. The deep implants generate an additional lateral electric field inside the sensor bulk, resulting in increased charge sharing. Through simulations, the sensor design was optimised to allow for position-dependent charge sharing close to the theoretical optimum, which results in an improved impact position interpolation. This talk presents first results of the characterisation of an ELAD sensor prototype.

T 52.7 Wed 17:45 KH 01.012

**The ATLAS High Granularity Timing Detector: Quality Control Results on Low Gain Avalanche Diodes** — •THEODOROS MANOUSSOS<sup>1,2</sup>, SIMON KOCH<sup>1</sup>, GUILHERME SAITO<sup>3</sup>, MARCO LEITE<sup>3</sup>, DOMINIK DANNHEIM<sup>1</sup>, STEFAN GUINDON<sup>1</sup>, and LUCIA MASETTI<sup>2</sup> — <sup>1</sup>CERN — <sup>2</sup>Johannes Gutenberg-Universität Mainz, Germany — <sup>3</sup>Universidade de São Paulo, Brasil

The increase in instantaneous luminosity at the High Luminosity-LHC will be a challenge for the ATLAS detector, as the pile-up is expected to increase to an average of 200 interactions per bunch crossing. To sustain current physics performance and mitigate pile-up effects, a High Granularity Timing Detector (HGTD) will be integrated into the ATLAS end-cap regions, covering a pseudorapidity range of  $2.4 \leq |\eta| \leq 4.0$ . HGTD aims to achieve 30 ps per-track time resolution for MIPs in the beginning of the lifetime, up to 50 ps after a maximum fluence of  $2.5 \cdot 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ . High-precision timing information improves the correct assignment of tracks to vertices. HGTD sensors are based on the Low Gain Avalanche Diode (LGAD) technology. They provide moderate internal gain, resulting in fast rise time and large signal-to-noise ratio, required for excellent time resolution. Each sensor is a  $15 \times 15$  array of  $1.3 \times 1.3 \text{ mm}^2$  LGAD pads. Along with the sensors, an equal amount of Quality Control-Test Structures (QC-TS) is produced to monitor the quality and uniformity of wafers and extract various technology and fabrication parameters during production. This contribution presents process quality control measurements on QC-TS of the initial phase of the HGTD sensor production.

T 52.8 Wed 18:00 KH 01.012

**Module assembly for the ATLAS High Granularity timing detector** — •HENDRIK SMITMANN<sup>1</sup>, JESSICA HÖFNER<sup>1</sup>, FREDERIC MAXIMILIAN MATTHIAS SILVAN FISCHER<sup>1</sup>, ANNIKA STEIN<sup>1</sup>, LUCIA MASETTI<sup>1</sup>, ANDREA BROGNA<sup>2</sup>, ATILA KURT<sup>2</sup>, FABIAN PIERMAIER<sup>2</sup>, STEFFEN SCHÖNFELDER<sup>2</sup>, QUIRIN WEITZEL<sup>2</sup>, and FLORIAN LIKA<sup>2</sup> — <sup>1</sup>Institut für Physik, Johannes-Gutenberg Universität Mainz — <sup>2</sup>PRISMA+ Detector Lab, Johannes-Gutenberg Universität Mainz

To meet the challenges of the High Luminosity Large Hadron Collider (HL-LHC), especially the increase of pile-up interactions, the ATLAS detector will need to be upgraded. One of the foreseen upgrades will be the installation of the High-Granularity Timing Detector (HGTD). The HGTD will mitigate the effects of pile-up in the ATLAS forward region, providing a time resolution of about 30 – 50 ps per track. The active detector area consists of 2-double-sided disks per end-cap. A disc side contains about 1000 modules, each consisting of two  $2 \times 2 \text{ cm}^2$  Low Gain Avalanche Detectors which are bump-bonded to two ASICs and glued to a PCB. Multiple modules are then glued onto a support unit to form a detector unit, which will then be built into the final detector at CERN. The current phase of pre-production is used to test and finalize all procedures towards production, for while around 1000 modules, roughly 10 % of the final detector, will be assembled at Johannes Gutenberg University Mainz, one of the six assembly sites. The complete assembly procedure of the final version of the detector module is presented, with focus on assembly, metrology, wire bonding, initial testing and the assembly process for the detector units.

## T 53: Scintillator Detectors II

Time: Wednesday 16:15–18:30

Location: KH 01.014

T 53.1 Wed 16:15 KH 01.014

**3d-Printing of Structured Plastic Scintillators** — •PHILIPP KARL KOLLAR, FABIAN PIERMAIER, SEBASTIAN RITTER, STEFFEN SCHÖNFELDER, and QUIRIN WEITZEL — JGU Mainz

Future experiments at high energy colliders call for calorimeters with high granularity. For scintillator-based sampling calorimeters, scintillator tiles, combined with a SiPM-based readout system, have established as a scalable solution to achieve such high granularity. To simplify production and assembly, structured scintillators-large scintillator plates, divided into optically isolated sections-offer a promising approach. Such structured scintillators can be produced in one single step by 3d-printing, while keeping the design customizable. In this presentation, the quality of 3d-printed scintillators will be discussed based on measurements utilizing cosmic muons. Additionally a comparison to injection-molded scintillators will be presented together with approaches for optimizing printing and polishing methods.

T 53.2 Wed 16:30 KH 01.014

**Increasing Photon Capture Rate of Wavelength-Shifting Fibers for Opaque Scintillator Experiments** — •BASTIAN KESSLER and SEBASTIAN BÖSER for the NuDoubt-Collaboration — Johannes Gutenberg-Universität Mainz

Wavelength-shifting optical fibers are widely used to collect and guide scintillation light from large detector volumes to photosensors, making them ideal for water Cherenkov and scintillator-based detectors. A key limitation, however, is

their low photon capture efficiency, which degrades energy resolution of fiber-based detectors.

Building on prior work, we show that capture efficiency can be enhanced by optimizing the fibers absorption profile and adding a low-refractive-index outer cladding to boost total internal reflection. Although this reduces the fibers effective active area - rendering it less suitable for transparent detectors - it is advantageous in opaque scintillators, where photons remain localized and may hit the fiber multiple times before they get absorbed in the scintillator.

In this work, we study the impact on photon capture rate, cluster size, and timing performance in the hybrid opaque scintillator experiment NuDoubt++. Also, results of the first prototypes of optimized wavelength-shifting fibers (OWLS) are shown.

T 53.3 Wed 16:45 KH 01.014

**Update on the Constuction of SuperSANDI for ANNIE** — •PHILIPP KERN, MICHAEL WURM, NOAH GOEHLKE, AMALA AUGUSTHY, and JOHANN MARTYN — JGU Mainz

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a Cherenkov neutrino detector at the Booster Neutrino Beam (BNB) at Fermilab. To also allow measurements with scintillation light, a water based scintillator (WbLS) is installed inside the detector. The advantage of WbLS in the detector is that it is possible to extract the energy of the neutrinos with the scintillation light as well as the trajectory of it with the Cherenkov cone. To allow us

to observe the full potential of the water based scintillator by a full reconstruction of extended neutrino event vertices, a vessel made of nylon holding 8000 litres will be deployed in 2026. To be able to deploy this vessel into ANNIE it must be inflatable to be able to fill out the whole volume of the detector. We will present you with the current status of the development of this vessel, Super-SANDI, which has unique challenges because of its size and the properties of the WbLS.

T 53.4 Wed 17:00 KH 01.014

**Characterisation of internal backgrounds in JUNO using BiPo-214 decays** — •UJWAL SANTHOSH<sup>1,2</sup> and LIVIA LUDHOVA<sup>1,2</sup> — <sup>1</sup> GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — <sup>2</sup> Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany  
The Jiangmen Underground Neutrino Observatory (JUNO) operates at a depth of 700 m underground in South China. The detector has multiple ambitious physics goals, but to achieve them, JUNO must maintain the radiopurity of the scintillator at very high levels. This work focuses on the <sup>238</sup>U decay chain, which is assumed to be in secular equilibrium because of its long lifetime and can therefore be determined by measuring <sup>214</sup>BiPo coincidences. <sup>214</sup>Bi decays into <sup>214</sup>Po with a characteristic prompt-delayed signature that can be isolated using spatial and temporal coincidence. However, the secular equilibrium of isotopes below <sup>222</sup>Rn in the <sup>238</sup>U chain can be disturbed by radon influx from the surrounding air. This is characterised by an increase in the BiPo-214 rate, as they are the decay products of radon. Such contamination can typically occur during detector filling in the presence of small leaks. In a closed system, the broken equilibrium is then restored in weeks due to the relatively short lifetime of radon. This study follows the <sup>214</sup>BiPo rate during filling to search for radon leaks and later in a stable data-taking period to extract the <sup>238</sup>U level.

T 53.5 Wed 17:15 KH 01.014

**First light in the MANGO target cell** — •ELENA WINIKER<sup>1</sup>, DANIELA FETZER<sup>1</sup>, MICHAEL WURM<sup>1</sup>, MANUEL BÖHLES<sup>1</sup>, HANS STEIGER<sup>2</sup>, and KAI LOO<sup>3</sup> — <sup>1</sup> Johannes Gutenberg-Universität Mainz — <sup>2</sup> Technische Universität München — <sup>3</sup> University of Jyväskylä

The Mainz Advanced Neutron Gamma Observatory (MANGO), currently in the final stages of construction in Mainz, is designed as a testing facility for scintillating detector materials used in neutrino experiments, such as JUNO.

High energy photons up to 9 MeV are generated by neutron capture on a converter and subsequently Compton scattered on the detector material. Varying the selected scattering angle enables the measurement of characteristics such as the linearity of the scintillation response across a wide range of energy depositions in the target, which is an important systematic for measuring the neutrino mass ordering in JUNO.

Additionally, the neutron converter can be removed to investigate the detector response to a neutron signal. The energy deposition of the scattered neutrons can be ascertained from the time of flight to the secondary detector.

This talk will outline the current status of construction of MANGO, focusing in particular on test measurements of coincidence events in the target cell.

T 53.6 Wed 17:30 KH 01.014

**Development and Performance of a High-Pressure Scintillator Test Cell for NuDoubt<sup>++</sup>** — •MAGDALENA EISENHUTH for the NuDoubt-Collaboration — JGU Mainz, Institute of Physics

The investigation of two-neutrino and neutrino-less double beta decay is crucial for understanding the Dirac or Majorana nature of neutrinos. In this context, the krypton isotope Kr-78 ( $Q=2.88$  MeV) stands out as a promising candidate for a first detection of two-neutrino producing decays, electron-capture beta-plus decay (2nuECb+) and double-beta decay (2nubb+). Detectors like the NuDoubt<sup>++</sup> experiment featuring hybrid opaque scintillator can profit from solving krypton gas in the scintillator at high pressure to increase the number of target nuclei, thereby enhancing the probability of observing the extremely rare double beta decay modes. This presentation explores the ongoing development of a small-scale scintillator test cell for high-pressure loading, designed to examine the loading factor of krypton in scintillator as well as the influence on scintillator properties. We discuss the calibration required for a quantitative determination

of the krypton concentration. Finally, we elaborate on the light yield and over-pressure performances of the test cell and possible improvements.

T 53.7 Wed 17:45 KH 01.014

**status of the cosmogenic analysis in the Jiangmen underground neutrino observatory** — •MARCEL BÜCHNER, TIM CHARISSE, ARSHAK JAFAR, MICHAEL WURM, DANIELA FETZER, OLIVER PILARCZYK, and MANUEL BÖHLES — Johannes-Gutenberg-Universität Mainz

The Jiangmen underground neutrino observatory (JUNO) is a 20 Kton liquid scintillator experiment located approx. 700m underground in the Guangdong province in China. Its main physics goal is the determination of neutrino mass ordering. To achieve that goal, it measures reactor neutrinos produced by two nuclear power plants that are located approx. 53 km away from the experimental site. Even at this depth, cosmic muons pass through the detector regularly. These muons are not only a significant background source but also produce various radioactive isotopes. This presentation focuses on the selection of these cosmogenic isotopes, which while producing an additional background can also be used to calibrate the detector for higher energies.

T 53.8 Wed 18:00 KH 01.014

**Quality control of wavelength-shifting optical modules for the SHiP Surrounding Background Tagger** — •IDA WÖSTHEINRICH for the SHiP-SBT-Collaboration — Humboldt-Universität zu Berlin  
SHiP (Search for Hidden Particles) is a general-purpose beam dump experiment in preparation at CERN. Its goal is to search for new Feebly Interacting Particles at the GeV-scale in an environment of effectively zero background. The Surrounding Background Tagger (SBT) is a key part of SHiP's background-suppression system. It detects muons entering SHiP's helium-filled decay volume from the sides, as well as muon and neutrino inelastic interactions within the volume. The SBT is based on liquid scintillator as the active detector material, read out by Wavelength-shifting Optical Modules (WOMs). An SBT WOM consists of a PMMA tube dip-coated with a dye that absorbs scintillation photons in the range of 280 nm to 400 nm and re-emits photons in the visible spectrum. The re-emitted photons are guided to a circular Silicon photomultiplier array at the end of the WOM tube via total internal reflection inside the tube walls. Approximately 1800 WOMs are required for the SBT, and their performance must be consistent and verifiable. This talk will discuss the development of a dedicated setup for standardised quality control of the SBT WOMs, along with first results. The setup measures the amplitude and homogeneity of the response at different positions on the WOM surface using a pulsed UV LED and photomultipliers in an automated system.

T 53.9 Wed 18:15 KH 01.014

**Probing hybrid scintillators for NuDoubt<sup>++</sup>** — •DORINA ZUNDEL for the NuDoubt-Collaboration — Johannes Gutenberg Universität Mainz

Neutrinoless double beta-plus decays ( $0\nu\beta^+\beta^+$ ,  $0\nu\beta^+\text{EC}$ ,  $0\nu\text{EDEC}$ ) have yet to be observed, posing a significant experimental challenge in the search for rare lepton-number-violating processes. The NuDoubt<sup>++</sup> project (Neutrino Double Beta Plus Plus) addresses this challenge by developing novel detection techniques that combine hybrid slow opaque scintillators with advanced light readout systems. The first prototype will employ enriched Krypton-78 gas at high pressure within an opaque scintillator vessel, enabling containment and detection of positrons and their annihilation photons. This configuration allows detailed reconstruction of event topology and particle identification, enhancing sensitivity to rare decay modes.

The characterization of slow scintillators is performed using the SCHLYP (Scintillation CHerenkov Light Yield Prism) laboratory setup. A hollow prism filled with scintillator samples is instrumented with three ultra-fast photomultipliers. A nearby <sup>137</sup>Cs source generates signals via Compton scattering, and a secondary detector selects recoil photons aligned with the prism geometry. Two PMTs detect Cherenkov and scintillation light, while the third detects only scintillation, allowing measurement of the relative contribution of Cherenkov and scintillation components. The talk will present improvements to the setup including a Cherenkov radiator, enabling precise determination of scintillator decay timing characteristics.

## T 54: Higgs Physics VI

Time: Wednesday 16:15–18:15

Location: KH 01.019

T 54.1 Wed 16:15 KH 01.019

**Search for heavy neutral Higgs bosons A and H in the  $t\bar{t}Z$  channel at CMS** — •YANNICK FISCHER, MATTEO BONANOMI, LUKAS EBELING, JOHANNES HALLER, and MATTHIAS SCHRÖDER — Institut für Experimentalphysik, Universität Hamburg

While the measurements of the Higgs boson at 125 GeV are so far consistent with the standard model (SM) prediction, the observed particle might well be

part of an extended Higgs sector. Such an extended Higgs sector is predicted by many theories of physics beyond the SM. Two Higgs Doublet Models (2HDM) assume the existence of a second Higgs doublet, giving rise to a total of five physical Higgs bosons. This talk presents a search for a hypothetical heavy CP-odd Higgs boson A decaying into a hypothetical CP-even heavy Higgs boson H and a Z boson, with the H decaying into a top quark-antiquark pair. This channel has been dubbed the "smoking gun" channel for electroweak baryogenesis in

2HDMs. We will present the status of  $A \rightarrow ZH$  with  $H \rightarrow t\bar{t}$  searches at CMS at 13 and 13.6 TeV centre-of-mass energy, focusing on the fully-hadronic decay channel of the  $t\bar{t}$  system. The results exclude masses of the  $A$  boson up to several TeV and constrain the 2HDM parameter space relevant for electroweak baryogenesis.

T 54.2 Wed 16:30 KH 01.019

**Strong First-Order Phase Transitions and Exotic Phases in the CP-Conserving 2HDM** — LISA BIERMANN<sup>1</sup>, •CHRISTOPH BORSCHENSKY<sup>2</sup>, RAFAEL BOTO<sup>2</sup>, MARGARETE MÜHLLEITNER<sup>2</sup>, RUI SANTOS<sup>3,4</sup>, and JOÃO VIANA<sup>3</sup> — <sup>1</sup>PSI Center for Neutron and Muon Sciences, Villigen, Switzerland — <sup>2</sup>Karlsruher Institut für Technologie, Germany — <sup>3</sup>Centro de Física Teórica e Computacional, Faculdade de Ciências, Universidade de Lisboa, Portugal — <sup>4</sup>Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Portugal

Extended scalar sectors can significantly influence the cosmological evolution of the early universe. The additional scalar degrees of freedom allow for strong first-order phase transitions (SFOPT) into the electroweak-broken vacuum, which induce gravitational waves that, for sufficiently strong signals, might be detectable in the near future. Additionally, the universe might have undergone exotic intermediate phases such as charge-breaking or CP-violating phases via a multi-step phase transition.

In this talk, the parameter space of the CP-conserving 2-Higgs-Doublet Model is investigated with the recent version 3 of the public code BSMPT. Within this model, we study the viability of SFOPTs in light of the recent experimental data from Higgs measurements and exotic Higgs searches. We present points involving different one- and multi-step phase histories, and study their features such as the size of the trilinear Higgs couplings as well as the strength of their gravitational wave signals.

T 54.3 Wed 16:45 KH 01.019

**Precision predictions of partial decay widths in the general Two-Higgs-Doublet Model** — •JOSE ANGEL HERNANDEZ CUEVAS, HEIDI RZEHAKE, MARTIN GABELMANN, and ROBIN FESER — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, 79104 Freiburg, Germany

The Standard Model (SM) of particle physics has achieved remarkable success in describing a broad spectrum of experimentally observed phenomena in particle physics with high precision. However, there are still some phenomena that lie beyond its description, such as the existence of dark matter, the matter-antimatter asymmetry of the universe, and the origin of neutrino masses. Several extensions to the SM have been proposed to account for these phenomena. Among them, the general Two-Higgs-Doublet Model (THDM) provides a framework with a rich phenomenology. It comprises the symmetry-constrained THDM scenarios as special limits, and enables the study of new sources of CP violation, Higgs-mediated flavor violation, generalized Yukawa structures, and the impact of complex parameters in both the potential and the Yukawa sector. In this talk, I will present next-to-leading-order (NLO) predictions of partial decay widths of the Higgs boson within the general THDM. I will focus on Higgs-boson decays into fermions and on exploring renormalization conditions, including on-shell and  $\overline{MS}$  renormalization conditions, together with different tadpole treatments, in order to establish criteria that can point to a good choice of renormalization schemes for some extensions of the SM.

T 54.4 Wed 17:00 KH 01.019

**tbH<sup>±</sup> Analysis with Multileptons Using Run-2 ATLAS Data** — •AZAD AFAN-DIZADA and ANDRÉ SOPCZAK — CTU in Prague

The latest results with Run-2 ATLAS data are presented for the search tbH<sup>±</sup> in the multilepton channel. The charged Higgs boson decay into WH is studied.

T 54.5 Wed 17:15 KH 01.019

**Search for a charged Higgs (H<sup>±</sup>) boson in Wh(h → bb) boosted channel using multivariate methods in ATLAS** — •SATYAJIT CHAKRABORTY and TATJANA LENZ — Physikalisches Institut, Universität Bonn, Germany

To address the shortcomings of the Standard Model, many models describing physics beyond the Standard Model (BSM) have been proposed. One such ex-

tension is the Two-Higgs-Doublet Model (2HDM), which predicts the existence of five Higgs Bosons: three neutral and two charged Higgs(H<sup>±</sup>).

This talk presents the search for a charged Higgs boson produced in association with a top quark and a bottom quark. The decay channel studied is  $H^\pm \rightarrow W^\pm h$ , where  $h$  is the Standard Model Higgs boson (125 GeV) and  $h \rightarrow b\bar{b}$ , while the  $W^\pm$  boson decays either hadronically ( $W^\pm \rightarrow qq'$ ) or leptonically ( $W^\pm \rightarrow \ell\nu$ ). The analysis is performed in the high- $p_T$  (Boosted) region using the full ATLAS Run-2 dataset. In this work,  $H^\pm$  masses ranging from 1.2 TeV to 3 TeV have been studied. Multivariate methods based on a Deep neural network (DNN) architecture have been used to separate signal from background following the strategy used in the previous analysis. The use of a mass parameterized neural network (PNN) has also been investigated. The resulting limits on the charged Higgs boson production cross-section times branching ratio are compared between the two approaches to assess their relative performances.

T 54.6 Wed 17:30 KH 01.019

**Jet Matching Performance with SPANet and GN3 in the Search for Charged Higgs Bosons Decaying to a cs Final State with the ATLAS Experiment** —

•JOHANNES KLAS, TATJANA LENZ, and JOCHEN DINGFELDER — Universität Bonn  
The discovery of the Higgs boson solved the mystery of particle masses. Although the Standard Model requires the existence of only one Higgs boson, an extension of the Higgs sector with at least four Higgs bosons is possible and required by many theories beyond the Standard Model, e.g. SUSY. This leads to the existence of a pair of charged Higgs bosons with the same mass and opposite electric charges. The main production mechanism is  $pp \rightarrow Wb\bar{b}H^\pm$  and the  $H^\pm \rightarrow cs$  decay is one of the favoured decay modes. Below the top quark mass this is realized via  $pp \rightarrow t\bar{t} \rightarrow Wb\bar{b}H^\pm$ . The search targets leptonic decays of the  $W$ , resulting in a final state with at least four expected jets and one lepton. Matching these jets to the appropriate particles is a difficult task. New developments like SPANet offer improved performance in jet matching and signal/background separation. The possibility of further improvements using the GN3 flavour tagger, which is currently in development, is being investigated. This is especially relevant when considering improvements in the correct matching of the s-jet and the rejection of gluon-initiated jets.

T 54.7 Wed 17:45 KH 01.019

**Search for resonances decaying to Higgs boson pairs at  $\sqrt{s} = 13.6$  TeV with the CMS experiment** — •HAOYU WANG<sup>1,2</sup>, SUMAN CHATTERJEE<sup>1</sup>, ELISABETTA GALLO<sup>1,2</sup>, RAINER MANKEL<sup>1</sup>, and ROBERVAL WALSH<sup>1</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607, Hamburg, Germany — <sup>2</sup>University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The Higgs boson, since its discovery, has been a powerful probe of physics beyond the standard model of particle physics. The CMS experiment at the Large Hadron Collider is analysing the data from the ongoing proton-proton collisions at  $\sqrt{s} = 13.6$  TeV, which provides an unprecedented opportunity to search for the production of Higgs boson pairs through the decays of heavy resonances. The analysis to be presented here targets such new physics signatures in the final state with four bottom quarks. Cutting-edge machine-learning techniques are employed for the reconstruction of Higgs boson pairs and the estimation of standard model background. We present the expected sensitivity for a large range of resonance masses, using data corresponding to an integrated luminosity of 170 fb<sup>-1</sup>.

T 54.8 Wed 18:00 KH 01.019

**The CMS Run2 resonant HH → bbττ analysis** — •TOBIAS KRAMER, MARCEL RIEGER, PETER SCHLEPER, ANA ANDRADE, NATHAN PROUVOST, and BOGDAN WIEDERSPAN — Hamburg University, Hamburg, Germany

This contribution presents an analysis in the search for the decays of heavy spin 0/2 resonances to a pair of Higgs bosons in the bbττ final state. A wide mass range of the hypothetical resonance from 250 GeV up to 3 TeV is covered. The analysed data correspond to 138 fb<sup>-1</sup> recorded by the CMS experiment at the LHC from 2016 to 2018. The talk highlights key aspects, such as the momentum regression of the neutrinos from the tau decays and the neural network for signal-background classification, and will present the results of the analysis.

## T 55: Silicon Detectors VI

Time: Wednesday 16:15–18:45

Location: KH 01.022

T 55.1 Wed 16:15 KH 01.022

**Simulation and development of the Mighty-Tracker for LHCb Upgrade II** — JOHANNES ALBRECHT, DOMINIK MITZEL, •DONATA OSTHUES, DIRK WIEDNER, and LUKAS WITOLA — TU Dortmund University, Dortmund, Germany

During the High-Luminosity LHC period, the LHCb detector will be operated at a significantly higher instantaneous luminosity compared to Run 3.

To adapt to higher radiation levels and hit occupancies, the LHCb detector will undergo a second upgrade. The SciFi tracker will be replaced by the Mighty-

Tracker, comprised of scintillating fibres in the outer region and silicon pixel sensors in the region closest to the beam pipe. The MightyPix modules are currently under development; the module design, serial powering and cooling solutions must be determined.

Simulation studies are a crucial input to these developments. This talk presents material budget scans, tracking efficiency calculations and momentum resolution results using a detailed detector geometry simulation based on the latest Mighty-Tracker design.

T 55.2 Wed 16:30 KH 01.022

**Low-Mass Mechanics: Support structure investigations for the LHCb Mighty Tracker** — •KSENIA SOLOVIEVA, TODOR TODOROV, and MARCO GERSABECK — Albert-Ludwigs University Freiburg

In preparation for the challenging environment of the High Luminosity LHC, the LHCb detector will undergo major improvements. The Upgrade II is scheduled to be installed during Long Shutdown 4 and includes a replacement of the downstream tracker. The current scintillating fibre tracker detector will be replaced with a hybrid system, the Mighty Tracker, comprising layers of improved scintillating fibres and 6 layers of silicon pixel detectors. The latter requires optimisation in the detector design, service routing and support structures to adhere to a strict material budget of below 1% X/X0 per layer. In this presentation, a potential support structure solution and progress towards its prototyping is discussed.

T 55.3 Wed 16:45 KH 01.022

**Performance Characterisation of LF-MightyPix for the LHCb Mighty Tracker** — •CELINA WELSCHOFF, SEBASTIAN BACHMANN, LUCAS DITTMANN, RUBEN KOLB, DAVID KUHN, and ULRICH UWER — Physikalisches Institut, Universität Heidelberg

For Run 5 of the LHC, LHCb will reach an instantaneous luminosity of up to  $1.0 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ . To cope with this challenging environment the current detector needs to be upgraded. One crucial part is the new main tracker, the Mighty Tracker. It will utilise scintillating fibres in the outer regions and silicon pixel sensors in the innermost region. For that inner region, prototype chips based on the High-Voltage Monolithic Active Pixel Sensor (HV-MAPS) technology have been developed. To fulfil the detector's requirements and support LHCb's physics performance, the sensors have to achieve a detection efficiency of  $> 99\%$  within the 25 ns bunch crossing period. LF-MightyPix is the first prototype sensor for the Mighty Tracker using the LFoundry process. The previous first and upcoming third prototype are produced with different foundries. Evaluating the performance of LF-MightyPix allows to qualify the LFoundry 150nm HV-CMOS process as possible technology for the Mighty Tracker pixel sensor. LF-MightyPix is a small scale prototype and has a size of  $3.5 \text{ mm} \times 4 \text{ mm}$  and a pixel size of  $100 \mu\text{m} \times 100 \mu\text{m}$ . In addition, it features a LHCb compatible readout. In this presentation the key features of LF-MightyPix are outlined and the performance of LF-MightyPix is presented utilising both lab and testbeam results. These results show a detection efficiency of  $> 99\%$  within 25 ns, fulfilling the Mighty Tracker requirements.

T 55.4 Wed 17:00 KH 01.022

**Investigation of X-ray-induced effects and resulting high backside currents in DePFET pixel sensors for the Belle II experiment** — FLORIAN BERNLOCHNER, JOCHEN DINGFELDER, and •GEORGIOS GIAKIOUSTIDIS — University of Bonn, Bonn, Germany

For the Belle II experiment at KEK (Tsukuba, Japan) the KEKB accelerator was upgraded to deliver  $e^+e^-$  collisions at a center-of-mass energy of  $E_{CM} = 10.58 \text{ GeV}$  and it has reached a record-breaking instantaneous luminosity of  $5.1 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$  in December 2024. During the so-called Long Shutdown 1 (LS1) the innermost part of the Belle II detector, the initially descope PiXel Detector (PXD1) with 20 modules, based on Depleted P-channel Field Effect Transistor (DePFET) technology, was replaced by a fully-populated, two-layer PXD with 40 modules. As the detector closest to the experiment's interaction region, the PXD is most exposed to radiation from the accelerator. Throughout the operation of the PXD1 a steady increase of backside current with irradiation was observed in several modules. Doping-profile measurements and electric field simulations show that this is a consequence of (partially) shorted guard rings at the backside leading to high electric fields and avalanche current multiplication. In this contribution, irradiation studies investigating both the X-ray-induced effects in DePFET sensors and the resulting high backside currents will be presented.

T 55.5 Wed 17:15 KH 01.022

**Fast Shutdown for the Belle II Pixel Detector** — •PAULA SCHOLZ<sup>1</sup>, JANNES SCHMITZ<sup>1</sup>, FLORIAN BERNLOCHNER<sup>1</sup>, JOCHEN DINGFELDER<sup>1</sup>, and MICHAEL RITZERT<sup>2</sup> — <sup>1</sup>Universität Bonn — <sup>2</sup>Universität Heidelberg

During beam loss events at the SuperKEKB accelerator in Japan, large amounts of radiation can severely damage the innermost layers of the Belle II Pixel Detector (PXD). Due to these events, the PXD has remained shut down since May 2024. The PXD consists of silicon pixel matrices based on DEPFET technology. Application-Specific Integrated Circuits (ASICs), known as "switchers", control these matrices by changing voltage levels of 20 V within a few nanoseconds during each 50 kHz readout cycle. Since the detector is safe when the switchers are unpowered, a secure method for rapidly powering down modules during beam loss events is required.

To address this, a modification of the custom-made power supply enabling an immediate pull-down of the switcher channels has been developed. Tests in the laboratory were conducted to verify its reliability and to observe the voltage evolution during the shutdown. The effectiveness of the fast shutdown was further

evaluated during a test beam campaign at the MAMI electron facility, where it was triggered before an electron beam reached the sensitive switchers to determine limits for minimum shutdown response times and tolerable beam currents. This upgrade is a key prerequisite for the safe reactivation of the PXD and therefore essential for restoring full vertexing capabilities in the next SuperKEKB run.

T 55.6 Wed 17:30 KH 01.022

**Investigation of neutron-induced single-event effects in the Belle II PXD overvoltage protection logic** — •JANNES SCHMITZ, FLORIAN BERNLOCHNER, JOCHEN DINGFELDER, and HANS KRÜGER — University of Bonn

The Belle II experiment at the SuperKEKB collider in Tsukuba, Japan, collects  $e^+e^-$  collision data reaching a record-breaking instantaneous luminosity of  $5.1 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$  in December 2024. The innermost Belle II sub-detector is the PiXel Detector (PXD), which is based on modules with Depleted P-channel Field Effect Transistor (DePFET) sensors. Each PXD module is powered by a custom-made power supply, providing 23 channels for the DePFETs operational voltages, linear post regulation and overvoltage protection circuitry. Although located on top of the Belle II detector and far away from the interaction region, the PXD power supplies triggered false overvoltage events induced by increased beam backgrounds during operation. Expecting a proportional increase up to the target instantaneous luminosity of  $6 \cdot 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ , investigations started to find the cause of these effects and minimize the resulting downtime of the detector.

This talk will discuss the observed neutron-induced single-event effects, covering improvements of the firmware as well as dedicated studies of its effectiveness in neutron-rich accelerator environments.

T 55.7 Wed 17:45 KH 01.022

**Wafer-level quality control procedure of silicon pixel sensors for the LHCb U2 Mighty-Tracker** — JOHANNES ALBRECHT, •JONAS RÖNSCH, DIRK WIEDNER, and LUKAS WITOLA — TU Dortmund University, Dortmund, Germany

To exploit the full flavour physics potential of the HL-LHC after long shutdown 4 (2034-2036), the LHCb detector will be operated at an instantaneous luminosity of  $1.0 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ . Due to the higher particle density, an upgrade is necessary to increase the granularity of the tracking system. The main tracking stations will be replaced by the Mighty-Tracker. It combines roughly  $285 \text{ m}^2$  of scintillating fibres in the outer region and  $8 \text{ m}^2$  of high voltage monolithic active pixel sensors (HVMAPS) called MightyPix in the inner region.

The pixel detector will be instrumented with approximately 46000 sensors, which all need to be thoroughly tested before being assembled into modules. Due to the large quantity the tests will be performed on a semi-automatic probe station. The wafer-level quality control procedure of the MightyPix will be presented in this talk.

T 55.8 Wed 18:00 KH 01.022

**Cluster Size Simulations in Allpix Squared for the LHCb Mighty Pixel Tracker**

— •RUBEN KOLB, SEBASTIAN BACHMANN, LUCAS DITTMANN, DAVID KUHN, ULRICH UWER, and CELINA WELSCHOFF — Physikalisches Institut Universität Heidelberg

During LHC's Run 5, the instantaneous luminosity of the LHCb experiment is expected to increase by at least a factor of five, imposing significantly more stringent requirements on the tracking detectors in terms of occupancy and radiation tolerance. To meet these challenges, the Upgrade II program foresees the replacement of the current scintillating fiber (SciFi) tracker with the so-called Mighty Tracker. This new tracking system combines scintillating fiber detectors in the outer regions with monolithic silicon pixel sensors (Mighty Pixel) in the innermost region.

One of the critical specifications to design the pixel detector is the expected hit rate. Here, the cluster size has a substantial impact, as the particles traverse the detector under an angle. This has implications on the expected data rate and the overall detector performance. Besides the incident angle, the cluster size depends on pixel geometry, depletion depth, sensor thickness and detection threshold. A data-validated simulation in Allpix Squared utilizing the angle distribution expected in the pixel region of the Mighty Tracker is presented in this talk. The results aid in the decision for critical sensor design choices and detector layout.

T 55.9 Wed 18:15 KH 01.022

**Particle-Weighted Material Budget Studies for the Mighty Pixel Layer and Enclosure Box in LHCb Upgrade II** — •REHAN WAHEED HAROON RASHID SAYYED, KSENIA SOLOVIEVA, and MARCO GERSABECK — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

The LHCb Upgrade II requires a complete redesign of the downstream tracking system to withstand extreme particle flux at increased luminosity. The Mighty Tracker design, featuring interleaved Mighty Pixel and Mighty SciFi layers, must minimise both active and passive material to preserve tracking performance. The work centers on optimising the layout of material in Mighty Pixel layers, focusing on the thermal enclosure box and the strategic placement of associated electronics (HDI and DCDC converters). Particle-weighted material budget estimations



are performed using simplified simulations of particle trajectories through these system components, including staves (comprising carbon foam, Nomex, titanium cooling tubes, and other materials), the readout-flex, the enclosure, and the electronics. The study specifically targets the geometric and material optimisation of these elements. A primary objective is to determine the optimal placement for high-density electronics, evaluating whether to integrate them within the enclosure volume, mount them on its exterior, or position them further away, based on their exposure to the particle flux. This work aims to design a Mighty Pixel layer system that minimises the degradation of track quality from material-particle interactions, thereby supporting the overall physics performance goals of the LHCb Upgrade II tracker.

T 55.10 Wed 18:30 KH 01.022

**Development and Validation of a TID irradiation setup based on a strong  $^{90}\text{Sr}$   $\beta$ -source** — •DAVID KUHN, SEBASTIAN BACHMANN, LUCAS DITTMANN, RUBEN KOLB, ULRICH UWER, and CELINA WELSCHOFF — Physikalisches Institut, Universität Heidelberg

During Long Shutdown 4 of LHC, the LHCb detector is planned to receive its Upgrade II to be able to cope with the significant increase in instantaneous luminosity to up to  $1.0 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ . As part of the upgrade the current scintillating fiber tracker will be replaced by the Mighty Tracker. This new main tracker will continue to use scintillating fibers in the outer region. In the inner region, however, the required granularity and radiation tolerance exceed the capabilities of this technology. There, a silicon-based pixel detector will be employed instead. The proposed technology for this is High Voltage Monolithic Active Pixel Sensor (HV-MAPS).

As the MightyTracker pixel detector will be subject to ionizing radiation damage up to dose of 40 Mrad during its lifetime, the associated influence on the operation of the pixel sensors needs to be studied precisely. For this, a setup utilizing a 3.7 GBq Strontium-90  $\beta$ -source is developed and simulated using FLUKA. The simulated dose rate of up to 10 krad/h for silicon pixel detectors in the irradiation setup can be validated by using dose rate and hit rate measurements. In this talk the development and validation process of the irradiation setup will be presented.

## T 56: Data, AI, Computing, Electronics VI

Time: Wednesday 16:15–17:45

Location: KH 02.014

T 56.1 Wed 16:15 KH 02.014

**How to make artificial intelligence more sustainable and precise? - Introducing the project PEARLS** — •SIMRAN GURDASANI<sup>1</sup>, VALERIE LANG<sup>2</sup>, PARDIS NIKNEJADI<sup>1</sup>, and NAMAN KUMAR BHALLA<sup>2</sup> — <sup>1</sup>DESY — <sup>2</sup>Albert-Ludwigs-Universität Freiburg

Artificial intelligence (AI) is increasingly applied in scientific research, but its growing computational demands raise concerns regarding reliability, transparency, and environmental impact. The PEARLS project: Precision in Energy-aware AI Research for Low-carbon Solutions, is an ErUM-Data consortium between DESY and the University of Freiburg and aims to address these challenges. Within PEARLS, we are developing tools to measure the Carbon footprint of Machine Learning applications, evaluate algorithm efficiency and precision, and improve the processing of data in ML workflows. In this talk, I will introduce the PEARLS project, report on the current progress from DESY and Freiburg, and outline plans for the future.

T 56.2 Wed 16:30 KH 02.014

**b-hive: a CMS wide Machine Learning Framework** — NICLAS EICH, ALEXANDER JUNG, ALEXANDER SCHMIDT, and •ULRICH WILLEMSSEN — III. Physikalisches Institut A, RWTH Aachen

b-hive is a state of the art machine learning framework with wide adaptation in various working groups in CMS. It is a pipeline for training and testing of machine learning algorithms allowing for a modular approach to developing and deploying ML models in high-energy physics applications. The framework provides standardized interfaces for data preprocessing, model training, validation, and inference, enabling researchers to efficiently prototype and compare different algorithms for jet identification and analysis tasks. This presentation will demonstrate the current capabilities of b-hive, showcase recent applications in b-tagging and discuss future development plans.

T 56.3 Wed 16:45 KH 02.014

**Foundation Model Based Approaches to Jet Tagging Using JEPA** — MIRAC NOYAN ÖZDEMİR, ALEXANDER SCHMIDT, •SERGIO SCHÖNEBERG, and ULRICH WILLEMSSEN — III. Physikalisches Institut A, RWTH Aachen University  
Foundation Models have gained significant traction in Natural Language Processing and Computer Vision and have recently become the focus of intensive research in the field of high-energy physics as they provide highly adaptable models that require less task-specific training and data. Moreover, their ability to leverage unlabelled data and their capacity to derive meaningful representations are promising opportunities for improving model robustness.

This talk presents the application of the Joint-Embedding Predictive Architecture (JEPA) to jet physics, capabilities of few-shot learning are demonstrated and the viability for jet flavor tagging is discussed. Finally, the broader implications for AI safety within high-energy physics are addressed.

T 56.4 Wed 17:00 KH 02.014

**Cross-Geometry Transfer Learning in Fast Electromagnetic Shower Simulation** — •LORENZO VALENTE<sup>1</sup>, GREGOR KASIECZKA<sup>1</sup>, and FRANK GAEDE<sup>2</sup> — <sup>1</sup>Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22607 Hamburg, Germany — <sup>2</sup>Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Fast and accurate particle shower simulation is essential for high-energy physics, but traditional Monte Carlo methods like Geant4 are computationally expensive, while machine learning alternatives typically require complete retraining

for each detector geometry. We present a transfer learning approach for generative calorimeter simulation using point cloud representations and diffusion/flow models. By pretraining on detector configurations and fine-tuning with limited target data, our method enables efficient adaptation across diverse geometries without geometry-specific preprocessing. We demonstrate significant performance improvements with minimal training samples through both full fine-tuning and parameter-efficient adaptation strategies. This work establishes transfer learning as a practical technique for geometry-flexible fast simulation, reducing computational requirements for detector design studies and physics analyses.

T 56.5 Wed 17:15 KH 02.014

**Agents of Discovery** — SASCHA DIEFENBACHER<sup>1</sup>, ANNA HALLIN<sup>2</sup>, GREGOR KASIECZKA<sup>1</sup>, MICHAEL KRÄMER<sup>1</sup>, ANNE LAUSCHER<sup>3</sup>, and •TIM LUKAS<sup>1</sup> — <sup>1</sup>University of Hamburg, Hamburg, Germany — <sup>2</sup>Lawrence Berkeley National Laboratory, Berkeley, USA — <sup>3</sup>RWTH Aachen University, Aachen, Germany  
Particle physics is becoming more and more data intensive, requiring increasingly complex analysis methods. Large parts of these methods belong to standard procedures which have to be implemented by hand, taking time away from more innovative work. With the rise of agentic AI systems other approaches become feasible: Tasking AI agents with implementing those known parts, making workflows more efficient.

In this work we present a framework allowing a team of AI Agents to work autonomously on a given task, including capabilities for writing code, code execution, error correction and logic checks. The setup uses state-of-the-art OpenAI LLMs and has been tested in the realm of anomaly detection. The performance was monitored throughout many different technical and physical metrics, allowing us to draw detailed conclusions on the capabilities of the different LLMs: Most are capable of solving the given task, while the best were able to match human level performance.

T 56.6 Wed 17:30 KH 02.014

**Development of Exclusive Tagging Algorithms for  $b$ -hadrons at FCC-ee** — •ELGI OROZI<sup>1</sup>, FLORIAN BERNLOCHNER<sup>2</sup>, VALERIO BERTACCHI<sup>2</sup>, THOMAS KUHR<sup>1</sup>, MARKUS PRIM<sup>2</sup>, and SLAVOMIRA STEFKOVA<sup>2</sup> — <sup>1</sup>Ludwig-Maximilians-Universität München (LMU), München, Germany — <sup>2</sup>Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

The FCC-ee physics programme will feature operations at energies ranging from  $\sqrt{s} = m_Z$  up to the  $t\bar{t}$  production threshold. The enormous statistics of  $Z$ -boson decays will allow the study of beauty-quark electroweak precision observables with exceptional statistical precision. Identifying  $b$ -hadrons in high-statistics  $Z \rightarrow b\bar{b}$  events is therefore crucial for probing small deviations from the Standard Model. While existing exclusive tagging approaches, such as the Belle II FEI, provide a conceptual framework, they must be adapted to the high-multiplicity environment at FCC-ee, where hadronisation, initial- and final-state radiation, and track densities are significantly more complex.

In this work, we develop and assess the performance of an exclusive  $B$ -tagging algorithm for FCC-ee, based on hierarchical decay reconstruction combined with gradient-boosted decision tree classifiers. This configurable framework performs track combination, vertex fitting, feature extraction, and multivariate classification. As a benchmark, we reconstruct the decay channel  $B^+ \rightarrow \bar{D}^0 [\rightarrow K^+ \pi^-] \pi^+$  from simulated  $Z \rightarrow b\bar{b}$  events, using the IDEA detector concept. This talk will provide insight into the feasibility of exclusive  $B$ -tagging at FCC-ee and outline future developments of advanced tagging strategies.

## T 57: Outreach I

Time: Wednesday 16:15–18:30

Location: KH 02.016

T 57.1 Wed 16:15 KH 02.016

**Vorstellung einer Teilchenphysik Masterclass über einen Stratosphären Ballonflug** — •LARA DIPPEL, KAI-THOMAS BRINKMANN, SIMON GLENNEMEIER-MARKE und HANS-GEORG ZAUNICK für die Netzwerk Teilchenwelt-Kollaboration — II. Physikalisches Institut, Justus-Liebig-Universität Gießen

Die vorgestellte Masterclass führt Schüler:innen in die Welt der Teilchen- und Detektorphysik ein. Zu Beginn erhalten sie anhand der vom Netzwerk Teilchenwelt bereitgestellten Materialien eine grundlegende Einführung in das Standardmodell der Teilchenphysik. Ergänzend wird das Thema Umweltradioaktivität behandelt und durch den praktischen Bau von Nebelkammern anschaulich vertieft.

Darauf folgt eine Einführung in die Detektorphysik mit besonderem Fokus auf Szintillatoren, bevor die kosmische Strahlung und ihre Eigenschaften erläutert werden. Anschließend wird der Stratosphärenballon-Flug thematisiert, dessen Messdaten im weiteren Verlauf analysiert werden.

Nach einer kurzen theoretischen Einführung in Python und Jupyter Notebooks werten die Schüler:innen selbstständig die Daten des während des Ballonflugs eingesetzten Teilchendetektors aus. Dabei erwerben sie grundlegende Kenntnisse der Programmierung und erleben unmittelbar, wie physikalische Fragestellungen mithilfe realer Daten beantwortet werden können.

T 57.2 Wed 16:30 KH 02.016

**Activities of the Belle II-ErUM-FSP Office in Outreach, Transfer, Networking and Young Talents Support** — •VERONIKA KRATZER<sup>1</sup>, FLORIAN BERNLOCHNER<sup>2</sup>, AMANDA CLOTH<sup>1</sup>, TORBEN FERBER<sup>3</sup>, ISABEL HAIDE<sup>3</sup>, JOHANNA HÄUSLER<sup>1</sup>, and THOMAS KUHR<sup>1</sup> — <sup>1</sup>Ludwig-Maximilians-Universität München — <sup>2</sup>Rheinische Friedrich-Wilhelms-Universität Bonn — <sup>3</sup>Karlsruher Institut für Technologie (KIT)

The Belle II-ErUM-FSP Office is the central unit for outreach, transfer, networking, and young talents support within the German research groups affiliated with the Belle II experiment that are organised in the Belle II Forschungsschwerpunkt (FSP). The office coordinates these activities across all groups, utilizing funding from the Federal Ministry for Research, Technology and Space (BMFT) in the ErUM (Erforschung von Universum und Materie) framework. Several online and offline activities are conducted, such as maintaining and updating the website belle2.de and social media channels, organizing outreach and community events, networking with outreach professionals within and beyond the ErUM community and facilitating knowledge transfer. This talk gives an overview of ongoing and planned activities.

T 57.3 Wed 16:45 KH 02.016

**Adaption of the Particle Therapy Masterclass for Use in Netzwerk Teilchenwelt** — •REBECCA SEIP and MICHAEL KOBEL for the Netzwerk Teilchenwelt-Kollaboration — TU Dresden, Dresden

The Particle Therapy Masterclass is a one-day program for students (mainly targeted for high school students). It aims to enhance participants' understanding of medical applications of particle physics, using radiation therapy as a representative example, and highlights the relevance of fundamental research in particle physics for everyday life. The Masterclass focuses on hadron therapy and the physics behind it. It was originally developed by Yioti Foka (GSI), Niklas Wahl (matRad, DKFZ) and collaborators, and the corresponding material is currently available in English and Greek. In order to make this Masterclass more accessible in Germany and to facilitate its integration into the activities of Netzwerk Teilchenwelt, it was translated to German and adapted to the German research landscape as well as the educational curricula. The Masterclass consists mainly of two parts: In the first part, students are introduced to the theoretical background. The second part is a hands-on session where the students apply their new knowledge to create a treatment plan for a tumor using matRad, an open-source treatment planning software employed for educational purposes and teaching. The talk will present the newly adapted materials for this Masterclass as well as experiences gained in the first implementation of the Particle Therapy Masterclass within Netzwerk Teilchenwelt.

T 57.4 Wed 17:00 KH 02.016

**Creativity as pathway into Physics for Primary Schools** — •MICHAEL HOCH and MARKUS KLUTE — KIT, Karlsruhe, Germany

Science and art at school at CERN is a pilot program exploring how artistic creativity can make science more engaging for primary school pupils. Building on Art@CMS and the ORIGINS initiative, it combines simple physics explorations with creative activities that help children aged 8\*10 intuitively grasp scientific ideas.

Tested in Karlsruhe and developed with two local schools in the Geneva region, the program provides practical tools for teachers and introduces pupils to broader STEM topics. The strong response from schools, families, and local communities - highlighted by exhibitions and CERN visits - shows the program's

motivational impact. The pilot also demonstrates clear scalability and adaptability, offering a promising model for inspiring young learners through science and art.

T 57.5 Wed 17:15 KH 02.016

**Schüler:innen für Physik begeistern** — •HEIKE VORMSTEIN — Johannes Gutenberg-Universität, Mainz, Deutschland

Schüler:innen nehmen Physik häufig als trocken und langweilig wahr. Die Erfahrung zeigt aber, dass durchaus Interesse an Physik und Forschung vorhanden ist, wenn der richtige Zugang gefunden wird.

Oft wird versucht, dieses Interesse durch möglichst viel Show und Effekte zu wecken. Gerade bei älteren Schüler:innen ist das jedoch nicht notwendig und nicht immer hilfreich. Meistens reicht es schon, wenn Begeisterung vermittelt und direkter Bezug zu aktueller Forschung hergestellt wird.

Eine besonders wirkungsvolle (und einfache) Möglichkeit ist es, Wissenschaftler:innen über die spannenden Aspekte ihrer eigenen Forschung sprechen zu lassen. Dabei bringen die Forschenden ihre intrinsische Motivation und Begeisterung mit, die von den Schüler:innen positiv wahrgenommen wird. Vor allem die Möglichkeit, offen Fragen zu stellen, sowohl zu fachlichen Themen als auch zum Alltag in der Forschung, hilft Schüler:innen, ein besseres Verhältnis zur Physik zu entwickeln. So wird Physik nicht als trockenes, altemodisches Fach erlebt, sondern als lebendiges, modernes Forschungsgebiet. Dies ermöglicht es uns, nachhaltiges Interesse zu wecken.

T 57.6 Wed 17:30 KH 02.016

**DIY Detector Workshop Concepts for Schools and Universities** — •SEBASTIAN LAUDAGE, FLORIAN BERNLOCHNER, and MAIKE HANSEN for the Netzwerk Teilchenwelt-Kollaboration — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

In the last two years, we developed and tested interactive workshops at the University of Bonn under the motto "Build Your Own Particle Detector." These hands-on workshops enable participants, regardless of prior experience, to construct their own functional particle detector in just a few hours. Participants can then use these detectors to measure cosmic rays or natural background radiation, gaining direct insights into the invisible world of particle physics. Building on the lessons learned from numerous workshops, we have developed next-generation detector concepts designed to be versatile, user-friendly, and accessible to a broad audience, from school students to university-level participants. To ensure sustainability of the project, we are currently creating comprehensive educational materials that will empower other institutions to host similar workshops independently. This contribution introduces our developed hardware and outlines our plans for the upcoming year.

T 57.7 Wed 17:45 KH 02.016

**Workshops zu Halbleiterdetektoren bei Science Camps Teilchen- und Astroteilchenphysik am KIT** — •GÜNTER QUAST und CAROLIN QUAST — Karlsruher Institut für Technologie

Im Rahmen von Science Camps zur Teilchen- und Astroteilchenphysik am KIT wurden mehrfach Workshops mit Jugendlichen zum Thema "Halbleiterdetektoren" durchgeführt. Thematische Schwerpunkte, Geräte und Materialien sowie Erfahrungen werden in diesem Vortrag beschrieben.

Den teilnehmenden Jugendlichen sollte die Möglichkeit gegeben werden, Grundlagen, Funktionsweise und Anwendungsgebiete von modernen, auf Halbleitern beruhenden Teilchendetektoren zu ergründen. Nach einer Klärung der physikalischen Grundlagen wurde zunächst eine einfache Schaltung mit einer PIN-Fotodiode zum Nachweis der Infrarotstrahlung von Fernbedienungen aufgebaut. Als Hauptprojekt bauten die Jugendlichen dann einen eigenen Halbleiter-Detektor auf, basierend auf dem am CERN entwickelten "DIY Particle Detector", und analysierten die Daten mit Hilfe eines Computers mit Soundkarte.

Als letzter Schritt wurde Umgebungstrahlung mit kommerziell erhältlichen Detektoren aufgenommen und ausgewertet: einem kostengünstigen Gamma-Spektrometer (RadiaCode) mit einem CsJ(Tl)-Kristall mit SiPM-Auslese und einem Si-Pixeldetektor mit 256x256 Pixeln (Advacam MiniPIX EDU) mit einem Timepix-Chip. Letzterer erlaubt die anschauliche Darstellung und Klassifizierung von Teilchenspuren.

T 57.8 Wed 18:00 KH 02.016

**Outreach Module for Detection of Cosmic Rays at Earth** — •NIKOLAI CHAUNIN<sup>1</sup>, JERZY PRYGA<sup>2</sup>, ANDRÉ SOPCZAK<sup>1</sup>, and VLADYSLAV TABACINIUC<sup>1</sup> — <sup>1</sup>CTU in Prague — <sup>2</sup>Jagiellonian University in Kraków

We present a new model as a part of the Czech Particle Physics Project (CPPP). This module is intended as a leaning tool in masterclasses aimed at high-school students (ages 15 to 18). The module is dedicated to the detection of cosmic rays at earth. The user will read a theoretical introduction, separate real shower

events from background noise and try to determine the direction of the showers. Afterwards the user can leave a feedback message on the same page. The module can be accessed at the following link: <http://cern.ch/cppp>

T 57.9 Wed 18:15 KH 02.016

**Bilderkennung für einfache Signal-Hintergrund-Trennung** — •ANDREAS ZEH-MARSCHKE für die Netzwerk Teilchenwelt-Kollaboration — Karlsruher Institut für Technologie: Karlsruhe, DE

Im Rahmen eines Science Camp Teilchen- und Astroteilchenphysik am KIT für Schülerinnen und Schüler wurde eine typische Anwendung aus der Physik bearbeitet: eine Mustererkennung. Diese einfache, leicht verständliche, physikalische Anwendung wurde mit Werkzeugen des maschinellen Lernens durchgeführt. Dies zeigt einen möglichen Einsatz von Künstlicher Intelligenz in Rahmen

der physikalischen Grundausbildung.

Anhand der Kontur, also des Verlaufs, einer Welle eines radioaktiven Zerfalls wird eine Trennung zwischen Signal (radioaktiver Zerfall) und Hintergrundrauschen durchgeführt. Dabei werden etwa 25 Pixel rund um den maximalen negativen Ausschlag analysiert. Diese Kontur ist ein eindimensionales Bild mit 25 Pixeln mit Graustufen. Somit ist die Signalerkennung ein Bilderkennungsproblem. Mittels maschinellen Lernens wird eine Trennung von Signal und Hintergrund vorgenommen. Dabei erfolgt eine Trennung auch dann mit großer Güte, wenn die Stärke des maximalen negativen Impulses vom Signal im Bereich des Hintergrundrauschens ist.

Die Wellen werden mit Hilfe des CERN-DIY-Detektor erfasst und mit einer Soundkarte aufgenommen und gespeichert. Für das maschinelle Lernen wurde als Werkzeug die Python-Bibliothek scikit-learn verwendet.

## T 58: Searches/BSM III

Time: Wednesday 16:15–18:00

Location: KH 02.018

T 58.1 Wed 16:15 KH 02.018

**Search for new physics in the final state with a tau lepton and missing transverse momentum using Run-3 CMS data** — THOMAS HEBBEKER, KERSTIN HOEPFNER, MIRAC NOYAN ÖZDEMİR, VALENTINA SARKISOVI, ALEXANDER SCHMIDT, and •JOSEPH KARL SCHUMACHER — III. Physikalisches Institut A, RWTH Aachen University

Various extensions to the Standard Model predict new particles, which can decay into final states characterized by high-energy lepton-neutrino pairs. The CMS detector at the CERN LHC is used to investigate deviations from predictions of the Standard Model in the high transverse mass region of the  $\tau + p_T^{\text{miss}}$  spectrum. Efficient identification of TeV-scale  $\tau$  leptons, precise modeling of the high transverse mass region and sensitivity to a wide range of models are essential in the search for Beyond the Standard Model (BSM) physics in this channel. CMS data recorded in Run-3 pp-collisions with a center-of-mass energy of 13.6 TeV have been analyzed to this end. This talk presents the key concepts of the analysis techniques used in the search for BSM physics in the  $\tau + p_T^{\text{miss}}$  channel, including statistical interpretations in terms of various BSM models, with a special interest in models with preferred coupling to third generation leptons.

T 58.2 Wed 16:30 KH 02.018

**Search for New Physics in Events with an Energetic Jet and Missing Transverse Momentum with the ATLAS Experiment** — •MORITZ HESPING, VOLKER BÜSCHER, CHRISTIAN SCHMITT, and DUC BAO TA — Johannes Gutenberg Universität Mainz

A wide range of theories beyond the Standard Model predict particles which only weakly interact with SM particles. If such particles are produced in collisions at the Large Hadron Collider, they are invisible to the detector. However, their presence can be inferred from a large missing transverse momentum when they recoil off a highly energetic jet. This requires a precise estimation of the SM processes resulting in a similar signature, such as the production of Z bosons decaying to neutrinos.

Searches for new physics in such events have been previously carried out at the ATLAS experiment using the full 140 fb<sup>-1</sup> dataset of the LHC Run 2 (2015–2018). This talk shows the progress of an updated analysis using data from the ongoing LHC Run 3, which at 160 fb<sup>-1</sup> for the years 2022–2024 has already exceeded Run 2 in luminosity, including an overview of the analysis strategy and data-simulation comparisons in the control regions, as well as systematic uncertainties.

T 58.3 Wed 16:45 KH 02.018

**Search for new physics in the electron plus missing transverse momentum channel using Run-3 CMS data** — THOMAS HEBBEKER, KERSTIN HOEPFNER, •MIRAC NOYAN ÖZDEMİR, VALENTINA SARKISOVI, ALEXANDER SCHMIDT, and KARL JOSEPH SCHUMACHER — III. Physikalisches Institut A, RWTH Aachen University

There are many Beyond the Standard Model (BSM) theories that predict new particles in the final state with a high-energy lepton and missing transverse momentum as their experimental signature. Now, using the newly acquired data of the CMS detector from the ongoing Run-3 at an unprecedented center-of-mass energy of 13.6 TeV, a new window is opened for searches in the high-energy regions.

This talk presents the main ideas behind the search for high-mass resonances and the analysis strategy in the electron plus missing transverse momentum channel. Among other results, the comparison of the observed data to the expected background, including a data-driven background estimation method, and several theoretical interpretations, will be shown.

T 58.4 Wed 17:00 KH 02.018

**Search for Asymmetric Leptoquark Production in the Multilepton Channel with ATLAS Data** — ONDREJ MATOUSEK, ANDRÉ SOPCZAK, and •ISHAAN UTKARSH — CTU in Prague

The latest results in the search for asymmetric leptoquark production in the multilepton channel are presented using ATLAS data.

T 58.5 Wed 17:15 KH 02.018

**Improved strategy for searches for Heavy Neutral Leptons decaying into  $\ell + \pi$  with ATLAS** — •ANDRÉ PRESCHER — Humboldt Universität zu Berlin

Heavy Neutral Leptons (HNLs) appear in beyond Standard Model scenarios and can address open problems such as neutrino masses and the matter-antimatter asymmetry. At the LHC, long-lived HNLs might be produced in leptonic W decays,  $W \rightarrow \ell N$  ( $\ell = e, \mu$ ), and lead to displaced decay signatures inside the detector.

The most stringent limits set in ATLAS searches so far have been achieved in the purely leptonic decay channels  $N \rightarrow \ell \ell' \nu$ . For small HNL masses, in the mass range of 2–3 GeV the two body decay  $N \rightarrow \ell + \pi$  might help to increase the search sensitivity.

In a recently published ATLAS analysis this decay channel however could not significantly improve the sensitivity beyond the one from  $N \rightarrow \ell \ell' \nu$ , due to higher background level in the  $N \rightarrow \ell + \pi$  search.

In this presentation we show studies how this background can be significantly reduced while keeping or even increasing the signal efficiency.

T 58.6 Wed 17:30 KH 02.018

**Exploring OmniJet- $\alpha$  for Model-Agnostic Anomaly Detection with CATHODE** — •SALOME FRESENBET<sup>1</sup>, GREGOR KASIECZKA<sup>1</sup>, LOUIS MOUREAUX<sup>1</sup>, ANNA HALLIN<sup>1</sup>, JOSCHKA BIRK<sup>1</sup>, HUMBERTO REYES GONZALEZ<sup>2</sup>, and SOUMYA SHAW<sup>3</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>RWTH Aachen University — <sup>3</sup>Saarland University

Model-agnostic anomaly detection has become an important complement to traditional, signal-driven searches for new physics at the LHC. One such method is CATHODE, which combines conditional density estimation in invariant-mass sidebands with a weakly supervised classifier in the signal region. In this talk, we present the integration of the jet foundation model OmniJet- $\alpha$  into CATHODE by training it to distinguish signal events from background events modeled by the generative component of CATHODE. We evaluate this approach on a dijet dataset with beyond-the-Standard-Model (BSM) benchmark resonance signals, which we use as a realistic anomaly-detection scenario. The aim of this ongoing study is to quantify the impact of jet foundation models on CATHODE's performance and how they may enhance the sensitivity of future model-agnostic searches.

T 58.7 Wed 17:45 KH 02.018

**Significance metrics for anomaly detection with the CATHODE method** —

•TORE VON SCHWARTZ, LOUIS MOUREAUX, GREGOR KASIECZKA, CHITRAKSHEE YEDE, and KRISTIAN WARNHOLZ — University of Hamburg, Hamburg, Germany  
Despite an extensive search program at the LHC, no evidence for new physics has been found so far. Anomaly detection has emerged as a promising approach bridging generic searches and analyses targeting specific signals. CATHODE, a model-agnostic anomaly detection method, is designed to enhance resonant signals in the smoothly falling dijet invariant mass spectrum. We present an investigation of different strategies for extracting the signal significance after applying this method, with the aim of improving sensitivity to potential new physics signals while maintaining calibration.

## T 59: Neutrino Astronomy III

Time: Wednesday 16:15–18:30

Location: KS H C

T 59.1 Wed 16:15 KS H C

**Extending the Advanced Northern Tracks Selection with Energy Uncertainty Estimation** — •LASSE DÜSER, SHUYANG DENG, SÖNKE SCHWIRN, PHILIPP SOLDIN, CHRISTOPHER WIEBUSCH, and MARCO ZIMMERMANN for the IceCube-Collaboration — RWTH Aachen University

The IceCube Neutrino Observatory is a cubic kilometer-sized detector located at the South Pole. It uses more than 5000 photomultipliers (PMTs) to detect particles via their Cherenkov radiation including muons induced by atmospheric and astrophysical neutrinos. Using a graph convolutional neural network that encodes the spatial geometry of the PMTs, the Advanced Northern Tracks Selection (ANTS) identifies these events and reconstructs important event features like the neutrino energy. Extending the existing ANTS framework allows for the simultaneous, event-based estimation of the uncertainty on the reconstructed energy. In this talk, we discuss the network's performance in terms of resolution and calibration. The reconstruction is compared to established methods and evaluated across different event topologies.

T 59.2 Wed 16:30 KS H C

**Event reconstruction for different detector geometries in a toy simulation of water-Cherenkov neutrino telescopes** — •FRANZISKA KIRCHNER for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Water-Cherenkov neutrino detectors are typically built with instrumentation strings placed on a triangular grid. Next-generation detectors such as P-ONE or IceCube-Gen2 are planned as less ordered structures so that no charged particle can pass through the detector without approaching any detector string. However, it is not fully understood which detector geometries result in an optimal resolution of event energies and event positions. The talk will present a toy simulation of various detector geometries and corresponding cascade and muon track event reconstructions, which is used to investigate the corresponding resolutions.

T 59.3 Wed 16:45 KS H C

**Approximating Photon Propagation in Ice Using Generative Neural Networks** — •AMITH ASHWATH NARAYAN for the IceCube-Collaboration — Technical University of Munich

The Precision Optical Calibration Module (POCAM) is an isotropic, self-monitored calibration device. As part of the IceCube upgrade an extension of the IceCube detector located at the geographical South Pole, POCAMs are being installed to tackle existing optical detector systematics with higher precision. Estimating these detector systematic uncertainties requires parsing a multidimensional parameter space, which is computationally intensive, therefore it is infeasible. Since an analytical approximation with sufficient precision does not exist, we employ machine learning: by sparsely sampling the parameter space and using a neural network to interpolate between simulated points. In this project, the focus is specifically on scattering coefficient, training the network to generate the corresponding detection optical module (DOM)-response histograms and total photon counts. The talk will focus on the neural-network architecture and its performance in generating DOM-response histograms and photon counts for the scattering coefficient, with the method being in principle extendable to the remaining detector systematics.

T 59.4 Wed 17:00 KS H C

**Advanced Northern Tracks Selection using a Graph Convolutional Neural Network for the IceCube Neutrino Observatory** — •PHILIPP SOLDIN, SHUYANG DENG, LASSE DÜSER, SÖNKE SCHWIRN, CHRISTOPHER WIEBUSCH, and MARCO ZIMMERMANN — RWTH Aachen University

The IceCube Neutrino Observatory is a large neutrino detector located in the ice at the geographic South Pole. It detects atmospheric and astrophysical neutrinos via Cherenkov radiation emitted by secondary charged particles, recorded by more than 5,000 digital optical modules equipped with photomultiplier tubes (PMTs). A central challenge for IceCube analyses is the efficient separation of muons produced in neutrino interactions from the dominant background of muons from cosmic-ray air showers. To address this challenge, the Advanced Northern Tracks Selection (ANTS) employs a two-stage, machine-learning-based event selection. A transformer-based autoencoder first performs dimensionality reduction of the time-resolved sensor data, followed by a deep graph convolutional neural network (GCNN) that explicitly exploits the irregular, node-like geometry of the IceCube detector. Compared to established selection methods, ANTS achieves a significant improvement in classification performance. This presentation examines the ANTS network architecture, training strategy, background-rejection capability, and computational efficiency.

T 59.5 Wed 17:15 KS H C

**Adapting the Advanced Northern Tracks Selections Neural Network for the IceCube Upgrade** — •SÖNKE SCHWIRN, SHUYANG DENG, LASSE DÜSER, HASTI MAGHSOUDIPOUR, PHILIPP SOLDIN, CHRISTOPHER WIEBUSCH, and MARCO ZIMMERMANN for the IceCube-Collaboration — III. Physikalisches Institut B, RWTH Aachen

The IceCube Neutrino Observatory is a neutrino detector located at the South Pole, consisting of over 5000 Digital Optical Modules (DOMs), each containing a single photomultiplier tube (PMT). In winter 2025/26, the IceCube Upgrade was deployed, including around 400 newly developed multi-PMT modules (mDOMs). Each mDOM contains 24 PMTs, providing in-module directionality information and increased effective area. A denser spacing of the modules also enables the detection threshold to be lowered to a few GeV. These new modules require modifications to existing event reconstruction methods. The Advanced Northern Tracks Selection (ANTS), developed for the original single-PMT DOMs, uses a multi-stage neural network approach that utilizes the full event information as measured by the DOMs for event selection and reconstruction of event parameters such as the particle direction and energy. This talk presents modifications of the ANTS network architecture to include the mDOMs of the IceCube Upgrade and discusses reconstruction performance at low energies.

T 59.6 Wed 17:30 KS H C

**The Pacific-Ocean Neutrino Experiment Design Optimization with Machine-Learning** — •KRISTIAN TCHIORNIY and LUKAS HEINRICH for the P-ONE-Collaboration — Technische Universität München, Physik-Department, James-Frank-Str. 1, Garching bei München, D-85748, Germany

The geometrical layout of any experiment or detector can have a large impact on its ability to produce meaningful outcomes for physics. Oftentimes we see that optimal geometries can be unintuitive. Studying and optimizing this is therefore essential. This has become a relevant topic for the optimization of cubic-kilometer-scale neutrino telescopes, in particular, the Pacific Ocean Neutrino Experiment (P-ONE), which is planned to be constructed in the coming years. With more than 70 lines across multiple kilometers of seafloor, the P-ONE geometry is yet to be finalized and studies on how to place these lines can inform crucial design decisions. In this presentation, the possible geometric optimization of such an experiment will be discussed, in particular, how it will employ machine-learning techniques to apply end-to-end optimization.

T 59.7 Wed 17:45 KS H C

**Neural Network-based DAQ System for in-ice Radio Detection of Neutrinos for RNO-G and IceCube-Gen2** — •ADAM RIFAIE for the RNO-G-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

Detecting astrophysical neutrinos at energies above 10 PeV is challenging due to their extremely low flux. The state-of-the-art detectors, such as RNO-G, and the planned IceCube-Gen2 Radio Array, exploit radio emissions via the Askaryan effect. The km-scale attenuation length of radio signals in ice enables large-scale detectors spanning several tens or hundreds of kilometres.

High trigger rates of such large-scale detectors demand efficient trigger systems and high data purity, such as Neural Network (NN)-based triggers. Previous simulation studies estimate an increase in the detection rates of astrophysical neutrinos by up to a factor of 2 at energies of 10 PeV, doubling the effective detection volume of the detector for no additional costs.

This presentation briefly describes the NNs we will be testing. Followed by the first lab measurements using the new DAQ system, NuRadioDAQ, and compares them to projected estimates based on simulated data.

T 59.8 Wed 18:00 KS H C

**Neural Network Tools for the IceCube-Gen2 Optical Array** — •FRANCISCO JAVIER VARA CARBONELL and ALEXANDER KAPPES for the IceCube-Collaboration — Universität Münster, Institut für Kernphysik

IceCube-Gen2 is a planned extension of the current IceCube neutrino observatory that will increase the in-ice instrumented volume by roughly a factor of eight and introduce 9600 new optical sensors with multiple photomultiplier tubes (PMTs) designed to provide nearly full solid-angle coverage. In this new configuration, neural networks are particularly strong candidates to replace or complement traditional algorithms in key tasks such as event reconstruction, topology classification, noise cleaning, and simulation, as they naturally exploit the additional information provided by the new sensors and can process large data volumes efficiently, especially when run on graphics processing units (GPUs). This talk will provide an overview of these methods, summarize their current performance in the IceCube-Gen2 context, and discuss their possible physics implications.

T 59.9 Wed 18:15 KS H C

**Combined Likelihood Analysis for Supernova Hunting** — •THILO BIRKENFELD, ACHIM STAHL, and CHRISTOPHER WIEBUSCH — III. Physikalisches Institut B, RWTH Aachen, Germany

The Combined Likelihood Analysis for Supernova Hunting (CLASH) is a software framework for the search for faint Supernova (SN) signals in various kinds of experimental data streams. Supernovae are frequently observed via optical telescopes. Observations via neutrinos and/or gravitational waves are highly anticipated,

as they will provide valuable insights into the nature of the explosion onset. However, the observation of neutrinos from an SN has succeeded only once so far, for SN 1987A. The chance of such an observation is given by the SN rate in Earth's vicinity and the limited detection range of individual experiments. We developed a likelihood-ratio test comparing the persistent signal hypothesis with a background-only model as a function of time. It can be applied to individual experiments of various kinds or multiple detectors in combination, increasing the observable range. In this talk, I present CLASH, its underlying methodology, and discuss its use for pertinent detectors such as JUNO and Hyper-K.

## T 60: Methods in Astroparticle Physics III

Time: Wednesday 16:15–18:30

Location: KS 00.004

T 60.1 Wed 16:15 KS 00.004

**Test setup for a potential electron tagger at KATRIN** — •PATRICK UNKHOFF, VOLKER HANNEN, CHRISTIAN HUHMANN, and CHRISTIAN WEINHEIMER for the KATRIN-Collaboration — Universität Münster

The neutrino mass experiment KATRIN has effectively collected 1000 days of tritium beta decay data, allowing to achieve a sensitivity for an upper limit on the electron neutrino mass of  $m < 300$  meV at 90% C.L.. After searching for sterile keV neutrinos with the TRISTAN detector at KATRIN a potential next generation experiment labeled KATRIN++ aims to go beyond this limit and probe the inverted mass ordering range down to neutrino masses  $m < 50$  meV. Besides the necessary development of an atomic tritium source, achieving the required sensitivity requires a new differential method with a sub-eV energy resolution. This may be possible through direct time-of-flight spectroscopy of beta-decay electrons. This approach requires detecting the electron start time when entering the KATRIN spectrometer with minimal change of its energy. In this talk, the concept of electron tagging using the image current technique is discussed. Here, the electrons are detected by measuring tiny currents induced by the motion of passing electrons on a nearby electrode structure. A cryogenic test setup has recently been developed at the University Münster to investigate the feasibility of this method and will be presented in this talk. This work is supported by BMFTR under contract number 05A23PMA.

T 60.2 Wed 16:30 KS 00.004

**Atomic tritium source development for future neutrino mass experiments** — •CAROLINE RODENBECK — Karlsruher Institut für Technologie, IAP-TLK

The Karlsruhe Tritium Neutrino experiment (KATRIN), which measures the tritium beta-decay spectrum, recently reached its goal of 1000 measurement days. It is now well on its way to achieving its targeted final neutrino mass sensitivity of  $0.3 \text{ eV}/c^2$ . Already, efforts are ongoing for future experiments aiming at sensitivities below  $0.05 \text{ eV}/c^2$ .

Beyond improved detector technologies, switching from a molecular to an atomic tritium source will likely be necessary: The molecular ro-vibrational excitations result in an effective broadening of the endpoint spectrum and thus in a reduced neutrino mass sensitivity, an issue avoided by the use of an atomic source.

Within the Karlsruhe Mainz Atomic Tritium Experiment (KAMATE), groups at the Johannes Gutenberg University (JGU) in Mainz and at the KIT's Tritium Laboratory Karlsruhe (TLK) benchmark different types of hydrogen dissociators (thermal dissociation versus RF-discharge plasma) as possible high-flux and high-efficiency sources. For the characterization of the dissociators, various analysis tools such as mass spectroscopy are under development.

After identifying suitable dissociators, key challenges such as multi-stage cooling and the magnetic trapping of atoms have to be addressed.

The talk gives an overview of the experimental achievements and an outlook for the cooling and trapping of atoms beyond the KAMATE efforts.

T 60.3 Wed 16:45 KS 00.004

**Development of the LUIGI ASIC for LEGEND-1000** — •JUAN PABLO ULLOA BETETA<sup>1</sup>, ANDREAS GIEB<sup>1</sup>, SUSANNE MERTENS<sup>1</sup>, MICHAEL WILLERS<sup>2</sup>, EDGAR SANCHEZ GARCIA<sup>1</sup>, HANNES BONET<sup>1</sup>, and FLORIAN HENKES<sup>2</sup> for the LEGEND-Collaboration — <sup>1</sup>Max-Planck-Institut für Kernphysik, Heidelberg DE — <sup>2</sup>Technische Universität München, München DE

The Large Enriched Germanium Experiment for Neutrinoless  $\beta\beta$  Decay (LEGEND) is a  $^{76}\text{Ge}$ -based experiment searching for the neutrinoless double-beta ( $0\nu\beta\beta$ ) decay. The second stage of the experiment, LEGEND-1000, aims to reach discovery sensitivity at half-lives beyond  $10^{28}$  years, covering the inverted-ordering neutrino mass region. Achieving this goal requires about 1000 kg of enriched germanium detectors, a substantial reduction of background in the region of interest, together with further improvements in noise performance and signal fidelity. An important contribution to the overall background budget arises from the readout electronics due to their proximity to the detectors. At the same time, the front-end electronics play a critical role for the energy resolution and pulse shape discrimination. In this context, we explore a novel approach to

ASIC-based charge-sensitive front-end electronics designed for operation close to high-purity germanium detectors in liquid argon under low-background restrictions.

T 60.4 Wed 17:00 KS 00.004

**Sputtered Transition Edge Sensors for the NUCLEUS Experiment** — •PHILIPP WASSER for the NUCLEUS-Collaboration — Technical University of Munich

Coherent elastic neutrino-nucleus scattering (CEvNS) enables sensitive studies of neutrino properties and physics beyond the Standard Model at low momentum transfer. The NUCLEUS experiment aims to measure CEvNS using MeV reactor antineutrinos from the Chooz nuclear power plant with gram-scale cryogenic calorimeters at 7 mK. Detecting the resulting sub-keV nuclear recoils requires transition edge sensors (TES) with ultra-low energy thresholds, realized using thin superconducting tungsten films.

Good detector performance requires a sharp superconducting transition near the bulk tungsten value (15 mK), motivating magnetron sputtering as a scalable alternative to electron-beam evaporation. I present the successful development of a dedicated sputter facility allowing to produce detector-grade tungsten films for TES applications.

On differently coated silicon substrates, reproducible transition temperatures around 15 mK and narrow transition widths below 0.5 mK were achieved, allowing the fabrication of highly sensitive TES. A systematic variation of the sputter power revealed a linear dependence of the critical temperature on the applied power, with values varying from 15 mK to 36 mK, enabling controlled tuning of the TES properties via deposition parameters. These results establish sputtered tungsten films as a viable TES technology for NUCLEUS.

T 60.5 Wed 17:15 KS 00.004

**Fabrication and characterization of MMC arrays for the ECHO-LE** — •KRITTIKA SARKAR for the ECHO-Collaboration — Kirchhoff Institute für Physik

The Electron Capture in Holmium-163 (ECHO) experiment is designed for the determination of the electron neutrino mass using the analysis of the 163-Holmium electron capture spectrum. It uses low temperature detectors called metallic magnetic calorimeters (MMCs) to measure the electron capture decay in samples of Holmium-163 that are implanted inside the MMCs. Each MMC pixel contains Ho-163 upto an activity of 10Bq. ECHO-LE aims to simultaneously operate ~20,000 such MMC detectors. Ten wafers hosting 40 arrays each will be fabricated. A quality check produce will be defined in order to confine the suitability of the arrays for the Holmium 163 implantation and therefore to be used in the experiment. Two such wafers have been fabricated and characterised. We present the quality control results obtained for the first two fabricated wafers and discuss the fabrication yield and its implications for the preparation of the ECHO-LE experiment.

T 60.6 Wed 17:30 KS 00.004

**Development of an Integrated Photon Phonon Detector to be used for  $0\nu\beta\beta$  Search** — •ASHISH JADHAV, CHRISTIAN ENSS, ANDREAS FLEISCHMANN, CLARA GÜNTHER, DANIEL HENGSTLER, SEBASTIAN HILSCHER, CAGLA MAHANOGU, IOANA-ALEXANDRA NITU, ANDREAS REIFENBERGER, CHRISTIAN RITTER, DANIEL UNGER, and LOREDANA GASTALDO — Kirchhoff Institute for Physics, Heidelberg, Germany

The AMoRE project uses scintillating crystals, enriched with  $^{100}\text{Mo}$ , which are operated at millikelvin temperatures to search for  $0\nu\beta\beta$  decay in this isotope of molybdenum. An advantage of using scintillating crystals is that they allow for particle discrimination based on the ratio of light to heat energy released by an event. We present an integrated photon-phonon (P2) detector based on metallic magnetic calorimeters (MMC) operated at 20 mK. The P2 detector design utilizes a 3" Si wafer, with a central area that serves as a photon absorber with a stripline geometry MMC sensor. This central area is connected to the rest of the wafer via seven bridges, which are fabricated using silicon etching techniques. In the outer region of the wafer, three MMC sensors with a double meander geometry are fabricated, on top of which the crystal is resting, to act as phonon de-

tectors. The three independent signals from these phonon detector units would allow a fiducial volume to be defined, while improving particle discrimination based on single- and multi-site events. We discuss the various fabrication challenges and the results of detector characterisation in a dilution refrigerator.

T 60.7 Wed 17:45 KS 00.004

**Development of an Experimental Platform for MMC Operation in the Next-Generation Neutrino Mass Experiment KATRIN++** — •ABDULLAH ÖZKARA<sup>1</sup>, SEBASTIAN KEMPE<sup>2,3</sup>, and MICHAEL MÜLLER<sup>2</sup> for the KATRIN-Collaboration — <sup>1</sup>Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT) — <sup>2</sup>Institute of Micro- and Nanoelectronic Systems (IMS), Karlsruhe Institute of Technology (KIT) — <sup>3</sup>Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology (KIT)

The Karlsruhe Tritium Neutrino (KATRIN) experiment measures the electron antineutrino mass via high-precision electron spectroscopy of tritium  $\beta$ -decay. Currently, KATRIN has established an upper limit of 0.45 eV for the absolute neutrino mass and aims to reach a final sensitivity of 0.3 eV (90% C.L.). With the future upgrade to KATRIN++, the goal is to push the sensitivity down to 0.05 eV to probe the inverted mass ordering. To achieve this, a new experimental platform will be implemented, incorporating metallic magnetic calorimeters (MMCs). MMCs are low-temperature single-particle detectors based on quantum technology, offering excellent energy resolution. We present the scheme of a novel platform featuring a magnetic cold chicane, enabling a barrierless transition from the room-temperature vacuum of the KATRIN main spectrometer to the cryogenic environment of the MMC detector.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 60.8 Wed 18:00 KS 00.004

**Microwave Multiplexing readout for the ECHO Experiment** — •DOMINIK ZAWIERUCHA for the ECHO-Collaboration — KIP im Neuenheimerfeld 227 Heidelberg 69120

The Electron Capture in Holmium-163 (ECHO) experiment uses metallic magnetic calorimeters (MMCs) to measure the energy spectrum of the electron-

capture decay of  $^{163}\text{Ho}$  implanted inside the detector. The analysis of the end-point region of this spectrum can be used to determine the effective electron neutrino mass. To achieve sub-eV sensitivity to the neutrino mass, a high-statistics energy spectrum with more than  $10^{13}$  events is required. This necessitates a multiplexed readout scheme that enables consistent, high-energy-resolution, simultaneous readout of approximately 20,000  $^{163}\text{Ho}$ -implanted MMC detectors over a long acquisition period.

In ECHO-LE (Large Experiment), this is achieved through the application of microfabricated microwave resonators coupled to radio-frequency superconducting quantum interference devices (rf-SQUIDs) used to acquire signals from the MMC detectors. In this scheme, each detector (400 in total) is coupled to an individual resonator with a resonance frequency in the 4–8 GHz range, allowing the simultaneous readout of multiple detectors by monitoring the transmission through a common feedline.

We discuss the preparation of the 25 high-frequency readout lines and present the status of the multiplexer development for ECHO-LE.

T 60.9 Wed 18:15 KS 00.004

**KATRIN++ - New Detector Technologies for a Future Neutrino Mass Experiment with Tritium** — •NEVEN KOVAC for the KATRIN-Collaboration — Institute for Astroparticle Physics - Karlsruhe Institute of Technology

Currently, the tightest constraints on the absolute scale of neutrino mass from a direct, model-independent approach, are obtained by the KATRIN experiment, giving an upper limit on the mass of the electron anti-neutrino of 0.45 eV (DOI: 10.1126/science.adq959), with final projected sensitivity below 0.3 eV. Going beyond this limit, and probing the inverted mass ordering (and beyond), will be the task for future neutrino mass experiments. In this regard, development of new detector technologies is of utmost importance, with quantum sensor arrays currently being the front runners due to their exceptional performance and excellent energy resolution.

In this talk we present our recent results where we demonstrate the feasibility for measurements of external electrons using metallic microcalorimeters, and report on our plans for first ever measurements of tritium  $\beta$ -spectrum using quantum sensors.

## T 61: Gamma Astronomy I

Time: Wednesday 16:15–17:45

Location: KS 00.005

T 61.1 Wed 16:15 KS 00.005

**MSH 15-52 in the high-energy regime: Exploring 3D eROSITA and H.E.S.S. data in a joint analysis with Gammapy** — •KATHARINA EGG and ALISON MITCHELL for the H.E.S.S.-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen Nürnberg

The pulsar wind nebula (PWN) MSH 15-52 is a fascinating system. It is not only a bright and prominent source in TeV gamma-rays, as seen by the H.E.S.S. telescope array, but is also visible in GeV gamma-rays with Fermi-LAT, as well as in X-ray data at keV energies. By characterizing the multiwavelength spectral energy distribution of MSH 15-52 we can draw conclusions about this PWN and its underlying physics.

In this vein, we present a multiwavelength analysis of MSH 15-52, using X-ray data from the eROSITA telescope, as well as H.E.S.S. data. Using 3D eROSITA data – comprising one spectral and two spatial dimensions – which we import into the open source analysis software Gammapy, enables us to conduct a joint analysis at photon event level over 12 orders of magnitude in energy, painting a comprehensive picture of this PWN in three dimensional data. We investigate different spectral and spatial models, test for energy-dependent morphology, and draw conclusions on the underlying particle spectrum of the source.

In this talk our current progress with the analysis will be illustrated and an outlook towards the future investigation of MSH 15-52 will be given.

T 61.2 Wed 16:30 KS 00.005

**Searching for Ultra-High Energy Photons applying Convolutional Neural Networks Using the Surface Detector of the Pierre Auger Observatory** — •FIONA ELLWANGER, RALPH ENGEL, MARKUS ROTH, STEFFEN HAHN, DAVID SCHMIDT, DARKO VEBERIC, and PIERRE AUGER COLLABORATION — Karlsruher Institut für Technologie, Karlsruhe, Germany

Identifying sources of cosmic rays is challenging, as the charged particles are deflected by magnetic fields and do not point back to their sources. Neutral particles, such as ultra-high energy (UHE)  $\gamma$ s will point directly to their sources, unless they interact in the interstellar medium or are absorbed. Cosmic ray detectors such as the 3000 km<sup>2</sup> surface array of the Pierre Auger Observatory are capable of observing UHE  $\gamma$ s above 10<sup>18</sup> eV. With increasing energy, their mean free path allows probing extragalactic sources up to a few Mpc. Different methods like BDTs and air-shower universality have been previously applied to the search of  $\gamma$ s at different energy ranges. Although no UHE  $\gamma$ s have been found,

the obtained bounds of the fluxes provide crucial constraints on cosmic-ray acceleration models. Neural networks have the potential to improve discrimination, enhancing the sensitivity to even lower fluxes. In this work, we present a convolutional neural network designed to distinguish between simulated UHE photon and proton showers. We evaluate possible systematics due to the imperfect simulation of air showers and detector effects using an independent test set and a burn sample consisting of 2% of the available data. Steps for a future unblinding of the search sample are discussed.

T 61.3 Wed 16:45 KS 00.005

**Shower based cross-calibration of swgo** — •FLORIAN FOITH, ALISON MITCHELL, and MARTIN SCHNEIDER for the SWGO-Collaboration — ECAP, FAU Erlangen-Nürnberg

This work discusses the possibility of calibrating the effective efficiencies of Water Cherenkov detectors (WCDs) at the Southern Wide-field Gamma-ray Observatory (SWGO) by utilizing pairwise charge asymmetry parameters. These parameters are computed for single shower events and then averaged over all conducted simulations. The concept, originally proposed for Imaging Atmospheric Cherenkov Telescopes (IACTs), has proven successful for the Cherenkov Telescope Array (CTA) and is now being tested with two possible approaches for asymmetry parameter computation for SWGO. We found that following preliminary testing against grid anomalies, our method demonstrates promising accuracy within the limitations of WCD-based gamma-ray observatories.

T 61.4 Wed 17:00 KS 00.005

**Effects of the geomagnetic field on IACT event reconstruction** — •MATHEUS GENARO DANTAS XAVIER, TIM UNBEHAUN, RODRIGO GUEDES LANG, and STEFAN FUNK — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

The observation of astrophysical gamma rays by Imaging Atmospheric Cherenkov Telescopes (IACTs) is based on the detection and imaging of Cherenkov light produced along the development of extensive particle air showers. The recorded images are then analyzed to reconstruct fundamental information of the primary gamma ray, such as its energy and direction. Due to Earth's magnetic field, charged particles in the shower are deflected during their trajectory, broadening the lateral development of the shower and the distribution of Cherenkov light on the ground. Consequently, distortions in the camera image

can lead to systematic effects in the reconstruction procedure. These effects are especially visible for low energy events ( $\sim 100$  GeV) and are believed to be significant when only one telescope is triggered (monoscopic reconstruction). In this work, we investigate the impact of the geomagnetic field on the largest H.E.S.S. telescope (CT5), based on simulations of gamma-ray-induced air showers. Due to its large light collection area and improved camera design, CT5 is crucial for lowering the energy threshold of observed sources. Therefore, to comprehend the geomagnetic field effects is especially important to quantify and possibly correct systematic errors present on the monoscopic analysis.

T 61.5 Wed 17:15 KS 00.005

**Get More for Less - Adaptive Sampling in Event Simulations For the Cherenkov Telescope Array Observatory** — •TRISTAN GRADETZKE and LUCA DI BELLA — TU Dortmund University, Dortmund, Germany

Monte Carlo (MC) simulations of particle induced extensive air showers are crucial to the analysis of observational data taken by Imaging Air Cherenkov Telescopes (IACTs). They serve the purpose of training and test data for the algorithmic reconstruction of particle type, energy, and direction of the originating particle. The performance of this reconstruction on the Monte Carlo data is mathematically described by the Instrument Response Functions (IRFs). Their usage however, comes at the extensive cost of computational resources. Consequently, considerable effort has been invested in improving the efficiency of these MC simulations. The objective of this work is to investigate the potential of adaptive sampling-based methods, that focus on specific phase-space regions

to enhance event statistics and, to a certain extent, possibly reduce uncertainties in the IRFs. Thus reducing the extent of Monte Carlo productions. Phase space in this context refers to, among others, detector field of view and primary particle energy. The main challenges arise from the definition of a metric, that is optimized by any given algorithm. Here, a simple event-per-bin based metric is adopted. Possible improvements in efficiencies and an overview of potential avenues for future research are presented.

T 61.6 Wed 17:30 KS 00.005

**Determining Telescope Pointing Direction Using Stellar Projections** — •DANIEL CECCHIN MOMESSO and CHRISTOPHER VAN ELDIK — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

This work presents a data-driven approach to improve the pointing accuracy of Imaging Atmospheric Cherenkov Telescopes (IACTs), such as those in the H.E.S.S. array. These telescopes detect Cherenkov light from gamma-ray-induced atmospheric showers, but are also sensitive to diffuse and stellar background light. This Night Sky Background (NSB) contains spatial information associated with the distribution of bright stars in the field of view. Based on stellar positions provided by catalogs, their projections onto the camera coordinates are compared with features observed in the NSB maps. This correspondence is the basis for correcting the pointing direction of the telescope and will be compared to the results of standard calibration methods.

## T 62: Cosmic Rays III

Time: Wednesday 16:15–18:15

Location: KS 00.006

T 62.1 Wed 16:15 KS 00.006

**Time Dependant Modelling of Astrophysical and DM Secondary Signatures in Dwarf Galaxies** — •JANNIS WAGNER<sup>1,2</sup>, JULIEN DÖRNER<sup>1,2</sup>, ATHITHYA ARAVINTHAN<sup>1,2</sup>, MILENA BRÜTTING<sup>1,2</sup>, and JULIA BECKER TJUS<sup>1,2,3</sup> — <sup>1</sup>Fakultät für Physik & Astronomie, Ruhr-Universität Bochum, D-44780 Bochum, Germany — <sup>2</sup>Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Dwarf galaxies are increasingly gaining traction as targets of indirect searches for Dark Matter (DM) due to their high mass-to-light ratios and low star-formation rates. Searches mainly focus on gamma rays in the GeV-TeV range created through different annihilation channels of Weakly Interacting Massive Particles (WIMPs). These signals are distorted by radiative emission of astrophysical Cosmic Rays (CRs), which necessitates joint modelling. Furthermore, the galaxies' decline in star-formation rate and its feedback on the galactic magnetic field require a time-dependent modelling of the CR distribution. Such a modelling would allow for better gauging of the morphological impact of DM and thus support future observation attempts for evidence of DM or in setting stronger constraints on its characteristics.

In this work, we explore this coupled modelling using the Monte-Carlo framework CRPropa, including leptonic DM secondaries and astrophysical CR electrons. We present a comparison of the morphologies of the resulting signatures for basic models of source distribution and magnetic field evolution.

T 62.2 Wed 16:30 KS 00.006

**Temporal and Geometrical Effects of the GMF on UHECRs** — •VERONIKA VAŠÍČKOVÁ, LEONEL MOREJON, and KARL-HEINZ KAMPERT for the Pierre Auger-Collaboration — Wuppertal, Germany

To understand the origin of the Ultra-High-Energy Cosmic Rays (UHECRs), it is important to explain features of their spectrum, as well as their arrival directions. Currently, this is done with modelling approaches neglecting time evolution, especially in the galactic magnetic field (GMF). We study the influence of the GMF on the arrival direction of UHECRs and on the spectrum, with the emphasis on temporal and geometrical effects, investigating the rigidity-dependent residence time of extragalactic cosmic rays entering our Galaxy using CRPropa. We probe both constant and time-varying flux scenarios and find that UHECRs entering the Milky Way can experience delays of hundreds of kiloyears. This temporal effect modifies the spectrum, introducing features such as a rigidity-dependent enhancement of the flux, a suppression of particles between  $10^{18} - 10^{19}$  V, or a natural softening of spectra with time. The comparatively short residence time of particles above a certain rigidity could explain the common maximum rigidity needed to describe the UHECR spectrum.

\*Supported by DFG (SFB 1491)

T 62.3 Wed 16:45 KS 00.006

**Study of Large scale Cosmic Ray Anisotropy with KASCADE and IceTop** — •JOSHUA TURNWALD, DONGHWA KANG, and ANDREAS HAUNGS for the IceCube-Collaboration — Karlsruher Institut für Technologie (KIT)

We present a study of anisotropies in the arrival directions of cosmic rays using data from KASCADE (Karlsruhe Shower Core and Array DEtector) and IceTop, the surface component of the IceCube Neutrino Observatory. These two experiments, located in the Northern and Southern Hemispheres respectively, provide complementary coverage of the cosmic-ray sky. Our analysis focuses on large-scale anisotropies in the energy range from 100 TeV to about 50 PeV. The relative intensity of the anisotropy is determined using a maximum likelihood method. In this contribution, the results of the dipole amplitude and its systematic studies will be discussed.

T 62.4 Wed 17:00 KS 00.006

**Investigation of the Diffusion Tensor for Different Turbulence Levels and Rigidities in the Resonant Scattering Regime** — •JAN-NIKLAS BOHNENSACK<sup>1</sup> and JULIA BECKER TJUS<sup>1,2,3</sup> — <sup>1</sup>Theoretical Physics IV: Plasma-Astroparticle Physics, Faculty for Physics & Astronomy, Ruhr-Universität Bochum, D-44780 Bochum, Germany; Supported by SFB1491 — <sup>2</sup>Ruhr Astroparticle And Plasma Physics Center (RAPP Center), Bochum, Germany — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden

The quasi-linear theory (QLT) describes the interactions between charged particles and astrophysical plasmas in the limit of  $b/B \ll 1$ . The goal of the underlying thesis was to verify the QLT's prediction that for small turbulence levels  $b/B$ , where  $b$  is the turbulent magnetic field strength and  $B$  is the homogeneous magnetic field strength, the diffusion coefficient behaves like  $\kappa \propto \rho^\gamma$  with  $\gamma = 1/3$ . To overcome those restrictions a code was developed in the underlying thesis to utilize methods of parallelization that calculate the running diffusion coefficient from particles propagated with CRPropa faster. The diffusion coefficients were generated for a range of reduced rigidities so that the particles scatter resonantly at any point in space for a given turbulence level. This talk shows new simulated data which better shows the behavior of the spacial diffusion coefficient against different turbulent levels and reduced rigidities. I will further give an outlook on how we will use the diffusion coefficients in future simulations and experiments (e.g. in laboratory plasmas or diffusive transport simulations).

T 62.5 Wed 17:15 KS 00.006

**mw-atlas: Inferring the 3D Galactic cosmic ray density of our Milky Way** — •MAREIKE BERKNER<sup>1</sup>, TORSTEN ENSSLIN<sup>2</sup>, HANIEH ZANDINEJAD<sup>2</sup>, and PHILIPP MERTSCH<sup>1</sup> — <sup>1</sup>RWTH Aachen University, Aachen, Germany — <sup>2</sup>Max-Planck-Institut für Astrophysik, Garching, Germany

Most models of the Galactic cosmic-ray (CR) distribution often rely on simplified source distributions and propagation scenarios. They consequently fail to capture the rich, non-axisymmetric structure of the Milky Way. The true, 3D distribution of CRs is however crucial in identifying CR sources and in understanding the feedback that CRs provide to the interstellar medium. In this contribution, we discuss methodological attempts for a data-driven reconstruction of the 3D CR density using Bayesian inference and Gaussian processes. Information of the CR density is provided by hadronic  $\gamma$ -rays, measured by Fermi-LAT. Morphological matching structure in the  $\gamma$ -ray sky with corresponding ones in



spatially resolved gas maps allows reconstructing the smooth, spatially correlated CR density field, including a measure of its uncertainty. This 3D map can be directly compared to predictions from propagation models. This will enable new tests of CR transport scenarios, improve models of diffuse gamma-ray emission, and offer a starting point for integrating CR physics consistently into ISM analyses.

T 62.6 Wed 17:30 KS 00.006

**Revised Diffusive Shock Acceleration with CRPropa3.2 for the description of cosmic ray spectra at supernova shocks** — •JAKOB DÖRNER<sup>1</sup>, SOPHIE AERDKER<sup>1,2</sup>, LUKAS MERTEN<sup>1,2</sup>, and JULIA TJUS<sup>1,2,3</sup> — <sup>1</sup>Theoretical Physics IV: Plasma-Astroparticle Physics, Faculty for Physics & Astronomy, Ruhr University Bochum, Germany; Supported by SFB1491 — <sup>2</sup>Ruhr Astroparticle and Plasma Physics Center (RAPP Center) — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

Supernova remnants (SNRs) play an important role in the acceleration of Galactic cosmic rays (CRs) that gain significant energy by repeatedly crossing the shock front. This acceleration process, known as diffusive shock acceleration (DSA), generally leads to a power-law spectral slope of  $E^{-2}$ . However, observations of nonthermal emission of SNRs imply CR energy distributions that are generally softer than  $E^{-2}$ , the DSA prediction. In contrast, non-linear theory of DSA would predict an even harder spectrum. Recent studies suggest that such soft spectra may arise from the additional drift of magnetic structures with respect to the thermal plasma downstream of the shock. We incorporate the effect of such drifts by changing the effective compression ratio of the shock in test particle simulations using the CRPropa framework, which solves the transport equation by utilizing stochastic differential equations. We obtain soft energy spectra, depending on the strength of the effective compression ratio, and concave energy spectra when the precursor is taken into account.

T 62.7 Wed 17:45 KS 00.006

**Gamma-ray signatures from anisotropic cosmic ray transport in the Milky Way** — •JULIEN DÖRNER<sup>1,2</sup>, JONAS HELLRUNG<sup>1,2</sup>, JULIA BECKER TJUS<sup>1,2,3</sup>, and HORST FICHTNER<sup>1,2</sup> — <sup>1</sup>Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — <sup>2</sup>Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

The magnetic field of the Milky Way is composed of a large-scale coherent background and a turbulent component. The spatial diffusion of cosmic rays (CRs) in this composed magnetic field configuration is expected to become anisotropic. The diffusion coefficient along the field line  $\kappa_{\parallel}$  is greater than in the degenerated perpendicular directions  $\kappa_{\perp}$ .

In this work, we utilize the open-source framework CRPropa to investigate the anisotropic diffusion of CRs within the Milky Way. We phenomenologically vary the ratio  $\epsilon = \kappa_{\perp}/\kappa_{\parallel}$ , ranging from nearly parallel diffusion ( $\epsilon = 10^{-3}$ ) to purely isotropic diffusion ( $\epsilon = 1$ ). The source parameters are optimized to match the observed CR data at Earth. Afterwards, the line-of-sight integration framework HERMES is used to calculate the all-sky gamma-ray emission. Based on the resulting all-sky maps, the feasibility of gamma-ray observations to constrain not only the parameters of such anisotropic transport but also the structure of the Galactic magnetic field will be discussed.

T 62.8 Wed 18:00 KS 00.006

**Forward Photon Measurement in Proton-Oxygen Run at the LHC with the LHCf Experiment** — •VLERA HAJDINI, PROF. DR. CIGDEM ISSEVER, and DR. CLARA LEITGEB — Physics Institute, Humboldt University of Berlin

The Large Hadron Collider forward (LHCf) experiment plays a fundamental role in Ultra High Energetic Cosmic Ray (UHECR) physics by providing tuning data for the hadronic interaction models used for Extensive Air Shower (EAS) simulations. LHCf measures neutral particles ( $\gamma$ ,  $\pi^0$ ,  $n$ ) in the very forward region ( $\eta > 8.4$ ) produced at the ATLAS interaction point (IP1), using two sampling calorimeters, Arm1 and Arm2, installed 140 m on both sides of the IP1.

In July 2025, LHCf participated in the first proton-Oxygen (p-O) collision run at the LHC, collecting data at  $\sqrt{s_{NN}} = 9.6$  TeV. Forward particle production in p-O collisions is particularly relevant for UHECR studies, as it reproduces one of the projectile-target combinations characteristic of atmospheric interactions initiated by primary cosmic rays.

With a photon energy resolution of about 2% and a position resolution better than 40  $\mu\text{m}$ , LHCf is well suited to investigate forward photon production with high precision. This contribution presents the current status of the photon analysis in p-O collisions.

## T 63: Invited Overview Talks IV

Time: Thursday 11:00–12:30

Location: AudiMax

### Invited Overview Talk

T 63.1 Thu 11:00 AudiMax

**Binary Black Hole Populations: Scientific Perspectives for the Einstein Telescope** — •MICHELA MAPELLI — Institut für Theoretische Astrophysik, Zentrum für Astronomie, Universität Heidelberg, Heidelberg, Germany

The fourth gravitational-wave transient catalog contains more than 200 binary compact-object merger candidates, the vast majority of which involve black holes. These data represent a genuine revolution in black hole science. In this talk, I will focus on the implications of these new observations for our understanding of the astrophysical formation of such systems across cosmic time. I will discuss the challenges of explaining the inferred black hole merger-rate density and of accounting for the most massive systems detected so far – with masses inside or above the pair-instability mass gap. In the second part of the talk, I will briefly touch upon the scientific prospects of next-generation detectors. The Einstein Telescope is expected to observe binary black hole mergers out to redshift  $z \sim 100$ . Together with LISA, it will open up the opportunity for multi-band gravitational-wave astronomy and will probe the largely uncharted territory of intermediate-mass black holes.

### Invited Overview Talk

T 63.2 Thu 11:30 AudiMax

**JUNO's First Light: High-Precision Reactor Neutrino Oscillations** — •MICHAEL WURM for the JUNO-Collaboration — Johannes Gutenberg-Universität Mainz, Germany

The JUNO experiment in southern China is designed for a high-precision measurement of reactor antineutrino oscillations. With a 20-kiloton liquid scintillator target and 17,600 20-inch photomultiplier tubes, JUNO is the largest detector of its kind and is expected to achieve an exceptional energy resolution of about 3% at 1 MeV. Located 55 km from the Taishan and Yangjiang nuclear

power plants, JUNO is located at the first solar oscillation maximum, enabling precise measurements of the oscillation pattern and sensitivity to the neutrino mass ordering. This configuration also provides outstanding sensitivity to the solar oscillation parameters,  $\theta_{12}$  and  $\Delta m_{21}^2$ .

JUNO began operations in August 2025. Following a brief calibration phase, 59 days of stable data-taking were analyzed to deliver the first oscillation results, improving the uncertainties on the solar oscillation parameters by a factor of 1.6 relative to the combination of all previous measurements.

Having demonstrated performance consistent with and in some cases exceeding design specifications, JUNO will continue data collection to accumulate the statistics required for a definitive determination of the neutrino mass ordering. In parallel, its unprecedented size makes JUNO a powerful observatory for astrophysical neutrinos, particularly those from the Sun and core-collapse supernovae.

### Invited Overview Talk

T 63.3 Thu 12:00 AudiMax

**Flavour physics at the precision frontier: recent highlights from the LHCb and Belle II experiments** — •EVELINA GERSABECK — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Gustav-Mie-Haus 02 025, Hermann-Herder-Straße 3b, D-79085 Freiburg im Breisgau

Quark flavour physics focuses on precision tests of the Standard Model and searches for hints of physics beyond the Standard Model by looking for deviations from SM predictions in measured branching fractions, angular observables, matter-antimatter asymmetries etc. The two leading flavour physics experiments, Belle II, located at KEK in Tsukuba, Japan, and LHCb at the LHC, CERN, Switzerland, are actively recording unprecedented amounts of data. In this talk I will discuss recent results from Belle II and LHCb, their complementarity and aspects of possible collaboration.

## T 64: Invited Topical Talks III

Time: Thursday 13:45–15:45

Location: AudiMax

## Invited Topical Talk

T 64.1 Thu 13:45 AudiMax

**Charting the Higgs Sector with Effective Field Theories** — •ILARIA BRIVIO — Dipartimento di Fisica e Astronomia, Università di Bologna and INFN, Sezione di Bologna, via Irnerio 46, Bologna, Italy

With no clear signs of new resonances at the LHC, searches for physics beyond the Standard Model are increasingly targeting small indirect effects potentially induced by heavy physics beyond the collider's reach, which are captured by Effective Field Theories (EFTs). While the Standard Model EFT (SMEFT) is the established framework for this purpose, there is growing interest in scenarios that lie outside its underlying assumptions. An interesting way to explore them is by adopting the Higgs EFT (HEFT) – also known as electroweak chiral Lagrangian – which provides a more general EFT extension of the SM.

In this talk, I will introduce the basic ideas behind HEFT and explain how it differs conceptually from SMEFT. I will highlight the kinds of phenomenological signatures that distinguish the two approaches and provide an overview of the state of the art in the theoretical development of HEFT and its application at the LHC.

## Invited Topical Talk

T 64.2 Thu 14:15 AudiMax

**Probing CP invariance of Higgs boson production and decay and its interpretation in effective field theories with the ATLAS detector** — •LORENZO ROSSINI — University of Freiburg

The origin of the observed baryon asymmetry in the universe is one open question that can be explained if the three Sakharov conditions are fulfilled. One of these conditions includes the violation of the invariance under combined charge (C) and parity (P) conjugation. However, the magnitude of CP violating effects in the Standard Model (SM) is not enough to explain the observations. The Higgs boson is a promising candidate to search for additional CP-violating interactions.

The ATLAS experiment at the LHC has a vast program of measurements of the properties of the Higgs boson, and in particular its CP properties in interactions with gauge bosons or fermions. This talk will summarize tests of CP invariance of Higgs boson production and decay, and the interpretation of the results using Effective Field Theory, with focus on analyses in which the decay mode into a pair of tau-leptons is exploited

Moreover, comparison (and future combinations) with other ATLAS analyses will be discussed. This talk will present results from analyses based on proton-proton collision data collected by the ATLAS experiment at a center-of-mass energy of  $\sqrt{s}=13$  TeV and  $\sqrt{s}=13.6$  TeV during Run 2 and early Run 3.

## Invited Topical Talk

T 64.3 Thu 14:45 AudiMax

**b-tagging unlocks the Higgs potential** — •NICOLE HARTMAN — Technical University of Munich — ORGINS Data Science Lab

The Higgs potential governs electroweak symmetry breaking, but its form has yet to be experimentally verified and could impact the future stability of the universe. A first experimental probe of the Higgs potential will come from measuring the simultaneous production of two Higgs bosons (di-Higgs), an exceptionally rare process. This talk presents the latest results from ATLAS on measurements for di-Higgs in the most abundant final state with four b-quarks, as well as searches for additional Higgs bosons predicted in beyond the SM scenarios. The central challenge for these analyses is an accurate prediction of the quantum chromodynamics background, and generative AI techniques (normalizing flows) are showcased to model these challenging-to-simulate backgrounds in high dimensions.

In our quest to discover di-Higgs, the discovery channels will all include b-jets. The state-of-the-art for b-jet identification (or b-tagging) on ATLAS is a transformer model, and we present the latest developments in b-tagging with multi-task, multi-modal models. By increasing the size of these models, we demonstrate that particle physics can benefit from the foundation model scale that launched the AI revolution of Large Language Models. By casting jet taggers as a first foundation model for LHC physics, they can also be customized for our physics goals. We highlight how an end-to-end optimizable analysis can fine-tune a jet-tagger for a HH physics search, and how differentiable building blocks can automate future scientific discovery.

## Invited Topical Talk

T 64.4 Thu 15:15 AudiMax

**Modern Machine Learning for LHC Event Generation** — •RAMON WINTERHALDER — TIFLab, Università degli Studi di Milano & INFN Sezione di Milano, Italy

High-precision simulations from first principles are a cornerstone of LHC physics. With the upcoming high-luminosity phase of the LHC and the significant increase in experimental data, traditional simulation pipelines face growing challenges in terms of computational cost and efficiency. In this talk, I will discuss how modern machine-learning methods and computing paradigms can accelerate event generation while preserving theoretical accuracy. I will focus on three distinct and complementary approaches: neural importance sampling, as implemented in the MadNIS framework; machine-learned surrogate models for expensive matrix-element calculations; and hardware-aware implementations that exploit GPU acceleration and parallelization for efficient large-scale deployment. Together, these developments significantly reduce computational cost and pave the way towards the first ML-based event generator.

## T 65: Invited Topical Talks IV

Time: Thursday 13:45–15:45

Location: MED 00.915

## Invited Topical Talk

T 65.1 Thu 13:45 MED 00.915

**Atmospheric neutrino oscillations with IceCube and the IceCube Upgrade** — •JAN WELDERT — Johannes Gutenberg Universität Mainz

DeepCore, the low-energy extension of the IceCube Neutrino Observatory, detects hundreds of thousands of atmospheric neutrinos per year at the basic filter level. This enables the oscillation properties of these elusive particles to be studied. Even in its current configuration, the detector achieves a level of precision to atmospheric oscillation parameters comparable to that of long-baseline accelerator experiments. One of DeepCore's particular strengths lies in its wide range of baselines, some of which pass through the Earth's dense core. As part of the so-called IceCube Upgrade, additional optical modules were added to the detector earlier this year. Compared to the existing modules, these new modules have larger photo cathode areas and are spaced closer together. This substantially increases the number of atmospheric neutrinos detected, particularly at energies of a few GeV. Additionally, the energy, direction and topology of the detected neutrinos can be reconstructed with greater precision. All of this significantly increases IceCube's sensitivity to atmospheric neutrino oscillation studies, especially the neutrino mass ordering.

In my talk, I will explain how we conduct atmospheric neutrino oscillation studies in IceCube, present our latest results and show the potential of the IceCube Upgrade. The focus will be on the determination of the atmospheric oscillation parameters and the neutrino mass ordering.

## Invited Topical Talk

T 65.2 Thu 14:15 MED 00.915

**Exploring the Gravitational Wave Universe with Pulsar Timing Arrays** — •ANDREA MITRIDATE — Imperial College London, London, UK

By tracking the radio emission from a collection of millisecond pulsars, several pulsar timing array collaborations have found evidence for a background of gravitational waves permeating our galaxy. In this talk, I will discuss how we obtained this evidence, the ongoing efforts to identify the source of this signal, and explore its implications for cosmology and astrophysics.

## Invited Topical Talk

T 65.3 Thu 14:45 MED 00.915

**Supernova Remnants as Accelerators of Galactic Cosmic Rays** — •ROBERT BROSE — Universität Potsdam

Particle acceleration in supernova remnants (SNRs) remains a cornerstone for understanding cosmic-ray (CR) origin. Multi-messenger signatures from SNRs are hereby crucial in pinning down the particularities of the acceleration process. Improvements in instrumental sensitivity from radio to gamma-ray energies and improved statistics in direct CR measurements have started to reveal cracks in the long-standing paradigm that SNRs are indeed the solely producers of Galactic CRs.

In this talk, we present a brief and candid overview of the numerical methods and assumptions typically employed in modeling shock acceleration in SNRs. Then we focus on multiwavelength (and multimessenger) signals from SNRs bridging from very early stages, a few years after the explosion, to times where CRs start to leak out of the SNR's interior and considerably change the observational signatures.

## Invited Topical Talk

T 65.4 Thu 15:15 MED 00.915

**Supermassive black holes and their relativistic jets: a beacon into the early universe** — •LEA MARCOTULLI — Deutsches Elektronen-Synchrotron (DESY), Zeuthen, Germany

About 10% of accreting supermassive black holes (AGN) at the center of galaxies are capable of launching extreme relativistic jets. Shining as bright as a hundred trillion Suns and detected at the dawn of time, these AGNs and their jets have been studied for decades, from radio up to gamma-rays. However, many open questions still remain about\* these powerful monsters. When, in the history of the universe, were the most luminous jets more numerous, and what is their

connection with rapid supermassive black-hole growth at early cosmic times? Is there an evolutionary sequence linking jets of different power? How can we find and identify more of these extreme jets in the very early universe? In this talk, I will highlight how we can tackle some of these open issues through means of multi-wavelength and time-domain studies, in particular exploiting the capabilities of current and future X-ray and gamma-ray missions.

## T 66: Neutrino Physics IV

Time: Thursday 16:15–18:00

Location: AudiMax

T 66.1 Thu 16:15 AudiMax

**Tests of a full Monte Carlo simulation for keV-sterile neutrino searches with the KATRIN experiment in a mockup** — •TOM GEIGLE for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT), Karlsruhe

Sterile neutrinos in the keV mass range are a compelling dark matter candidate predicted by many extensions of the Standard Model. A distinctive signature would be a kink-like distortion in the tritium  $\beta$ -decay spectrum. While KATRIN currently probes the endpoint region to determine the effective neutrino mass, its next phase, TRISTAN, will extend the search across the full spectrum using a novel multi-pixel silicon drift detector and upgraded readout infrastructure, complemented by dedicated beamline modifications.

Sensitivity in this regime is strongly influenced by systematics such as electron scattering in the source and detector-response effects. To address these challenges, we have developed KAMELEON\* a high-efficiency, Geant4-based Monte Carlo simulation of the entire KATRIN beamline. In this presentation, we outline its architecture and performance, compare simulation results with dedicated detector-mockup measurements, and present initial studies of systematic uncertainties relevant for the keV-scale sterile neutrino search.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 66.2 Thu 16:30 AudiMax

**Long-term evolution of the KATRIN background** — •FLORIAN FRÄNKLE for the KATRIN-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT)

The Karlsruhe Tritium Neutrino (KATRIN) experiment is a large-scale effort with the objective to determine the effective electron anti-neutrino mass with an unprecedented sensitivity of better than  $0.3 \text{ eV}/c^2$  (90% CL) in a model-independent way based on precision  $\beta$ -decay spectroscopy of molecular tritium. KATRIN completed its neutrino mass measurement campaigns at the end of 2025 and so far has improved the upper bound on the effective electron-neutrino mass to  $0.45 \text{ eV}/c^2$  (90% CL) based on data collected before July 2021.

A major limiting factor for the KATRIN sensitivity is a background level which is an order of magnitude higher than the original design specification. This presentation will provide an overview of the long-term evolution of the background during the neutrino mass measurement campaigns and share insights on the underlying background mechanisms.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 66.3 Thu 16:45 AudiMax

**Status of Theia simulations** — •JOHANN MARTYN, AMALA AUGUSTHY, NOAH GOEHLKE, ALFONS WEBER, and MICHAEL WURM — Johannes Gutenberg-University Mainz

Theia is a large-scale neutrino detector concept, designed to simultaneously exploit Cherenkov and scintillation light, potentially enabling a broad range of physics goals. The detector concept leverages recent advancements for the separation of Cherenkov and scintillation light, such as water-based liquid scintillator (WbLS), fast photo-detectors, dichroicons, and novel reconstruction techniques. This allows for the reconstruction of the particle direction, as well as particle identification via Cherenkov light while providing an enhanced energy resolution and low energy threshold from the scintillation. The proposed scientific program includes long-baseline neutrino oscillation measurements and CP violation searches, precision solar neutrino studies, search for the diffuse supernova neutrino background (DSNB), and ultimately neutrinoless double beta decay. This talk presents an overview of Theia and the current status of the Geant4 based Theia simulation framework, focusing on the ongoing efforts to optimize the detector configurations.

T 66.4 Thu 17:00 AudiMax

**Sensitivity studies for neutron flux measurements in the LEGEND experiment** — •LORIS STEINHART for the LEGEND-Collaboration — University of Tuebingen

Achieving the ambitious background goals of the next phase of the Large Enriched Germanium Experiment for Neutrinoless Double-Beta Decay (LEGEND) requires a precise understanding of neutron-induced backgrounds within the detector array. In this contribution, sensitivity studies for measuring the neutron flux in LEGEND are presented using a dedicated Gadolinium-loaded polyethylene (GdPE) string introduced into the experimental setup. Neutron captures on gadolinium produce characteristic signatures that can be identified via coincident energy depositions in the surrounding germanium detectors. By exploiting these correlations, neutron capture rates in the GdPE can be reconstructed and used to infer the neutron flux at the center of the detector array. This talk will discuss the underlying analysis strategy, simulation-based sensitivity estimates, and first experimental considerations, and will outline the relevance of this measurement for constraining neutron-related backgrounds and improving the overall sensitivity of LEGEND to the  $0\nu\beta\beta$  decay search.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 66.5 Thu 17:15 AudiMax

**DUNE-PRISM: An innovative technique for neutrino oscillation analysis** — •IOANA ALEXANDRA CARACAS — JGU Mainz, Germany

As long baseline neutrino experiments are entering the high-precision era, an increased sensitivity towards constraining the oscillation parameters space is expected. A classical approach for the oscillation predictions is prone to systematic uncertainties, due to the incompleteness of neutrinos interaction cross section modelling. This would in turn limit the capability to obtain the physics goals for modern long baseline experiments, such as the Deep Underground Neutrino Experiment (DUNE). An innovative technique, the Precision Reaction Independent Spectrum Measurement (PRISM) has been proposed and studied within the DUNE collaboration. This novel method is designed to measure and predict neutrino oscillated spectra on a data-driven basis, thus avoiding many neutrino interaction uncertainties. In this regard, the Near Detector (ND) is designed to move off the neutrino beam axis at several locations up to a distance of 28.5 m. Different neutrino fluxes are thus sampled and these ND off-axis results are further used to predict the neutrino oscillated spectrum at the DUNE Far Detector. The prediction obtained with the DUNE-PRISM analysis framework and preliminary results regarding the systematics impact on the oscillation parameters will be presented. Ongoing studies to improve the overall sensitivity to the oscillation parameters and reduce their dependence on the interaction model will also be discussed. The importance of sampling the entire off-axis space will also be high-lighted.

T 66.6 Thu 17:30 AudiMax

**JUNO detector response determination through calibration data** — •MARCO MALABARBA<sup>1,2</sup> and LIVIA LUDHOVA<sup>1,2</sup> — <sup>1</sup>GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — <sup>2</sup>Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

JUNO (Jiangmen Underground Neutrino Observatory) is a multipurpose neutrino physics experiment in China. Its construction ended in 2024 and it has been taking data since August 2025. The target consists of 20 kton of organic liquid scintillator. The optical photons are collected by photomultiplier tubes which provide a geometrical coverage of  $\sim 78\%$ . JUNO has already achieved world leading precision on the neutrino solar oscillation parameters with 59.1 days of data taking. To obtain this result, as well as to achieve its future goal of determining the neutrino mass ordering, an evaluation of the detector response, in terms of temporal stability, detector non-uniformity, energy resolution, and energy non-linearity, is needed. All these quantities can be determined both through calibration ( $^{137}\text{Cs}$ ,  $^{54}\text{Mn}$ ,  $^{68}\text{Ge}$ ,  $^{40}\text{K}$ ,  $^{60}\text{Co}$ , AmC, and laser) and natural sources (such as  $^{214}\text{Po}$ , spallation neutrons, and some cosmogenic isotopes as  $^{12}\text{B}$  and  $^{11}\text{C}$ ). In this talk, an analysis of the calibration sources will be presented. In particular, different fit models have been developed to take into account the different decay details of each individual nuclide. The results allow to infer the concentration of  $^{14}\text{C}$  and, when combined with the spectra of  $^{12}\text{B}$  and  $^{11}\text{C}$ , also to determine the energy non-linearity for  $e^-$ ,  $e^+$ , and  $\gamma$ , an essential building block for reactor neutrino analysis.

T 66.7 Thu 17:45 AudiMax

**Liquid Handling System and radiopurity of the OSIRIS detector** — MANUEL BÖHLES<sup>1</sup>, MARCEL BÜCHNER<sup>1</sup>, DANIELA FETZER<sup>1</sup>, ARSHAK JAFAR<sup>1</sup>, •OLIVER PILARCZYK<sup>1</sup>, TOBIAS STERR<sup>2</sup>, and MICHAEL WURM<sup>1</sup> — <sup>1</sup>Johannes Gutenberg-University Mainz — <sup>2</sup>Eberhard Karls Universität Tübingen

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator experiment in Jiangmen (China). Its main scientific goal is to determine the neutrino mass ordering by measuring electron antineutrinos from two nearby nuclear power plants at a distance of ~53 km. To achieve this goal the liquid scintillator had to be thoroughly cleaned to make sure it meets the optical and radiopurity requirements.

The 20m\* OSIRIS pre-detector is the last device behind these purification plants in an underground hall close to the main JUNO detector. Its task was to monitor the radiopurity of the purified scintillator before it was filled in the JUNO detector. OSIRIS was operated in batch-mode to qualify the purity of scintillator samples and its own experimental sensitivity before and during JUNO filling. To ensure every batch of the scintillator stays about 24h inside OSIRIS a temperature gradient can be established in the detection volume. This talk covers the operations and results from the commissioning phase of the OSIRIS detector as well as the background levels and sensitivity that were reached for U/Th.

The work is supported by the DFG Research Unit 'JUNO' (FOR5519) and the Cluster of Excellence PRISMA+.

## T 67: Top Physics III

Time: Thursday 16:15–18:00

Location: KH 00.011

T 67.1 Thu 16:15 KH 00.011

**Towards a top quark mass measurement in the all-jets final state using full Run 2 data** — •LENNERT GRIESING, PETER SCHLEPER, JOHANNES LANGE, HARTMUT STADIE, LUKAS SCHALLER, and YANNEK GRUEL — Institute of Experimental Physics, Hamburg University, Germany

A precise measurement of the top quark mass is important for testing the Standard Model of particle physics. While the CMS experiment has achieved high precision using a profile likelihood fit in the lepton+jets final state, it has not been applied to the all-jets final state, yet. This final state remains challenging due to the large QCD multijet background and the complexities of the event reconstruction.

A new measurement in this channel is being developed using data collected with the CMS experiment at the LHC during Run 2 at  $\sqrt{s} = 13$  TeV. The analysis strategy combines optimized event selection, data-driven background estimation, and systematic uncertainty studies tailored to the all-jets final state. A profile-likelihood fit is employed to extract the top quark mass while simultaneously constraining systematic uncertainties. Leveraging the full statistical power of the dataset, this analysis aims to provide a complementary, high-precision measurement of the top quark mass. We report on the current status of this analysis.

T 67.2 Thu 16:30 KH 00.011

**Comparing Parton-Shower Models in Top-Quark Production and Reweighting Between Models with Machine Learning** — •ARSHIL SHAIKH<sup>1,2</sup>, ROMAN KOGLER<sup>1,2</sup>, and DOMINIC STAFFORD<sup>2</sup> — <sup>1</sup>Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — <sup>2</sup>Deutsches Elektronen-Synchrotron (DESY), Notkestr.85, 22607 Hamburg, Germany

Accurate modeling of parton-shower dynamics is essential for precision studies of top-quark production. In our setup, next-to-leading-order matrix-element events are generated with POWHEG, which can be interfaced with different parton-shower approaches. These include the transverse-momentum-ordered dipole shower of Pythia8 and the antenna-based shower implemented in Vincia. Their distinct approximations can lead to notable differences in jet and jet-substructure observables.

In this work, we study  $pp \rightarrow t\bar{t} \rightarrow$  semileptonic events produced with POWHEG+Pythia8 and POWHEG+Vincia, comparing the  $t\bar{t}$  system kinematics, jet characteristics, and jet-substructure variables such as  $N$ -subjettiness, generalised angularities, and energy-correlation functions. Furthermore, we use the DCTR (Deep neural networks using Classification for Tuning and Reweighting) technique to reweight Pythia8 events such that they reproduce Vincia-like distributions, without requiring the computationally expensive step of re-running the full detector simulation. This study highlights key differences between parton-shower models and demonstrates the potential of machine-learning-based reweighting to efficiently bridge them.

T 67.3 Thu 16:45 KH 00.011

**Investigation of boosted top quarks and overlapping jets in the all-jets top quark mass measurement** — •YANNEK RUWEN GRUEL, PETER SCHLEPER, JOHANNES LANGE, HARTMUT STADIE, LENNERT GRIESING, and LUKAS SCHALLER — Universität Hamburg, Hamburg, Germany

At high momenta, the distances between the jets of top quark decay products are smaller due to the Lorentz boost. As a result, the jets may overlap or even merge. This study investigates the influence of these effects on the measurement of the top quark mass with a resolved selection in the all-jet channel with the CMS experiment. For the event reconstruction, a kinematic fit is used that operates on the hypothesis of non-overlapping jets. Due to the strict trigger cuts for  $p_T$ , a large number of top quarks with high  $p_T$  are expected. The number of events with overlapping and merged jets is quantified and the distortion of the event reconstruction is studied.

T 67.4 Thu 17:00 KH 00.011

**Unfolding tops - using ATLAS to create detector-independent data** — •ELIA SCHMIDT, RICHARD NISIUS, CHANGQIAO LI, XUEWEI JIA, and DIMBINIATNA

RAFANO HARANA — Max Planck Institute for Physics

The top-quark mass is an important fundamental parameter of the standard model. While its exact value has profound implications for Particle Physics, e.g. the stability of the QCD vacuum, its determination is hampered by theoretical ambiguities. The most precise measurements, performed by the big LHC Collaborations, are systematically limited and suffer from substantial modelling uncertainties.

In this presentation I will give a short overview of the theoretical issues associated with top-quark mass measurements and motivate the concept of data unfolding. The ongoing ATLAS analysis I am involved in has the goal of publishing an unfolded invariant mass distribution of lepton-jet pairs from  $t\bar{t}$  decays. I use it as an example to show how data from ATLAS are processed to create a distribution which is essentially independent of detector-related uncertainties. The unfolded distribution can then be compared to all theoretical predictions, allowing conceptually sound top-quark mass determinations within a chosen model.

T 67.5 Thu 17:15 KH 00.011

**Measurement of the top-quark mass using singly produced top-quarks in the t-channel** — •LUKAS KRETSCHMANN, DOMINIC HIRSCHBÜHL, and WOLFGANG WAGNER — Bergische Universität Wuppertal, Germany

Almost all measurements of the top-quark mass have been performed using top-quark-antiquark pair-production events, measurements in other channels can be important inputs for a global combination. First studies for a measurement of the top-quark mass using t-channel single top-quark events are shown. This channel is statistically independent to the top-quark-antiquark pair-production measurements and has different systematic uncertainties associated to it, e.g. modelling uncertainties from Monte Carlo event generators. The high rate of background-events is a major challenge in this channel, for this a Graph Neural Network (GNN) is trained to enrich the selection in single top-quark t-channel events. For the determination of the top-quark mass the invariant mass of the charged lepton and the b-quark jet is used as a sensitive observable employing a maximum likelihood fit.

T 67.6 Thu 17:30 KH 00.011

**Quark mass effects in the gradient flow observables** — •ROBERT MASON and ROBERT HARLANDER — TTK, RWTH Aachen University, Aachen, Germany

The gradient flow provides a consistent scheme for matching perturbation theory and lattice field theory. In the continuum this has typically been done with the simplifying assumption that quarks are massless. However, this neither reflects lattice computations nor physical reality. In this talk we discuss the computation of three quantities fundamental to the gradient flow, the vacuum expectation values of the flowed fermion and gluon condensates and the fermion kinetic operator, and consider their quark mass effects to the three loop level. We then briefly discuss the idea of Takaura et. al. to use these mass effects with lattice data for precision estimates of the quark masses.

T 67.7 Thu 17:45 KH 00.011

**New method for extracting the mass of valence quarks in protons** — •JIANMING WANG — Department of Physics, Lanzhou University, Lanzhou, China

In this paper, the extraction of the mass of valence quarks in protons no longer depends on the exact mass of each quark, but seeks the exact mass ratio of different valence quarks in the same system through experiments. By finding the exact ratio of the mass of the up quark and the down quark, the relationship among the three valence quarks can be found. Based on the experimental results of Sequest carried out by Fermilab in 2021, through analysis, the accurate ratio of up quark to down quark mass ( $m_u/m_d = 0.707$ ) is obtained, and the mass triangle is established. It is deduced that the sum of squares of up quark mass in protons is equal to the square of down quark mass. The mathematical expression is:  $m_u^2 + m_u^2 = m_d^2$ .

## T 68: Standard Model Physics III

Time: Thursday 16:15–17:45

Location: KH 00.014

T 68.1 Thu 16:15 KH 00.014

**Study of sensitivity of VBS VZjj semi-leptonic final states to vector boson polarisation observables** — •ARYAN BORKAR, THOMAS TREFZGER, RAIMUND STRÖHMER, and GIA KHORIAULI — University of Würzburg

The electroweak symmetry breaking mechanism can be experimentally tested in the electroweak vector boson scattering (VBS) processes that occur in proton-proton collisions at the LHC.

The unitarity of VBS cross sections of longitudinally polarised bosons  $V_{1,L} V_{2,L} \rightarrow V_{3,L} V_{4,L}$ , where  $(V = W^\pm, Z)$ , in the Standard Model are preserved due to inclusion of the Feynman diagrams with the Higgs boson propagator in calculations. Thus, precise measurements of VBS processes of longitudinally polarised vector bosons are important experimental tests of the validity of the Brout-Englert-Higgs mechanism.

We present the preliminary study of the potential of measurements of VZ VBS polarisation observables, in the fiducial phase space as defined by the geometry of ATLAS detector. VBS processes with semi-leptonic final states, where Z decays to a pair of same-flavour oppositely charged leptons and V decays hadronically, are considered in the study.

T 68.2 Thu 16:30 KH 00.014

**Measurement of the differential di-boson cross-section in semileptonic final states at  $\sqrt{s} = 13$  TeV in  $140 \text{ fb}^{-1}$  of  $pp$  collisions with the ATLAS detector** — •ANUBHAV GUPTA, CHRIS M. DELITZSCH, and AMARTYA REJ — TU Dortmund University, Otto-Hahn-Str. 4A 44227 Dortmund

The measurement of electroweak vector boson pair (VV) production cross-sections is a critical test of the Standard Model (SM), probing electroweak boson self-interactions and the electroweak theory. While VV production has been well-studied in fully leptonic decay channels at  $\sqrt{s} = 13$  TeV, semileptonic channels have only been measured at  $\sqrt{s} = 8$  TeV.

This analysis presents the first measurement of di-boson production in the semileptonic channel (leptons and a large radius jet) at  $\sqrt{s} = 13$  TeV, taking advantage of its higher branching fraction compared to fully leptonic decays and a cleaner signature than fully hadronic decays. The semileptonic channel is particularly sensitive at high energies, offering strong potential for detecting new physics beyond the SM in the tails of kinematic distributions.

The study includes particle-level inclusive and differential cross-section measurements, along with constraints on dimension-6 Effective Field Theory (EFT) operators in the Warsaw basis, affecting electroweak triple gauge couplings, at the folded level.

T 68.3 Thu 16:45 KH 00.014

**Analysis of multi- $\tau$  final states of diboson processes with the ATLAS detector** — PHILIP BECHTLE, YANN BUCHHOLZER, KLAUS DESCH, CHRISTIAN GREFE, and •SIMON THIELE — Rheinische Friedrich-Wilhelms Universität Bonn

The process  $ZZ \rightarrow 4\tau$  is a theoretically well understood standard model process but has never been observed. In addition to the small cross section and branching ratio there are several challenges posed by this channel. Among them are the fake estimation of combinations of up to four hadronic tau-candidates, the mass reconstruction in final states with at least four neutrinos, the pair-wise combination of the  $\tau$ 's, and the selection of triggers to use.

Additionally to being itself an interesting discovery, the work on multi- $\tau$  final states can serve as a template for future  $HH \rightarrow 4\tau$  searches, which could add to the discovery potential for triple Higgs couplings at the LHC. Furthermore there is the potential to discover other heavy scalars in the  $4\tau$  final state if there is resonant  $A \rightarrow HH$  production as opposed to merely the off-shell standard model production.

In this talk I will present an overview of previous efforts and the initial work already done in this analysis, going over theoretical expectations and the analysis strategy.

T 68.4 Thu 17:00 KH 00.014

**Sensitivity and background studies related to the measurement of the tau-lepton's anomalous magnetic moment in proton collisions with the ATLAS detector.** — •RUBEN BIES, VALERIE LANG, and MARKUS SCHUMACHER — University of Freiburg

Anomalous magnetic moments are a property of leptons that modify their behaviour in electromagnetic fields through higher order corrections in quantum field theory. These quantities have been measured with great precision for electrons and muons and have shown some tensions with the predictions in the Standard Model (SM). Measurements of the tau-lepton's anomalous magnetic moment are predicted to be most sensitive to beyond SM effects, but the tau-lepton's lifetime is too short for similar experiments as for electrons and muons. In recent years, measurements of the anomalous magnetic moment for the tau-lepton have been successfully performed using ultra-peripheral heavy-ion collisions as well as proton collisions at the Large Hadron Collider (LHC).

This presentation will outline the analysis strategy of the ATLAS collaboration to perform a measurement of the tau-lepton's anomalous magnetic moment in proton collisions using the datasets from the second and third running periods of the LHC. Initial studies on the selection optimization and improvements of the signal to background ratio, as well as first background estimates will be shown.

T 68.5 Thu 17:15 KH 00.014

**Measuring the  $\tau$  Lepton Polarization in  $Z \rightarrow \tau_{\text{lep}} \tau_{\text{had}}$  Decays with ATLAS Run 2 Data** — •LAMAM GULIYEVA<sup>1</sup>, PHILIP BECHTLE<sup>2</sup>, and CHRISTIAN GREFE<sup>2</sup> — <sup>1</sup>Bergische Universität Wuppertal, Gaußstr. 20, D-42119 Wuppertal — <sup>2</sup>Physikalisches Institut der Universität Bonn, Nußallee 12, D-53115 Bonn

The polarization of leptons produced in Z-boson decays is a key parameter of the electroweak sector, as it provides direct insight into the parity-violating structure of the  $Z\ell\ell$  coupling. In particular,  $\tau$  leptons constitute a sensitive probe of electroweak interactions due to their short lifetime and decays occurring within the detector volume. Their hadronic decay modes are especially sensitive to spin-dependent observables, enabling a precise determination of their polarization in Z-boson decays.

This contribution presents a new measurement of the  $\tau$ -lepton polarization in  $Z \rightarrow \tau_{\text{lep}} \tau_{\text{had}}$  decays using ATLAS Run-2 data collected in 2018 at  $\sqrt{s} = 13$  TeV. This measurement is based on a statistically independent and substantially larger dataset than the Run 1 analysis, making it fully complementary to the previous ATLAS result.

T 68.6 Thu 17:30 KH 00.014

**Sensitivity to lepton-flavour-violating decays of the Z boson using a data-driven background estimate with the ATLAS experiment** — •NAMAN KUMAR BHALLA, VALERIE LANG, and MARKUS SCHUMACHER — Albert-Ludwigs-Universität Freiburg

One of the primary goals of the Large Hadron Collider (LHC) program is to look for phenomena beyond the Standard Model (SM) of particle physics. One such phenomenon is lepton flavour violation (LFV), which has already been observed in neutrino oscillations, but not in processes involving charged leptons. A search for LFV in decays of the Z boson with charged leptons in the final state, such as  $Z \rightarrow e\tau_\mu$  and  $Z \rightarrow \mu\tau_e$ , is of high interest and well motivated by various beyond-SM theories. This search can be performed using a data-driven background estimate, which takes advantage of the idempotency of SM backgrounds under the exchange of an electron and a muon. The symmetry is broken only by the difference in branching ratios between LFV decays with  $e\tau$  and  $\mu\tau$  final states.

This talk discusses the achievable sensitivities for the search of LFV decays of the Z boson using this data-driven background estimate. The full Run-2 data set is used, which was collected by the ATLAS detector in  $pp$  collisions at  $\sqrt{s} = 13$  TeV, corresponding to  $L_{\text{int}} = 140 \text{ fb}^{-1}$ . The talk presents the data-driven estimate and a new methodology to construct and implement a robust statistical model.

## T 69: Methods in Particle Physics IV

Time: Thursday 16:15–17:45

Location: KH 00.020

T 69.1 Thu 16:15 KH 00.020

**Investigating the use of fast detector simulation for jet flavor identification algorithms in ATLAS** — DIPTAPARNA BISWAS, CAROLINA COSTA, MARKUS CRISTINZIANI, CARMEN DIEZ PARDOS, IVOR FLECK, GABRIEL GOMES, JAN JOACHIM HAHN, NIKOLAOS KAMARAS, VADIM KOSTYUKHIN, NILS BENEDIKT KRENGEL, •AUSTIN OLSON, INÊS PINTO, SEBASTIAN RENTSCHLER, ELISABETH

SCHOPF, KATHARINA VOSS, WOLFGANG WALKOWIAK, and ADAM WARNERBRING — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

In the ATLAS experiment, identification of quark flavor in a given jet is done with machine learning algorithms known as “taggers”, trained with simulated events. Taggers' performance depend on accurate simulation of jet constituents.

Previously, only tracks associated to jets were used in training, but the latest tagger, GN3, also uses all particle-flow constituents. At the same time, approximation of calorimeter showers with generative modeling (FastSim) is becoming more adopted by the ATLAS Collaboration in lieu of full Geant4 simulation (FullSim).

Many rare signal samples and several background samples are produced using FastSim, making it essential to evaluate the performance of these samples in this new GN3 model. Recent studies indicate significant scope for improving performance of GN3-like models solely by increasing the amount of training data, making FastSim samples a desirable option for model training itself. This talk presents comparisons of FastSim and FullSim samples in the context of ATLAS taggers.

T 69.2 Thu 16:30 KH 00.020

**Identification of low  $p_T$  b-hadrons at the ATLAS experiment** — •HAGEN MÖBIUS — DESY, Zeuthen, Germany

The identification of b-hadrons in an event, called b-tagging, is an important part of the physics program of the ATLAS experiment, in particular for Standard Model precision measurements, studies of the Higgs boson and searches for physics beyond the Standard Model. The starting point for standard b-tagging techniques in the ATLAS experiment are jets, bundles of particles. This leads to constraints on the energy of both the b-hadron and the surrounding hadronic activity and consequently low  $p_T$  b-hadrons in a jet below the jet reconstruction threshold are not reconstructed.

This talk presents an algorithm with a jet-independent b-hadron identification strategy. The algorithm, called the NewVrtSecInclusiveTool, reconstructs secondary vertices that can be associated with the decay of low  $p_T$  b-hadrons. The procedure and performance of the algorithm are discussed. Furthermore, the origins of the tracks contributing to these secondary vertices are examined to assess the accuracy of the b-hadron reconstruction.

T 69.3 Thu 16:45 KH 00.020

**Tagging at ATLAS with GN3: Beyond heavy-flavour** — •DIPAPARNA BISWAS<sup>1</sup> and ATLAS COLLABORATION<sup>2</sup> — <sup>1</sup>Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen, Germany — <sup>2</sup>CERN, Geneva, Switzerland

Accurate identification of jets that originate from heavy-flavour hadrons is pivotal for many ATLAS analyses, from Higgs-boson and top-quark measurements to searches for new physics. We present GN3, our newest jet flavour tagger, which introduces a full-transformer architecture tailored to the environment of LHC Run-2 and Run-3.

GN3 processes low-level track, neutral particle, and muon information to extract correlations between the inputs and infer the origin of the jet. Compared with the current Run-3 baseline, GN2, the new model achieves a significantly better separation of  $b$ - and  $c$ -jets from light-flavour jets across a wide kinematic phase-space.

In this talk, we will discuss the architecture and training workflow, as well as the newest results from GN3. Furthermore, we will highlight the new capabilities added to GN3, which extend its functionality into the realm of  $s$ -tagging.

T 69.4 Thu 17:00 KH 00.020

**Reconstruction of Heavy Neutral Lepton decaying into lepton +  $\rho$  in SHiP** — •HARSHIVRAJ JATINBHAI OZA for the SHiP-SBT-Collaboration — Humboldt Universität zu Berlin, Berlin, Germany

As part of the ongoing search for physics beyond the standard model, CERN has recently approved a new general-purpose beam dump experiment at SPS: SHiP (Search for Hidden Particles). SHiP aims to explore the intensity frontier by searching for feebly interacting particles in the GeV mass regime. Among several well-motivated candidates, the experiment is optimized for the discovery of Heavy Neutral Leptons (HNLs), hypothetical particles that could explain neutrino masses and mixing, provide a mechanism for baryogenesis, and potentially contribute to the dark-matter sector.

This talk presents the mass reconstruction strategy for the HNL decaying into a lepton +  $\rho$  ( $\rightarrow \pi\pi^0$ ), without explicitly reconstructing the  $\pi^0$  exploiting the mass constraint  $(P_\pi + P_{\pi^0})^2 = m_\rho^2$ . Furthermore we explore the feasibility of taking advantage of the Surrounding Background Tagger (SBT) to identify photons from the  $\pi^0$  decay as a means of improving the signal reconstruction and background suppression.

T 69.5 Thu 17:15 KH 00.020

**Reconstruction of Neutrons and Sensitivity to the Decay  $B \rightarrow K n \bar{n}$  at Belle II** — •TIMUR LENKEIT, ALEXANDER HEIDELBACH, THOMAS KUHR, and THOMAS LUECK — Ludwig-Maximilians-Universität München (LMU), München, Germany

Neutrons are often not taken into account in the detector design or the reconstruction software, but can nevertheless play an important role in understanding physical processes. We examine methods to improve neutron reconstruction at the Belle II experiment. Unlike photons or electrons, neutrons do not interact electromagnetically; their energy is recorded only indirectly through secondary particles from hadronic interactions, which results in irregular and diffuse signatures in the electromagnetic calorimeter (ECL). These features make it challenging to distinguish neutrons from other neutral particles. To address this, we investigate machine-learning-based classifiers that combine ECL variables to enhance neutron particle identification. In addition, we explore the use of variables related to the  $K_L^0$  and Muon detector to recover information from neutrons that leave no signal in the ECL.

We then assess how these reconstruction strategies affect the background composition and the achievable sensitivity to the decay  $B \rightarrow K n \bar{n}$ . With these studies, we aim to enable a determination of the corresponding branching fraction.

T 69.6 Thu 17:30 KH 00.020

**Measurement of the  $\eta$  Reconstruction Efficiency at Belle II** — •JOHANNES MIRFANGER, THOMAS KUHR, and THOMAS LUECK — Ludwig-Maximilians-Universität München (LMU), München, Germany

The precise reconstruction of  $\eta$  mesons is essential for a wide range of physics analyses at Belle II. This work presents a data-driven determination of the  $\eta$  reconstruction efficiency using the decay  $D^{*+} \rightarrow D^0 \pi^+$ , comparing the two  $D^0$  decay modes  $D^0 \rightarrow K^- \pi^+$  and  $D^0 \rightarrow K^- \pi^+ \eta$ . By forming the ratio of these channels and correcting for the known branching fractions, we extract the  $\eta$  reconstruction efficiency of the Belle II detector. A key strength of this method is the ability to directly compare data and Monte Carlo simulation, enabling a clean assessment of potential discrepancies between them.

The extracted efficiency is further studied as a function of key kinematic variables, including the  $\eta$  momentum and polar angle. This offers detailed insight into detector performance across phase space. Ongoing work focuses on evaluating the robustness of the efficiency under varied event-selection criteria and on optimizing cut strategies for future analyses. The presentation will discuss the current status and give an outlook on the analysis.

## T 70: Electronics, Trigger, DAQ III

Time: Thursday 16:15–18:00

Location: KH 00.023

T 70.1 Thu 16:15 KH 00.023

**The Hypothesis Firmware for the ATLAS L0 Trigger system for HL-LHC** — •EMANUEL MEUSER — Institut für Physik, Johannes Gutenberg-Universität Mainz

During the upgrade for HL-LHC, parts of the ATLAS detector will be upgraded, and the time-multiplexed L0Global Trigger system will be added to the first-level trigger. As part of this L0Global Trigger system, a hypothesis firmware to evaluate all the trigger objects/candidates of an event in a serialized and non-LHC-synchronous manner will go into operation in 2031.

This hypothesis firmware has to perform multiplicity triggers, as well as topological ones, as configured by a trigger menu. Since this trigger menu can change in periods too short to rebuild and validate new firmware, the hypothesis firmware needs to be runtime-configurable within certain boundaries. The design and implementation of the hypothesis firmware, focusing on resource optimization, robustness, and configuration via a trigger menu, will be discussed.

T 70.2 Thu 16:30 KH 00.023

**Commissioning, Validation, and Simulation of the JUNO hardware trigger logic** — •ZE CHEN<sup>1,2</sup> and LIVIA LUDHOVA<sup>1,2</sup> — <sup>1</sup>GSF Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — <sup>2</sup>Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a large-scale neutrino experiment using a 20-kt liquid scintillator as the Central Detector (CD) surrounded by a 35-kt water Cherenkov veto Detector (WCD). The experiment completed full detector commissioning and subsequently began physics data taking on August 26 2025. Using an exposure of 59.1 days, JUNO has achieved world-leading precision in the measurement of solar neutrino oscillation parameters. Reaching this level of performance requires a robust and accurately functioning hardware trigger system for both subdetectors.

In this talk, we present a comprehensive validation of the JUNO hardware trigger logic using commissioning data. The two JUNO subdetectors employ different trigger logics: the CD uses a multiplicity trigger with dedicated handling of muons, while the WCD adopts a regional scheme that fires when a cluster of Photomultiplier tubes (PMTs) in a local area is hit. To evaluate trigger perfor-

mance, PMT hit information is analysed across all event categories. In particular, we examine the dynamic CD trigger conditions, which aim to suppress consecutive muon-induced triggers and mitigate DAQ I/O bottlenecks. We also implemented the trigger logic in JUNO's detector simulation framework, enabling future optimization of trigger configurations.

T 70.3 Thu 16:45 KH 00.023

**The Mu3e DAQ build system and CI** — •ALEXANDR KOZLINSKIY for the Mu3e-Collaboration — Johann-Joachim-Becher-Weg 45, 55128 Mainz, Germany

The *Mu3e* experiment is designed to search for the lepton flavor violating decay  $\mu^+ \rightarrow e^+ e^- e^+$  with the aim of reaching a branching ratio sensitivity of  $10^{-16}$ . The experiment is located at the Paul Scherrer Institute (Switzerland). The existing beam line will provide  $10^8$  muons per second and at first will allow to reach a sensitivity of a few  $10^{-15}$ .

The readout system of *Mu3e* uses Intel FPGA chips for which the firmware and IP components are compiled with the Quartus software. To improve the development and testing of the *Mu3e* DAQ firmware, custom scripts were developed to build firmware directly from the command line. The continuous integration is used to build and test the firmware on each commit. This allows for faster development of firmware and tracking of regressions during development.

The talk will cover the scripts, tools and the design of the *Mu3e* DAQ build system.

T 70.4 Thu 17:00 KH 00.023

**Online Track Reconstruction for the Mu3e Experiment** — •HARIS AVUDAIYAPPAN MURUGAN for the Mu3e-Collaboration — Institute of Nuclear Physics, Johannes Gutenberg University of Mainz, Germany

The Mu3e experiment aims to find or exclude the lepton flavour violating decay of a positive muon to two positrons and an electron with a branching fraction sensitivity of  $10^{-16}$ . To observe such a rare event, we require a tracking detector from custom-designed High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) together with timing detectors made from scintillating fibres and tiles for the experiment. The detector will be streaming up to 1 TBit/s of data to the filter farm composed of graphics processing units (GPUs), in which the data rate is reduced to less than 100 MB/s and this filtered data is stored for later analysis. This reduction can be achieved by selecting potential signal events with two positrons and one electron originating from a single vertex through online track and vertex reconstruction on the GPU. During the 2025 beam run we were able to perform/test online tracking and selection of events using the filter farm.

T 70.5 Thu 17:15 KH 00.023

**The Tile Calorimeter Trigger and Data Acquisition interface: Realtime and Readout Developments** — •ANNA DUNZ and THOMAS JUNKERMANN — Kirchhoff-Institut für Physik, Heidelberg

With the Phase-II Upgrade of the ATLAS experiment, the front- and back-end electronics for the Tile Calorimeter will be replaced. This upgrade is made necessary by the increase in luminosity of the LHC. The new electronics are designed to improve signal reconstruction while coping with more simultaneous Proton-Proton collisions.

The Tile Calorimeter Trigger and Data Acquisition interface (TDAQi) is part of the new electronics design. It is an ATCA rear transition module equipped with an AMD Kintex Ultrascale+ FPGA. The TDAQi provides an interface be-

tween the Tile Calorimeter electronics and the ATLAS trigger systems. Following the requirements of the Level-0 trigger subsystems, different algorithms are performed to calculate trigger inputs. Cell energies from the Calorimeter are decoded and high energy cells are identified. Cells are summed up to provide lower granularity objects to the electron and jet triggers. For the muon trigger, cells are summed up at a high granularity, and threshold comparisons are performed. The processing algorithms and data transmission are carried out on the FPGA. An overview of the firmware is presented with a focus on the muon system showcasing the real-time as well as read-out capabilities of the TDAQi.

T 70.6 Thu 17:30 KH 00.023

**The DAQ and Trigger System for the DELight Experiment** — •LEA BURMEISTER for the DELight-Collaboration — Kirchhoff-Institute for Physics, Heidelberg University

While heavy WIMP searches have reached unprecedented sensitivities, the light dark matter (DM) sector remains largely unexplored. Probing light dark matter candidates requires novel detector concepts with ultra-low thresholds. The Direct search Experiment for Light dark matter (DELight) will employ superfluid helium-4 as the target medium monitored with MMC-based large-area microcalorimeters (LAMCALS) operating at mK temperatures, which provide excellent energy resolution with a detection threshold of a few eV.

The DELight experiment requires a data acquisition (DAQ) system capable of detecting extremely small energy depositions without acquiring deadline. This talk presents ongoing R&D work on the DELight DAQ and trigger system, with focus on its FPGA-based Level-1 (L1) trigger. The L1 trigger will process digitized microcalorimeter waveforms in real time using downsampling, filtering, and flexible threshold logic to distinguish low-energy events from noise. The filtering step will be achieved using an FIR filter whose coefficients resemble a time-domain optimal filter.

T 70.7 Thu 17:45 KH 00.023

**Development of a Stand-Alone Drift-Tube-Based Muon Trigger for the ATLAS and CRESST Experiments** — •STEFAN EDER, DAVIDE CIERI, OLIVER KORTNER, SANDRA KORTNER, FEDERICA PETRICCA, MICHELE MANCUSO, and ALEXANDER LANGENKÄMPER — Max Planck Institute for Physics

The upcoming High-Luminosity LHC era will require substantially improved selectivity in the ATLAS first-level muon trigger system. To meet these demands, new FPGA-based trigger processor boards have been developed that, for the first time, incorporate precision tracking information from Monitored Drift Tube (MDT) chambers directly into the Level-0 trigger decision. Before operation in Run 4, the MDT detectors, their readout, and trigger processors must be commissioned using cosmic-ray muons. This requires a dedicated track-finding algorithm that relies solely on information from drift-tube detectors.

This presentation introduces a standalone drift-tube-based muon trigger algorithm designed for this purpose, along with its FPGA gateway implementation and expected performance. In addition to cosmic-ray commissioning, the newly developed standalone track reconstruction algorithm enables trigger decisions during ATLAS operation without input from fast trigger detectors. Beyond its application in ATLAS, the algorithm also opens the possibility of serving as a muon veto in the CRESST dark matter experiment by installing spare ATLAS MDT chambers around the cryogenic CRESST detector setup. The adaptation of the algorithm for this use case will also be discussed.

## T 71: Data, AI, Computing, Electronics VII

Time: Thursday 16:15–18:00

Location: KH 00.024

T 71.1 Thu 16:15 KH 00.024

**Shapes are not enough: Preservattack and its use for finding vulnerabilities and uncertainties in machine learning applications** — PHILIP BECHTLE<sup>1</sup>, LUCIE FLEK<sup>2</sup>, PHILIPP ALEXANDER JUNG<sup>3</sup>, AKBAR KARIMI<sup>2</sup>, •TIMO SAALA<sup>1</sup>, ALEXANDER SCHMIDT<sup>3</sup>, MATTHIAS SCHOTT<sup>1</sup>, PHILIPP SOLDIN<sup>4</sup>, CHRISTOPHER WIEBUSCH<sup>4</sup>, and ULRICH WILLEMSSEN<sup>3</sup> — <sup>1</sup>Institute of Physics, University of Bonn, Germany — <sup>2</sup>Bonn-Aachen Institute of Technology, University of Bonn, Germany — <sup>3</sup>Institute of Experimental physics III B, RWTH Aachen University, Germany — <sup>4</sup>Institute of Experimental physics III A, RWTH Aachen University, Germany

In High Energy Physics, machine learning has become crucial for advancing our understanding of fundamental phenomena. Deep learning models increasingly analyze both simulated and experimental data, supported by rigorous tests of physically motivated systematic uncertainties. Numerical evaluations quantify differences between data and simulation, and comparisons of marginal distributions and feature correlations in control regions are standard. However, physical guidance and regional constraints cannot guarantee capturing of all deviations.

We propose a novel adversarial attack exploiting the remaining space of hypothetical deviations between simulation and data after such tests. The resulting perturbations stay within uncertainty bounds - evading standard validation -

while still fooling the underlying model. We also suggest mitigation strategies and argue that robustness to adversarial effects is crucial when interpreting deep learning results in particle physics.

T 71.2 Thu 16:30 KH 00.024

**Utilizing Adversarial Training for IceCube's Advanced Northern Track Selection** — •MARCO ZIMMERMANN, SHUYANG DENG, LASSE DÜSER, PHILIPP SOLDIN, SÖNKE SCHWIRN, and CHRISTOPHER WIEBUSCH — Rwth Aachen

IceCube is a neutrino observatory at the South Pole equipped with over 5000 photomultiplier tubes (PMTs), capable of detecting Cherenkov light from neutrino and cosmic-ray induced muons. The Advanced Northern Track Selection (ANTS) differentiates between these two types of muons with a deep neural network approach. The ANTS network first encodes the charge-time series from each PMT into ten abstract features via a Transformer. These features then serve as input for graph neural networks, which perform the aforementioned differentiation as well as energy and directional reconstructions, and event topology classification. To improve robustness, a network can be trained with adversarial attacks, where the input is modified by adding minimal perturbations with the aim of producing incorrect outputs. We will discuss the application of adversarial training of the ANTS' networks, with the example of the event topology classifier, and present methods to visualize the effect of the added perturbations.



T 71.3 Thu 16:45 KH 00.024

**Investigating Robustness of Newtonian Noise Mitigation using Deep Learning at the Einstein Telescope** — •JAN KELLETER<sup>1</sup>, MARKUS BACHLECHNER<sup>2</sup>, DAVID BERTRAM<sup>2</sup>, JOHANNES ERDMANN<sup>1</sup>, PATRICK SCHILLINGS<sup>1</sup>, and ACHIM STAHL<sup>2</sup> — <sup>1</sup>III. Physikalisches Institut A, RWTH Aachen — <sup>2</sup>III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope is a proposed gravitational wave detector of the third generation. It aims to improve sensitivity by at least an order of magnitude compared to current detectors. The dominant noise source in the region of 1 to 10 Hz is expected to be Newtonian Noise (NN) from seismic activity in the surrounding rock. In order to reach the desired sensitivity, NN must be actively mitigated. Seismometers will be installed in boreholes around the mirrors to measure the seismic activity. In this talk, we investigate the robustness of neural networks designed for Newtonian Noise mitigation against different instrumental failures.

T 71.4 Thu 17:00 KH 00.024

**A Machine-Learning based Topological Algorithm for the Level-1 Trigger System of CMS** — •LUKAS EBELING, JOHANNES HALLER, ARTUR LOBANOV, and MATTHIAS SCHRÖDER — Institut für Experimentalphysik, Universität Hamburg

At CMS, the level-1 trigger (L1T) system is crucial to select events of interest in order to keep the data-taking rate at a level that can be processed by the readout and storage system. We present a machine-learning (ML) based algorithm for the L1T system, designed to identify di-Higgs (HH) production events. The algorithm leverages the full event topology and improves the HH signal efficiency at low  $p_T$  compared to previous single-object based triggers. Despite being constrained in architecture by strict latency requirements and limited FPGA hardware, the ML trigger achieves high signal efficiencies while maintaining acceptable rates. The talk will highlight the achieved trigger performance, discuss the integration into the CMS software framework as well as the development of a realistic trigger scenario for running in 2026 collisions.

T 71.5 Thu 17:15 KH 00.024

**Finding Symbolic Representations of Graph Neural Networks used for Track Finding** — •URS FISCHER, SEBASTIAN DITTMEIER, and ANDRE SCHÖNING — Physikalisches Institut, Universität Heidelberg, Germany

Graph Neural Networks (GNNs) have been shown to efficiently solve the combinatorial challenge of track finding at high luminosity collider experiments [1]. The available logic resources of Field-Programmable Gate Arrays (FPGAs) limit the size of possible neural networks that can be deployed in hardware triggers or accelerator cards.

In this study, we apply symbolic regression to the different steps of the GNN track finding process. Symbolic regression fits analytic expressions by combining algebraic operators stochastically to find the best representation in terms of simplicity and accuracy. The resulting algebraic functions have the potential to reduce computational costs of the Multi-Layer Perceptrons for FPGA deployment and allow for interpretation of the internal structure of the neural network, by offering an explicit representation of it.

This talk introduces this method and presents first results on its application to tracking at the ATLAS experiment.

[1] S. Farrell et al., "Novel deep learning methods for track reconstruction", in 4th International Workshop Connecting The Dots 2018. 2018. arXiv:1810.06111.

T 71.6 Thu 17:30 KH 00.024

**Symbolic Regression for the Extraction of Detector Response Formulas** — •JOHANNES MERTEN and JOHANNES ERDMANN — III. Physikalisches Institut A, RWTH Aachen University

Detector simulations are an essential part of high-energy physics research, enabling the interpretation of experimental data and the design of future experiments. Full-scale simulations, such as those based on GEANT4, provide high-fidelity representations of particle interactions within detectors but are computationally expensive. To facilitate large-scale analyses, fast simulation frameworks employ parameterizations to approximate detector responses. These parameterizations rely on simplified functional forms that may not fully capture the underlying complexities of the detector response, which may lead to systematic biases.

In this work a data-driven approach is proposed to derive these interpretable parametrizations directly from high-fidelity simulation data using Normalizing Flows and Kolmogorov-Arnold Networks.

T 71.7 Thu 17:45 KH 00.024

**Improving Machine-Learning-Driven Anomaly Detection for New Physics Searches at Belle II** — •GIANNI DI PAOLI, DAVID GIESEGH, and THOMAS KUHR — Ludwig-Maximilians-Universität München (LMU), München, Germany

Anomaly detection based on machine-learning techniques, using semi- or unsupervised methods, offers a complementary strategy to traditional theory-driven searches for New Physics beyond the Standard Model. Previous studies have provided a proof of principle by enhancing the visibility of simulated New Physics signals.

In this work, the performance of the existing network architectures is improved. For the autoencoder-based method, refinements of the network design lead to more stable reconstruction-error distributions, and thus to increased visibility of anomalies. For the density-estimation approach, alternative likelihood-estimation techniques and their behavior in high-dimensional feature spaces relevant for Belle II are investigated and implemented to improve sensitivity to anomalies.

Ongoing work focuses on further developing these techniques and preparing them for application to real Belle II collision data, including studies of their behavior under realistic detector and background conditions. This talk will present the current status of the algorithmic developments, and outline the next steps toward an operational anomaly-detection pipeline for model-independent New Physics searches at Belle II.

## T 72: Flavour Physics IV

Time: Thursday 16:15–18:15

Location: KH 01.011

T 72.1 Thu 16:15 KH 01.011

**Early Studies on rare  $B_s^0 \rightarrow \mu^+ \mu^-$  decays and related control modes in Run 3 at the LHCb experiment** — JOHANNES ALBRECHT, •LUKAS BERTSCH, MICK MULDER, KATHARINA POPP, and JAN WAGNER — TU Dortmund University, Germany

Rare  $B_s^0 \rightarrow \mu^+ \mu^-$  decays provide a sensitive test of the Standard Model owing to their exceptional suppression, clean experimental signature, and precise theoretical predictions. Searches for these decays have been conducted since the start of the LHCb experiment, accomplishing the observation of  $B_s^0 \rightarrow \mu^+ \mu^-$  in 2014, together with the CMS collaboration. However, the more strongly suppressed  $B^0$  meson counterpart of the decay has not yet been measured with statistical significance, due to interfering backgrounds and limited data. Much larger datasets collected during Run 3 of the LHC provide a clear opportunity to find evidence for the  $B^0 \rightarrow \mu^+ \mu^-$  decay, but also pose new challenges due to the busy collision environment. Therefore, early studies on the new dataset are performed in this work, providing a first implementation of required analysis tools and verifying the analysis procedure on Run 3 data. Based on  $11 \text{ fb}^{-1}$  of data recorded in 2024 and early 2025, branching fractions of control modes are measured following the signal-channel analysis strategy, and a preliminary estimate of the sensitivity to the  $B^0 \rightarrow \mu^+ \mu^-$  decay is obtained.

T 72.2 Thu 16:30 KH 01.011

**Multivariate analysis of the rare decays  $B_{(s)}^0 \rightarrow \mu^+ \mu^-$  in Run 3 at the LHCb experiment** — JOHANNES ALBRECHT, LUKAS BERTSCH, MICK MULDER, •KATHARINA POPP, and JAN PETER WAGNER — TU Dortmund University, Dortmund, Germany

Studies of the rare  $B_{(s)}^0 \rightarrow \mu^+ \mu^-$  decays are core to the physics programme of the LHCb experiment, as they provide sensitivity to physics beyond the Standard Model. While the decay  $B_s^0 \rightarrow \mu^+ \mu^-$  has been observed in the previous analyses using data from Run 2 of the LHC, the process  $B^0 \rightarrow \mu^+ \mu^-$  is still to be observed. With the LHCb Upgrade I detector in Run 3, an upgraded strategy is required for the search for these processes. A major challenge arises from the amount of background events caused by random combinations of muons from  $b$ -hadron decays, which superimpose the signal processes. Thereby, a powerful tool for the suppression of combinatorial background is provided by considering the isolation of the final state muon tracks with respect to other tracks in the event. This aspect has already proven useful in previous analyses, where a combination of Boosted Decision Trees has been utilised. For the analysis with Run 3 data, the existing strategy for the suppression of combinatorial background is revisited and improvements are pursued, in order to enhance the signal significance of the decay  $B^0 \rightarrow \mu^+ \mu^-$ .

T 72.3 Thu 16:45 KH 01.011

**Transformer-based classification of  $B_s^0 \rightarrow \tau^+ \tau^-$  decays in  $Z \rightarrow b\bar{b}$  events at the FCC-ee** — •ALEJANDRO QUIROGA TRIVINO<sup>1</sup>, JAN KIESELER<sup>1</sup>, MARKUS KLUTE<sup>1</sup>, JOSCHA KNOLLE<sup>1</sup>, ANUAR SIFUENTES NAME<sup>1</sup>, SAMUEL WYROWSKI<sup>1</sup>, and XUNWU ZUO<sup>2</sup> — <sup>1</sup>Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — <sup>2</sup>Ecole polytechnique federale de Lausanne (EPFL), Lausanne, Switzerland

Experimental indications of potential deviations from lepton flavor universality have intensified interest in rare B meson decays involving tau leptons. Among these, the decay  $B_s^0 \rightarrow \tau^+ \tau^-$  remains largely unexplored experimentally due to its

challenging final state and the limited sensitivity of current detectors. The high-statistics and low-background environment of electron-positron collisions at the Z pole that will be provided by the FCC-ee creates a unique opportunity to study this process with unprecedented precision. Leveraging these conditions, advanced machine-learning techniques can be brought to bear to enhance the separation between signal candidates and the overwhelming  $Z \rightarrow b\bar{b}$  background. In this contribution, the application of a transformer model to separate between  $Z \rightarrow b\bar{b}$  events with and without a  $B_s^0 \rightarrow \tau^+\tau^-$  decay is discussed. The usage of different sets of input features, relying either on reconstructed hadronic tau lepton candidates or on tracks and neutral particles, are compared. The achieved background rejection paths the way towards the observation of this rare standard model process.

T 72.4 Thu 17:00 KH 01.011

**Prospects for  $B_s^0 \rightarrow \tau^+\tau^-$  searches in final states with six charged pions at the FCC-ee** — •ANUAR SIFUENTES NAME<sup>1</sup>, JAN KIESELER<sup>1</sup>, MARKUS KLUTE<sup>1</sup>, JOSCHA KNOLLE<sup>1</sup>, ALEJANDRO QUIROGA TRIVINO<sup>1</sup>, SAMUEL WYROWSKI<sup>1</sup>, and XUNWU ZUO<sup>2</sup> — <sup>1</sup>Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — <sup>2</sup>Ecole polytechnique federale de Lausanne (EPFL), Lausanne, Switzerland

Recent results from the LHCb and Belle-II experiments have reported hints of lepton flavor universality (LFU) violation in rare B meson decays. One particularly interesting probe for this potential deviation from the standard model (SM) of particle physics is the measurement of the branching fraction of the rare decay  $B_s^0 \rightarrow \tau^+\tau^-$ , for which the expected LHCb sensitivity at the end of the HL-LHC era is several orders of magnitude away from the SM prediction. The future circular collider (FCC), operated with electron-positron collisions at the Z pole, will offer an experimentally clean environment to search for this decay. In this contribution, an analysis strategy is presented that targets the final state corresponding to the decay chain  $B_s^0 \rightarrow \tau^+\tau^- \rightarrow 6\pi^\pm 2\nu$ . Through an optimized set of dedicated kinematic cuts and training of machine-learning discriminants, a sufficient separation between the signal and the background from other  $Z \rightarrow b\bar{b}$  events is achieved to demonstrate the capability of the FCC to probe LFU in beyond-the-SM scenarios.

T 72.5 Thu 17:15 KH 01.011

**FCC-ee Sensitivity Estimation to the Direct CP-Violating Decay-Rate Asymmetry  $A_{CP}(D^0 \rightarrow \pi^0\pi^0)$**  — •WILLY WEBER<sup>1,2</sup>, KEVIN KRÖNINGER<sup>1</sup>, ROMAIN MADAR<sup>2</sup>, and STÉPHANE MONTEIL<sup>2</sup> — <sup>1</sup>TU Dortmund University, Department of Physics, Dortmund — <sup>2</sup>Université Clermont-Auvergne, Laboratoire de Physique de Clermont, Clermont-Ferrand

The Future Circular Collider (FCC-ee) is a proposed electron-positron collider designed to enable high-energy collisions. It is expected to produce  $O(10^{12})$   $Z \rightarrow q\bar{q}$  events, significantly enhancing our ability to perform precision measurements of electroweak observables.

CP violation in  $D^0$  decays to charged particles has been observed by LHCb. Our understanding of CP violation in the charm sector can be further improved by studying the decays into neutral particles. This presentation considers the potential for precise measurement of CP violation in  $D^{*\pm} \rightarrow (D^0 \rightarrow \pi^0(\rightarrow \gamma\gamma) + \pi^0(\rightarrow \gamma\gamma))\pi^\pm$  decays at FCC-ee to complement the knowledge gathered by LHCb with charged modes. Monte Carlo samples, including a simulated detector response based on the IDEA detector concept, are used for this purpose. It is demonstrated that the FCC-ee will significantly improve the precision of the measurement of the CP-Violating decay-rate asymmetry  $A_{CP}(D^0 \rightarrow \pi^0\pi^0)$ . Furthermore, the necessary detector requirements for this future measurement are investigated.

T 72.6 Thu 17:30 KH 01.011

**Branching fraction measurements of the rare decays  $B_{(s)}^0 \rightarrow \pi^+\pi^-\mu^+\mu^-$  at LHCb** — JOHANNES ALBRECHT<sup>1</sup>, THOMAS BLAKE<sup>2</sup>, MICK MULDER<sup>1</sup>, JANINA NICOLINI<sup>3</sup>, and •JAN PETER WAGNER<sup>1</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>University of Warwick, Coventry, United Kingdom — <sup>3</sup>CERN, Geneva, Switzerland

Rare flavour-changing neutral-current decays with  $b \rightarrow q\ell^+\ell^-$  quark transitions ( $q = s, d$ ) provide powerful probes of the Standard Model and are central to the LHCb physics programme. Owing to the smaller CKM matrix elements,  $b \rightarrow d\ell^+\ell^-$  decays are further suppressed relative to  $b \rightarrow s\ell^+\ell^-$  processes, making them particularly challenging to observe. Using Run 1 data, the LHCb collaboration observed the decay  $B_s^0 \rightarrow \pi^+\pi^-\mu^+\mu^-$  with a significance of  $7.2\sigma$ , while evidence for the analogous decay  $B^0 \rightarrow \pi^+\pi^-\mu^+\mu^-$  was reported with a significance of  $4.8\sigma$ .

This contribution reports the current status of the branching-fraction measurements of  $B_{(s)}^0 \rightarrow \pi^+\pi^-\mu^+\mu^-$  decays using the full  $9\text{fb}^{-1}$  data sample recorded by LHCb in Runs 1 and 2 of the LHC. First studies based on Run 3 data are also presented, providing an outlook on the improved sensitivity and future prospects for measurements of rare  $b \rightarrow d\ell^+\ell^-$  and  $b \rightarrow s\ell^+\ell^-$  decays with the upgraded LHCb detector.

T 72.7 Thu 17:45 KH 01.011

**Measurement of the Energy Dependence of Strong Isospin Violation in  $Y(4S)$  Decays** — •LENA NOWATZKI, THOMAS KUHR, and THOMAS LÜCK — Ludwig-Maximilians-Universität München (LMU), München, Germany

Precise measurements of B meson branching fractions are essential both for testing Standard Model predictions and for many measurements that rely on accurate modeling of data composition in flavor-physics analyses. At Belle II, B mesons are produced via the process  $e^+e^- \rightarrow Y(4S) \rightarrow B\bar{B}$ . The total number of such events can be determined with high precision, yet using this quantity for B meson branching fraction measurements requires knowledge of the production fractions of neutral and charged B meson pairs in  $Y(4S)$  decays, respectively  $f_{00}$  and  $f_\pm$ . Although strong isospin symmetry predicts equal production rates, recent theoretical studies indicate a possible energy dependence of the ratio  $f_\pm/f_{00}$ , motivating an experimental investigation.

In this analysis, we aim to measure the energy dependence of the  $Y(4S)$  decay fractions using Belle II data. We employ two different approaches. The first relies on direct B meson energy measurements using the channels  $B^+ \rightarrow J/\psi K^+$  and  $B^0 \rightarrow J/\psi K_S^0$ . The second includes a multivariate classifier based on event-level observables to distinguish between neutral and charged  $B\bar{B}$  pair production. This talk will present the current status and an outlook on future developments of this analysis.

T 72.8 Thu 18:00 KH 01.011

**Analysis of Rare Charm Three-Body Decays using LHCb Run 3 data** — DOMINIK MITZEL, CAROLINA DA SILVA BOLOGNANI, and •CHRISTOPHER BREITFELD — TU Dortmund University, Dortmund, Germany

Flavor-changing neutral currents in the charm sector provide a sensitive testing ground for the Standard Model. Certain observables, such as CP and forward-backward asymmetries are highly suppressed and their measurements therefore constitute null tests. Dominated by non-perturbative long-distance contributions, these decays are also challenging to study theoretically. It is thus essential not only to perform null-test measurements but also to provide experimental information on the resonant structure.

Using data collected with the upgraded LHCb detector during Run 3 of the LHC, the rare decays  $D_{(s)}^+ \rightarrow \pi^+\mu^+\mu^-$  and  $\Lambda_c^+ \rightarrow p\mu^+\mu^-$  are studied. The analysis aims to measure the CP and the forward-backward asymmetry in bins of the dimuon mass, and to perform an amplitude analysis to disentangle the interference of intermediate resonances.

In this talk, an introduction and the general analysis strategy are presented.

## T 73: Calorimeters I

Time: Thursday 16:15–17:45

Location: KH 01.012

T 73.1 Thu 16:15 KH 01.012

**Quality Control of Scintillator Tiles for the CMS Endcap High Granularity Upgrade** — •MOHAMMED ADNAN ALI — University of Hamburg, Mittelweg 177, 20148 Hamburg — Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany)

Preparing the CMS detector for the High-Luminosity LHC (HL-LHC) requires major upgrades, including the installation of the High Granularity Calorimeter (HGCal) to replace the existing endcap calorimeters. In its hadronic section, plastic scintillator tiles coupled with SiPMs are used in regions exposed to moderate radiation levels.

HGCal achieves its fine spatial resolution through the use of approximately 280,000 scintillator tiles, with sizes ranging from  $2\text{cm}^2$  to  $30\text{cm}^2$ ; around

160,000 of these tiles will be wrapped and quality-controlled at DESY. Each tile is individually wrapped and integrated through an automated assembly procedure, and the detector design imposes strict mechanical tolerances on their final geometry.

In this talk, I will present the quality control strategy developed at DESY, which includes micron-level dimensional checks after wrapping as well as standardized measurements of the light-yield performance. These studies are essential to ensure uniform detector response and to meet the performance requirements of the HGCal upgrade.

T 73.2 Thu 16:30 KH 01.012

**Ensuring Quality of High Granularity Calorimeter Tileboards for the High-Luminosity upgrade of CMS** — •FARUK KURTULUS — University of Hamburg Mittelweg 177, 20148 Hamburg, Germany — Deutsches Elektronen-Synchrotron (DESY) Notkestraße 85, 22607 Hamburg, Germany

The CMS experiment is preparing for an upgrade to operate in the harsh environment of the High-Luminosity Large Hadron Collider (HL-LHC). To function reliably under these conditions, CMS must replace its current end-cap calorimeters, which are already losing detection capability, with the High Granularity Calorimeter (HGCAL), designed to withstand the increased luminosity and pile-up of HL-LHC operation.

In the lower-radiation region of HGCAL, the SiPM-on-Tile technology is used, coupling Silicon Photo-Multipliers (SiPMs) to thin scintillator tiles. SiPMs are soldered onto a common PCB with readout electronics and later combined with scintillators to form a Tilemodule. Before scintillators are installed, the unit is referred to as a Tileboard. Each Tileboard hosts one or two readout chips providing readout for 72 channels. The detector will contain about 3800 Tileboards. Before Tilemodule assembly, a quality-control (QC) procedure is required to verify electrical functionality and readout stability.

This presentation will outline the QC procedure developed for Tileboard certification, including the sequence of tests and qualification criteria. Results from several hundred production boards will be shown, highlighting common issues and the overall readiness of Tileboards for the HGCAL upgrade.

T 73.3 Thu 16:45 KH 01.012

**Changes and Upgrades for the ATLAS Liquid Argon Purity System** — •MAXIMILIAN LINKERT, CHRISTOPHER ENGEL, and STEFAN TAPPROGGE — Institut für Physik, Johannes Gutenberg-Universität, Mainz

With the high luminosity LHC and the Phase 2 upgrade of the ATLAS Detector the Liquid Argon Purity System faces new operational challenges. The purpose of the system is to measure possible contaminations of the liquid argon, hence calculating the impurity level. Therefore 30 devices with ionization chambers are distributed throughout the calorimeter. Due to upgrades of the low voltage power supply used to power the front end electronics the voltages will change from a positive and negative to a single positive line. Since the purity devices rely critically on the negative voltage, a modified version of the bPOL48V buck DCDC converter will be needed. Moreover the software has been updated to ensure proper operation in the future. The current status of the purity system, the DCDC converter and extended functionalities for the maintenance workflow will be presented.

T 73.4 Thu 17:00 KH 01.012

**Shower Direction Reconstruction with the SHiP High-Granularity ECAL** — •SEBASTIAN RITTER, VOLKER BÜSCHER, RAINER WANKE, MATEI CLIMESCU, and CLAUDIA DELOGU — Johannes-Gutenberg Universität, Mainz

The SHiP experiment at CERN targets the hidden sector by, among others, searching for neutral long-lived particles (LLPs) produced in a high-intensity beam dump. To reconstruct LLP decays into photons, the experiment requires a pointing electromagnetic calorimeter (ECAL). In this talk, test-beam results of the SHiP ECAL prototype are presented.

Using SPS electron beams in the 10\*288 GeV range, we measure the transverse and longitudinal shower development to reconstruct the shower direction and extract the pointing resolution based on the calorimeter response and put it into perspective with the physics requirements. Comparisons with GEANT4 simulations are outlined.

We conclude with a status update on preparations for calorimeter construction in Mainz and the installation of the detector in the SHiP experiment at the upgraded beam dump facility.

T 73.5 Thu 17:15 KH 01.012

**Processing of ATLAS Liquid Argon Calorimeter Signals by Convolutional Neural Networks and its Impact on Calorimeter Energy Reconstruction** — •MANUEL GUTSCHE, MARKUS HELBIG, ARNO STRAESSNER, JOHANN CHRISTOPH VOIGT, and PHILIPP WELLE — Technische Universität Dresden

During the Phase-II upgrade of the ATLAS detector, over 500 high-performance FPGAs will be installed in the off-detector electronics of the Liquid Argon Calorimeter to cope with the increased luminosity and, therefore, pileup. Under these challenging conditions, the energies of the 182468 detector cells will be reconstructed by the FPGAs. Different methods are being considered. One possible approach is the implementation of 1-dimensional convolutional neural networks (CNNs), which are limited by resource constraints of the Intel Agilex-7 FPGAs to about 400 parameters.

A total of 23 dedicated CNNs are applied to account for differences between cells, mainly in terms of pulse shape and noise. This is achieved by grouping similar cells into clusters, and then training a model of fixed architecture on simulated data expected for a representative cell of each cluster.

These CNNs are integrated into the ATLAS simulation and analysis framework, Athena, in order to compare the performance of the energy reconstruction by CNNs with the current implementation based on an optimal filter. The impact of the two methods on the calculated cell energies, as well as on reconstructed physics objects, is studied.

T 73.6 Thu 17:30 KH 01.012

**Fast Hadron Shower Simulation Methods with the CALICE AHCAL Prototype** — •ANDRÉ WILHAHN and STAN LAI — Georg-August-Universität Göttingen, Göttingen, Germany

Extensive simulations of particle showers are crucial for high energy physics experiments. As many calorimeters are designed with increasing granularity, while having to cope with higher energy deposits and higher luminosity conditions, the accurate simulation of particle showers in a computationally efficient manner is of utmost importance. This talk describes investigations into a data-driven fast calorimeter simulation that is meant to describe particle showers accurately, without simulating every individual particle interaction with the calorimeter material.

We start by investigating pion showers in the CALICE AHCAL (Analogue Hadron Calorimeter) prototype, which is a highly granular hadronic calorimeter comprising a total of 38 active layers embedded in a stainless-steel absorber structure. Each active layer contains a grid of  $24 \times 24$  scintillator tiles that are read out individually via silicon photomultipliers. Correlated hit energies have been simulated to obtain good modelling for kinematic shower variables with the help of kernel density estimators. The results and future plans for improving and expanding the fast calorimeter simulation will be discussed.

## T 74: Gaseous Detectors II

Time: Thursday 16:15–18:00

Location: KH 01.014

T 74.1 Thu 16:15 KH 01.014

**Upgrading the CMS muon end cap for the high-luminosity LHC using ME0 GEM detectors** — ERIK EHLERT, KERSTIN HOEPFNER, DANIEL KLEE, ALEXANDER SCHMIDT, and •SHAWN ZALESKI — III. Physikalisches Institut, RWTH Aachen University, Aachen, Germany

Gas electron multiplier (GEM) chambers have been operating as part of the CMS Muon end cap system since the beginning of Run 3. The GE1/1, first GEM system installed alongside the CSC chambers, provides an improved transverse momentum measurement of muons that pass through the CMS end caps. The ME0 system, a planned upgrade of the CMS Muon system for the high-luminosity LHC, is similar in design to that of the GE1/1 system, however it consists of a stack of six triple-GEM chambers. These ME0 stacks will be installed adjacent to the new high granularity hadron calorimeter (HGCAL) and will extend the pseudorapidity reach of the Muon system from 2.4 to 2.8. The GEM collaboration has built more than six stacks that will be installed during Long Shutdown 3 (LS3). All stacks that will be installed must undergo a rigorous set of quality control (QC) checks, the final of which is testing the full ME0 stack using a cosmic ray muon test stand (QC8). This talk will give an overview of the QC8 setup and present some results from the ME0 cosmic ray test stand QC checks.

T 74.2 Thu 16:30 KH 01.014

**Integration of new Gas Monitoring Chambers into the ND280 Near Detector Gas System** — STEFAN ROTH, •DAVID SMYCZEK, JOCHEN STEINMANN, and NICK THAMM — RWTH Aachen University - Physics Institute III B, Aachen, Germany

A new pair of Time Projection Chambers for high angle measurements (HAT) has been installed during the upgrade of the T2K near detector ND280. To improve their calibration, drift velocity and gain are continuously monitored using new Gas Monitoring Chambers (GMC) which were installed in November 2025. One pair of GMCs is monitoring the supply and the exhausts of the ND280 Time Projection Chambers. A second pair of GMCs is monitoring the freshly mixed gas. One of those GMCs has been equipped with resistive Micromegas to compare the results to its counterpart using conventional Micromegas. The first measurements of these new monitoring chambers will be presented.

T 74.3 Thu 16:45 KH 01.014

**Modeling Electron Transport Properties in Gaseous Detector Gases** — STEFAN ROTH, •MAX SCHMIT, DAVID SMYCZEK, JOCHEN STEINMANN, and NICK THAMM — RWTH Aachen University - Physik Institute III B, Aachen, Germany

Electron transport parameters in gases can be derived by solving the Boltzmann equation. Two approaches are commonly used: analytical solutions and Monte Carlo methods. Both modeling approaches are outlined, with emphasis on their

treatment of the electron energy distribution function and the use of electron-molecule cross-section data. Differences in required inputs and in the resulting transport coefficients are discussed. Electron drift velocity and diffusion coefficients are evaluated for commonly used detector gases. Comparison results and the current status of the study are presented, highlighting their implications for detector simulations.

T 74.4 Thu 17:00 KH 01.014

**Performance Studies on Ecofriendly Gas Alternatives for RPC Detectors** — ROBERTO GUIDA<sup>2</sup>, STEFANIA JUKE<sup>3</sup>, •MAXIMILIAN KERKER<sup>1</sup>, BEATRICE MANDELLI<sup>2</sup>, GIANLUCA RIGOLETTI<sup>2</sup>, STEFAN ROTH<sup>1</sup>, and MATTIA VERZEROLI<sup>4</sup> — <sup>1</sup>RWTH Aachen University — <sup>2</sup>CERN — <sup>3</sup>Université Paris Saclay — <sup>4</sup>Shanghai Jiao Tong University

Resistive Plate Chambers are important particle detectors used as muon triggers in many experiments at the Large Hadron Collider. At the ALICE, ATLAS, and CMS LHC experiments, a gas mixture made of 65-95% R-134a, 4.5-10% i-C4H10 and 0.3-0.5% SF6 is used. R-134a and SF6 are greenhouse gases having a significant global warming potential of 1430 and 24300 respectively. In this work, a study was conducted searching for alternatives for SF6. In particular, two chlorinated hydrofluoroolefins, R-1233zd and R-1224yd, were identified as possible SF6 replacements. These gases were tested in different concentrations both in laboratory conditions and at the Gamma Irradiation Facility at CERN under LHC-like conditions. The RPC performance was evaluated by measuring the detector's efficiency, currents, streamer probability, cluster size and time resolution. The results were compared against SF6-based gas mixtures. Preliminary results will be presented.

T 74.5 Thu 17:15 KH 01.014

**Replacing SF6 in Resistive Plate Chamber Detectors for HL-LHC Experiments and Beyond** — •GIORGIA PROTO and OLIVER KORTNER — Max Planck Institute for Physics

The Resistive Plate Chambers (RPC) are gaseous detectors with excellent timing performance and are used for triggering on muons in the LHC experiments. They operate with the standard gas mixture, composed of C2H2F4/i-C4H10/SF6, that has a high Global Warming Potential (GWP) of 1430 due to the presence of C2H2F4 (GWP~1450) and SF6 (GWP~22400). The C2H2F4 and SF6 are not recommended for industrial uses anymore, thus their availability will be increasingly reduced over time and the search for an alternative gas mixture is of absolute priority. The most critical component to replace is the SF6, because it acts as streamer suppressor, thus allowing for RPC operation at low current, for high rate capability and longevity. In this work the SF6 is replaced with the Chloro-Trifluoropropene (C3H2ClF3, GWP~5), never been tested in the RPC detectors before. The performance of the RPC detector in terms of efficiency, streamer probability and time resolution have been studied in the Gamma Irradiation Facility (GIF++) at CERN at high irradiation rates, as expected at the

High Luminosity LHC. The performance of the RPC detector with environment-friendly gases and status of the aging campaign performed using the new gas is presented.

T 74.6 Thu 17:30 KH 01.014

**Investigation of the protection layers used in GridPix detectors** — •FELIX BECKER, JOCHEN KAMINSKI, KLAUS DESCH, SABINE HARTUNG, and YEVGEN BILEVYCH — Physikalisches Institut, Universität Bonn

The GridPix detector is a gaseous detector based on the Timepix technology. It is based on a pixel readout ASIC with a grid structure applied on top of it, which grants gas amplification. In the production process of the GridPix, a high-resistive protection layer is applied on the surface of the Timepix. This protection layer helps avoiding the chip getting damaged by sparks inside the detector and increases the longevity immensely. However, the exact electric properties, such as the resistivity of the layer, are not completely known. The main goal of this investigation is to find a reliable method for measuring the layer's resistivity. To do so, the results of multiple measuring methods, are compared. The first method is using charged particles. Because electrons accumulate at the surface of the protective layer if its resistivity is non-zero, a potential builds up on its surface. This potential lowers the effective electric field between the grid and the surface of the protective layer, what lowers the gas amplification. This effect takes place, until a steady state is reached. This charge-up effect and the discharge of the protective layer can be used to calculate the material resistivity. A second method is detaching the grid and measuring the resistivity directly via an voltage-current measurement. The presentation will describe the steps taken in the analysis, including the considerations behind each measurement method.

T 74.7 Thu 17:45 KH 01.014

**From Wafer to Detector: GridPix Production at the FTD** — •SABINE HARTUNG, YEVGEN BILEVYCH, JOCHEN KAMINSKI, and KLAUS DESCH — Physikalisches Institut Universität Bonn

GridPix detectors combine a pixel ASIC with an integrated Micromegas-type amplification structure (InGrid). The photolithographic fabrication of the grid directly on the Timepix/Timepix3 ASIC enables precise alignment of grid holes to the pixels and a well-defined amplification gap. This provides single-electron efficiency and an excellent spatial resolution. Such properties make GridPix detectors a promising candidate for precision TPCs as well as X-ray and low-background applications.

The production of GridPixes requires a sequence of photolithographic steps. To reduce the probability of spark damage during the operation, the chip is first coated with a Si<sub>x</sub>N<sub>y</sub> protection layer. As amplification gap an aluminium grid is built on top of freestanding pillars. Achieving high production yield demands precise control of technological conditions.

In this contribution, the first results of the GridPix production as implemented in the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn are presented.

## T 75: Higgs Physics VII

Time: Thursday 16:15–18:15

Location: KH 01.019

T 75.1 Thu 16:15 KH 01.019

**Projection Studies of the ttHH 1L Channel for the HL-LHC** — •DOĞA ELITEZ<sup>1</sup>, LUCIA MASETTI<sup>2</sup>, and PAUL GESSINGER<sup>1</sup> — <sup>1</sup>CERN — <sup>2</sup>JGU Mainz

The Higgs boson self-coupling is a central ingredient of electroweak symmetry breaking, and constraining this coupling is essential for validating the Standard Model and determining the shape of the Higgs potential. The cross-section for Higgs-pair production in association with top quarks (ttHH) is expected to increase significantly at higher LHC beam energies, making ttHH production a compelling process to study in the high-luminosity LHC (HL-LHC) era. A particularly challenging and informative decay channel is the ttHH(6b) one-lepton channel, in which one of the top quarks decays semi-leptonically and produces an electron or muon, while the Higgs pair decays into four b-quarks. In this talk, projection studies of the ttHH(6b) one-lepton channel for the HL-LHC are presented.

T 75.2 Thu 16:30 KH 01.019

**Higgs self-coupling measurement from di-Higgs production at a future e-e collider** — •JULIE TORNDAL<sup>1,2</sup>, JENNY LIST<sup>1</sup>, BRYAN BLIEWERT<sup>1,2</sup>, MIKAEL BERGGREN<sup>1</sup>, JUNPING TIAN<sup>3</sup>, TAIKAN SUEHARA<sup>3</sup>, DIMITRIS NTOUNIS<sup>4</sup>, and CATERINA VERNIERI<sup>4</sup> — <sup>1</sup>DESY, Hamburg, Germany — <sup>2</sup>Universität Hamburg, Hamburg Germany — <sup>3</sup>SLAC, Menlo Park, United States — <sup>4</sup>The University of Tokyo, Tokyo, Japan

Linear  $e^+e^-$  colliders have the energy reach to directly access the Higgs self-coupling at tree-level through di-Higgs production while offering a clean experimental environment. At a centre-of-mass energy of 550 GeV, two processes contribute, who have different dependencies on the value of  $\kappa_\lambda$  offering a com-

plementarity important for BSM scenarios. The leading contribution comes from Higgs strahlung, ZHH, with a small addition from the WW fusion. In this contribution, the ongoing analysis of the  $HH \rightarrow 4b$  channel will be presented using fast SGV (Simulation à Grande Vitesse) based simulation of the ILD (International Large Detector) concept with the full SM background. Improvements in flavour tagging and kinematic reconstruction will be discussed, and the status of the event selections using advanced machine learning techniques will be presented before evaluating the cross-section precisions for each channel and translating those into a precision on  $\kappa_\lambda$  for the SM and BSM case. The precise measurement of the Higgs self-coupling offers new insights central to the Higgs sector, in determining the shape of the Higgs potential and understanding the mechanism behind electroweak symmetry breaking.

T 75.3 Thu 16:45 KH 01.019

**Improving the event reconstruction and scalability of the Higgs self-coupling analysis at ILD** — MIKAEL BERGGREN<sup>1</sup>, •BRYAN BLIEWERT<sup>1,2</sup>, JENNY LIST<sup>1</sup>, DIMITRIS NTOUNIS<sup>3</sup>, TAIKAN SUEHARA<sup>4</sup>, JUNPING TIAN<sup>4</sup>, JULIE MUNCH TORNDAL<sup>1,2</sup>, and CATERINA VERNIERI<sup>3</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron DESY, Germany — <sup>2</sup>Universität Hamburg, Germany — <sup>3</sup>SLAC National Accelerator Laboratory, USA — <sup>4</sup>University of Tokyo, Japan

The shape of the Higgs potential gives crucial insight into the Higgs mechanism. At future  $e^+e^-$  colliders and center-of-mass energies of  $\geq 550$  GeV, the Higgs potential can be probed directly by measuring the self-coupling  $\lambda$  through di-Higgs production. In an ongoing effort, the projected sensitivities for  $\lambda$  are updated assuming the ILD concept at an LCF 550-like facility. In our contribution, we discuss recent advancements in event reconstruction: First, we cover the identifica-

tion and removal of low- $p_t$  hadrons (overlay) using machine learning (ML) and its effect on the di-jet invariant mass resolution. Second, we present how variables based on leading order matrix elements improve the event selection. Furthermore, we have designed our analysis using a modern distributed pipelining system (luigi/law) and present key concepts of this framework. It covers all steps from detector simulation to sensitivity extraction, greatly improving automation, reproducibility and scalability and producing results in a few hours for 150M events with  $\sim 1000$  computing nodes. We conclude by showing the impact of the reconstruction advances on the measurement of the di-Higgs cross-section and the corresponding precision on  $\lambda$ .

T 75.4 Thu 17:00 KH 01.019

**Assessing uncertainties in the determination of the trilinear Higgs self-coupling from single-Higgs observables** — HENNING BAHL<sup>1</sup>, PHILIP BECHTLE<sup>2</sup>, JOHANNES BRAATHEN<sup>3</sup>, SVEN HEINEMEYER<sup>4</sup>, JENNY LIST<sup>3</sup>, MURILLO VELLASCO<sup>2</sup>, and GEORG WEIGLEIN<sup>3,5</sup> — <sup>1</sup>Institute for Theoretical Physics (ITP), Universität Heidelberg, Germany — <sup>2</sup>Physikalisches Institut, Universität Bonn, Germany — <sup>3</sup>Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — <sup>4</sup>Instituto de Física Teórica (UAM/CSIC), Universidad Autónoma de Madrid, Spain — <sup>5</sup>Institut für Theoretische Physik, Universität Hamburg, Germany

Probing the nature of the Higgs potential is a primary objective of the next generation of flagship particle physics experiments, for which measuring  $\lambda_{\text{hhh}}$ , the trilinear Higgs self-coupling, will play a crucial role. Despite operating below the di-Higgs production threshold, circular  $e^+e^-$  machines will still have indirect access to  $\lambda_{\text{hhh}}$  via its loop-level contributions to single-Higgs production observables. In this work, we investigate how well  $\lambda_{\text{hhh}}$  can be determined by such indirect effects within a global EFT fit. While most studies to date assume that future measurements will be compatible with SM predictions, here we consider non-SM values of  $\lambda_{\text{hhh}}$ , using an inert doublet extension of the SM as an example of a New Physics scenario that could be realised in nature. We find that theory uncertainties related to the truncation of the EFT expansion and to higher-order corrections, which are often neglected, can have a substantial impact on the resulting precision for  $\lambda_{\text{hhh}}$ .

T 75.5 Thu 17:15 KH 01.019

**Beam-beam effects at the Hybrid Asymmetric Linear Higgs Factory** — SHRIYANSH RANJAN<sup>1,2</sup>, JENNY LIST<sup>1</sup>, and MIKAEL BERGGREN<sup>1</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — <sup>2</sup>Universität Hamburg, Hamburg, Germany

Since the discovery of the Higgs boson in 2012, probing the Higgs potential has become a primary objective for understanding vacuum stability and searching for Beyond Standard Model (BSM) physics. This precise measurement of the Higgs potential requires the clean environment of an  $e^+e^-$  collider. The Hybrid Asymmetric Linear Higgs Factory (HALHF) utilizes plasma-wakefield acceleration (PWFA), an emerging accelerator technology, to create high-energy collisions capable of such precision.

However, the resulting beam conditions drive strong-field QED processes that reshape the luminosity spectrum and increase detector backgrounds. To address these challenges, advanced simulation tools are required. Our study models these beam-induced backgrounds for HALHF using cutting edge simulation software, providing inputs helpful in designing the asymmetric ILD detector at HALHF.

This talk presents simulation results for the highly asymmetric  $e^+e^-$  collisions at HALHF, evaluating the beam-induced backgrounds as well as the luminosity spectrum and its impact on key physics measurements. The outcomes will be discussed across different center-of-mass energies from 250 GeV to 550 GeV.

T 75.6 Thu 17:30 KH 01.019

**Probing Strong First-Order Electroweak Phase Transition scenarios in 2HDM with FCC-ee/CEPC** — ANISHA ANISHA<sup>1,2</sup>, FRANCISCO ARCO<sup>3</sup>, STEFANO DI NOI<sup>1</sup>, CHRISTOPH ENGLERT<sup>4</sup>, and MARGARETE MÜHLEITNER<sup>1</sup> — <sup>1</sup>Institute for Theoretical Physics, Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede Straße 1, D-76131, Karlsruhe, Germany — <sup>2</sup>Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, D-76344, Eggenstein-Leopoldshafen, Germany — <sup>3</sup>Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, D-22607 Hamburg, Germany — <sup>4</sup>Department of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom

We investigate the potential of future electron-positron colliders, such as FCC-ee and CEPC, to probe 2-Higgs-doublet models (2HDMs) that facilitate a strong first-order electroweak phase transition (SFOEWPT), a necessary condition for electroweak baryogenesis. Focusing on a 2HDM in the CP-conserving limit, we identify parameter regions consistent with an SFOEWPT and evaluate their compatibility with projected precision electroweak and Higgs measurements, as well as searches for exotic Higgs bosons. We show that radiative corrections to  $e^+e^- \rightarrow hZ$  production introduce deviations in the cross section that are resolvable with the anticipated sub-percent precision at lepton colliders even when experimental outcomes of the LHC and Z pole measurements are in agreement with the SM. This underscores the opportunities of a precision lepton collider to explore BSM quantum corrections to the Higgs sector more broadly.

T 75.7 Thu 17:45 KH 01.019

**Higgs Measurements at Photon Colliders** — AYOADE SOTONA — Universität Hamburg

The Photon-Collider offers a complementary experimental programme for possible future linear colliders to  $e^+e^-$ . The cross-section of photon-photon collisions can be multitudes higher than those of corresponding electron-positron collisions, which makes them particularly interesting for (Di-)Higgs production and the measurement of trilinear couplings.

T 75.8 Thu 18:00 KH 01.019

**Probing the Higgs potential via Higgs pair production at photon-photon colliders** — GUDRID MOORTGAT-PICK<sup>1,2</sup>, MARTEN BERGER<sup>1</sup>, GEORG WEIGLEIN<sup>2</sup>, and JOHANNES BRAATHEN<sup>2</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>Deutsches Elektronen-Synchrotron

A  $\gamma\gamma$  collider, either in conjunction with an  $e^+e^-$  linear collider or as a stand-alone facility, offers a very attractive Higgs physics programme at relatively low centre-of-mass (c.m.) energies. A c.m. energy as low as 280 GeV can probe the Higgs potential via the Higgs pair production process providing access to the trilinear Higgs-boson self-coupling. High polarisation of the photon beams (produced via Compton back-scattering) can be achieved and adjusted by flipping the polarisation of the incident laser. The prospects for exploring the Higgs pair production process at a  $\gamma\gamma$  collider are assessed by comparing different running scenarios utilising different types of the incident laser. The possibility to use photon polarisation has been exploited as well.

## T 76: Silicon Detectors VII

Time: Thursday 16:15–18:15

Location: KH 01.022

T 76.1 Thu 16:15 KH 01.022

**High-resolution timing measurement of a TJ-Monopix2 DMAPS utilizing a 30ps TDC on FPGA implementation** — RASMUS PARTZSCH, CHRISTIAN BESPIN, JOCHEN DINGFELDER, FABIAN HÜGGING, HANS KRÜGER, RAMON LEISER, and LARS SCHALL — Physikalisches Institut der Universität Bonn, Bonn, Germany

The development and characterization of monolithic active pixel sensors with depleted substrates (DMAPS) in the last years lead the way to various applications in future tracking detectors. Increases in luminosity of high-energy physics experiments demand strict timing conditions on the detectors. To enable characterizations with precise timing, an on-FPGA time-to-digital converter utilizing a tapped delay line has been developed achieving a timing resolution down to 30 ps. TJ-Monopix2 is a large-scale DMAPS designed in TowerJazz 180 nm CMOS technology, and features a small charge collection electrode with a pixel size of  $33 \times 33 \mu\text{m}^2$ . High-resistivity silicon substrate and high bias voltage capabilities allow for a full depletion of the sensitive volume and fast charge collection enabling operation in high-rate environments, especially after NIEL irradiation. Its successor chip, OBELIX, is designed for the BELLE II vertex detector upgrade (VTX).

This contribution outlines the implementation of the TDC as part of the read-out system. Additionally, we present the latest test-beam results for TJ-Monopix2 after irradiation to  $1\text{e}15 \text{ neq/cm}^2$  NIEL fluence, focussing on its timing performance.

T 76.2 Thu 16:30 KH 01.022

**Development of a DMAPS-based beam telescope** — WIEBKE BUHMANN, CHRISTIAN BESPIN, JOCHEN DINGFELDER, FABIAN HÜGGING, NICO KLEIN, HANS KRÜGER, RASMUS PARTZSCH, LARS SCHALL, and ALEXANDER WALSEMANN — Physikalisches Institut der Universität Bonn, Bonn, Germany

Testbeam telescopes serve as high-resolution tracking devices in beam test experiments. A new beam telescope is proposed to utilize depleted monolithic active pixel sensors (DMAPS) combining fast charge collection with high spatial resolution and low material budget.

The first iteration will use TJ-Monopix2 sensors that provide a spatial resolution of  $<10\mu\text{m}$  and time resolution  $<2\text{ns}$  with 40MHz hit-timestamping. These characteristics make the telescope applicable for low momenta and high-rate beam environments.

In this contribution, the current development status regarding the data acquisition system, control software and mechanics will be presented. Additionally first test-beam results with TJ-Monopix2 optimized for these conditions will be shown.

T 76.3 Thu 16:45 KH 01.022

**Characterization of the AstroPix v3 HVMAPS** — LENNART HUTH<sup>1</sup>, •STEPHAN LACHNIT<sup>1</sup>, RICHARD LEYS<sup>2</sup>, ELIZAVETA SITNIKOVA<sup>1</sup>, SIMON SPANNAGEL<sup>1</sup>, and NICOLAS STRIEBIG<sup>2</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — <sup>2</sup>Karlsruher Institut für Technologie KIT, Karlsruhe, Germany  
AstroPix is a High-Voltage Monolithic Active Pixel Sensor (HVMAPS) designed for space-based medium-energy gamma-ray observatories like NASA's AMEGO-X. It aims to deliver a dynamic range from 25 to 700 keV with an energy resolution of 10 % at 122 keV. To achieve a high quantum efficiency, full depletion of the sensor is essential. Due to power and cooling restrictions in space, the power consumption of the sensor is limited to less than 1.5 mW/cm<sup>2</sup>.

The third iteration of the sensor (AstroPix v3) consists of a 35 × 35 pixel matrix with a pixel pitch of 500 μm. It has been characterized at the DESY II Test Beam Facility in order to evaluate the detection efficiency, spatial resolution and depletion depth of the sensor using charged particles.

In this contribution, laboratory measurements and first results of this test beam campaign will be shown.

T 76.4 Thu 17:00 KH 01.022

**Optimising high resolution time measurement in HVMAPS** — •ALEXANDER SCHMIDT for the HVMAPS HD-Collaboration — Physikalisches Institut Heidelberg

The phase 2 upgrade of the Mu3e experiment aims for a time resolution of 100ps to suppress coincidental background events. In the many-channel context of pixel sensors, time measurement circuits (TDCs) are constrained by size and current consumption.

This talk gives an overview on the current-capacitance based ramp approach to time measurement. Current HVMAPS prototypes, such as Telepix, achieve TDC resolution of 100ps at 125MHz base clock with minimal optimisation.

In this type of TDC, current consumption is largely driven by constant current sources. It can be reduced drastically by switched current sources. This talk demonstrates a circuit topology which avoids nonlinearity typically introduced by switching transistors.

T 76.5 Thu 17:15 KH 01.022

**Systematic studies of photon irradiated HV-CMOS MAPS towards the LHCb Mighty-Tracker** — •NICLAS SOMMERFELD, HANNAH SCHMITZ, KLAAS PADEKEN, and SEBASTIAN NEUBERT — HISKP Bonn

With the high luminosity upgrade to the LHC during LS3 the instantaneous luminosity at the LHCb experiment will be eventually increased by more than a factor of 6 to  $1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$  for Run 5. As a part of Upgrade II the LHCb downstream tracker (Mighty-Tracker) is foreseen to be instrumented with 10m<sup>2</sup> of HV-CMOS MAPS around the beam pipe. This is intended to meet the increased requirements in terms of granularity and radiation tolerance imposed by the higher luminosity.

As a part of the ongoing efforts to develop the HV-CMOS MAPS foreseen for the Mighty-Tracker, the impact of Total Ionizing Dose (TID) damage on key performance requirements is further investigated under experimental conditions. The results of systematic studies of in-house irradiated sensors are presented within this talk.

T 76.6 Thu 17:30 KH 01.022

**Results from an HV-MAPS-Based Detector Prototype for Position-Resolved μSR Measurements** — •LUKAS MANDOK for the HVMAPS HD-Collaboration — Physikalisches Institut, Heidelberg, Germany

Muon Spin Spectroscopy (μSR) is a well-established technique in material science for probing magnetic properties at the atomic scale. Conventional μSR spectrometers based on scintillators are fundamentally limited by coarse granularity and strict pile-up constraints, which restrict the usable muon rate and prevent spatially resolved measurements.

To overcome these limitations, we developed a pixel-based μSR detector using four ultra-thin HV-MAPS tracking layers based on MuPix11 sensor modules, which record incoming muons and decay positrons with high spatial precision. This enables accurate track reconstruction and a sub-millimeter determination of the decay vertex inside the sample. The approach further supports measurements of multiple samples and composite materials, while the resulting spatial information allows three-dimensional sample reconstruction and provides access to local magnetic fields by correlating vertex positions with the position-dependent precession signal.

The detector was operated several times at the πE3 beamline at PSI, demonstrating stable performance at beam intensities two orders of magnitude beyond the limits of scintillator-based systems. Its combination of high-rate capability and precise vertexing marks a significant step toward next-generation μSR spectrometers.

T 76.7 Thu 17:45 KH 01.022

**Electrical Simulation and Characterization of All-Silicon Modules for CMOS Monolithic Pixel Detectors** — MARKUS CRISTINZIANI<sup>1</sup>, QADER DOROSTI<sup>1</sup>, STEFAN HEIDBRINK<sup>2</sup>, DENISE MÜLLER<sup>1</sup>, NOAH SIEGEMUND<sup>1</sup>, •DARSHIL VAGADIYA<sup>1</sup>, WOLFGANG WALKOWIAK<sup>1</sup>, JENS WINTER<sup>2</sup>, and MICHAEL ZIOLKOWSKI<sup>2</sup> — <sup>1</sup>Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — <sup>2</sup>Elektronikentwicklungslabor Physik, Universität Siegen

Silicon pixel detectors offer high spatial and temporal resolution with a low material budget. Traditional multi-chip modules add material through bump-bonding, flexible PCBs, cooling, and support structures. A new approach explores post-processing monolithic wafers with redistribution layers interconnecting multiple chips, enabling thin and lightweight structures based on low-power monolithic CMOS sensors. In current production, this concept is used in all-silicon modules that integrate four sensors cut from a single wafer and rely on the OBELIX monolithic active pixel sensor, which reduces component count and support low-material designs suitable for future collider environments. The research in Siegen focuses on the electrical performance of signal and data interconnections at high transmission speeds. Current structures reach 0.25 Gbps, with a target of at least 1 Gbps. Prototype measurements covering impedance, signal integrity, S-parameters, and electrical simulations of differential trace geometry, dielectric layers, and vias are used to identify speed limitations and guide optimization of the interconnection layout for higher data-rate operation.

T 76.8 Thu 18:00 KH 01.022

**Thermomechanical Simulation of an All-Silicon CMOS Pixel Detector Ladder** — •NANA CHYCHKALO, JOERN GROESSE-KNETTER, and ARNULF QUADT — Georg-August-Universität Göttingen, Göttingen, Germany

This work investigates a new monolithic ladder concept for the All-Silicon CMOS pixel detectors, in which several chips are integrated into a single self-supporting silicon structure. This approach aims to reduce the material budget compared to conventional hybrid assemblies and offers a promising option for future high-luminosity experiments.

A key feature of this concept is the use of a Redistribution Layer (RDL) for both power delivery and data transmission across the ladder, eliminating the need for additional support circuitry. The combination of active CMOS areas and RDL components in a thin monolithic structure, requires, however, careful evaluation of the resulting thermal and mechanical behavior.

This contribution presents thermomechanical simulations performed to understand the ladder heat dissipation under realistic operating conditions. These studies are used to estimate cooling requirements and to define suitable air-cooling parameters for stable operation.

## T 77: Higgs Physics VIII

Time: Thursday 16:15–18:15

Location: KH 02.013

T 77.1 Thu 16:15 KH 02.013

**ttH Analysis with Two Light Leptons and One Hadronically Decaying Tau Lepton with Run-2 ATLAS Data** — EPHREM ALEMU, •DAVID ERWIN, and ANDRÉ SOPCZAK — CTU in Prague

The latest results of the ttH analysis in the 2lSS1tau channel are presented with focus on machine learning using ATLAS Run-2 data.

T 77.2 Thu 16:30 KH 02.013

**Mass-decorrelated jet-particle assignment for ttH(bb) events in dileptonic and semileptonic final states using Run 3 CMS Simulation** — •PHILIPP NATTLAND<sup>1</sup>, KAI ADAMOWICZ<sup>1</sup>, LUTZ FELD<sup>1</sup>, DANYER PEREZ ADAN<sup>1</sup>, VALE-

RIA BOTTA<sup>1</sup>, MATIN TORKIAN<sup>2</sup>, MARIA ALDAYA MARTIN<sup>2</sup>, and DAINA LEYVA PERNIA<sup>2</sup> — <sup>1</sup>RWTH Aachen — <sup>2</sup>DESY

The associated production of a top-quark pair with a Higgs boson (ttH) directly probes the top-Higgs Yukawa coupling in the Standard Model. This study examines the ttH(bb) channel in the semileptonic and dileptonic final states, using Run 3 CMS simulation data. For a robust, data-driven estimation of the dominant tt+bb background the final state is reconstructed using advanced machine learning techniques for jet assignment. To use the invariant mass of jets assigned to the Higgs candidate as an unbiased fit variable, the reconstruction is decorrelated from the Higgs mass.

T 77.3 Thu 16:45 KH 02.013

**Mass-decorrelated signal versus background classification for ttH(bb) events in single- and dileptonic final states using Run 3 CMS Simulation** — •KAI ADAMOWICZ<sup>1</sup>, LUTZ FELD<sup>1</sup>, VALERIA BOTTA<sup>1</sup>, DANYER PEREZ ADAN<sup>1</sup>, PHILIPP NATTLAND<sup>1</sup>, MATIN TORKIAN<sup>2</sup>, MARIA ALDAYA MARTIN<sup>2</sup>, and DAINA LEYVA PERNIA<sup>2</sup> — <sup>1</sup>RWTH Aachen University — <sup>2</sup>DESY

The ttH process provides a direct probe of the top-Higgs Yukawa coupling, an important parameter of the Standard Model. Due to a large and difficult to accurately model ttbb background, its measurement in the  $H \rightarrow b\bar{b}$  channel has proven challenging in previous attempts by the CMS and ATLAS collaborations. Using the transformer based neural network architecture "SPANet", the prospect of a mass decorrelated kinematic reconstruction of the final states and event classification is studied on Run 3 CMS simulation. This way, the invariant mass of the jets assigned to the Higgs candidate may be used as an unbiased fit variable.

T 77.4 Thu 17:00 KH 02.013

**Analysis of tH(bb) production with ATLAS Run-2 data** — •FILIP RUCKA and ANDRÉ SOPCZAK — CTU in Prague

The latest results of the analysis tH(bb) are presented with focus on machine learning using ATLAS Run-2 data.

T 77.5 Thu 17:15 KH 02.013

**Higgs-to-Bottom Decays at next-to-leading order in the Sherpa Event Generator** — •LEA BAUMANN<sup>1</sup>, FRANK SIEGERT<sup>1</sup>, MAREEN HOPPE<sup>1</sup>, and MAREK SCHÖNHERR<sup>2</sup> — <sup>1</sup>TUD Dresden University of Technology, Institute of Nuclear and Particle Physics — <sup>2</sup>University of Durham, Institute for Particle Physics Phenomenology

Monte Carlo event generators play a central role in particle collider data analysis by providing accurate theoretical predictions of complex scattering processes. Event generators like Sherpa use the narrow-width approximation to describe short-lived resonances as on-shell particles, allowing the factorisation of production and decay of these "hard" particles.

Until now, Sherpa's hard decays have been implemented only at leading order in perturbative quantum chromodynamics (QCD). In this talk, the next-to-leading order (NLO) QCD calculation for the decay of a Higgs boson into a bottom-antibottom pair within the hard-decay framework will be presented. The computation includes the evaluation of virtual loop corrections, real-emission contributions, and the cancellation of infrared singularities using subtraction terms. The resulting NLO matrix element can later be matched to parton shower programmes. This NLO implementation improves the precision of Higgs-decay simulations within Sherpa and enables more accurate modelling of processes.

T 77.6 Thu 17:30 KH 02.013

**Search for the Higgs boson decay into charm-anticharm quark pairs in the vector boson associated production mode with the CMS Experiment** —

•VALENTYN VAULIN, ALEXANDER SCHMIDT, ANDREY POZDNYAKOV, PATRICK KERSTEN, PEDRO GOUVEIA PINTO DA COSTA, ISHMEET KAUR VOHRA, JAN TERÖRDE, and ARND MEYER — III. Physics Institute A, RWTH Aachen University, Aachen, Germany

The most sensitive channel to constrain the Higgs-charm quark coupling is the Higgs boson decay into charm-anticharm quarks in the associated production with vector bosons, the so called VH ( $H \rightarrow c\bar{c}$ ) channel. Results on the searches in this approach have been published by CMS using data from LHC Run 2. This talk will give an overview of the ongoing developments and expectations for this analysis. Highlights include a new analysis framework which provides improved sensitivity using machine learning methods. The analysis now also probes the VH ( $H \rightarrow c\bar{c}$ ) and VH ( $H \rightarrow b\bar{b}$ ) channels at the same time. Preliminary results with data from LHC Run 3 will be shown.

T 77.7 Thu 17:45 KH 02.013

**Integration of the PAIReD Tagger for the Higgs-boson Decay into Charm - Anticharm Quark Pairs in Vector-Boson Associated Production with the CMS Experiment** — •ISHMEET KAUR VOHRA, ALEXANDER SCHMIDT, ARND MEYER, ANDREY POZDNYAKOV, VALENTYN VAULIN, PEDRO GOUVEIA PINTO DA COSTA, PATRICK KERSTEN, and JAN TERÖRDE — III. Physics Institute A, RWTH Aachen University, Aachen, Germany

Reconstructing hadronically decaying heavy particles at low to moderate boosts is challenging when using only small-radius jets. The PAIReD and PAIReDELipso approaches address this by forming jet candidates from pairs of small-radius jets and in the elliptical variant, by including all particles inside an extended elliptical region in the  $\eta - \phi$  plane. Their performance has been studied for Higgs boson decays into bottom-antibottom (bb) and charm-anticharm (cc) quark pairs produced in association with a vector boson (V), using ParticleTransformer-based algorithms for jet regression and classification. The methods show improved reconstruction efficiency and background separation in the lowboost regime compared to standard AK4 techniques, while remaining competitive at higher boosts. This contribution covers the integration of the PAIReD Tagger into the analysis of the VH( $H \rightarrow c\bar{c}$ ) channel, including an initial investigation of the related systematic uncertainties.

T 77.8 Thu 18:00 KH 02.013

**Investigation on the use of multiclass BDTs in the search for the Higgs boson decay to a charm-anticharm pair in vector boson associated production mode at CMS in Run 3** — •PEDRO GOUVEIA PINTO DA COSTA, ALEXANDER SCHMIDT, ANDREY POZDNYAKOV, VALENTYN VAULIN, PATRICK KERSTEN, ISHMEET KAUR VOHRA, JAN TERÖRDE, and ARND MEYER — III. Physikalisches Institut A, RWTH Aachen University

The most sensitive channel to search for the decay of the Higgs boson into charm quarks is the vector boson associated production mode (VH channel) in which the Higgs boson is produced along with a W or Z boson. Analyses targeting this channel use multiple different machine learning models to help distinguish between signal and background events. Among the main backgrounds are W/Z plus jet production and top quark pair production. Events are classified into several categories with different signal and background compositions to facilitate a multi-parameter fit. This talk presents a study in which the potential of a multi-class boosted decision tree (BDT) is investigated in comparison to the previously used binary classification.

## T 78: Flavour Physics V

Time: Thursday 16:15–18:15

Location: KH 02.014

T 78.1 Thu 16:15 KH 02.014

**Measurement of Charm and Beauty Production in Proton-Proton Collisions at  $\sqrt{s} = 5$  TeV with the CMS Experiment** — •LUCAS KARWATZKI<sup>1,2</sup>, ACHIM GEISER<sup>1</sup>, ALEXANDER SCHMIDT<sup>2</sup>, and ARND MEYER<sup>2</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron, Hamburg, Germany — <sup>2</sup>Physics Institute III A RWTH Aachen University, Aachen, Germany

Measuring the charm and beauty production cross sections is not only a crucial test of the Standard Model but also provides valuable input for refining the proton parton distribution functions at low  $x$ , and for the determination of the charm and beauty quark masses.

In this talk, I will present a double-differential measurement of the  $D^*$ -meson production cross section in transverse momentum  $p_T$  and absolute rapidity  $|y|$  in proton-proton collisions at  $\sqrt{s} = 5$  TeV using the CMS detector. The decay topology of the  $D^*$  meson allows access to very low transverse momenta ( $p_T$ ) and by combining these results for the high-rapidity phase space with LHCb measurements, total cross sections for heavy-flavour production can be measured with only small extrapolation.

$D^*$  mesons can originate either directly from charm-quark hadronisation or from the decay of B hadrons. The longer lifetime of B hadrons enables the use of the impact parameter and decay length significance to effectively separate the two contributions, and therefore allows for the measurement of both the charm and beauty production cross sections.

T 78.2 Thu 16:30 KH 02.014

**Measurement of strangeness production in pNe collisions at LHCb** — JOHANNES ALBRECHT<sup>1</sup>, •THEODOR ZIES<sup>1</sup>, NOAH BEHLING<sup>1</sup>, FELIX RIEHN<sup>1</sup>, SÁVIO MARIANI<sup>2</sup>, and CHIARA LUCARELLI<sup>2</sup> — <sup>1</sup>TU Dortmund, Germany — <sup>2</sup>CERN

In the Standard Model, the strong interaction is described by quantum chromodynamics (QCD) and is generally well understood. Processes with low momentum transfer (soft QCD) require complex, data-driven models describing hadronic interactions. Measurements of various hadron production cross-sections serve as essential inputs to constrain these models and tune their parameters, ensuring they provide accurate predictions across different energies. A mismatch in the number of muons produced in simulations and data of cosmic-ray induced air showers hints at insufficiencies in current models. In this work, a measurement of the baryon-to-meson and baryon-to-antibaryon strange hadron production cross-section ratios  $R_{\Lambda^0/K_S^0}$  and  $R_{\Lambda^0/\bar{\Lambda}^0}$  is performed. Data from fixed-target pNe collisions acquired using the SMOG2 system of the LHCb Upgrade I detector are used, collected during Run 3 of the LHC and corresponding to an integrated luminosity of  $\mathcal{L}_{\text{int}} = 225 \text{ nb}^{-1}$  at a center-of-mass energy of  $\sqrt{s_{\text{NN}}} = 113 \text{ GeV}$ . The results are calculated differentially as a function of transverse momentum and rapidity. A comparison with predictions of the commonly used hadronic interaction models EP05-LHC and QGSJet enables the study of how accurately these models describe strangeness production. Overall agreement is observed in most kinematic bins, while the newer tunes of the models show slightly better consistency.



T 78.3 Thu 16:45 KH 02.014

**Reconstruction of multi-strange baryons  $\Xi$  and  $\Omega$  in pp collisions at  $\sqrt{s} = 13.6$  TeV with the ALICE detector** — BILGE JIN ONEN<sup>1</sup> and AYBEN KARASU UYSAL<sup>2</sup> — <sup>1</sup>Istanbul Technical University, Istanbul, Turkey — <sup>2</sup>Yildiz Technical University, Istanbul, Turkey

Strangeness production has long been regarded as a key signature of the quark-gluon plasma (QGP), a deconfined state of matter created in ultra-relativistic heavy-ion collisions. Similar features such as collective flow and enhanced yields of strange and multi-strange baryons have also been observed in high-multiplicity small collision systems, including proton-proton (pp) interactions at the LHC. These findings make the study of strangeness a central topic within the ALICE experiment, where pp collisions provide a unique environment to investigate QGP-like effects without the presence of large-volume nuclear matter.

In this work, the reconstruction of the multi-strange baryons  $\Xi$  (dss) and  $\Omega$  (sss) in pp collisions at  $\sqrt{s} = 13.6$  TeV is presented using standard topological selections and invariant-mass analysis techniques. The cascade weak decays  $\Xi \rightarrow \Lambda \pi^-$  and  $\Omega \rightarrow \Lambda K^-$ , with  $\Lambda \rightarrow p \pi^-$ , are reconstructed from charged decay tracks identified with the ITS, TPC and TOF detectors. The obtained corrected yields agree with published ALICE results within uncertainties, validating the classical reconstruction. This analysis provides a solid reference for future studies exploring machine-learning-based selection strategies.

T 78.4 Thu 17:00 KH 02.014

**Total and differential charm production cross sections in pp collisions at  $\sqrt{s} = 13$  TeV** — AVIRAL AKHIL and ACHIM GEISER — Deutsches Elektronen-Synchrotron, Hamburg, Germany

Charm production sits at the boundary where perturbative QCD begins to lose precision and non-perturbative effects become significant, making it a powerful probe of the strong interaction. To explore this challenging regime, we present measurements of  $D^*$ -meson differential charm production cross sections at a proton proton center-of-mass energy of  $\sqrt{s} = 13$  TeV using the CMS detector. The analysis reconstructs charm hadron decays across the largest accessible phase space to minimize extrapolation to the full charm production region. Results are reported as differential cross sections in transverse momentum and rapidity and compared to QCD predictions as well as to measurements from other LHC experiments. The fiducial cross sections are then extrapolated to the total charm-pair cross section using a data-driven parameterization of charm fragmentation fractions that incorporates recent measurements of meson-baryon ratios dependent on  $p_T$ . The use of non-universal, experimentally constrained fragmentation improves the fragmentation treatment relative to earlier extractions. These results provide constraints on key QCD parameters such as the charm-quark mass and parton distribution functions at low momentum fraction and contribute to a more detailed understanding of heavy-flavour production dynamics at the LHC.

T 78.5 Thu 17:15 KH 02.014

**$\bar{\Lambda}^0/K_S^0$  production cross-section ratio at LHCb in Run 3** — JOHANNES ALBRECHT<sup>1</sup>, NOAH BEHLING<sup>1</sup>, LUKAS CALEFICE<sup>2</sup>, BILJANA MITRESKA<sup>3</sup>, and TITUS MOMBÄCHER<sup>4</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>Universitat de Barcelona, Barcelona, Spain — <sup>3</sup>University of Manchester — <sup>4</sup>University of Cincinnati

Hadron production ratios are a useful probe to test and improve hadronisation models. In this work, the production ratio of  $K_S^0$  and  $\bar{\Lambda}^0$  is studied with Run 3 proton-proton collision data from the upgraded LHCb experiment. These studies are also essential to calibrate and validate the performance of the upgraded detector. The proper operation of all subsystems must be ensured step-by-step to carry out precise measurements with data recorded recently and in the future. The performance of the tracking system can be evaluated with the measured ratio.

Meson-to-baryon ratios and strangeness production also contribute to the understanding of hadronic processes in cosmic-ray-induced extensive air showers, which are dominated by soft-QCD effects in the forward region. In air-shower data, an excess of muons produced with respect to Monte Carlo event generators

has been observed, which could originate from mismodelling of the hadronisation process. The LHCb experiment offers a unique environment to test hadronic models in the forward region.

The current status of the analysis and recent studies on detector performance will be presented. Additionally, the connection of collider experiments to air-shower measurements will be discussed.

T 78.6 Thu 17:30 KH 02.014

**Charm mesons production asymmetries at LHCb in Run 3** — LUCA BALZANI<sup>1</sup>, SERENA MACCOLINI<sup>2</sup>, and DOMINIK STEFAN MITZEL<sup>1</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>CERN, Geneva, Switzerland

Ahead of Run 3 of the LHC, the LHCb detector was profoundly upgraded to leverage the programmed increase in luminosity. Studying the features of the upgraded detector is of paramount importance in order to reliably perform measurements.

Production asymmetries are ideal candidates to investigate the characteristics of the new LHCb detector. These observables depend on the colliding system characteristics but shall not be influenced by experimental effects. Therefore, having these latter contributions under control is essential to perform a consistent measurement. Precise measurements of production asymmetries also allow for a better understanding of QCD models used in Monte Carlo generators, especially in the high-rapidity region. The production asymmetry for neutral charm meson has been measured for the first time in proton-proton collisions at the LHC energies and is part of the first published result from LHCb with Run 3 data. This contribution will discuss the general strategy and the techniques used for the measurement, providing some insights on the characteristics of the new LHCb Run 3 data.

T 78.7 Thu 17:45 KH 02.014

**Charm and beauty separation using reconstructed  $D^*$  mesons with the b-hive framework in CMS** — SHRUTI SHETTY<sup>1</sup>, LUCAS KARWATZKI<sup>1,2</sup>, ALEXANDER SCHMIDT<sup>1</sup>, ACHIM GEISER<sup>2</sup>, and ARND MEYER<sup>1</sup> — <sup>1</sup>III. Physikalisches Institut A, RWTH Aachen University — <sup>2</sup>DESY, Hamburg

Reliable separation of charm and beauty hadrons is essential for precision measurements and searches involving heavy flavour at the LHC. In this study, reconstructed  $D^* \rightarrow D^0 \pi_s$  candidates, with  $D^0 \rightarrow K \pi$  decays, are investigated using simulated proton-proton collision samples from the CMS experiment. For the first time, hadron-level particle identification is implemented within the b-hive framework, a modular training framework for state-of-the-art object tagging in the Python ecosystem used by the CMS experiment. This approach provides the basis for future optimization of charm and beauty identification and its application in physics analyses.

T 78.8 Thu 18:00 KH 02.014

**Measurement of the Oscillation Frequency  $\Delta m_s$  with 2024 Data of the Upgraded LHCb Experiment** — JOHANN NICOLAS HIMBERT<sup>1</sup>, STEPHANIE HANSMANN-MENZEMER<sup>1</sup>, LENNART UECKER<sup>1</sup>, SARA CELANI<sup>2</sup>, and MARC QUENTIN FÜHRING<sup>3</sup> — <sup>1</sup>Physikalisches Institut Heidelberg University, Heidelberg, Germany — <sup>2</sup>CERN, Switzerland — <sup>3</sup>TU Dortmund University, Dortmund, Germany

The measurement of the oscillation frequency  $\Delta m_s$  in the  $B_s^0 - \bar{B}_s^0$  system is an excellent showcase of the capabilities of the upgrade LHCb experiment in Run 3. The LHCb detector in Run 3 is collecting data at a five times larger instantaneous luminosity than in Run 2. To cope with this increased luminosity, all subdetectors and their readout-electronics have undergone major upgrades and a fully software based trigger has been implemented. The later improves the acceptance of softer decays for multi-body hadronic final states, which results in a three times larger yield of signal candidates per fb<sup>-1</sup>. For the measurement of  $\Delta m_s$  new dedicated Run 3 flavour-tagging algorithms and the excellent decay time resolution of the upgrade detector are exploited to resolve the oscillation. On a small test data set of 1.2 fb<sup>-1</sup> the decay channel  $B_s^0 \rightarrow D_s^- \pi^+$  with  $D_s^- \rightarrow \phi^0 (\rightarrow K^- K^+) \pi^-$  is studied and the oscillation frequency,  $\Delta m_s$ , resolved with a statistical uncertainty of 0.0156 ps<sup>-1</sup>.

## T 79: Searches/BSM IV

Time: Thursday 16:15–17:45

Location: KH 02.018

T 79.1 Thu 16:15 KH 02.018

**Quantum work for deriving and explaining the Lorentz transformations** — GRIT KALIES<sup>1</sup>, DUONG D. DO<sup>2</sup>, and CORNELIA BREITKOPF<sup>3</sup> — <sup>1</sup>HTW University of Applied Sciences, Dresden, Germany — <sup>2</sup>The University of Queensland, Brisbane, Australia — <sup>3</sup>Technical University of Dresden, Dresden, Germany

The Lorentz transformations of mass and time are derived and explained within the framework of quantum-process thermodynamics. To this end, we use various forms of quantum work for describing the behavior of an accelerated particle, for example an electron. We find that during acceleration, a particle does

not only change its velocity and (external) motion energy, but also its internal energies and structure. A new equation for the motion energy of an object is presented, which generalizes kinetic and electromagnetic energy. We compare our results with those of special relativity and discuss various microscopic and macroscopic experiments. Since energetic explanations are provided, quantum-process thermodynamics seems well suited to establishing a direct link between classical thermodynamics and quantum physics.

T 79.2 Thu 16:30 KH 02.018

**Constraining a Beyond Standard Model Theory with Neutrino Public Data** — •SOFIA LONARDI<sup>1,2</sup> and PHILIPP ELLER<sup>2</sup> — <sup>1</sup>Arnold Sommerfeld Center, Ludwig-Maximilians-Universität (LMU), Theresienstraße 37, 80333 Munich, Germany — <sup>2</sup>Technical University Munich (TUM), James-Frank-Strasse 1, 85748 Garching, Germany

Neutrino experiments provide a powerful window into physics beyond the Standard Model. While oscillation measurements precisely determine mixing angles and mass splitting parameters, non-oscillation experiments constrain absolute neutrino masses, together offering complementary probes of new physics.

This work relies on a global analysis framework that combines publicly available data from leading experiments: Daya Bay, MINOS, KamLAND, KATRIN, GERDA, and JUNO. These data are used to test the "Naturalness" theory, a Beyond Standard Model theory that simultaneously addresses neutrino mass generation and the electroweak hierarchy problem through multiple copies of the Standard Model in hidden sectors with varying Higgs masses.

By fitting the data with this model across different neutrino mass orderings and Majorana or Dirac scenarios, we establish lower bounds on the number of hidden sectors and on the theory's fine-tuning parameter, effectively constraining the parameter space and excluding a class of theory realisations.

T 79.3 Thu 16:45 KH 02.018

**Collision operators in electroweak baryogenesis** — •JOHANN PLOTNIKOV<sup>1</sup>, MARGARETE MÜHLEITNER<sup>1</sup>, RUI SANTOS<sup>2</sup>, and JOÃO VIANA<sup>2</sup> — <sup>1</sup>KIT, Karlsruhe, Germany — <sup>2</sup>Universidade de Lisboa, Lisboa, Portugal

It is known that extensions of the Standard Model are necessary to explain the observed Baryon Asymmetry of the Universe (BAU) as they are able to provide a strong first-order phase transition needed for electroweak baryogenesis. During the phase transition bubbles are created which separate the true vacuum from the broken vacuum. As the particles of the plasma collide with the bubble wall, the particles and anti-particles scatter differently to create the BAU. However, at the same time the surrounding plasma tries to wash out this asymmetry via collisions between the plasma particles. In our work we perform a careful derivation of the strength of these collisions and study their influence on the resulting BAU.

T 79.4 Thu 17:00 KH 02.018

**Interplay between Dark Matter and the Electroweak Phase Transition** — •TIM VINCENT KRAUSE<sup>1</sup>, ANDRÉ MILAGRE<sup>2</sup>, JOHANN PLOTNIKOV<sup>1</sup>, MILADA MAGARETE MÜHLEITNER<sup>1</sup>, RUI SANTOS<sup>3</sup>, and JOÃO SILVA<sup>2</sup> — <sup>1</sup>Karlsruher Institut für Technologie — <sup>2</sup>Instituto Superior Técnico, Universidade de Lisboa — <sup>3</sup>Universidade de Lisboa, Campo Grande

Current extensions to the scalar sector of the Standard Model (SM) are able to explain the matter anti-matter asymmetry in the universe via Electroweak Baryogenesis (EWBG) and simultaneously provide a dark matter candidate. In many cases these two phenomena are treated separately as they usually take place at different times in the evolution of the universe. However, there are scenarios where the electroweak phase transition necessary for EWBG and the production of DM take place during the same time period. As the phase transition influences the mass evolution of the SM particles it also plays a crucial role in the calculation of the relic density for DM. In our work we study the interplay between EWBG and DM generation as well as analyze its impact on the final relic abundance.

T 79.5 Thu 17:15 KH 02.018

**Parameter determination for singlino dark matter scenarios in the NMSSM** — •LAURENZ KRIEGE<sup>3</sup>, GUDRID MOORTGAT-PICK<sup>1</sup>, and SVEN HEINEMEYER<sup>2</sup> — <sup>1</sup>DESY and Hamburg U., Inst. Theor. Phys. II — <sup>2</sup>Madrid, IFT — <sup>3</sup>UHH

We study the reconstruction of the underlying parameters of the Next-to-Minimal Supersymmetric Standard Model (NMSSM) by assuming certain chargino and neutralino measurements at a future e+e- collider. We take scenarios with singlino dominated dark matter, with bino, wino, and gluino masses obeying the approximate GUT relations and an overall scenario consistent with the measured excesses at ATLAS and CMS and all experimental constraints. We demonstrate that both the dark matter relic density and most of the relevant NMSSM parameters can be reconstructed.

T 79.6 Thu 17:30 KH 02.018

**Testing Supersymmetric Dark Matter Scenarios through Electroweakino Parameter Determination** — •NELE PETERS and GUDRID MOORTGAT-PICK — Department of Physics, University of Hamburg

Supersymmetric models provide well-motivated candidates for particle dark matter, but testing their viability requires precise knowledge of the underlying electroweakino parameters. In this talk, we investigate how accurately a future International Linear Collider (ILC) could determine the key parameters M1, M2, and  $\mu$  in dark-matter motivated supersymmetric scenarios, here evaluated for an NMSSM benchmark. Using simulated measurements of polarized chargino-pair production and the masses of the lightest chargino and neutralino, we assess the sensitivity of these observables to the electroweakino sector and quantify the achievable reconstruction precision. From the reconstructed parameter sets, the dark-matter relic density is computed and compared to the benchmark values. The study demonstrates the potential of precision lepton-collider data to constrain supersymmetric dark-matter scenarios and to evaluate their consistency with cosmological observations.

## T 80: Axions/ALPs II

Time: Thursday 16:15–17:45

Location: KH 02.019

T 80.1 Thu 16:15 KH 02.019

**The IAXO-D1 Demonstrator for the BabyIA XO Intermediate Step** — •JORGE PORRÓN LAFUENTE — University of Zaragoza — Centro de Astropartículas y Física de Altas Energías (CAPA)

The International Axion Observatory (IA XO) is a large-scale helioscope searching for solar axions and axion-like particles via the Primakoff effect. BabyIA XO, its prototype at DESY, serves both as a testbed for IAXO technologies and a functional helioscope, requiring high efficiency in the 1-10keV range and ultra-low background ( $<10^{-7}$  counts/keV/cm<sup>2</sup>/s).

The IAXO-D1 Micromegas X-ray detector in Zaragoza characterizes cosmic background at surface level. It features 20cm lead shielding, a  $4\pi$  muon veto, and radiopure materials to reduce intrinsic background. Cosmogenic neutrons, which can mimic axion signals, are tagged using the REST-for-Physics framework. Previous detectors achieved  $8.6 \cdot 10^{-7}$  counts/keV/cm<sup>2</sup>/s at surface and approx.  $2 \cdot 10^{-7}$  counts/keV/cm<sup>2</sup>/s underground. Simulations indicate cosmic neutrons produce secondary signals in the veto, enabling identification.

Initial IAXO-D1 measurements without the veto reached  $2 \cdot 10^{-6}$  counts/keV/cm<sup>2</sup>/s. Ongoing improvements in veto design, shielding, and analysis aim to meet the  $<10^{-7}$  counts/keV/cm<sup>2</sup>/s goal, enhancing BabyIA XO's sensitivity and informing the design of the full-scale IAXO experiment.

T 80.2 Thu 16:30 KH 02.019

**Towards a low background SDD for IAXO** — •LUCINDA SCHÖNFELD<sup>1</sup>, CHRISTIAN BUCK<sup>1</sup>, SUSANNE MERTENS<sup>1</sup>, CHRISTOPH WIESINGER<sup>1</sup>, MICHAEL WILLERS<sup>2</sup>, and JUAN PABLO ULLOA BETETA<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Kernphysik, Heidelberg, DE — <sup>2</sup>Technische Universität München, Garching, DE

Axions are hypothetical particles that solve the strong CP problem and are candidates for dark matter. The International Axion Observatory (IA XO) is aiming to find these elusive particles by converting solar axions to X-rays. Detecting this rare signal requires highly efficient ultra-low background X-ray detectors,

for which Silicon Drift Detectors (SDDs) are well suited. I will present the current status of the TRISTAN SDD for IAXO (TAXO) project, which is developing such an SDD. A particular focus will be the latest results of background measurements, as well as simulations to find an optimal shielding setup.

T 80.3 Thu 16:45 KH 02.019

**Axion search with RADES** — •ELISA GABBRIELLI for the RADES MPP-Collaboration — Max Planck für Physik, Munich

RADES (Relic Axion Detection Exploratory Setup) is a haloscope experiment designed to search for axions originating from the local dark matter galactic halo in the  $\mu$ eV mass range, under the assumption that dark matter is entirely composed of axions. The detection technique relies on a resonant cavity placed inside a strong magnetic field, which enhances the conversion of axions into detectable photons. The collaboration has achieved significant progress regarding the development of new cavity geometries, leading to two physics results at axion masses around 30  $\mu$ eV.

An innovative RADES setup incorporating transmon qubits is currently being developed within the collaboration. This talk focuses on the activities at the Max Planck Institut für Physik in Garching. To maximise the signal-to-noise ratio, the experiment operates at cryogenic temperatures using a dilution refrigerator that can reach approximately 10 mK. At these extremely low temperatures, superconducting devices such as transmon qubits can be employed as single-photon detectors to further improve signal sensitivity.

T 80.4 Thu 17:00 KH 02.019

**First measurements with a MADMAX 8 disk prototype booster system for the search of dark matter** — •UMASHI FERNANDO for the MADMAX-Collaboration — Max-Planck-Institut für Physik, Boltzmannstr. 8, 85748 Garching

The main aim of the MADMAX experiment (Magnetised Disc and Mirror Axion Experiment) is to search for the hypothetical particle that solves the strong

CP problem and is also an excellent cold dark matter candidate: the axion. The electric field oscillations due to axion conversion to photons in the presence of a strong magnetic field can be detected, but the signal is very weak. Thus, a configuration with dielectric disks in front of a mirror is used to resonantly enhance the signal over a controllable frequency range.

In this talk, measurements taken with an 8-disk closed prototype booster system CB200 will be discussed. Some details of the used receiver chain and data acquisition system will be given.

T 80.5 Thu 17:15 KH 02.019

**MADMAX analysis procedures and preliminary results of CB100 cold experiment** — •HAOTIAN WANG for the MADMAX-Collaboration — III. Physikalisches Institut A, RWTH Aachen University, Aachen

MADMAX is a dielectric haloscope experiment that searches for QCD axion dark matter in the mass range of a few tens to a few hundred micro-eV by exploiting axion-photon conversion in a strong magnetic field enhanced by a dielectric booster. In this contribution, we present the general MADMAX data analysis procedures, developed for the treatment of large sets of power spectra, including background modeling, the combination of multiple measurements, and the statistical inference of exclusion limits. These methods are then applied to data from the CB100 closed-booster prototype operated in a magnetic field at cryogenic temperatures, and preliminary exclusion limits are shown.

T 80.6 Thu 17:30 KH 02.019

**Determining the MADMAX boost factor using the bead pull method** — •LEA STANKEWITZ for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg

The MAGnetised Disk and Mirror Axion eXperiment is a dielectric haloscope which aims to search for dark matter axions between  $40 \mu\text{eV}$  and  $400 \mu\text{eV}$ . It converts axions into photons using a strong magnetic field. The conversion probability is enhanced by arranging multiple dielectric disks in a resonant configuration, the so called booster. The boost factor, that quantifies how much the axion signal power is amplified relative to a simple dish-antenna configuration, can be determined from the electric field strength in between the disks. To measure the electric field the bead pull method is used, where a small dielectric object is moved through the setup to measure the electric field at different positions. For the next axion search, which will measure multiple frequency ranges, calibration of multiple disc configurations is required. The bead pull measurements inside the cryostat will have a limited range, therefore good reference measurements are required. In this talk I present the results of the boost factor determination for the open booster setup with a three disks configuration using a high-precision bead pull setup. These measurements will be used to calibrate the system for the first cryogenic axion search with MADMAX in the MORPURGO magnet at CERN.

## T 81: Search for Dark Matter III

Time: Thursday 16:15–17:45

Location: AM 00.014

T 81.1 Thu 16:15 AM 00.014

**Study of few-electron backgrounds in the XENONnT detector** — •SOPHIE ARMBRUSTER — Max Planck Institut für Kernphysik, Heidelberg

When searching for light-mass dark matter with low-energy ionization signals down to the level of a single extracted electron using a dual-phase liquid xenon time projection chamber, it is crucial to understand and mitigate ionization backgrounds in the few-electron regime. Delayed single- and few-electron emissions are small charge signals that appear after a large charge signal but do not stem from independent low-energy interactions. Possible origins include photoionization processes, electron trapping by impurities, and temporary trapping of electrons at the liquid\*gas interface. This talk presents a dedicated study of these delayed electron emissions using XENONnT data, focusing on their correlations with detector parameters. The results provide new insight into the phenomenology of few-electron backgrounds and support improved background modeling for future light dark matter searches with liquid xenon detectors.

T 81.2 Thu 16:30 AM 00.014

**Novel Purity Sensors in Liquid Xenon Time Projection Chambers** — •TOM SONIUS — Karlsruhe Institute of Technology, Institute for Astroparticle Physics  
The XLZD observatory will be a next-generation, multi-tonne xenon detector capable of probing dark matter and neutrino physics at unprecedented sensitivity. Its design features a dual-phase time projection chamber (TPC) containing 60 tonnes of liquid xenon (LXe).

Attaining the anticipated sensitivities requires extremely pure xenon so that rare event ionization signals are not degraded by their capture by electronegative impurities diffused in the liquid. Achieving this purity relies on advanced purification techniques, continuous recirculation, and dedicated purity monitoring systems.

Conventional LXe purity monitoring modules are bulky and must be placed outside the sensitive detector volume. A novel approach with minimal footprint and scalability is the use of carbon nanotube-based sensors that can be placed directly in the instrumented volume.

In this talk, I will present the current R&D efforts at KIT on the development of purity sensors based on single-layer carbon nanotubes, along with the status of their design and production, as a step towards novel purity sensing technologies for future LXe-TPCs.

This work is supported by the Impuls und Vernetzungsfonds of the Helmholtz Association (grant no. VH-NG-21-02).

T 81.3 Thu 16:45 AM 00.014

**Studies of dielectric breakdown in liquid xenon with the MOTION detector** — •KEYU DING — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Next-generation liquid xenon (LXe) dark matter detectors are expected to double their linear dimensions compared to current-generation experiments. The future XLZD Observatory aims to build a detector with an inner diameter and height of nearly 3 m, hosting 60 tonnes of LXe in a time-projection chamber (TPC). The result, a tenfold increase in mass, enables dark matter searches approaching the neutrino fog, as well as rare-event searches such as neutrinoless double-beta decay and supernova neutrinos.

With the increased TPC height, the voltage delivered to the cathode exceeds previously tested ranges in LXe at this scale. Although LXe is predicted to sustain bulk fields near 1 MV/cm, experiments consistently observe dielectric breakdown at values much closer to the operating fields ( $\mathcal{O}(10\text{--}100)$  kV).

The MOTION detector, an  $\sim 70$  kg LXe setup at the Karlsruhe Institute of Technology, is used to study dielectric breakdown in LXe. We investigate how local field enhancement at electrode asperities and stressed electrode areas affect breakdown using various diagnostic methods. This work is supported by the Impuls und Vernetzungsfonds of the Helmholtz Association (grant no. VH-NG-21-02).

T 81.4 Thu 17:00 AM 00.014

**Optimization of Gold Collector Pads for remoTES Sensors on NaI Crystals in the COSINUS Experiment** — •MORITZ DÖRFLER for the COSINUS-Collaboration — Max Planck Institute for Physics, Garching, Germany

Cryogenic calorimeters based on scintillating sodium iodide (NaI) crystals provide a promising approach for direct dark matter searches, as pursued by the COSINUS experiment (Cryogenic Observatory for Signatures seen in Next generation Underground Searches) at the Laboratori Nazionali del Gran Sasso (LNGS). In COSINUS detector modules, particle interactions in the absorber crystal are detected via phonon signals, which are read out by remote Transition Edge Sensors (remoTES). An efficient thermal coupling between the NaI crystal and the sensor is achieved by thin metallic collector pads deposited on the crystal surface and a wire bond connection. This contribution focuses on the development and characterization of gold collector pads used for phonon collection in COSINUS detector modules. The geometry, thickness, and deposition parameters of the gold films are critical for efficient phonon transport from the NaI crystal to the remoTES sensor, while maintaining sufficient mechanical stability and reproducibility. Optimizing the gold\*NaI interface is an essential step toward improving the sensitivity and reliability of future COSINUS detector modules and contributes to the overall goal of achieving low-threshold, background-discriminating dark matter searches with NaI-based cryogenic detectors.

T 81.5 Thu 17:15 AM 00.014

**Results of a multi-wafer, double TES detector in the CRESST Experiment** — •FELIX DOMINSKY for the CRESST-Collaboration — Max-Planck-Institut für Physik, Garching, Germany

CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is a leading direct-detection experiment for dark matter that implements Transition Edge Sensors (TESs) to measure minute energy depositions in cryogenic target crystals. As several other experiments in this field, CRESST observes an unexpected excess of events close to the detection threshold up to  $200\text{eV}$ , commonly referred to as the low-energy excess (LEE). The current detector generation of CRESST employs two TES per crystal to better characterize this excess and investigate possible origins. Following this approach, CRESST has additionally deployed a stacked module, consisting of four vertically stacked, thin silicon on sapphire (SoS) wafer double-TES detectors. Their reduced target mass results in enhanced energy resolution, while the vertical arrangement allows the outer wafers to act as an active veto for the inner ones. This contribution will present the concept and motivation of this stacked-detector module and discuss first preliminary results and insights from its operation.

T 81.6 Thu 17:30 AM 00.014

**Low Energy Excess Studies in the CRESST Experiment** — •JUDITH DOHM for the CRESST-Collaboration — Eberhard-Karls-Universität Tübingen, 72076 Tübingen, Deutschland

The Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) is a direct dark matter detection experiment located in the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. CRESST operates cryogenic calorime-

ters equipped with Transition Edge Sensors (TES) operating in the millikelvin range. In the third phase (CRESST-III), energy thresholds of about 10eV have been reached, placing CRESST-III among the world-leading experiments in the search for sub-GeV dark matter. The experiment's sensitivity in the low mass region is currently limited by an unexplained rise of events below 200eV, the so-called low energy excess (LEE). The latest studies of the temporal behaviour and the energy spectrum of the LEE performed by CRESST will be presented in this talk.

## T 82: Neutrino Astronomy IV

Time: Thursday 16:15–18:00

Location: KS H C

T 82.1 Thu 16:15 KS H C

**Simulation of the atmospheric neutrino production height with CORSIKA 8** — •TIM SCHÖNAUER — TU Dortmund, Dortmund, Germany

Atmospheric neutrinos are produced in cosmic-ray air showers. Yet the neutrino production height remains largely unexplored, although it exhibits significant seasonal and regional variability, especially in polar atmospheres where the density profile undergoes strong annual modulation. To investigate the production height of neutrinos, air-shower simulations were carried out using CORSIKA 8, the recently developed C++-based successor to the established CORSIKA framework. Its architecture enabled controlled variation of physical parameters and allowed detailed comparisons with legacy simulations, providing a basis for validation and for identifying deviations introduced by the modernized implementation. The production heights of atmospheric neutrinos were simulated for summer and winter atmospheric profiles at the South Pole and other geographical locations. The resulting distributions quantified the magnitude and energy dependence of seasonal shifts in the neutrino production region and provide refined input for analyses sensitive to atmospheric model uncertainties in present and future neutrino observatories.

T 82.2 Thu 16:30 KS H C

**Water Properties Studies with atmospheric muons in the ORCA/ARCA KM3NeT detector** — •EVI SAKKOU for the KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

The KM3NeT detector is an underwater neutrino observatory that detects atmospheric neutrinos in a range of energies. ORCA and ARCA detectors rely on precise knowledge of the optical properties of the surrounding water helping to enhance neutrino event reconstruction. In this study, we use atmospheric muons to study the water attenuation length. To this end we compare the light yield of muons between data and Monte Carlo simulations generated with different true values of the water attenuation length.

T 82.3 Thu 16:45 KS H C

**Unfolding the Electron Neutrino Spectrum** — •LENE VAN ROOTSELAAR and LUKAS LILAND for the IceCube-Collaboration — TU Dortmund, Dortmund, Germany

The IceCube Neutrino Observatory, a cubic-kilometre detector located in the Antarctic ice at the South Pole, provides unique sensitivity to neutrinos over energies spanning from the GeV to the PeV scale. In this energy regime, the observed neutrino flux is expected to arise from a combination of conventional atmospheric neutrinos produced in pion and kaon decays, a possible prompt atmospheric contribution from charmed hadron decays, and an astrophysical component of extragalactic origin. Disentangling these contributions, in particular in the transition region where the prompt flux may become relevant, is essential for advancing our understanding of high-energy particle interactions in the atmosphere.

This contribution describes the current status of an analysis aimed at determining the electron neutrino energy spectrum in IceCube in the range from roughly 1 TeV to 4 PeV using a cascade event sample. A spectral unfolding technique is used to infer the neutrino energy distribution while minimizing dependence on assumed flux models. Ongoing studies of the detector response, Monte Carlo validation, and the impact of systematic uncertainties will be presented.

T 82.4 Thu 17:00 KS H C

**Atmospheric tau neutrino appearance analysis with 11 years of IceCube DeepCore data** — •SOL BENKEL for the IceCube-Collaboration — DESY Zeuthen

DeepCore, a region of the IceCube Neutrino Observatory with denser instrumentation, enables the detection of atmospheric neutrinos between 5 and 150 GeV, where a strong tau neutrino signal has been observed. DeepCore has continually provided high precision measurements of atmospheric neutrino oscillations, repeatedly setting world-leading results. In this talk, I present the design and current progress of a new analysis strategy for atmospheric tau neutrino ap-

pearance using 11 years of IceCube DeepCore data. This strategy explores new metrics by which high resolution neutrino events can be isolated from the analysis sample, thus potentially improving the sensitivity to measure muon to tau neutrino oscillations. Rather than applying cuts, which would discard low-purity data, these metrics will only bin the data, thus isolating high-quality events while preserving the statistical power of the full dataset. With this approach, we expect to increase sensitivity to the signatures of  $\nu_\tau$  appearance from  $\nu_\mu$  oscillation, as this binning strategy would provide enhanced discrimination against the background from other cascade events.

T 82.5 Thu 17:15 KS H C

**Studying the Diffuse Supernova Neutrino Background with JUNO** — •TIM CHARISSÉ<sup>1,2</sup>, GEORGE PARKER<sup>2</sup>, DAVID MAKSIMOVIĆ<sup>2</sup>, MARCEL BÜCHNER<sup>2</sup>, OLIVER PILARCZYK<sup>2</sup>, ARSHAK JAFAR<sup>2</sup>, MANUEL BÖHLES<sup>2</sup>, DANIELA FETZER<sup>2</sup>, ELENA WINIKER<sup>2</sup>, and MICHAEL WURM<sup>2</sup> — <sup>1</sup>Helmholtzzentrum für Schwerionenforschung, Planckstrasse 1, D-64291 Darmstadt, Germany — <sup>2</sup>Johannes Gutenberg-Universität Mainz, Institute of Physics and EC PRISMA+

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton liquid scintillator detector situated in Southern China that started data taking in August 2025. Its large fiducial volume together with low radiopurity and high photocoverage results in excellent energy resolution. While JUNO's main physics goal is the determination of the neutrino mass ordering and precision measurement of neutrino oscillation parameters, it is also able to detect core-collapse Supernova (CCSN) neutrinos. Apart from directly observing these neutrinos in the rare event of a close-by CCSNe, JUNO also aims to measure the so-called Diffuse Supernova Neutrino Background (DSNB). This predicted isotropic flux consisting of remnant neutrinos from all CCSNe that happened in the visible universe is yet to be observed. Its measurement will offer insights into CCSNe, Astrophysics and Cosmology. Current efforts towards a detection of the DSNB with JUNO will be presented in this talk.

T 82.6 Thu 17:30 KS H C

**Machine Learning for DSNB Detection in JUNO: Utilizing Spatial-Temporal PMT Hit Patterns for Background Suppression** — •DAVID MAKSIMOVIĆ<sup>1</sup>, MICHAEL WURM<sup>1</sup>, DANIEL TOBIAS SCHMID<sup>1</sup>, and DHAVAL J. AJANA<sup>2</sup> — <sup>1</sup>Johannes Gutenberg-University — <sup>2</sup>Florida State University

The detection of the Diffuse Supernova Neutrino Background (DSNB) poses a significant challenge in neutrino astronomy, primarily due to backgrounds mimicking the extremely rare antineutrino events via Inverse Beta Decay (IBD). The Jiangmen Underground Neutrino Observatory (JUNO) uses a liquid scintillator to detect these neutrinos in the 12 to 30 MeV range. There, especially Neutral-Current (NC) interactions of atmospheric neutrinos dominate the predicted DSNB signal by 1-2 orders of magnitude. In this talk, we present a comparative study of ML discrimination algorithms, ranging from 3D Convolutional Neural Networks (3D CNNs), LSTMs and Convolutional LSTMs (ConvLSTMs) and utilizing Fourier Transformations. These techniques analyze time-sequenced data from photomultiplier tube (PMT) hit patterns to capture the spatial-temporal dynamics of particle interactions. Here we present the resulting background reduction capabilities for JUNO.

T 82.7 Thu 17:45 KS H C

**Charm Contributions to Multi-Messenger Emissions in Dense AGN Environments\*** — •VLADIMIR KISELEV<sup>1,2</sup>, JULIA BECKER TJUS<sup>1,2,3</sup>, RIKARD ENBERG<sup>4</sup>, and JULIEN DÖRNER<sup>1,2</sup> — <sup>1</sup>Theoretical Physics IV: Plasma Astroparticle Physics, Ruhr University Bochum — <sup>2</sup>RAPP Center, Bochum — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden — <sup>4</sup>Department of Physics and Astronomy, Uppsala University, Sweden

Active galactic nuclei (AGN) are compelling sites for high-energy neutrino production, yet the balance between light-meson ( $\pi, K$ ) and charm-hadron channels in dense, magnetised environments remains unresolved. We present a simulation-driven framework that couples a version of CRPropa designed for the AGN/jet environment with a Hadronic Interaction Module for  $pp$  interactions with secondary tagging. Inclusive energy-differential cross sections  $d\sigma/dx_E$

are computed and tabulated using chromo with Sibyll 2.3d, enabling consistent propagation from cosmic-ray injection to neutrino yields on finely sampled energy grids. By comparing decay, synchrotron, hadronic, and adiabatic timescales, regimes are identified in which  $\pi/K$  channels can be suppressed while short-lived charm hadrons remain effectively prompt and can contribute

significantly to the neutrino signal. The analysis points to coronae and dense jet substructures as potential “charm factories” within realistic acceleration limits. Validation of these qualitative indications using the framework through the spectral shape and flavour composition to isolate charm contributions is ongoing. \*Supported by DFG (SFB 1491)

## T 83: Methods in Astroparticle Physics IV

Time: Thursday 16:15–18:00

Location: KS 00.004

T 83.1 Thu 16:15 KS 00.004

**The Monte Carlo simulation of JUNO's pre-detector OSIRIS** — •LUKAS BIEGER, DHANUSHKA BANDARA, SILVIA CENGIA, JESSICA ECK, ADRIAN KEIDERLING, FLORIAN KIRSCH, TOBIAS LACHENMAIER, ANURAG SHARMA, and TOBIAS STERR — Eberhard Karls Universität Tübingen

The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose neutrino experiment with a 20 kt liquid scintillator detector located in southern China. Its primary objective is to determine the neutrino mass ordering by measuring the oscillated energy spectrum of electron antineutrinos from nearby nuclear power plants with unprecedented energy resolution. The scintillator filling of JUNO was completed in August 2025 and JUNO started data-taking. The Online Scintillator Internal Radioactivity Investigation System (OSIRIS) monitored the radiopurity of the liquid scintillator during the filling, ensuring that the required contamination upper limits were met. OSIRIS is an 18 t liquid scintillator detector, instrumented with 64 20-inch PMTs to detect the light produced by events in the detector's sensitive volume. A precise Monte Carlo simulation is essential for understanding the detector's performance and for optimizing analysis methods. This talk will present the comprehensive simulation framework developed for OSIRIS, with particular emphasis on the MC tuning strategy employed to improve the accuracy of the simulation, as well as on its validation using calibration data, which demonstrates good agreement between simulation and measurements.

T 83.2 Thu 16:30 KS 00.004

**Validation of Simulation Data for the IceAct Telescopes** — •CEM GÜR, LARS HEUERMANN, LARS MARTEN, SÖNKE SCHWIRN, and CHRISTOPHER WIEBUSCH — III. Physikalisches Institut B - RWTH Aachen University  
AUTHORS: Cem Gür, Lars Heuermann, Lars Marten, Sönke Schwirn, Christopher Wiebusch

TITLE: Validation of Simulation Data for the IceAct Telescopes

ABSTRACT: IceAct is a surface array of Imaging Air-Cherenkov Telescopes stationed at the South Pole as part of the IceCube Neutrino Observatory. Each telescope features a 61 SiPM pixel based camera with a Fresnel lens imaging on to it, resulting in a field-of-view of 12 degrees. The main goals of IceAct include the calibration of the IceTop surface array and the in-ice detector, as well as improving cosmic-ray composition studies. An agreement and understanding of the measured data and simulation is vital to reconstruct relevant parameters of cosmic-ray-induced extensive air showers for IceAct. Detailed comparisons allow the investigation of possible mismatches, their causes, and impact on reconstruction performance. In this talk we present three years of measured data to validate the IceAct simulation.

T 83.3 Thu 16:45 KS 00.004

**Simulations of Particle Transmission and Electric Fields for the Munich Electrostatic Storage Ring (ESR)** — •NILS DOLL, CHIARA BRANDENSTEIN, PETER FIERLINGER, ADIL W. MUGGO, DARIO RÜCKWARTH, WOLFGANG SCHOTT, VITUS SCHUSTER, HANS TH. J. STEIGER, KONSTANTIN WALTER, and FLORIAN ZÖTL — School of Natural Sciences, Physics-Department, Technical University of Munich, 85748 Garching, Germany

Stored ions or ionic molecules in a non-relativistic electrostatic storage ring can serve as a versatile platform for various fundamental experiments. Through precise control of beam dynamics and polarization, searches for electric dipole moments (EDMs) or axion-like particles (ALPs) become feasible in a rather unique and novel setting. Recent progress on the implementation of such a device is being discussed. COMSOL Multiphysics was used for a detailed field-based analysis of beam propagation, capturing emittance growth, phase-space evolution and nonlinear effects from realistic electrode geometries. A comparative simulation study of ion beam stability in an electrostatic storage ring is presented, focusing on the influence of fringe fields, space-charge effects, and radio-frequency (RF) systems for energy and trajectory control of barium and copper ions.

T 83.4 Thu 17:00 KS 00.004

**DPG Abstract: Clustering algorithm for event reconstruction in LiquidO detectors** — •SUSANNA WAKELY and KITZIA HERNANDEZ for the NuDoubt-Collaboration — Johannes Gutenberg University, Mainz

LiquidO is an innovative technology that uses opaque liquid scintillators for particle detection. A LiquidO scintillator combines a short scattering length and a

long absorption length to stochastically confine optical photons close to their creation point. The result is balls of light where energy is deposited in the detector, with different particles producing different characteristic topologies of light balls. A fine array of wavelength-shifting fibres collects and transports the scintillation light for readout by SiPMs. A LiquidO detector will have unprecedented position resolution compared to current transparent scintillators and be capable of particle identification via event topology.

This talk will outline the development of a clustering algorithm, based on the Cambridge-Aachen jet clustering algorithm, for particle identification in LiquidO detectors. This work is done in the context of the CLOUD and NuDoubt++ experiments.

The CLOUD collaboration is designing a 5-10 ton LiquidO ultra-near reactor anti-neutrino detector. The NuDoubt++ experiment will be the first double-beta-plus ( $\beta\beta^{++}$ ) decay experiment. It is expected to make the first  $5\sigma$  observation of the  $2\nu\beta\beta^{++}$  decay, and discover or improve the half-life limit of the  $0\nu\beta\beta^{++}$  process by 3 orders of magnitude.

T 83.5 Thu 17:15 KS 00.004

**A new optical model for LEGEND-200 with the remage simulation stack** — •MANUEL HUBER, ROSANNA DECKERT, LUIGI PERTOLDI, and STEFAN SCHÖNERT — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

To reach ultra-low backgrounds for the detection of the neutrinoless double-beta decay of  $^{76}\text{Ge}$ , the Large Enriched Germanium Experiment for Neutrinoless  $\beta\beta$  Decay (LEGEND) operates germanium detectors in scintillating liquid argon. A quantitative model of the complex optical instrumentation of the liquid argon is crucial for developing optimal methods to discriminate signal from background. I will present the development of a Monte Carlo model for the number of detected photons in the light readout channels deployed in the currently running stage of the experimental program, LEGEND-200. It is facilitated by the new Monte Carlo simulation stack *remage*, based on Geant4 and our Python-based package ecosystem around *pyg4ometry*, that I will present. To demonstrate the applicability of the new model, comparisons of the simulated detector response with LEGEND-200 characterization data will be presented.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFT Verbundprojekt 05A2023 (LEGEND).

T 83.6 Thu 17:30 KS 00.004

**Development of an Optimized Liquid Argon Anti-Coincidence Classifier for LEGEND-200** — •NELE SIERIG, ROSANNA DECKERT, NIKO LAY, and STEFAN SCHÖNERT for the LEGEND-Collaboration — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

The LEGEND-200 experiment searches for neutrinoless double beta decay of  $^{76}\text{Ge}$  using up to 200 kg of high-purity germanium detectors immersed in instrumented liquid argon (LAr). To ensure ultra-low backgrounds, the experiment is operated deep underground at the Laboratori Nazionali del Gran Sasso. The LAr not only provides shielding and cooling, but also enhances active background suppression through an optical instrumentation system that detects scintillation light emitted upon interactions by ionizing radiation.

In this talk, I will present a novel LAr classifier, developed to tag and reject backgrounds efficiently. Our methodology integrates spatial and temporal information from the LAr scintillation light and utilizes detector-type-specific models. This development is essential for meeting the ambitious background goals and maximizing the overall sensitivity of LEGEND-200.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFT Verbundprojekt 05A2023 (LEGEND).

T 83.7 Thu 17:45 KS 00.004

**Quantitative Study of Cherenkov-Scintillation Separation for Background Suppression in Large Scale Neutrino Detectors** — •MEISHU LU<sup>1</sup>, MANUEL BÖHLES<sup>2</sup>, LOTHAR OBERAUER<sup>1</sup>, MICHAEL WURM<sup>2</sup>, and STEFAN SCHÖNERT<sup>1</sup> — <sup>1</sup>School of Natural Sciences, Technical University of Munich, 85748 Garching, Germany — <sup>2</sup>Institute for Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

The first physics results from the Jiangmen Underground Neutrino Observatory (JUNO) demonstrate the potential of next-generation large liquid-scintillator detectors. Beyond precision oscillation measurements, improved event reconstruction and background suppression are required for rare-event searches such as the diffuse supernova neutrino background (DSNB) and neutrinoless double-beta decay ( $0\nu\beta\beta$ ). Separation of Cherenkov and scintillation light provides additional timing and topological information and has been firstly demonstrated by the Borexino collaboration. Building on previous tabletop studies at TUM,

we present a new investigation of key factors affecting the separation ability, including emission spectra and photon-sensor quantum efficiency. These results indicate the potential of hybrid detection for future large-scale detectors and upgrades. We acknowledge support from the Deutsche Forschungsgemeinschaft under Germany's Excellence Strategy EXC 2094 - 390783311 and EXC 2118 - 390831469 and through the Sonderforschungsbereich SFB 1258 "Neutrinos and Dark Matter in Astro- and Particle Physics", as well as the DFG Forschungsgruppen FOR 2319 - 268668443 and FOR 5519 - 498394246.

## T 84: Gamma Astronomy II

Time: Thursday 16:15–17:45

Location: KS 00.005

T 84.1 Thu 16:15 KS 00.005

**Enhancing SWGO Sensitivity to Galactic Center PeVatrons with GNNs** — •MARTIN SCHNEIDER for the SWGO-Collaboration — ECAP, FAU Erlangen-Nürnberg

The Southern Wide-field Gamma-ray Observatory (SWGO) will provide continuous, wide-field monitoring of the Southern Hemisphere gamma-ray sky, offering unprecedented access to high-energy phenomena in the region around the Galactic Center. A central challenge for SWGO is achieving robust gamma/hadron separation to suppress the overwhelming cosmic-ray background, which is crucial for studies of diffuse emission and potential Galactic PeVatron activity. In this contribution, we present a new study demonstrating the advantages of Graph Neural Networks (GNNs) over traditional machine-learning classifiers. Using two years of simulated SWGO observations, we evaluate how improved background rejection from GNN-based models enhances the sensitivity to a spectral cutoff in the diffuse emission near the Galactic Center. Such sensitivity is essential for testing the PeVatron hypothesis and to disentangle the sources and processes shaping this region.

T 84.2 Thu 16:30 KS 00.005

**Progress on the Medium-Sized Telescope Structure for the Cherenkov Telescope Array Observatory** — •BASTIAN HESS for the MST Project-Collaboration — Institut für Astronomie und Astrophysik, Tübingen, Germany

The Cherenkov Telescope Array Observatory (CTAO) will consist of three different sizes of telescope categories: the small-sized telescopes (SSTs), medium-sized telescopes (MSTs), and large-sized telescopes (LSTs). Two MST pathfinder telescopes are currently in production and undergoing pre-assembly. They will be deployed at the CTAO southern site in Paranal, Chile. The MST reflector comprises 86 hexagonal mirror segments, each 1.2 m measured across flats. These mirrors are mounted to the optical support structure using high-precision motorized actuators that enable fine alignment to achieve and maintain optimal telescope optics. This contribution presents an overview of the manufacturing and testing progress of the MST structures, with particular emphasis on the performance and quality assurance of the active mirror control system and its components.

T 84.3 Thu 16:45 KS 00.005

**Analysis of the PWNe in the Kookaburra Region with Fermi-LAT and H.E.S.S.** — •LUKAS GROSSPIETSCH, GIOVANNI COZZOLONGO, and ALISON MITCHELL for the H.E.S.S.-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen 91052, Germany

The wings of the Kookaburra region host the two extended very-high-energy gamma-ray sources HESS J1420-607 and HESS J1418-609, forming a rare complex environment of two adjacent pulsar wind nebulae (PWNe) shaped by energetic pulsars and asymmetric ambient conditions. This makes the region a valuable target for studying particle acceleration, transport, and energy losses in evolved PWNe. In this work, we present an analysis of the region using a combination of recent and archival observations from the H.E.S.S. array together with Fermi-LAT data. Advanced background estimation and analysis techniques complement the upgraded H.E.S.S. system to enable a refined investigation of morphology and emission processes in the very-high-energy gamma-ray range. These findings aim to deepen our understanding of the interplay of pulsar-driven outflows and their surrounding medium in the Kookaburra complex.

T 84.4 Thu 17:00 KS 00.005

**Analysis of the of the 2016 Flaring Period of 1ES1959+650 with the MAGIC Telescopes using the Database Driven Software autoMAGIC** — •JUSTUS KOCZWARA and FELIX WERSIG — TU Dortmund University, Dortmund, Germany

When entering the atmosphere, the high-energy gamma-rays interact with atoms and produce showers of high-energy charged particles that move faster

than the speed of light in the air, emitting Cherenkov radiation. This effect enables us to observe the remnants of these interactions and reconstruct the energy and origin of a gamma ray from the optical image taken by a ground-based telescope. The MAGIC telescopes are a system of so-called Imaging Air Cherenkov Telescopes that have used this detection method since 2003, accumulating a large dataset over the years. As the standard way of analysing MAGIC telescope data includes various manual interventions, increasing the rate of potential error sources, and is very time-consuming, the database-driven software tool autoMAGIC was developed to automate the low-level analysis up to the community-standard data level 3. In the scope of this work, the strong flaring periods of the BL Lac blazar 1ES 1959+650 in 2016 were re-analyzed as a cross-check for a manual low-level analysis, performing the low-level analysis with autoMAGIC and a high-level analysis with Gammapy. The results from this analysis are then compared with the results of the manual analysis published in a paper by the MAGIC Collaboration to understand whether flare characteristics found in the manual analysis can be reproduced in the autoMAGIC analysis.

T 84.5 Thu 17:15 KS 00.005

**Directional Search for Ultra-High-Energy Photons Using the SD-1500 Array of the Pierre Auger Observatory** — •TIM FEHLER, MARCUS NIECHCIOL, and MARKUS RISSE for the Pierre Auger-Collaboration — Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen

In addition to its capabilities for precise measurement of ultra-high-energy (UHE,  $E > 10^{17}$  eV) cosmic rays through the observation of extensive air showers, the Pierre Auger Observatory offers the potential to effectively detect UHE photons. Their connection to UHE cosmic rays is manifold; constraints on their flux provide valuable hints on the elusive nature of the UHE cosmic rays. Contrary to charged cosmic rays, which are deflected by magnetic fields, UHE photons have the inherent advantage that their origin can be traced back directly, which promotes the search for directional excesses of photon-like events in the sky. This contribution details the full modular analysis pipeline for a new direction-dependent search for UHE photons, based on a novel photon-tagging approach using the paradigm of air-shower universality. With sole dependence on the SD-1500 array, given its 100% duty cycle, the full 19 years of Phase-I data will be available for analysis, providing unprecedented exposure to a potential UHE photon flux. Beyond the methodology, the contribution also covers the first preliminary application to data for final cross-checks.

*Supported by the BMFT Verbundforschung Astroteilchenphysik under project No. 05A23PS1.*

T 84.6 Thu 17:30 KS 00.005

**Optical Light Curves of Classical Novae from H.E.S.S. Night-Sky Background Data** — •SAYAK GHOSH, ALISON MITCHELL, and GERRIT ROELLINGHOFF for the H.E.S.S.-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

Imaging Atmospheric Cherenkov Telescopes (IACTs) are designed for very-high-energy gamma-ray astronomy, but their large mirror areas and fast cameras also record variations in the optical night-sky background (NSB). In this work, we explore the use of NSB data from the H.E.S.S. telescope array to extract relative optical light curves of classical novae.

We develop an analysis framework based on pixel-level NSB rates from the H.E.S.S. CT1-CT4 cameras. The approach accounts for instrumental and atmospheric effects and isolates time-dependent variations in the NSB signal. Corrected NSB values are combined over selected pixel regions and time intervals to construct relative optical light curves on intra-night and multi-night timescales.

We apply this to H.E.S.S. observations of classical novae, and we discuss variations and limitations of the method. This study shows that NSB data from H.E.S.S. can be used to investigate relative optical variability in bright transient sources, while clearly outlining the constraints of this approach.

## T 85: Cosmic Rays IV

Time: Thursday 16:15–17:45

Location: KS 00.006

T 85.1 Thu 16:15 KS 00.006

**Simulating Cosmic-Ray Hadronic Interactions: Analytic vs. Monte Carlo** — •LEONEL MOREJON — Bergische Universitaet Wuppertal, Wuppertal, Germany  
Cosmic-ray hadronic interactions are important in explaining the production of very-high-energy photons and high-energy neutrinos arriving at Earth. For example, galactic neutrino emissions recently reported by IceCube, are expected to result from cosmic-ray interactions in the central region of the galaxy. Hadronic interactions can be modeled with Monte Carlo codes, but the computational effort to explore a variety of model parameters may produce limitations. Conversely, continuous production models exist and are faster to evaluate, but neglect the inherent stochasticity of these interactions.

An alternative approach is presented in this work, describing sequences of hadronic interactions analytically, using the precomputed tables for the products of individual interactions. This has the advantage of including stochastic effects in the sequence (unlike in continuous models) and reinteractions, while keeping the computation analytic, scalable and efficient. The correctness of this approach is verified by comparing to Monte Carlo simulations.

T 85.2 Thu 16:30 KS 00.006

**Pythia 8/Angantyr and CORSIKA 8: Muon Puzzle and tuning\*** — •CHLOÉ GAUDU for the CORSIKA8-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The field of air-shower physics seeks to understand the development of cosmic-ray interactions with the Earth's atmosphere. A key challenge in this field is the discrepancy in the muon content of extensive air showers (EAS), widely referred to as the "Muon Puzzle", observed by cosmic-ray experiments when comparing to predictions from commonly used hadronic interaction models. This puzzle might stem from limitations in modeling high-energy hadronic interactions, arising as model parameters are tuned to accelerator data probing lower energies than those relevant to EAS, thus requiring extrapolations into unmeasured phase space. With PYTHIA 8/Angantyr now fully integrated into the CORSIKA 8 particle-shower simulation code, analyses of EAS are feasible. Initial studies indicate that its default configuration fails to reproduce key measurements from the Pierre Auger Observatory. The PYTHIA 8/Angantyr model remains a promising candidate for shedding light on the Muon Puzzle, owing to its user-friendly tunability.

In this work, the first dedicated efforts to tune PYTHIA 8/Angantyr for air-shower physics using fixed-target measurements are presented. The tuned PYTHIA configuration is compared to its default configuration, to other hadronic interaction models used in cosmic-ray physics, and to existing experimental data, highlighting the impact of tuning on muon production and other relevant shower properties.\*Supported by DFG (SFB 1491)

T 85.3 Thu 16:45 KS 00.006

**Constraints on the Atmospheric Muon Flux from Stopping and High-Energy Muons in IceCube** — •PASCAL GUTJAHR<sup>1,2</sup>, LUCAS WITTHAUS<sup>1,2</sup>, and LENE VAN ROOTSELAAR<sup>1,2</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>Lamarr Institute, Dortmund, Germany

Atmospheric muons detected by the IceCube Neutrino Observatory provide a sensitive probe of cosmic-ray interactions in the atmosphere. These muons originate from conventional pion and kaon decays as well as from prompt decays of short-lived heavy hadrons, with the latter expected to become significant at the highest energies. This contribution presents an unfolding of the atmospheric muon energy spectrum in IceCube, combining low-energy stopping muons with high-energy through-going muons to cover a broad energy range from several hundred GeV to the PeV scale. Stopping muons, which lose all their energy in the ice, constrain the surface muon spectrum at TeV energies, while high-energy muons provide sensitivity to the prompt component. Event classification and energy reconstruction are performed using deep learning techniques to improve resolution and background rejection. The unfolded spectra are used to study the

relative contributions of conventional and prompt muons and are compared to predictions.

T 85.4 Thu 17:00 KS 00.006

**Testing newly released hadronic interaction models with KASCADE-Grande** — •DONGHWA KANG and ANDREAS HAUNGS for the KASCADE-Grande-Collaboration — Karlsruhe Institute of Technology (KIT)

KASCADE-Grande was designed to study the energy spectrum and mass composition of cosmic rays in the energy range from 10 PeV up to 1 EeV. The measurements revealed a knee-like structure in the heavy components at energies around 100 PeV, consistent with expectations from rigidity-dependent scenarios. In addition, a spectral hardening was observed in the light component near 120 PeV. With the recent release of updated post-LHC hadronic interaction models - QGSJet-III-01, EPOS.LHC-R, and Sibyll 2.3d - we test their validity using KASCADE-Grande data. In this contribution, we present the reconstructed all-particle energy spectra as well as the energy spectra of individual mass groups derived from shower size observables, using the newly released hadronic interaction models.

T 85.5 Thu 17:15 KS 00.006

**CORSIKA 8: A modern and universal framework for particle cascade simulations** — •MARVIN GOTTOWIK for the CORSIKA8-Collaboration — Karlsruher Institut für Technologie, Institut für As- troteilchenphysik, Karlsruhe, Germany  
CORSIKA 8 represents a major advancement in the simulation of particle cascades in arbitrary media, building on the long-standing foundation of CORSIKA 7. It has been completely redesigned as a modular, modern C++ framework, overcoming key limitations of its predecessor and providing a flexible platform for both established and emerging use cases. In addition to traditional air-shower simulations, CORSIKA 8 supports applications such as cross-media particle cascades and improved modeling of radio emission, especially propagation through complex media. The framework includes state-of-the-art descriptions of electromagnetic cascades via PROPOSAL and supports hadronic interactions with current and next-generation models, such as EPOS LHC-R, QGSJet-III, and Pythia 8. In this presentation, we will outline the design principles, current capabilities, and ongoing validation efforts of CORSIKA 8, and discuss its role as a versatile simulation tool for future astroparticle and particle-physics experiments.

T 85.6 Thu 17:30 KS 00.006

**Classifying photon- and proton-induced air-showers with a transformer-based approach at the Pierre Auger Observatory** — •ALEXANDER DOEKER, MARCUS NIECHCIOL, and MARKUS RISSE for the Pierre Auger-Collaboration — Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The Pierre Auger Observatory is the world's largest detector for ultra-high-energy (UHE) cosmic rays, capable of observing particles with energies exceeding  $10^{20}$  eV. Only the most extreme cosmic events can accelerate particles to such energies. Detecting an accompanying flux of UHE photons would deepen our understanding of these extreme cosmic events, probe the GZK suppression mechanism, and potentially reveal signatures of exotic scenarios like super-heavy dark matter.

In this work, a transformer-based approach to classify simulated air showers induced by photons and protons will be presented. Transformer networks, with their ability to capture complex patterns in sequential data, offer a promising tool for distinguishing between these signals. The current transformer network uses the photomultiplier tube signals from the water Cherenkov detector stations of the surface detector array as its primary input.

This approach demonstrates the potential of transformer networks to enhance the identification of UHE photon events, possibly advancing our understanding of the most energetic phenomena in the universe.

Supported by the BMFTR Verbundforschung Astroteilchenphysik under project No. 05A23PS1.

## T 86: Members' Assembly

Time: Thursday 18:30–19:30

Location: AM 00.014

All members of the Particle Physics Division are invited to participate. Pretzels and drinks will be provided.



## T 87: Neutrino Physics V

Time: Friday 9:00–10:30

Location: AudiMax

T 87.1 Fri 9:00 AudiMax

**Position and Energy Reconstruction in OSIRIS** — THILO BIRKENFELD, •ELISABETH NEUERBURG, ACHIM STAHL, and CHRISTOPHER WIEBUSCH — RWTH Aachen

During the filling of the Jiangmen Underground Neutrino Observatory (JUNO) in 2025, the Online Scintillator Internal Radioactivity Investigation System (OSIRIS) monitored the radiopurity of the liquid scintillator (LS). OSIRIS has 64  $20''$ -PMTs surrounding a cylindrical acrylic vessel holding 20-ton batches of LS. Uranium and Thorium impurities are estimated by counting the Bismuth-Polonium coincidence occurring in both decay chains, identified using time, distance, and energy cuts. The position of an event is reconstructed using a maximum-likelihood estimation, with Lookup Tables to calculate the expected amount of light. The energy is reconstructed from the event's position and the amount of light detected. The resolutions are estimated from simulation data and cross-checked against calibration data obtained by lowering a multi-gamma source into the vessel. In this talk, the position and energy reconstruction methods in OSIRIS and their respective performances are presented.

T 87.2 Fri 9:15 AudiMax

**Gravitationally induced Decoherence in Neutrino Oscillations: Bridging between Phenomenological and Microscopic Models** — ALBA DOMI<sup>1</sup>, JOÃO COELHO<sup>3</sup>, KRISTINA GIESEL<sup>1</sup>, MAX JOSEPH FAHN<sup>2</sup>, RENATA FERRERO<sup>1</sup>, and •ROMAN KEMPER<sup>1</sup> — <sup>1</sup>Friedrich-Alexander Universität Erlangen-Nürnberg, Germany — <sup>2</sup>Università di Bologna, Italy — <sup>3</sup>APC, Paris

In this talk, the role of gravitationally induced decoherence in open quantum systems is discussed in the context of neutrino oscillations. Often in phenomenological models, the decoherence parameters appear as free parameters encoded in a vectorised dissipator. The properties of a class of such dissipators are examined. Possible links to underlying gravitational microscopic models are discussed, which can provide a physical interpretation of the involved decoherence parameters. In addition, it is considered how different physical assumptions entering the decoherence model are reflected in the resulting neutrino oscillation probabilities.

T 87.3 Fri 9:30 AudiMax

**Quantum Decoherence with KM3NeT/ORCA** — •MAYS MASSARWA for the KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP, Erlangen, Germany

KM3NeT is a research infrastructure currently under construction in the Mediterranean Sea, that consists of two water Cherenkov detectors: ARCA, whose main purpose is to search for cosmic neutrinos in the TeV-PeV range and ORCA that uses atmospheric neutrinos for measurements of neutrino oscillations. ORCA is sensitive to effects beyond the standard model (BSM), such as quantum decoherence.

Treating neutrinos as an open quantum system interacting with an external environment leads to non-unitary time evolution, which can be described by a Lindblad master equation. This results in deviations from the standard neutrino oscillation probabilities and provides a phenomenological description of neutrino decoherence.

Several models propose that quantum gravity could leave a potentially observable imprint in the evolution of the neutrino as an open quantum system. This motivates the study of neutrino decoherence with the ORCA detector by investigating deviations from the expected standard 3-flavour neutrino oscillations. This contribution will report the projected sensitivity of an intermediate detector configuration of ORCA to this effect.

T 87.4 Fri 9:45 AudiMax

**Electron-nucleus scattering at MAMI as a benchmark for precision neutrino interaction models.** — •KHWAJA IDREES HASSAN and LUCA DORIA — Institut für Kernphysik, JGU Mainz

Achieving the precision required for next-generation neutrino experiments depends critically on a detailed understanding of the fundamental processes governing neutrino-nucleus interactions in detectors. At present, uncertainties associated with these interactions remain at the O(10%) level, whereas upcoming experiments demand O(1%) precision.

Electron-nucleus scattering provides a high-precision benchmark for event generator codes used in neutrino experiments, helping reduce systematic uncertainties and ensure the consistency of nuclear models.

The A1 Collaboration at MAMI has initiated an experimental program to precisely measure nuclear cross sections relevant to neutrino physics, with particular emphasis on the needs of future long-baseline experiments such as DUNE and Hyper-Kamiokande. In this contribution, we present current results on  $^{12}\text{C}$  and  $^{40}\text{Ar}$  cross-section measurements and provide an outlook on future experiments for  $^{16}\text{O}$ .

T 87.5 Fri 10:00 AudiMax

**Extended range measurement of the KATRIN energy loss function up to 200 eV** — •VOLKER HANNEN for the KATRIN-Collaboration — Universität Münster, Institut für Kernphysik, Wilhelm-Klemm-Str. 9, 48149 Münster

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims to determine the effective electron neutrino-mass via a precision measurement of the endpoint region of the tritium beta-decay spectrum. One of the dominant systematic uncertainties of the measurement are energy losses of the decay electrons due to inelastic scattering off tritium molecules while traversing the gaseous tritium source of the experiment. Measurements of the energy loss function in a range up to 60 eV, which is relevant for the neutrino mass analysis, have already been performed using an angular selective, mono-energetic photo-electron source. The energy loss function is also required for the determination of the column density of the tritium source where regular measurements are taken at selected surplus energies up to 200 eV. To avoid uncertainties related to the extrapolation of the current energy loss function to this value, we have performed extended range measurements of the inelastic electron scattering up to 200 eV. The talk will present results of the analysis of the new energy loss data in this extended range. This work is supported by BMFTR under contract number 05A23PMA.

T 87.6 Fri 10:15 AudiMax

**The Plasma Systematic in the KATRIN Experiment** — •KARO ERHARDT for the KATRIN-Collaboration — Karlsruher Institut of Technologie

The KATRIN experiment aims at a direct kinematic measurement of the absolute neutrino mass with an expected sensitivity below 300 meV (90% CL), achieved through high-resolution, high-statistics spectroscopy of tritium beta decay. To reach this sensitivity, systematic effects that modify the measured electron spectrum must be modeled and controlled via dedicated calibration measurements. One key systematic effect is related to the starting potential of electrons in the gaseous molecular tritium source, which behaves as a cold plasma in a tesla-scale magnetic field. In this talk, after introducing the starting-potential-related effects, we present the analysis of calibration measurements using gaseous krypton-83m. The impact on the neutrino mass analysis is evaluated, and steps toward a robust source-potential description are discussed. This work is supported by the Helmholtz Association and by the Ministry for Research, Technology and Space BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6)

## T 88: Top Physics IV

Time: Friday 9:00–10:30

Location: KH 00.011

T 88.1 Fri 9:00 KH 00.011

**Measurement of  $t\bar{t}$  spin correlations using Run 2 and 3 data with the ATLAS detector** — DIPTAPARNA BISWAS, CAROLINA COSTA, MARKUS CRISTINZIANI, CARMEN DIEZ PARDOS, IVOR FLECK, GABRIEL GOMES, JAN JOACHIM HAHN, •NIKOLAOS KAMARAS, VADIM KOSTYUKHIN, NILS BENEDIKT KRENGEL, AUSTIN OLSON, INÉS PINTO, SEBASTIAN RENTSCHLER, ELISABETH SCHOPF, KATHARINA VOSS, WOLFGANG WALKOWIAK, and ADAM WARNERBRING — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The top quark is the heaviest known elementary particle and decays before hadronization. Consequently, measurements of the angular distributions of top quark decay products provide direct access to the top quark's spin, enabling a pre-

cise test of perturbative Quantum Chromodynamics in top-antitop quark pair ( $t\bar{t}$ ) production. This contribution presents studies towards the measurement of  $t\bar{t}$  spin correlations using the Run 2 and Run 3 datasets collected with the ATLAS detector from proton-proton collisions at a centre-of-mass energy of 13 TeV and 13.6 TeV, respectively. The analysis focuses on the dilepton decay channel, requiring two leptons of opposite charge (electrons or muons) and at least two jets, with at least two identified as originating from a b-quark. To reconstruct the top quark kinematics and subsequently the angular distributions of the decay products, several top reconstruction methods are employed. The  $t\bar{t}$  spin correlation coefficients will be extracted from these angular distributions using a standard profile likelihood fit for unfolding to both parton and particle level.

T 88.2 Fri 9:15 KH 00.011

**Quantum entanglement in top-quark pairs using events with large transverse momentum with the ATLAS detector** — •CHIARA DEPONTE and ANDREA KNUE — Technische Universität Dortmund, Deutschland

Quantum entanglement of top-quark pairs is studied by measuring the full spin density matrix using data recorded with the ATLAS experiment in Run 2. Since top quarks have a very short lifetime, their spin information is transferred to its decay products. The angular distributions of these particles in a helicity-based coordinate system in the  $t\bar{t}$  rest frame are then used to measure the entries of the spin density matrix. After the reconstruction of the full  $t\bar{t}$  event, Profile Likelihood Unfolding is performed to remove detector and reconstruction effects. Entanglement is predicted at the  $t\bar{t}$  production threshold and for high  $M_{t\bar{t}}$ . The presented analysis is performed in a phase-space region with high top-quark velocities and production angles. In this region the expected number of events is low so the analysis is statistically limited. Therefore, the single-lepton channel is used to find a balance between statistical and systematic uncertainties. This talk focuses on studies regarding the size of the jet-related systematic uncertainties.

T 88.3 Fri 9:30 KH 00.011

**Quantum Spin Correlations at Colliders** — •MONIKA ALEXANDRA WÜST and THORSTEN OHL — University of Würzburg, Institute of Theoretical Physics and Astrophysics, Würzburg

The study of beyond-classical correlations in final states at colliders has received a lot of attention recently. For example, entanglement of particle pairs has been observed at the LHC. Most importantly, measurements of such correlations provide new tests of the Standard Model. More complicated final states are being studied and future colliders with polarized initial states will boost the interest even further. Experimentally, the challenge is to reconstruct the spin-density matrix of a final state from phase space distributions. As a practical matter, the computation of spin-density matrices is beyond the reach of analytical calculations for multi-particle final states. While the event generator WHIZARD has computed the spin density matrix from the beginning, most of it is projected out in the common event formats. We present first results from an automated framework for the computation of general density matrices and quantum observables using event samples generated by WHIZARD. We discuss applications for spin-1/2 (qubit) and spin-1 (qutrit) particles in bipartite and tripartite quantum states at colliders. Analytic calculations are used to test components of WHIZARD matrix elements that have not been tested by comparing cross sections and classical correlations.

T 88.4 Fri 9:45 KH 00.011

**Is Assignment All You Need?** — •SIEMEN AULICH, KATHARINA BEHR, and ELEANOR JONES — DESY, Hamburg, Germany

Many of the recent highlights of particle physics research are related to top quark physics. These include both the tests of spin correlations and quantum effects in pairs of top quarks ( $t\bar{t}$ ), and the observation of a possible quasi-bound state resonance in the  $t\bar{t}$  invariant mass spectrum. Both effects are predominantly studied in dilepton decays in a mass range close to the production threshold.

Probing this system requires a precise reconstruction of the top quarks, which is complicated by the presence of the two neutrinos. While analytical regression

strategies primarily focus on inferring the neutrino momenta, the problem of correctly assigning b-jets to their parent top quarks remains largely unstudied. However, many of the sensitive variables used in  $t\bar{t}$  precision measurements depend critically on the correct assignment of the jets. Inspired by the success of machine learning architectures in tackling the assignment challenge for hadronic decay channels, this work investigates using a transformer model for the dilepton channel. An architecture specifically tailored to these channels topology is shown to outperform all existing methods. Furthermore, it is investigated how these efforts can be combined with neutrino regression methods to offer a full reconstruction pipeline. Applying these methods to existing and upcoming analyses promises further enhancements in the sensitivity and precision of searches and measurements alike.

T 88.5 Fri 10:00 KH 00.011

**ML-Based Kinematic Top Quark Reconstruction in Dileptonic Decays** — •MADS HANSEN BAATTRUP<sup>1</sup>, ALEXANDER GROHSJEAN<sup>2</sup>, PEER STELLDINGER<sup>3</sup>, and CHRISTIAN SCHWANENBERGER<sup>1,2</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron, Notkestr. 85, 22607 Hamburg, Germany — <sup>2</sup>Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — <sup>3</sup>Hochschule für Angewandte Wissenschaften Hamburg, Berliner Tor 5, 20099 Hamburg, Germany

Reconstruction of the full kinematic properties of dileptonic  $t\bar{t}$  events is important for precision tests of the standard model and also plays a role for many searches beyond the standard model (BSM). It is intrinsically challenging because of the presence of two undetected neutrinos, leaving the system underconstrained. Conventional analytical methods rely on assumptions and fixed mass constraints to close the system of equations. These methods introduce significant biases in important observables - particularly in the  $m_{t\bar{t}}$  threshold region, which is highly relevant for both precision measurements and BSM-sensitive analyses.

In this work, we investigate supervised machine-learning-based reconstruction methods using transformer architectures and conditional generative models. We aim to learn the conditional phase-space distribution of parton-level quantities given event observables. This will reduce reconstruction biases while improving resolution relative to traditional analytical methods.

T 88.6 Fri 10:15 KH 00.011

**Enhancing Top-Quark Reconstruction Across Topologies in ATLAS** — •CONSTANTIN ECKARDT — DESY, Zeuthen, Germany

Searches for beyond-the-standard-model physics at particle detectors such as ATLAS often involve top-quark associated events. Top-quark reconstruction in most searches is typically optimized for a specific decay topology. By incorporating multiple reconstruction algorithms, each tailored to different top-decay configurations, one can further expand the reconstruction reach and improve overall efficiency. This work presents studies of a range of top-quark reconstruction algorithms developed for different decay topologies and applied to a variety of physics cases. These studies are used to guide the further optimization of a recently launched umbrella tool within ATLAS – THAT (Top Hacker Across Topologies) – which recommends the most effective reconstruction algorithm on a per-event basis. Such a tool has the potential to enhance many different analyses that rely on accurate and efficient top-quark reconstruction.

## T 89: Higgs Physics IX

Time: Friday 9:00–10:30

Location: KH 00.014

T 89.1 Fri 9:00 KH 00.014

**Test of CP invariance in Higgs boson production via vector boson fusion at the HL-LHC exploiting the  $H \rightarrow \tau\tau$  decay mode** — •DANIEL BAHNER, LORENZO ROSSINI, and MARKUS SCHUMACHER — Albert-Ludwigs-Universität, Freiburg, Deutschland

The observed baryon asymmetry of the Universe can be accounted for only if the three Sakharov conditions are satisfied, one of which is the violation of CP invariance. However, the amount of CP violation predicted by the Standard Model is insufficient to generate the observed asymmetry through electroweak baryogenesis. Precision measurements of the Higgs boson therefore offer a promising avenue to search for additional sources of CP violation. In particular, the vector-boson fusion (VBF) production mode provides sensitivity to potential CP-violating contributions in the  $HVV$  coupling.

This talk focuses on VBF Higgs boson production followed by its decay into a pair of tau leptons. ATLAS published an analysis in 2025 that set the most stringent limits to date on the CP-violating coupling parameters in the  $HVV$  vertex using data collected from 2015 to 2018 corresponding to an integrated luminosity of  $\mathcal{L}_{\text{int}} = 140 \text{ fb}^{-1}$ . Building on that work, the extrapolation of the analysis to the High-Luminosity LHC dataset, corresponding to  $\mathcal{L}_{\text{int}} = 3000 \text{ fb}^{-1}$  at  $\sqrt{s} = 14 \text{ TeV}$ , will be discussed. The study performs a profile-likelihood fit to the CP-odd optimal observable to test CP invariance and to constrain the magnitude of possible new CP-violating interactions. Results from the published analysis,

the extrapolation methodology, and the expected sensitivity to the coupling parameter at the HL-LHC will be presented.

T 89.2 Fri 9:15 KH 00.014

**Measurements of  $H \rightarrow \tau\tau$  CP properties at FCC-ee** — •SOFIA GIAPPICHINI<sup>1</sup>, MARKUS KLUTE<sup>1</sup>, MATTEO PRESILLA<sup>1</sup>, and XUNWU ZUO<sup>2</sup> — <sup>1</sup>Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — <sup>2</sup>Ecole Polytechnique Federale de Lausanne (EPFL), Lausanne, Switzerland

The Future Circular Collider (FCC-ee), a key pillar of the European Strategy for Particle Physics, offers unprecedented precision for studying the Higgs boson. The decay  $H \rightarrow \tau\tau$  stands out due to its sizable branching ratio, clean experimental environment, and sensitivity to tau polarization, making it an ideal channel to probe the CP properties of the Yukawa couplings and search for signs of CP violation beyond the Standard Model. We highlight the prospects for measuring CP-odd components in the  $H \rightarrow \tau\tau$  decays through angular and polarization observables in associated ZH production at a center-of-mass energy of 240 GeV within the Anomalous Coupling and the Effective Field Theory frameworks.

T 89.3 Fri 9:30 KH 00.014

**Probing CP invariance in the decay  $H \rightarrow \tau\tau$  at a future  $e^+e^-$  Linear Collider** — •LEA KUTTLER, MICHAEL BÖHLER, and MARKUS SCHUMACHER — Institute of Physics, Albert-Ludwigs-University Freiburg, Freiburg, Germany  
Sources of CP violation (CPV) beyond the Standard Model (SM) are required to explain the baryon asymmetry observed in our universe (BAU). The Yukawa coupling of the Higgs boson to the tau lepton may deliver a sufficient source of CPV, which allows explaining the observed size of the BAU.

This analysis investigates the CP-nature of the  $H\tau\tau$  Yukawa coupling, considering  $ee \rightarrow ZH$  events at an  $e^+e^-$  linear collider, operating at  $\sqrt{s} = 250$  GeV, assuming an integrated luminosity of  $2 \text{ ab}^{-1}$  and  $e^-/e^+$  beam polarizations of 80%/30%. Events are simulated for the International Large Detector concept.

In  $H \rightarrow \tau\tau$  decays, the strength of CP violation can be parametrized by a single mixing angle  $\psi_\tau$ . Two observables sensitive to  $\psi_\tau$  are the azimuthal angle difference  $\Delta\phi$  between the tau lepton polarimeter vectors and the matrix-element-based optimal observable  $\mathcal{O}\bar{\mathcal{O}}$ .

This contribution demonstrates the use of these observables to constrain  $\psi_\tau$  at a future  $e^+e^-$  linear collider using the decay modes  $\tau \rightarrow \rho\nu$  and  $\pi\nu$  and compares their sensitivity. In this context, methods for fully reconstructing the tau leptons and for identifying hadronic tau decays are presented.

T 89.4 Fri 9:45 KH 00.014

**Future collider perspective on Higgs CP violation** — •YUYANG ZHANG<sup>1,3</sup>, AIDAN ROBSON<sup>1</sup>, CHRISTOPH ENGLERT<sup>2</sup>, ANDREW PILKINGTON<sup>2</sup>, JAY NESBITT<sup>1</sup>, JENNY LIST<sup>3</sup>, and JUNPING TIAN<sup>4</sup> — <sup>1</sup>U of Glasgow, Glasgow, UK — <sup>2</sup>U of Manchester, Manchester, UK — <sup>3</sup>DESY, Hamburg, Germany — <sup>4</sup>U of Tokyo, Tokyo, Japan

Future Higgs factories based on electron-positron colliders are expected to provide unprecedented precision in the measurement of Higgs boson properties, offering a new window for the discovery of physics beyond the Standard Model. In particular, the observation of CP-violation in Higgs interactions would serve as an important indication for electroweak baryogenesis.

In this work, we study the sensitivity to CP-violating Higgs couplings at future Higgs factories within the framework of the SM Effective Field Theory. We focus on Higgs production via the Higgsstrahlung process at  $\sqrt{s}=250$  GeV and top-quark-associated Higgs production at  $\sqrt{s}=550$  GeV at a linear collider facility with polarised beams.

The introduction of machine-learning techniques benefits the analysis in two ways. By constructing observables to discriminate between the CP-even and CP-odd contributions we demonstrate that the interference introduced by dimension-six operators can lead to sensitivity to CP-violating Higgs interactions. We also enhance sensitivity through improved reconstruction techniques. The use of polarised beams further increases the CP-sensitive interference contributions. Overall, the sensitivity obtained at a linear collider becomes comparable to that expected at circular colliders with higher luminosity.

T 89.5 Fri 10:00 KH 00.014

**Impact of polarized beams for Electroweak and Higgs Physics** — •GUDRID MOORTGAT-PICK<sup>1,2</sup>, CHENG LI<sup>4</sup>, JAYITA LAHIRI<sup>5</sup>, and JUHI DUTTA<sup>3</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>Deutsches Elektronen Synchrotron — <sup>3</sup>IMSc Chennai — <sup>4</sup>SYSU, Guangzhou — <sup>5</sup>Krakow University

Polarized beams are substantial to achieve the precision requirements in the electroweak and Higgs sector. Most of the future high-energy lepton collider designs offer the availability of beam polarization. In this talk we summarize the polarization-related results for different Beyond the Standard Models Extensions (MSSM, 2HDMS, inflation models) and discuss CP-violating effects, flavour aspects, high precision electroweak observables and Higgs couplings.

T 89.6 Fri 10:15 KH 00.014

**Study of CP-violation in extended Higgs sectors at a Gamma-Gamma collider** — •MURIEL BLENCK<sup>1</sup>, GUDRID MOORTGAT-PICK<sup>1,2</sup>, MARTEN BERGER<sup>1</sup>, and AYOADE SOTONA<sup>1</sup> — <sup>1</sup>II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, Hamburg — <sup>2</sup>Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, Hamburg

A  $\gamma\gamma$  collider offers a rich Higgs physics program at relatively low center of mass energies. The polarisation of the photon beams, which are obtained via Compton backscattering, are controlled by the incident laser and can reach high levels. This allows the study of CP-violating effects in extended Higgs sectors by constructing CP-odd observables that have higher sensitivity to CP-violating effects when transverse or longitudinal polarisation is used. The SM predicts the Higgs boson to be scalar-even particle, but BSM models like the 2HDM and 2HDMS allow an admixture of CP-even and CP-odd states, which could introduce additional CP-violating effects that would help explain the large baryon-antibaryon asymmetry in the universe. In this talk we present the possibility to use a  $\gamma\gamma$  collider to measure these effects and determine the CP-mixing angle in the extended Higgs sectors.

## T 90: Calorimeters II

Time: Friday 9:00–10:15

Location: KH 00.015

T 90.1 Fri 9:00 KH 00.015

**Integrated Cooling Solutions for a Highly Granular Scintillator-Based Hadronic Calorimeter** — •ANDRE KLOTZBÜCHER<sup>1</sup>, LUCIA MASETTI<sup>1</sup>, REINHOLD DEGELE<sup>1</sup>, STEFFEN SCHÖNFELDER<sup>2</sup>, and KONRAD BRIGGL<sup>3</sup> — <sup>1</sup>Institut für Physik, Johannes-Gutenberg Universität Mainz — <sup>2</sup>Prisma+ Detektorlabor, Johannes-Gutenberg Universität Mainz — <sup>3</sup>Kirchhoff-Institut für Physik, Universität Heidelberg

This talk discusses the adaptation of the analogue hadronic calorimeter (AHCAL), originally developed by the CALICE collaboration for the International Linear Collider (ILC), to meet the demanding requirements of future circular colliders. The AHCAL is based on the SiPM-on-tile technology, where the HCAL Base Units (HBUs) combine scintillator tiles read out by silicon photomultipliers (SiPMs) with embedded front-end electronics. For the linear collider environment, no integrated cooling system was necessary, as power consumption was effectively managed through power pulsing. However, this approach is no longer feasible due to the significantly higher interaction rate in circular colliders, requiring the electronics to remain continuously powered. This must be achieved with a small temperature gradient to ensure uniform SiPM gain and with minimal additional material to preserve the detector's physics performance. To address this challenge, an integrated cooling system is being developed. In this context, a dedicated dummy PCB was designed to allow systematic tests of different cooling strategies. Initial tests with a copper plate thermally coupled to the PCB and the resulting PCB temperatures will be presented.

T 90.2 Fri 9:15 KH 00.015

**Wrapping 160.000 scintillators in 300 days. HGCAL upgrade challenges** — •JORGE ORTIZ — Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany — Universität Hamburg, Mittelweg 177, 20148 Hamburg, Germany

The High Granularity Calorimeter (HGCAL) will replace the current endcap calorimeters of the CMS detector to meet the challenging conditions of the High-Luminosity LHC, including unprecedented radiation levels and pile-up. The hadronic section of the HGCAL requires approximately 280,000 plastic scintil-

lator tiles in 35 different sizes, which are produced in the US. At DESY, around 160,000 of these tiles will be wrapped in reflective foil and subjected to quality control. Given the scale of the task, automation is essential.

In this talk, I will present the system developed at DESY to automate the wrapping, detailing the technical challenges and the current performance of the setup based on the first production batch of more than 10.000 tiles.

T 90.3 Fri 9:30 KH 00.015

**Quality Control of the Tilemodules for the High Granularity Calorimeter upgrade of the CMS experiment** — •ANURAG SRITHARAN — Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany

The CMS experiment will upgrade its detectors to cope with higher luminosities and collision rates during the High-Luminosity era of the LHC. One key upgrade of the CMS is the High Granularity Calorimeter (HGCAL), which will completely replace the current end-cap calorimeter. The hadronic calorimeter is split into two sections using different technologies, depending on the expected amount of radiation damage at the end of life. Where the expected fluence is below  $5 \times 10^{13} n_{eq}/cm^2$ , the SiPM-on-Tile technology was chosen. It consists of small scintillator tiles read out by silicon photo-multipliers on a PCB, named "Tilemodule". A Tilemodule will house 1 or 2 readout chips (called HGCROCs), and each can read out 72 channels. To test and qualify the Tilemodules and the functionality of the readout chips, a robust and modular software framework for quality control has been developed. Additionally, in September 2025, 15 Tilemodules were tuned through the software framework, assembled into a stainless steel absorber stack, and tested at CERN SPS. The test setups, results, and a first look into the analysis of the calorimetric stack will be presented.

T 90.4 Fri 9:45 KH 00.015

**Upcoming Upgrades of the ATLAS Liquid Argon Purity System for the High-Luminosity Upgrade** — •CHRISTOPHER ENGEL, MAXIMILIAN LINKERT, and STEFAN TAPPROGGE — Institut für Physik, Johannes Gutenberg-Universität, Mainz

The ATLAS Liquid Argon Purity system monitors the possible impurities of the Liquid Argon within the calorimeter system ensuring excellent data taking qual-

ity. In preparation of the upcoming Long Shutdown of the LHC for the High Luminosity Upgrade, the Purity system has to undergo some changes and upgrades. This includes a complete redesign of the power distribution board due to the incoming voltage changing from a positive and negative voltage to a single higher positive voltage. The monitoring modules need to have negative voltage resulting in an on-board solution creating the voltage locally. The current design, test setup and production status of the power distribution board is presented.

T 90.5 Fri 10:00 KH 00.015

**Optimisation of the SHiP calorimeter system** — •MATEI CLIMESCU<sup>1</sup>, VOLKER BÜSCHER<sup>2</sup>, CLAUDIA DELOGU<sup>3</sup>, SEBASTIAN RITTER<sup>2</sup>, and RAINER WANKE<sup>2</sup> — <sup>1</sup>Ghent University — <sup>2</sup>University of Mainz — <sup>3</sup>INFN Genova

## T 91: Methods in Particle Physics V

Time: Friday 9:00–10:15

Location: KH 00.020

T 91.1 Fri 9:00 KH 00.020

**Positron Source for Future Collider Designs (HALHF, LCF, ILC, CLIC)** — •GUDRID MOORTGAT-PICK<sup>1,2</sup>, NICLAS HAMANN<sup>2</sup>, MANUEL FORMELA<sup>2</sup>, MALTE TRAUTWEIN<sup>1</sup>, GREGOR LOISCH<sup>2</sup>, TIM LENGELER<sup>3</sup>, DIETER LOTT<sup>3</sup>, and SABINE RIEMANN<sup>2</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>Deutsches Elektronen Synchrotron — <sup>3</sup>Hereon

Higgs Physics and Beyond Standard Model Physics require high-energetic lepton colliders of at least a cms of 550 GeV. In particular the positron source is a challenge for all future lepton colliders. In the talk new R&D developments for polarized positron sources for the high-energy designs as Hybrid Asymmetric Linear Higgs Factory (HALHF), Linear Collider Facility at CERN (LCF), International Linear Collider (ILC) and Compact Linear Collider (CLIC) are discussed. The talk includes physics requirements, status of target and OMD prototypes, automated simulation tools.

T 91.2 Fri 9:15 KH 00.020

**Jet energy resolution in future  $e^+e^-$  Higgs factory experiments with ML and 5D calorimetry** — •BOHDAN DUDAR and LUCIA MASETTI — Johannes Gutenberg-Universität Mainz, Mainz, Germany

The Pandora particle-flow algorithm (PFA) remains one of the best tools for event reconstruction aiming at an excellent jet energy resolution for future  $e^+e^-$  collider experiments. Moreover, the rapid development of picosecond-timing sensors and their potential implementation in the calorimeter would allow for developing a new PFA with timing information, with improved performances in shower separation and particle tracking. Yet, this needs to be integrated in a full PFA reconstruction framework.

In this study, we examine the potential impact of timing in calorimetry on jet energy resolution, using an approach entirely based on machine learning. We develop an energy regression neural network (NN) with and without time information, and compare our results to the Pandora PFA. We use beam-background-free MC samples of  $Z \rightarrow q\bar{q}$  ( $q = u, d, s$ ) reconstructed with the International Large Detector (ILD) in full simulation.

T 91.3 Fri 9:30 KH 00.020

**Calibration of calorimeter signals in the ATLAS experiment using an uncertainty-aware neural network** — •ISABEL SAINZ SAENZ-DIEZ — Kirchhoff Institute for Physics, Heidelberg University

The measurement of energy deposits in the calorimeters is a key aspect of particle reconstruction. In the case of the ATLAS experiment at the Large Hadron Collider (LHC), the calorimeter signals are reconstructed as clusters of topologically connected cells (topo-clusters) and need to be calibrated for energy losses that take part in hadronic showers and do not leave energy in the calorimeter cells. Machine Learning (ML) methods have been proposed in order to perform the hadronic calibration of the clusters. The talk will present the current status of the implementation and performance of a Deep Neural Network (DNN) which

The SHiP/NA67 experiment is an approved beam-dump experiment which will be located in the CERN North Area and is scheduled to start taking data starting 2032. It will operate at very high intensities and requires no background. To this effect, its calorimeter system consists of a SplitCal electromagnetic section and a hadronic section which are optimised for particle identification and high-resolution vertexing of neutral final states from Feebly-Interacting-Particle decays. The optimisation of the calorimeter system is presented.

T 91.4 Fri 9:45 KH 00.020

**Background suppression of neutrino inelastic interactions in SHiP with a GNN using the Surrounding Background Tagger** — •DARJA LUND for the SHiP-SBT-Collaboration — Humboldt Universität zu Berlin, Berlin, Germany

The SHiP (Search for Hidden Particles) fixed target experiment will be realised in a dedicated beam-dump facility in the ECN3 cavern in CERN's north area. It will take advantage of the 400 GeV SPS proton beam to search for feebly interacting long-lived particles at the MeV-GeV scale over many orders of magnitude in coupling. The search for decay signatures will be facilitated by the full reconstruction and particle identification of Standard model final states using the detector setup. Located downstream of the hadron stopper and the magnetic muon shield is the 50m long decay volume, encased by the SBT (Surrounding Background Tagger). A major focus of the experiment, and a key functionality of the SBT, is the detection and suppression of muon and neutrino inelastic scattering background inside the 50m long decay volume. For this, a GNN (Graph Neural Network) to identify background is in constant development. This talk will give an overview of the neutrino background suppression using a GNN-based veto.

T 91.5 Fri 10:00 KH 00.020

**Background suppression in the SHiP experiment with the Surround Background Tagger and different selection criteria** — •KATHARINA ALBRECHT for the SHiP-SBT-Collaboration — Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany

SHiP (Search for Hidden Particles) is an experiment that will be installed in a dedicated beam-dump facility in the ECN3 cavern, located in the CERN north area. SHiP will search for feebly interacting particles (FIPs) produced by 400 GeV/c protons from the SPS impinging on a heavy-metal target. Over a 15-year span, the objective is to accumulate  $6 \times 10^{20}$  protons on target with a detector setup that allows suppression of possible background to a negligible level. The experiment focuses on optimizing the sensitivity for models featuring long-lived FIPs below 10 GeV/c<sup>2</sup> by minimizing backgrounds induced by the huge flux of neutrinos and muons emerging from the beam-dump target. The Surround Background Tagger (SBT) is a critical component surrounding the 50 m long helium-filled decay volume. The SBT is instrumental to detect charged particles entering the decay volume from the sides as well as inelastic interactions of neutrinos and muons taking place inside the helium-filled decay volume, but also in the SBT itself. The presentation will discuss the suppression of these backgrounds from simulation studies, focusing on different selection criteria between standard and modified cuts.

## T 92: Electronics, Trigger, DAQ IV

Time: Friday 9:00–10:15

Location: KH 00.023

T 92.1 Fri 9:00 KH 00.023

**Implementation of a two-level AI-enhanced trigger on a single chip with AI cores for live reconstruction** — •PATRICK SCHWÄBIG for the Lohengrin-Collaboration — Physikalisches Institut, Universität Bonn, Deutschland

For years, data rates generated by modern detectors and the corresponding readout electronics exceeded by far the limits of data storage space and bandwidth available in many experiments. The approach of using fast triggers to discard uninteresting and irrelevant data remains a solution used to this day: Using FP-

GAs, ASICs or directly the readout chip, a fixed set of rules based on low level parameters is applied as a pre-selection. In contrast to this stands live track reconstruction for triggering, which was rarely possible due to limited computation power in the past. With the emergence of highly parallelized processors for AI inference, attempts to sufficiently accelerate tracking algorithms become viable. The AMD Versal Adaptive Compute Acceleration Platform (ACAP) is one such technology and combines FPGA and CPU resources with dedicated AI cores.

Our approach is to implement a two-level trigger on a single chip by utilizing the tightly integrated combination of FPGA and AI cores to profit from their individual strengths. In this talk our concept for a two-level trigger setup, implemented on an AMD VC1902, including classical and quantized AI algorithms, Timepix3 readout, as well as first testbeam results, will be shown. A similar setup will be used in an envisioned mid-size ultra-high rate fixed-target dark matter experiment (Lohengrin) at the ELSA accelerator at the University of Bonn.

T 92.2 Fri 9:15 KH 00.023

**Track Finding with Graph Neural Networks at the ATLAS Event Filter** — •GIULIA FAZZINO, SEBASTIAN DITTMEIER, and ANDRÉ SCHÖNING — Physikalisches Institut, Universität Heidelberg, Germany

The upcoming High Luminosity upgrade of the Large Hadron Collider will increase the number of simultaneous interactions per bunch-crossing in the ATLAS experiment from  $\langle\mu\rangle \approx 56$  to  $\langle\mu\rangle \approx 200$ .

To cope with the computational demands resulting from the corresponding rise in data rate, the Trigger and Data Acquisition System of the experiment will undergo several upgrades. The trigger will consist of a hardware trigger and a software trigger, the Event Filter. In the latter, charged particle tracks in the Inner Tracker (ITk) will be reconstructed for event selection. To reduce the computational resources required for this task, the possibility of using hardware accelerators and new tracking algorithms has been extensively investigated over the last years.

One promising approach uses Graph Neural Networks (GNNs) for track finding, one of the most computationally expensive steps of track reconstruction. The algorithm first builds a graph from the hits in the ITk, then uses a GNN to score its edges, and lastly applies a segmentation procedure to generate track candidates. The high parallelizability of the method makes it suited for implementation on FPGAs or GPUs.

This talk will present an overview of GNN-based track finding for the ATLAS Event Filter, with a focus on its implementation and optimization for FPGA deployment.

T 92.3 Fri 9:30 KH 00.023

**Graph Neural Network based Algorithms for the Belle II Upgrade of the Electromagnetic Calorimeter Trigger on Versal SoCs with integrated AI Engines** — •THOMAS LOBMAIER, ISABEL HAIDE, and TORBEN FERBER — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

In order to reach the target design luminosity of Belle II, the instantaneous luminosity has to be increased by adjustments of the SuperKEKB accelerator. Especially with the planned long shutdown II in 2030 a significant gain in luminosity is expected, which directly increases trigger rates.

Planned upgrades for the electromagnetic calorimeter electronics increase the readout granularity, which also allows the subsequent trigger algorithms to access higher granularity inputs. In addition to the associated better energy and position resolutions, this enables the utilization of shower shape information to reconstruct the event more accurately and improves background suppression.

We show a first implementation of a GNN on Versal SoCs with integrated AI Engines, which enables the processing of up to 256 inputs per event. We

present the performance on datasets with different input reduction strategies for the Belle II Long Shutdown 2 upgrade.

T 92.4 Fri 9:45 KH 00.023

**Low-latency GNN-based hit filtering for the Belle II Level-1 track trigger** — •GRETA HEINE<sup>1</sup>, FABIO MAYER<sup>2</sup>, MARC NEU<sup>2</sup>, GIACOMO DE PIETRO<sup>1</sup>, JÜRGEN BECKER<sup>2</sup>, and TORBEN FERBER<sup>1</sup> — <sup>1</sup>Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>2</sup>Institute for Information Processing Technology, Karlsruhe Institute of Technology, Karlsruhe, Germany

The Belle II experiment encounters increasing beam-induced background with rising instantaneous luminosity, which places tighter requirements on online and offline tracking algorithms. The Level-1 trigger must maintain a high efficiency for physics signals while operating under strict latency and bandwidth constraints. To keep trigger rates within data acquisition limits, effective background suppression, in particular in the Central Drift Chamber (CDC), is essential.

This talk presents a Graph Neural Network (GNN)-based hit filter for the Belle II Level-1 CDC hardware trigger, with a focus on the hardware-aware design workflow for FPGA deployment, including model compression via quantization-aware training and network pruning. Performance results are presented in terms of the trade-off between filtering performance and resource utilization: hit-level background rejection, impact on subsequent track reconstruction and trigger rates, as well as resource usage and sub-microsecond latency for an AMD Ultra-scale FPGA implementation that meets timing after place-and-route.

T 92.5 Fri 10:00 KH 00.023

**AI-enabled FPGA trigger for autonomous radio detection of cosmic rays** — ALPEREN AKSOY<sup>3</sup>, ILJA BEKMAN<sup>3</sup>, MARKUS CRISTINZIANI<sup>1</sup>, ERIC-TEUNIS DE BOONE<sup>1</sup>, •VESSELIN DIMITROV<sup>1</sup>, QADER DOROSTI<sup>1</sup>, CHIMEZIE EGUZO<sup>3</sup>, STEFAN HEIDBRINK<sup>2</sup>, WALDEMAR STROH<sup>2</sup>, JENS WINTER<sup>2</sup>, and MICHAEL ZIOLKOWSKI<sup>2</sup> — <sup>1</sup>Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen — <sup>2</sup>Elektronikentwicklungslabor des Departments Physik, Universität Siegen — <sup>3</sup>Peter Grünberg Institute - Integrated Computing Architectures, Forschungszentrum Jülich

Radio detection of extensive air showers induced by ultra-high-energy cosmic rays provides crucial information on their origin, composition and energy. Radio arrays detect these events, but cosmic-ray signals are exceedingly rare compared to the overwhelming radio noise and RFI. Since storing all data is not feasible, a trigger system must decide in real time which data to record. FPGAs are a fitting option for this requirement because they provide deterministic low latency and low energy consumption compared to CPUs or GPUs. In this collaborative work between the University of Siegen and the Forschungszentrum Jülich, we investigate a novel approach where a machine-learning-based trigger is implemented on an FPGA. The goal is to achieve reliable discrimination between cosmic-ray signals and background, by employing a quantized neural network with minimal latency and power consumption. We aim to validate the quantized model on an FPGA and assess resource usage, latency, power consumption and trigger efficiency, while strongly reducing the false-trigger rate for cosmic-ray events.

## T 93: Data, AI, Computing, Electronics VIII

Time: Friday 9:00–10:15

Location: KH 00.024

T 93.1 Fri 9:00 KH 00.024

**Electromagnetic Shower Shape Correction using Normalizing Flows** — •MARIUS MELCHER, ARNO STRAESSNER, and ASMA HADEF — Technische Universität Dresden

The interplay between data and simulation is essential for precision measurements at the ATLAS experiment. The GEANT4-based simulation of electromagnetic showers in the calorimeter, however, exhibits notable discrepancies with data, particularly in derived shower-shape variables used for electron and photon identification. These mismatches can impact the efficiency and background rejection of identification algorithms, making corrections to simulated showers crucial for physics analyses.

This talk presents a machine-learning-based approach using normalizing flows to correct shower-shape variables in simulation. This model is applied to electron shower-shapes measured by ATLAS during LHC Run 3. Resulting improvements in data-simulation agreement are discussed.

T 93.2 Fri 9:15 KH 00.024

**Speeding up the MC Background Simulation at Belle II** — •OLIVER SCHUMANN, NIKOLAI KRUG, THOMAS KUHR, and THOMAS LÜCK — Ludwig-Maximilians-Universität München (LMU), München, Germany

By striving for ever-higher luminosities, the Belle II detector is set to observe rare decay signals. However, these high luminosities correspond to an increased

demand for MC-generated background. Therefore, an efficient algorithm to simulate background events for the detector in large quantities is vital for the successful interpretation of Belle II's data. While the generation and skimming of events in the MC simulation chain are quick and easy to compute, the detector simulation and reconstruction of these particles are a slow task. A neural network (NN) is introduced into the chain to classify skim-passing events and discard those which fail to pass the NN before the detector response simulation, thereby saving valuable computing resources and time.

This work explores a new approach for parallelisation of the NN training process, in hopes of achieving convergence with the resources available in less (real) time. It involves an on-the-fly training pipeline on multiple machines, retrieving the updated NN, and redistributing it to the clients. This talk aims to provide an overview of the current work in progress and to give an outlook on future prospects.

T 93.3 Fri 9:30 KH 00.024

**CaloHadronic: review and updates** — •MARTINA MOZZANICA<sup>1</sup>, GREGOR KASIECZKA<sup>1</sup>, FRANK GAEDÉ<sup>2</sup>, and KATJA KRÜGER<sup>2</sup> — <sup>1</sup>University of Hamburg — <sup>2</sup>DESY, Hamburg

Simulating showers of particles in highly-granular calorimeters is a key frontier in the application of machine learning to particle physics. Achieving high accuracy and speed with generative machine learning models can enable them to aug-

ment traditional simulations and alleviate a major computing constraint. Recent developments have shown how diffusion based generative shower simulation approaches that do not rely on a fixed structure, but instead generate geometry-independent point clouds, are very efficient. We present CaloHadronic: a diffusion model for the generation of hadronic showers in both the highly granular electromagnetic and hadronic calorimeters of the International Large Detector, ILD. In addition, we detail several updates to the dataset and architectural design.

T 93.4 Fri 9:45 KH 00.024

**OmniJet-alpha for Calorimeters - Autoregressive generation of Calorimeter Showers** — JOSCHKA BIRK<sup>1</sup>, FRANK GAEDE<sup>2</sup>, ANNA HALLIN<sup>1</sup>, GREGOR KASIECZKA<sup>1</sup>, MARTINA MOZZANICA<sup>1</sup>, and •HENNING ROSE<sup>1</sup> — <sup>1</sup>Institute for Experimental Physics, Universität Hamburg Luruper Chaussee 149, 22761 Hamburg, Germany — <sup>2</sup>Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

We present an autoregressive approach for the generation of high-granularity calorimeter showers based on the OmniJetAlpha architecture. The proposed method directly embeds individual calorimeter shower hits, enabling end-to-end autoregressive generation without relying on discrete tokenization or vector-quantized codebooks. To model hit features efficiently, the architecture employs separate prediction heads for each feature dimension, allowing the overall model size to remain compact even at very high spatial and energy granularities, while avoiding codebook collapse and related representational bottlenecks. This design facilitates stable training and scalable generation in regimes where traditional token-based approaches become impractical. Our results demonstrate that gen-

erative pre-training can be performed directly at the data level for calorimeter shower modeling, removing the need for intermediate representations. This is a significant step toward leveraging transformer-based foundation models in high-energy physics, as autoregressive pre-training has proven exceptionally effective in generative modeling, as evidenced by recent advances in large language models.

T 93.5 Fri 10:00 KH 00.024

**PanShower: One model for all calorimeter showers** — •THORSTEN BUSS<sup>1,2</sup>, HENRY DAY-HALL<sup>2</sup>, FRANK GAEDE<sup>2</sup>, GREGOR KASIECZKA<sup>1</sup>, and KATJA KRÜGER<sup>2</sup> — <sup>1</sup>Universität Hamburg, Hamburg, Germany — <sup>2</sup>Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

Accurate and efficient detector simulation is essential for modern collider experiments. To reduce the high computational cost, various fast machine learning surrogate models have been proposed. Traditional surrogate models for calorimeter shower modeling train separate networks for each particle species, limiting scalability and reuse. We introduce PanShower, a unified generative model that simulates calorimeter showers across multiple particle types using a single generative model. PanShower is a continuous normalizing flow model with a Transformer architecture, enabling it to generate complex spatial and energy correlations in variable-length point cloud representations of showers. Trained on a diverse dataset of simulated showers in the highly granular ILD detector, the model demonstrates the ability to generate realistic showers for electrons, photons, charged and neutral hadrons over a wide range of incident energies and angles without the need for retraining.

## T 94: Flavour Physics VI

Time: Friday 9:00–10:30

Location: KH 01.011

T 94.1 Fri 9:00 KH 01.011

**Semileptonic Kaon Decays at NA62** — •ATAKAN AKMETE — Mainz University  
Semileptonic charged kaon decays  $K^+ \rightarrow \pi^0 \ell^+ \nu(\gamma)$  ( $K_{\ell 3}$ ) provide a clean test of  $e$ - $\mu$  lepton universality and a direct probe of the first row of the CKM matrix unitarity  $|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$ . Current measurements indicate a near three-sigma tension in the determination of  $V_{ud}$  and  $V_{us}$ , with semileptonic kaon decays alone contributing at the  $2.6\sigma$  level.

This study aims to update the branching fractions of  $K_{\ell 3}$  together with the other dominant  $K^+$  modes using an unbiased low-intensity dataset collected by the NA62 experiment at CERN, providing a clean environment for per-mille-level statistical precision.

From this dataset, events with a single positively charged downstream track are selected, defining a topology that allows all six main decay modes to be measured simultaneously without explicit particle identification. This approach naturally separates decay modes into distinct kinematic regions, effectively acting as a PID substitute and reducing the systematic uncertainties associated with neutral-pion reconstruction and calorimetry.

In this talk, I will present the current status of the analysis, including preliminary results and ongoing systematic studies.

T 94.2 Fri 9:15 KH 01.011

**Search for  $B \rightarrow D^{(*)} \eta \ell \nu$  at Belle II** — •DAVID GIESEGH, THOMAS KUHR, and THOMAS LÜCK — LMU Munich, Germany

Even though semileptonic B meson decays have been a field of intensive study over the past decades, there are still unresolved questions. One of these is the so-called gap problem, which describes a discrepancy between measurements of the inclusive semileptonic branching fraction and the sum of exclusive semileptonic branching fractions. This difference could be attributed to one or several as of yet unobserved decays, an example for which is  $B \rightarrow D^{(*)} \eta \ell \nu$ , which is allowed within the Standard Model and commonly used in MC simulations of generic B meson decays to fill the gap.

In the analysis presented here we aim to measure this branching fraction for the first time using data collected by the Belle II Experiment. We leverage Belle II's well known initial state kinematics to derive the angle between the decaying B meson and its visible daughters, which is used for signal extraction. Additionally, MVA methods are employed for candidate selection and background suppression, which is especially important in the reconstruction of  $\eta$  candidates. In the talk we will discuss the current status and future outlook of this analysis.

T 94.3 Fri 9:30 KH 01.011

**Measurement of the Branching Ratio and  $q^2$ -spectrum of  $B \rightarrow D^{**} \ell \nu$  decays at Belle II** — •EYLÜL ÜNLÜ, THOMAS KUHR, and THOMAS LÜCK — Ludwig-Maximilians-Universität München (LMU), München, Germany

There is currently some tension between the measured value of  $R(D^{**}) = \mathcal{B}(B \rightarrow D^{**} \tau \nu_\tau) / \mathcal{B}(B \rightarrow D^{**} \ell \nu_\ell)$  and the Standard Model prediction, hinting at lepton universality violation. Semileptonic B meson decays to  $D^{**}$  mesons are background to the  $R(D^{**})$  measurement, where  $D^{**}$  denotes the orbitally excited

P-wave charm mesons:  $D_1(2420)$ ,  $D_2^*(2460)$ ,  $D_3^*(2300)$ , and  $D_1'(2430)$ . These decays are not well understood, and discrepancies have been observed between past measurements of their yields made by BaBar and Belle. Hence, improving understanding of these decays reduces an important systematic uncertainty on  $R(D^{**})$  measurements.

The present study aims to use data from the Belle II experiment to study these decays, particularly to determine the  $q^2$  spectrum, which is a key input for theory predictions.

We reconstruct one of the B mesons from the  $\Upsilon(4S) \rightarrow BB$  decay in the signal channel,  $B \rightarrow D^{**}(D^{(*)} \pi) \ell \nu$ , and the other B meson in various hadronic modes using the Full Event Interpretation algorithm. The signal yield is determined by a maximum likelihood fit to the mass difference  $M(D^{(*)} \pi) - M(D^{(*)})$ . The resulting  $q^2$  spectrum is fitted using a differential decay rate model after correcting for detector resolution effects. The status of the analysis will be presented including results on simulation and a first assessment of systematic uncertainties.

T 94.4 Fri 9:45 KH 01.011

**Angular analysis of  $B^0 \rightarrow D^* \tau \nu$  in Run 2 at the LHCb experiment** — TOBIAS KNOSPE<sup>1</sup>, JOHANNES ALBRECHT<sup>1</sup>, GREG CIEZAREK<sup>2</sup>, MARCO GERSABECK<sup>3</sup>, LUCIA GRILLO<sup>4</sup>, •BILJANA MITRESKA<sup>5</sup>, CHRIS PARKES<sup>5</sup>, MANUEL SCHILLER<sup>4</sup>, DEREK YEUNG<sup>5</sup>, and HAVVA HASRET NUR<sup>4</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>CERN, Geneva, Switzerland — <sup>3</sup>Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — <sup>4</sup>University of Glasgow, Glasgow, UK — <sup>5</sup>The University of Manchester, Manchester, UK

The global average of the ratio  $R(D^{**})$  between the  $B^0 \rightarrow D^* \tau \nu$  and  $B^0 \rightarrow D^* \mu \nu$  branching fractions is at tension with the SM prediction. The angular structure of the  $b \rightarrow c \ell \nu$  transition using effective field theory allows to probe potential New Physics (NP) effects with greater sensitivity than a measurement of the branching fraction. An angular analysis of the  $B^0 \rightarrow D^* \tau \nu$  decay is presented, based on proton-proton collision data collected by the LHCb experiment, corresponding to an integrated luminosity of  $1.6 \text{ fb}^{-1}$ . The signal distribution is extracted through a multidimensional fit to the data, using templated distributions derived from both simulation and data control samples. The  $R(D^{**})$  ratio and several NP Wilson coefficients are measured in different combinations. Additionally, the  $R(D^{**})$  ratio as well as the hadronic form factors are measured in a Standard Model scenario using BGL and BLPR parameterizations.

T 94.5 Fri 10:00 KH 01.011

**$R(D^{**})$  measurements with ATLAS Run 2 data** — •LAILY SULTANALIYEVA<sup>1</sup>, LEONID GLADILIN<sup>2</sup>, and VLADIMIR TIKHOMIROV<sup>2</sup> — <sup>1</sup>University of Bonn, Bonn, Germany — <sup>2</sup>Moscow, Russia

Semileptonic decays of hadrons can be used for testing the equality of the couplings of the three charged leptons to the gauge bosons, i.e. Lepton Flavour Universality (LFU). Sensitive to LFU violation ratios of branching fractions for various hadrons decays have been previously studied by BaBar, Belle and LHCb experiments. The aim of this analysis is to measure  $R(D^{**}) \equiv \mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) / \mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)$  with proton-proton ( $pp$ )

collisions data collected by the ATLAS experiment during LHC Run 2 and compare with the current world-average result, which now exceeds the Standard Model predictions by  $\sim 2.7\sigma$ .

The ratio of branching fractions  $R(D^*)$  is measured with data recorded during  $pp$  collisions with  $\sqrt{s} = 13$  TeV corresponding to the integrated luminosity of  $140 \text{ fb}^{-1}$ . The  $\tau^\pm$  leptons are reconstructed through the semileptonic decay  $\tau^\pm \rightarrow \mu^\pm \bar{\nu}_\mu \nu_\tau$ , while for  $D^*$  mesons the following decay chain is used:  $D^{*\pm} \rightarrow D^0 \pi^\pm \rightarrow (K^\mp \pi^\pm) \pi^\pm$ . Both  $\tau^-$  and  $\mu^-$  decay modes of  $B^0$  mesons have the same number of detectable particles in the final state, and thus can be selected and analysed together. A multi-dimensional fit then can be used to separate two signal processes from each other as well as from background processes. In this talk the current state of the analysis will be presented.

T 94.6 Fri 10:15 KH 01.011

**R(D) and R(D\*) Measurement using an Inclusive Tagging Method** — •FABIO NOVISSIMO<sup>1</sup>, TIA CRANE<sup>2</sup>, THOMAS LÜCK<sup>1</sup>, and THOMAS KUHR<sup>1</sup> — <sup>1</sup>Ludwig-Maximilians-Universität München (LMU), München, Germany — <sup>2</sup>DESY - Universität Hamburg

Lepton flavour universality (LFU) is a fundamental symmetry of the Standard Model (SM). This symmetry states that the three generations of leptons (electrons, muons and taus), couple with equal strength to the W boson. Any deviation from this symmetry is a clear sign of new physics. In this regard, the semileptonic decays of B mesons are an invaluable portal for LFU tests. More specifically, the measurement of the ratios  $R(D)$  and  $R(D^*)$  defined as

$$R(D^{(*)}) = \frac{\mathcal{B}(B \rightarrow D^{(*)} \tau \nu_\tau)}{\mathcal{B}(B \rightarrow D^{(*)} \ell \nu_\ell)}$$

are two great ways to probe this symmetry, since the ratios allow many uncertainties to cancel and are predicted with a very high precision in the SM. Latest averaged results show that there is a  $3.8\sigma$  tension with the SM prediction, making this measurements very relevant. The analysis presented in this talk aims to obtain an even more precise measurement of the ratios  $R(D)$  and  $R(D^*)$  using Belle II data, and adopts an inclusive tagging approach, which allows increased statistics at the expenses of higher background levels. This talk will provide an overview of the analysis, as well as the current status and future outlook.

## T 95: Gaseous Detectors III

Time: Friday 9:00–10:30

Location: KH 01.014

T 95.1 Fri 9:00 KH 01.014

**Background Studies at the SHiP Spectrometer Straw Tracker** — •HANNAH LIMBERG, CAREN HAGNER, DANIEL BICK, WEI-CHIEH LEE, and WALTER SCHMIDT-PARZEFALL — Institute of Experimental Physics, University of Hamburg, Hamburg, Germany

SHiP (Search for Hidden Particles) is a general-purpose beam-dump experiment currently in preparation at the CERN SPS. The experiment is designed to explore physics beyond the Standard Model by searching for feebly interacting particles (FIPs), which are predicted by several theoretical models of the hidden sector. When the high-intensity proton beam from the SPS hits a thick target, the collisions can potentially create hidden particles. These particles enter a 50 m decay volume and decay into Standard Model particles. They are detected by the spectrometer straw tracker located behind the decay volume. While only moderate particle rates from the target are expected, backgrounds from secondary interactions, for example in the tracker frames, will contribute significantly to the total number of hits in the spectrometer. The influence of background and its impact on the detection efficiency are investigated through simulation studies. The results will be presented in this talk.

T 95.2 Fri 9:15 KH 01.014

**Implementation of 2nd coordinate measurement for 3D tracking with Drift Tube Chambers** — •NICK MEIER, JULIA OKFEN, and OLIVER KORTNER — Max-Planck-Institute for Physics, Garching, Germany

This work investigates the implementation of a second coordinate measurement in drift-tube detectors to enable full 3D hit reconstruction in drift tube chambers. Two concepts are studied: the Twin-Tube configuration, where signals are looped through paired tubes, and a Double-Sided Readout with independent readout on both ends. For ATLAS muon drift-tube (MDT) chambers, measurements of signal propagation and attenuation allow reconstruction of the hit position along the wire. Using the signal propagation delay measurement, a second coordinate resolution of approximately 200 mm is achieved at various tube lengths. A second-coordinate measurement efficiency exceeding 96% can be achieved under HL-LHC background conditions. For small diameter muon drift-tube (sMDT) chambers, resolutions between 100-140 mm are obtained at the different positions along the tube, reaching 95 mm for a 100 GeV muon beam and 52 mm when combining the information of four tubes. The utilization of the second coordinate for the rejection of  $\gamma$  background hits in track reconstruction will also be discussed in the presentation. Overall, the results demonstrate that a second coordinate can be integrated into gaseous drift-tube detectors with high efficiency, providing a promising option for future high  $\gamma$  background rates as expected for the muon systems at the HL-LHC and the FCC.

T 95.3 Fri 9:30 KH 01.014

**Testbeam Performance of 20x20 cm<sup>2</sup> triple GEM Detector** — •NICK SCHNEIDER, OTMAR BIEBEL, VALERIO D'AMICO, RALF HERTENBERGER, ESHITA KUMAR, LILLA SCHNEIDER, CHRYSOSTOMOS VALDERANIS, and FABIAN VOGGEL — LMU Munich

Micro-Pattern Gaseous Detectors are heavily used for the detection of charged particles with excellent temporal and spatial resolution. The investigated detector is a triple-GEM detector with a size of 20x20 cm<sup>2</sup>. Additionally the GEM-foils are split into 4 sectors on the top sides to reduce the capacity in case of a violent discharge, making it less likely for the foils to be damaged in such an event. While testing the detector in the lab with a <sup>55</sup>Fe source a charge-up effect was noticed. To further investigate this effect and determine efficiency and resolution of this

detector it is tested in a 120 GeV muon testbeam at CERN and a high-rate  $\approx 3$  GeV electron testbeam at ELSA (University of Bonn). For the muon testbeam additional tracking detectors are used to determine the efficiency and the resolution of detector under test. Due to multiple scattering, it is very difficult to track the particles in the electron testbeam. Consequently, the high electron flux of this beam is used to further investigate high-rate and charge-up effects. Some of the results of these testbeams will be presented.

T 95.4 Fri 9:45 KH 01.014

**Rate characteristics of triple GEM detectors with results from the ELSA test-beam measurements** — ERIK EHLERT, KERSTIN HOEPFNER, STELLA ISRAEL, •DANIEL KLEE, MARKUS MERSCHMEYER, ALEXANDER SCHMIDT, and SHAWN ZALESKI — III. Physikalisches Institut, RWTH Aachen University, Aachen, Germany

Gas electron multipliers (GEM detectors) are often used in challenging conditions. For example in the CMS experiment the new ME0 detector will see particle-fluxes of up to 150 kHz/cm<sup>2</sup>. For a muon detector it is not trivial to cope with such high rates. GEM detectors are particularly well suited for this environment because of their high rate capability and good spatial resolution. This talk will present results on studies of operating a GEM detector at high and highest rates. In particular, we present the influence of boundary conditions, such as variation of protection resistors. Besides measuring the rate capability of a triple GEM test detector with an X-Ray source, the presented results also include measurements recorded at the Elektronen-Stretcher-Anlage (ELSA) in Bonn. Here we were able to reach even higher rates, pushing the GEM detector to its limits.

T 95.5 Fri 10:00 KH 01.014

**BASTARD: A GEM based neutron detector with VMM readout** — •JAN GLOWACZ<sup>1</sup>, THOMAS BLOCK<sup>1</sup>, KLAUS DESCH<sup>1</sup>, SAIME GÜRBÜZ<sup>1</sup>, JOCHEN KAMINSKI<sup>1</sup>, and MARKUS KÖHL<sup>2,3</sup> — <sup>1</sup>University of Bonn — <sup>2</sup>Heidelberg University — <sup>3</sup>StyX Neutronica GmbH

In the neutron science community the high price of helium-3 pushes the use of solid neutron converters like boron or gadolinium in detectors. The boron based multi stage tracking detector (BASTARD) is such a detector with focus on high spatial resolution and high readout rates. It is a multi-layer gaseous detector, where a boron coated cathode is used to convert neutrons into helium and lithium ions. A GEM-like gas amplification stage is used to detect the ions. The readout is implemented using VMM3a hybrids and the DRD1 Scalable Readout System. A prototype detector with an active area of 10cm x 10cm is currently under development. We present our first results from tests with the prototype.

T 95.6 Fri 10:15 KH 01.014

**A Time-Projection-Chamber for Neutron Science** — •THOMAS BLOCK<sup>1</sup>, KLAUS DESCH<sup>1</sup>, JOCHEN KAMINSKI<sup>1</sup>, MARKUS KÖHL<sup>2,3</sup>, SAIME GÜRBÜZ<sup>1</sup>, JAN GLOWACZ<sup>1</sup>, and CAN CETINKAYA<sup>1</sup> — <sup>1</sup>Physikalisches Institut, Rheinische Friedrich-Wilhelms Universität Bonn — <sup>2</sup>Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg — <sup>3</sup>StyX Neutronica GmbH, Mannheim

Due to the increased price of helium-3, alternative approaches for detectors in neutron science are highly demanded. This work combines the concept of a time projection chamber (TPC) with a boron-coated scintillator and optical guides. The GridPix-based readout with high granularity and high time resolution makes it a suitable candidate for imaging instruments and mid-rate scattering experiments. The enriched boron absorbs incoming thermal neutrons and decays into



an alpha particle and a lithium ion. One ion enters the drift volume of the TPC and creates a trace of electron-ion pairs, which subsequently is projected onto the readout. The other ion of the same decay, which is emitted in the opposite direction, creates photons in the scintillator layer, which is used to trigger the readout. The light is coupled via an optical guide to a FPGA-controlled silicon

photomultiplier trigger board. This timing information is necessary to reconstruct the three-dimensional ionisation track and hence the point of neutron conversion. We present the detector concept, its current stage of development and first measurements.

## T 96: Outreach II

Time: Friday 9:00–10:30

Location: KH 01.020

T 96.1 Fri 9:00 KH 01.020

**From Research to Impact: Outreach and Knowledge Transfer Across the German LHC Community** — •DANIEL HEUCHEL, KIM WEGNER, and SOPHIA HAVES — LHC Germany Office, Hamburg, Germany

The LHC-ErUM-FSP Office coordinates outreach and knowledge- and technology-transfer activities within the German LHC community. All 29 German universities and research institutes participating in ALICE, ATLAS, CMS, and LHCb are supported through structures that enhance communication, visibility, and strategic interaction beyond the academic environment. These activities reinforce public engagement, enable interdisciplinary exchange, and highlight the broader impact of frontier research at the LHC. In this context, latest strategic emphasis is placed on fostering and supporting knowledge transfer towards industry and on communicating the societal benefit of research outcomes.

In this contribution, outreach and transfer initiatives of the LHC-ErUM-FSP office will be presented, newly developed formats will be outlined, and their contribution to building the bridge between the German LHC community, our society, industry, and politics will be illustrated.

T 96.2 Fri 9:15 KH 01.020

**Teilchenphysik Outreach im Wandel der Zeit - Chancen und Herausforderungen in der Nachwuchsgewinnung** — •DAVID BORGELT und CHRISTIAN KLEIN-BÖSING für die Netzwerk Teilchenwelt-Kollaboration — Institut für Kernphysik, University of Münster, Münster, Germany

Das Netzwerk Teilchenwelt, NRW-FAIR und weitere Outreach-Akteure kommunizieren moderne Teilchenphysik-Forschung, um Jugendliche zu gewinnen, ihnen Teilhabe zu ermöglichen und sie zu informieren. Dabei werden bewährte Methoden wie Masterclasses oder Praktika genutzt, welche von Vermittler:innen aus der Forschung geleitet sind. Um weiterhin der jungen Zielgruppe gerecht zu werden, werden neue Wege entwickelt, über welche Jugendliche erreicht werden können. Hierbei ist besonders der Umgang mit Social Media für Kommunikation und Interaktion, sowie die gemeinsame Arbeit mit Jugendlichen auf Augenhöhe, angelehnt an Peer Teaching, zu nennen. In diesem Talk werden Erfahrungen mit Social Media für den Outreach und partizipativer Wissenschaftskommunikation vorgestellt, sowie niedrigschwellig zu adaptierende Methoden um junge Leute zu begeistern, präsentiert.

T 96.3 Fri 9:30 KH 01.020

**Universe in Creation: Student Art Inspired by Dark Matter Research** — •MARKUS KLUTE and MICHAEL HOCH — KIT, Karlsruhe, Germany

Over the course of a full school year, KIT and the ZKM collaborated with an all-girls Gymnasium in Karlsruhe to explore dark matter and the universe through the lens of artistic creation. Girls aged 11-14 met bi-weekly at KIT and the ZKM, where particle physicists and art educators introduced them to concepts from particle physics and cosmology and supported them in developing their own creative interpretations.

Working at the intersection of science and art, the pupils transformed ideas about the invisible universe into drawings, installations, and digital works. The project culminated in a public exhibition at the ZKM, showcasing their artworks and highlighting how creative practice can empower young women to engage confidently with complex scientific themes. The collaboration explores the value of longer term STEAM programs in fostering curiosity and participation in physics.

T 96.4 Fri 9:45 KH 01.020

**EXPLORE: a multi-experiment open-access platform for education and training with LHC open data** — •BAIDA ACHKAR, ARNULF QUADT, and SEBASTIAN WOZNIEWSKI — II. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

EXPLORE is an open-access analysis platform developed at the University of Göttingen within PUNCH4NFDI, the NFDI consortium for Particle, Astro-, Nuclear, and Hadron Physics. The service provides FAIR-aligned, barrier-free access to ATLAS Open Data, enabling students, educators, and the public to carry out realistic particle-physics analyses without requiring CERN credentials or local software installations. Its technical foundation consists of an HTCondor overlay batch system, containerized environments via CVMFS and Apptainer, and dynamic resource provisioning through the COBaLD/TARDIS framework. Users currently access 145 ATLAS Open datasets and structured tutorial examples supporting sustainable learning workflows. EXPLORE is actively used in the HEP Masterclasses at Göttingen University and was introduced as a global resource during the ATLAS Open Data Tutorial (24 - 27 November 2025) at CERN. Since entering full production in late 2024, the platform has onboarded 28 users and processed around 190,000 analysis jobs. To broaden its educational reach, EXPLORE is being expanded to also support CMS Open Data workflows, with deployment planned ahead of the DPG Spring Meeting. The contribution will present the platform architecture, operational experience, educational deployments, and upcoming multi-experiment capabilities for LHC Open Data.

T 96.5 Fri 10:00 KH 01.020

**Erfahrungsbericht zum Science Camp Teilchen- und Astroteilchenphysik mit erweitertem CERN-Programm** — MICHAEL GAUSS, MICHELLE GENSMANN, CHRISTIAN GOFFING, DORIAN GUTHMANN, CAROLIN QUAST, GÜNTER QUAST, CEDRIC VERSTEGE und •CHRISTIAN WINTER — Karlsruhe Institute of Technology, Karlsruhe, Germany

Das Science Camp Teilchen- und Astroteilchenphysik am KIT bietet Schülerinnen und Schülern jährlich mit einer Verbindung aus theoretischen Impulsen, selbstständiger Projektarbeit und authentischen Einblicken in die Forschung die Möglichkeit, Teilchenphysik praxisnah zu erleben. Durch die Projektarbeit und Masterclasses lernten die Jugendlichen typische wissenschaftliche Arbeitsweisen z.B. kritischen Umgang mit Messdaten kennen, um diese dann selbstständig durchzuführen und auszuwerten. Besonders der Besuch am CERN als Höhepunkt beim diesjährigen Camp wirkte als starker motivierender Faktor, da die Teilnehmenden Forschung nicht nur konzeptuell, sondern hautnah erleben durften. Mit Führungen bei sieben Forschungsanlagen und Experimenten, sowie einem Besuch beim neuen Science Gateway und durch die direkte Begegnung mit Wissenschaftlerinnen und Wissenschaftlern wurden die theoretischen Konzepte greifbar und eine realistische Berufsorientierung ermöglicht. Dieser Vortrag vermittelt insbesondere unsere Erfahrungen und das Feedback des Besuchs am CERN, in dem die Teilnehmende direkten Kontakt zur aktuellen Forschung erfahren durften.

T 96.6 Fri 10:15 KH 01.020

**Outreach Module for Supersymmetric Particle Search** — NIKOLAI CHAUNIN<sup>1</sup>, JERZY PRYGA<sup>2</sup>, ANDRÉ SOPCZAK<sup>1</sup>, and •VLADYSLAV TABACINIUC<sup>1</sup> — <sup>1</sup>CTU in Prague — <sup>2</sup>Jagiellonian University in Kraków

We present a new model as a part of the Czech Particle Physics Project (CPPP). This module is intended as a leaning tool in masterclasses aimed at high-school students (ages 15 to 18). The module is dedicated to the detection of new supersymmetric particles by separating signal from background. The chosen process is scalar top pair-production in the final state containing a b-jet, a c-jet, a light lepton, and large missing transverse energy (MET). The user will compare simulated signal and background distributions with actual recorded data. The module can be accessed at the following link: <http://cern.ch/cppp>.

## T 97: Silicon Detectors VIII

Time: Friday 9:00–10:15

Location: KH 01.022

T 97.1 Fri 9:00 KH 01.022

**MIP detection on a plastic scintillator and SiPM system in very noisy environments** — •KATJANA NEUMANN, MASSIMILIANO ANTONELLO, LUKAS BRINKMANN, ERIKA GARUTTI, and JÖRN SCHWANDT — Universität Hamburg, Hamburg, Deutschland

Radiation damage to a silicon photomultiplier (SiPM), as occurs during the lifetime of the planned CMS HGCal detector, increases the dark current and degrades the signal to noise (S/N) separation and thus the minimum ionizing particles (MIP) detection efficiency. To investigate this, a system consisting of a plastic scintillator tile directly coupled to a SiPM is used to detect the MIP from a  $^{90}\text{Sr}$  source. The aim of this thesis was to compare the effects of true radiation-induced damage with a method that increases the dark-count rate (DCR) exclusively through DC light illumination. This second approach does not induce any physical structural damage. This allows the isolation of the effect of increased DCR as the primary factor degrading the SiPM response. The results show that an increase in the DCR, regardless of whether it was induced by irradiation or DC illumination, leads to a comparable reduction in the MIP-response and the S/N ratio. This confirms that the dominant factor for the performance degradation is the increased DCR itself and not additional damage or defects introduced in the silicon. This study highlights a significant insight: the primary consequence of radiation damage on SiPMs can be effectively mimicked under laboratory settings using optical illumination to increase the DCR.

T 97.2 Fri 9:15 KH 01.022

**A digital SiPM in liquid xenon** — •TIFFANY LUCE — Physikalisches Institut, Universität Freiburg, 79104 Freiburg, Germany

Silicon PhotoMultipliers (SiPMs) are photosensors commonly used in many experiments. However, achieving single-photon sensitivity in the experiments is limited by the high dark count rate (DCR) of these devices. Digital SiPMs, where the digitization happens directly on the chip, can show DCRs competitive to that of traditional photomultiplier tubes (PMTs) with the added benefit of not needing analog to digital converters and greatly reducing the data rate. This would open up to cheaper and thus larger systems. We present results of the test of a digital SiPM in cryogenic liquid xenon, one of the most important detector target for dark matter searches.

T 97.3 Fri 9:30 KH 01.022

**Characterisation of commercially available SiPMs** — THEODOROS AVGITAS<sup>1</sup>, ZOE BALMFORTH<sup>1</sup>, IOANNIS MANTHOS<sup>1</sup>, KONSTANTINOS NIKOLOPOULOS<sup>1,2</sup>, and •CHRISTOS TOUKMENIDIS<sup>1</sup> — <sup>1</sup>University of Hamburg (UHH) — <sup>2</sup>University of Birmingham (UoB)

Silicon Photomultipliers (SiPMs) are increasingly employed in particle physics experiments thanks to a number of desirable properties such as single-photon sensitivity, high intrinsic gain, and compact design. Nevertheless, their performance depends strongly on the operating conditions such as the applied volt-

age and temperature. In this talk, a detailed characterisation of commercially available SiPMs is presented over an extended range of temperatures and SiPM bias. Key performance parameters are studied including breakdown voltage, gain, dark count rate (DCR), afterpulsing probability, and optical crosstalk.

T 97.4 Fri 9:45 KH 01.022

**Radiation damage of red sensitive SiPMs** — •MOMO SCHARF, MASSIMILIANO ANTONELLO, LUKAS BRINKMANN, ERIKA GARUTTI, KATJANA NEUMANN, and JÖRN SCHWANDT — Universität Hamburg

A new generation of red sensitive Silicon Photomultipliers (SiPMs) are being developed by Broadcom. These feature a high Photo Detection Efficiency (*PDE*) for near infrared light with a peak *PDE* of 38 % at 700 nm and a wide dynamic range due to the small pixel pitch with 6216 SPADs per  $\text{mm}^2$ . The influence of radiation damage on the performance of this new SiPM design is investigated. Sets of samples have been neutron irradiated in the TRIGA reactor facility at JSI (Ljubljana) at four different fluences up to  $1 \times 10^{13} \text{ cm}^{-2}$ . The characterization of the SiPMs includes performance parameters such as breakdown voltage, gain, correlated noise, dark count rate and non-linear response. The correction function is obtained with the single-step method on non-irradiated samples and the applicability to irradiated samples tested. This presentation shows first results of the comparison for irradiated and non-irradiated samples.

T 97.5 Fri 10:00 KH 01.022

**On the temperature, voltage, gate-length, and pixel-pitch dependence of the SiPM non-linear response** — •LUKAS BRINKMANN, MASSIMILIANO ANTONELLO, ERIKA GARUTTI, KATJANA NEUMANN, MOMO SCHARF, and JÖRN SCHWANDT — Universität Hamburg, Hamburg, Germany

The finite number of pixels in a silicon photomultiplier (SiPM) limits its dynamic range to light pulses up to typically 80 % of the total number of pixels in a device. Correcting the non-linear response is essential to extend the SiPM's dynamic range. One challenge in determining the non-linear response correction is providing a reference linear light source. Instead, the single-step method used to calibrate PMTs is applied, based on the difference in responses to two light sources.

A systematic study of the SiPM's response dependence on the operating voltage, temperature and gate length is performed for a KETEK SiPM design with different pixel sizes. The correction function, determined at reference conditions ( $T = 20^\circ\text{C}$ ,  $\Delta V = 5 \text{ V}$ ), is applied to data spanning a temperature range of  $-20^\circ\text{C}$  to  $+20^\circ\text{C}$  and an overvoltage range of 3 V to 5 V.

The method successfully corrects the non-linearity of the SiPM response across this parameter space for sub-nanosecond illumination with light intensities up to a mean number of Geiger discharges equal to the number of pixels, with an average deviation from linearity below 3 %. No significant dependence of the correction function on temperature, overvoltage, gate length or pixel size is observed for the tested devices.

## T 98: Higgs Physics X

Time: Friday 9:00–10:30

Location: KH 02.013

T 98.1 Fri 9:00 KH 02.013

**Towards a CP-independent cross section measurement of  $t\bar{t}H$  and  $tH$  production in the  $H \rightarrow \gamma\gamma$  decay channel at CMS** — JOHANNES ERDMANN, JAN HERMANN, •FLORIAN MAUSOLF, and PETER WISSMANN — III. Physikalisches Institut A, RWTH Aachen University

The top-quark Yukawa coupling, the Higgs boson's strongest interaction with fermions, plays a central role in theory and experiment. While a purely CP-odd structure has been excluded experimentally, the possibility of a significant CP-odd admixture remains consistent with current LHC constraints. The presence of a CP-odd component or a change in the CP-even coupling strength would influence both the cross sections and kinematics of top-quark-associated Higgs-boson production processes. Particularly, the effect on the kinematics can lead to model dependencies of the measurement due to its effect on selection efficiencies.

This talk presents a measurement of  $t\bar{t}H$  and  $tH$  production cross sections, with a special focus on minimizing model dependencies related to the CP-properties of the top-quark Yukawa coupling. This is achieved by using neural network classifiers trained with a decorrelation against such model assumptions in the training samples. The events are then categorized with a novel differentiable categorization optimization technique and the cross sections are extracted via a maximum likelihood fit using data recorded in 2022 and 2023 with the CMS detector.

T 98.2 Fri 9:15 KH 02.013

**Focusing the Inference Lens: Probing the top-Higgs CP Structure with Neural Simulation-Based Inference** — •STEFAN KATSAROV<sup>1</sup>, LEVI EVANS<sup>1</sup>, ALEXANDER HELD<sup>2</sup>, STEPHEN JIGGINS<sup>1</sup>, JUDITH KATZY<sup>1</sup>, NINO KOVACIC<sup>3</sup>, JAY SANDESARA<sup>2</sup>, and CHRIS SCHEULEN<sup>4</sup> — <sup>1</sup>DESY, Hamburg — <sup>2</sup>University of Wisconsin-Madison — <sup>3</sup>University of Zagreb — <sup>4</sup>University of Geneva

Neural Simulation-Based Inference (NSBI) is an emerging statistical framework that leverages modern neural networks as powerful function approximators to achieve the statistical objective of accurately estimating probabilistic relationships between data and parameters of interest. This approach enables inference directly from the full dimensionality of reconstruction-level data.

We implement NSBI to measure the CP structure of the top-Higgs coupling in a  $t\bar{t}H$  and  $tH$  enriched signal region. This measurement is directly sensitive to a CP-odd top-Higgs coupling, which has not yet been experimentally excluded. It could provide direct evidence of physics beyond the Standard Model, potentially hinting at an explanation for the observed matter-antimatter asymmetry in the Universe.

The  $t\bar{t}H$  and  $tH$  processes exhibit interference effects, leading to degenerate structures in conventional observables. These otherwise prohibitive features lend themselves well to the high-dimensional approach of NSBI. I will outline the methodology used to construct our likelihood ratio function and compare the resulting fits with an analysis that used physics-motivated observables and a conventional classifier.

T 98.3 Fri 9:30 KH 02.013

**Searching for  $H \rightarrow c\bar{c}$  in  $t\bar{t}H$  production with the ATLAS detector** — DIP-TAPARNA BISWAS, CAROLINA COSTA, MARKUS CRISTINZIANI, CARMEN DIEZ PARDOS, IVOR FLECK, GABRIEL GOMES, JAN JOACHIM HAHN, NIKOLAOS KAMARAS, VADIM KOSTYUKHIN, \*NILS BENEDIKT KRENGEL, AUSTIN OLSON, INÊS PINTO, SEBASTIAN RENTSCHLER, ELISABETH SCHOPF, KATHARINA VOSS, WOLFGANG WALKOWIAK, and ADAM WARNERBRING — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Since the discovery of the Higgs boson in 2012, its couplings to other particles have been investigated extensively by the LHC experiments as key tests of the Standard Model. Significant effort is now directed toward measurements of the Yukawa couplings to second-generation fermions. The measurement of the charm-quark-Yukawa coupling with the ATLAS experiment is being expanded by an additional mode  $t\bar{t}H(c\bar{c})$ , in which a Higgs boson is produced in association with a top-antitop quark pair and decays into a charm-anticharm quark pair.

The experimental challenges of  $t\bar{t}H(c\bar{c})$  lie in the efficient simultaneous identification of bottom and charm jets and the discrimination of signal from background processes. Especially in the all hadronic channel, the rejection of QCD multijet background is challenging, yet the addition of this channel, if feasible, can provide a significant boost to the sensitivity of the analysis. This presentation will showcase first investigations of the all-hadronic channel and how modern machine learning methods, such as transformers, can help overcome the experimental challenges.

T 98.4 Fri 9:45 KH 02.013

**Search for  $H \rightarrow c\bar{c}$  in the Vector Boson Fusion Channel with CMS Run-3 Data** — \*JIALIANG SUN, KONSTANTINOS NIKOLOPOULOS, and PHILIPP GADOW — University of Hamburg, Hamburg, Germany

Quark Yukawa couplings to the Higgs boson have so far been experimentally established only for the third generation. Observation of Higgs decays to a charm quark-antiquark pair would provide direct access to the charm Yukawa coupling, testing the Higgs coupling to second-generation quarks and probing potential deviations from the Standard Model. Currently, the most stringent constraints on this coupling are obtained by searches for associated Higgs production with a vector boson or a top-quark pair. Further improvements are expected by combining these results with the vector boson fusion (VBF) production mode using

Run-3 data. In this talk we present a sensitivity study of Higgs decays to a charm quark-antiquark pair in the VBF channel, using CMS proton-proton collision data collected in 2024 at a center-of-mass energy of 13.6 TeV. Backgrounds from QCD multijet production and  $Z/W$ +jets are estimated using data-driven methods. A boosted decision tree is trained to suppress the overwhelming QCD background, and a preliminary expected upper limit on the  $H \rightarrow c\bar{c}$  signal strength is derived.

T 98.5 Fri 10:00 KH 02.013

**Investigation of a boosted event topology in the search for the Higgs boson decay to a charm-anticharm pair in vector boson associated production mode at CMS in Run 3** — \*PATRICK KERSTEN, ALEXANDER SCHMIDT, ANDREY POZDNYAKOV, VALENTYN VAULIN, PEDRO GOUVEIA PINTO DA COSTA, ISHMEET KAUR VOHRA, JAN TERÖRDE, and ARND MEYER — III. Physikalisches Institut A, RWTH Aachen University

The search for the Higgs boson decay into a charm-anticharm pair in events where the Higgs boson is produced in association with a W or Z boson is an important contribution to the aim of measuring the Higgs boson coupling to charm quarks. In addition to the so-called "resolved" event topology, the topology with highly energetic Higgs boson decays, resulting in a boosted event topology is explored. The potential improvement on the analysis sensitivity when adding the boosted topology is investigated. This talk presents the first expected results using early Run-3 data recorded by the CMS experiment focusing on the preliminary expected limits on the Higgs-charm coupling.

T 98.6 Fri 10:15 KH 02.013

**Investigations on the  $\kappa_c/\kappa_b$  ratio measurement using Higgs boson decays to charm quarks in the vector boson associated production mode at CMS** — \*JAN TERÖRDE, ALEXANDER SCHMIDT, ANDREY POZDNYAKOV, VALENTYN VAULIN, PATRICK KERSTEN, PEDRO GOUVEIA PINTO DA COSTA, ISHMEET KAUR VOHRA, and ARND MEYER — III. Physikalisches Institut A, RWTH Aachen University

The associated production of a Higgs boson and a vector boson (Z or W boson), is one of the most promising channels in the search for the decay of the Higgs boson to charm (c) quarks. The simultaneous treatment of the  $H \rightarrow c\bar{c}$  and  $H \rightarrow b\bar{b}$  channels improves the overall sensitivity and enables to extract combined limits as well as to potentially constrain the  $\kappa_c/\kappa_b$  ratio. This contribution focuses on the  $\kappa_c/\kappa_b$  ratio measurement, the systematic uncertainties of the analysis and how these uncertainties affect the measurement of  $\kappa_c/\kappa_b$ .

## T 99: Searches/BSM V

Time: Friday 9:00–10:30

Location: KH 02.014

T 99.1 Fri 9:00 KH 02.014

**Next-to-Leading-Order QCD and EW Corrections to the Dark Matter Relic Density in the Framework of the CxSM** — \*PAVAO BRICA<sup>1</sup>, KARIM EL YAOUTI<sup>1</sup>, PEDRO GABRIEL<sup>2</sup>, MILADA MARGARETE MÜHLLEITNER<sup>1</sup>, and RUI SANTOS<sup>2</sup> — <sup>1</sup>Karlsruher Institut für Technologie — <sup>2</sup>Universidade de Lisboa

This talk presents the computation of the next-to-leading-order (NLO) QCD and electroweak (EW) corrections to the annihilation of dark matter particles into the dominant final states, processes that play a key role in determining the dark matter relic density. The analysis is performed within the Complex Singlet Extension of the Standard Model (CxSM), which enlarges the Standard Model scalar sector by a complex singlet field and provides a viable dark matter candidate. The treatment of the ultraviolet (UV) and infrared (IR) divergences encountered in the calculation is briefly discussed. The relic density is evaluated at NLO accuracy, and the impact of the QCD and EW corrections on the final prediction is examined together with its phenomenological implications.

T 99.2 Fri 9:15 KH 02.014

**Dark Matter phenomenology in an Effective Field Theory framework** — \*MARIA GONÇALVES<sup>1,2</sup>, MARGARETE MÜHLLEITNER<sup>1</sup>, RUI SANTOS<sup>2,3</sup>, and TOMÁS TRINDADE<sup>2</sup> — <sup>1</sup>Karlsruher Institut für Technologie - ITP, Karlsruhe, Germany — <sup>2</sup>Faculdade de Ciências da Universidade de Lisboa - CFTC, Lisboa, Portugal — <sup>3</sup>Instituto Politécnico de Lisboa - ISEL, Lisboa, Portugal

Dark matter (DM) remains one of the greatest mysteries in modern physics. From a particle physics perspective, effective field theories (EFTs) provide a powerful tool to explore possible extensions of the Standard Model (SM). In this work, we use current experimental data to constrain the coefficients of higher-dimensional operators in the EFT description. This approach allows us to identify promising directions for extending the SM to include viable DM candidates.

T 99.3 Fri 9:30 KH 02.014

**Automatic Construction of Green's Bases for Effective Field Theories with AutoEFT** — \*LARS BÜNDGEN<sup>1</sup>, ROBERT HARLANDER<sup>1</sup>, and MAGNUS CORNELIUS SCHAAF<sup>2</sup> — <sup>1</sup>RWTH Aachen University, Germany — <sup>2</sup>Technical University of Munich, Germany

Effective field theories (EFTs) are an important tool in particle physics. They can be used both for describing the low-energy behavior of Standard Model processes, as well as for model-independent searches for BSM physics.

Working in an EFT requires a basis of independent operators. There are two types of bases: One is the on-shell basis, where each Wilson coefficient is an independent parameter to the observables. The other basis is one of independent Green's functions. It contains additional operators and is required for calculations such as renormalization and RGE evolution, which happen at the level of Green's functions.

In this talk I present a new version of the program AutoEFT that can construct both on-shell and Green's bases for EFTs. The algorithm supports EFTs with particles of spin 0 and spin 1/2, as well as gauge bosons of internal  $SU(n)$  and  $U(1)$  symmetries. A group-theoretical approach is used to determine the invariants of the Lorentz and gauge groups and to eliminate the redundancies between them.

Finally I will explore how a projection algorithm for EFT operators can be implemented. This is important because the choice of basis operators is arbitrary, so different authors may be using different bases for their calculations. A projection algorithm will facilitate the translations of results between different bases.

T 99.4 Fri 9:45 KH 02.014

**New Physics Models in Recola2** — \*LUIS MIGUEL MARQUES LOURENCO — JMU, Emil-Hilb-Weg 22, 97074 Würzburg

Our understanding of fundamental interactions depends on our ability to make high precision predictions for observables that can be compared with experimental measurements. After the Higgs discovery, the focus in elementary particle physics has shifted toward precision tests of the Standard Model (SM) and the search for possible extensions motivated by the unresolved shortcomings of the SM. Precise theoretical predictions for BSM scenarios are needed to interpret deviations and identify which model they might indicate.

In recent years, the automation of one-loop QCD and electroweak corrections has substantially improved our ability to produce such predictions across a wide range of models. Recola2 provides automated one-loop matrix elements, including QCD and EW corrections, in the SM as well as for several BSM scenarios. A central ingredient in this progress is the use of flexible universal model for-

models that can encode not only tree-level interactions but also the counterterm information needed for higher-order calculations. The UFO framework, and its extended version UFO2, provide a practical way to supply such information to modern matrix-element generators. In this talk, I will present a new UFO2 interface for Recola2, which translates the UFO2 files into Recola's Fortran model files. This tool will enable the use of Recola for external models that already include the necessary counterterms, and streamline the path from model building to more precise phenomenological studies, which will be the objective of future work.

T 99.5 Fri 10:00 KH 02.014

**Simulation of Heavy Neutral Lepton production and decay with the Sherpa event generator.** — •ANTONIA BÄHR<sup>1</sup>, MARZIEH BAHMANI<sup>2</sup>, MICHAEL KOBEL<sup>1</sup>, and FRANK SIEGERT<sup>1</sup> — <sup>1</sup>IKTP, TU Dresden, Dresden, Germany — <sup>2</sup>HU Berlin, Berlin, Germany

Although the Standard Model has been proven to be a successful theory for explaining the fundamentals of particle physics, some questions still remain unanswered: Contrary to its initial assumption, neutrinos have been shown to possess mass. However, their masses are much lighter ( $m < 0.45$  eV) than those of all other fundamental fermions ( $m \sim 0.5$  MeV ... 0.2 TeV).

There are numerous theories trying to explain these findings. In this talk, we focus on the type 1 see-saw mechanism, where heavy neutral leptons (HNLs) emerge as additional mostly right-handed mass eigenstates.

I will present the implementation of production and decay of HNLs, for masses

of a few GeV at the LHC with Sherpa, a Monte Carlo event generator for the simulation of high-energy particle reactions. Besides validating the simulation results by comparing them to simulations done by Madgraph+Pythia, I will especially focus on the inclusion of semileptonic decay channels and the successful consideration of spin-correlation in the Sherpa simulations, which is not available for the other generators.

T 99.6 Fri 10:15 KH 02.014

**On-the-fly reweighting for beyond Standard Model parameter variations in the Sherpa Event Generator** — •FLORENS FÖRSTER and FRANK SIEGERT — TUD Dresden University of Technology, Institute of Nuclear and Particle Physics

The research for Beyond the Standard Model physics relies on the study of different models containing higher dimensional operators. The effects of these models, which depend on certain model parameters, can be simulated, for example using the Sherpa event generator. Currently, the simulation with different parameters can only be done by changing their values manually and running the event generation once for each variation, which is neither user friendly nor particularly efficient.

In this study, the variation of model parameters is implemented within the Sherpa event generator using on-the-fly reweighting. This is supposed to save computational resources and make the usage of BSM Models easier in Sherpa. The newly implemented features are then tested and validated by studying the effects of BSM physics on certain scattering processes, particularly the electroweak  $\gamma\gamma\gamma$  production.

## T 100: Miscellaneous

Time: Friday 9:00–9:45

Location: KH 02.016

T 100.1 Fri 9:00 KH 02.016

**On a supplement to special relativity** — •FRITZ RIEHLE — Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

It is well known that the restricted orthochronous Lorentz transformations form a group which contain the 'right' symmetries (rotations and boosts) of special relativity. They represent direct isometries where not only the magnitude of every angle is preserved but also the sense of the angle (clockwise or counterclockwise). This group is a subgroup in the Poincaré group containing all isometries of Minkowski space. We found that the transformations associated with the derived energy-momentum relationship in Einstein's basement [1] correspond to reflections in velocity space. We investigate how these transformations can be identified with opposite isometries and discuss some of their consequences.

[1] Fritz Riehle and Sebastian Ulbricht, arXiv:2402.13679 [gr-qc]

T 100.2 Fri 9:15 KH 02.016

**The mass quantum and the upper limit of particle masses** — •HERRMANN HANS-DIETER — Berlin

A particle model is proposed living in a circular extra space, called basic space. The particle mass has two sources: The rotational energy of circulating mass quanta and the Coulomb self-energy of circulating elementary charges. The hadron models contain mass quanta enhanced by circulating charge clusters. This allows to calculate particle masses up to the TeV region, however, such particles are not realized in nature. A predicted parton mass at 1.5 TeV could not be found experimentally. The top quark seem to represent the highest model mass

realized in nature. Models of the Z and Higgs bosons could not be achieved using the regular model formulas. One obtains plausible models of the bosons only by assuming a cluster splitting from 48 charges per cluster into  $2 \times 24$  or into  $3 \times 16$  charges. We conclude, that masses above the mass of the top quark are not realized. We predict an upper limit of particle masses near the mass of toponium, at around 400 GeV. The planning of future experiments should be focused on particles already discovered such as neutrinos, the Z and the Higgs boson. Possibly the TeV region could be empty of particles. An overview on the dual space concept is given in <https://tonsa.de/>

T 100.3 Fri 9:30 KH 02.016

**Particle QM results are improved by a classical model** — •ALBRECHT GIESE — Taxusweg 15, 22605 Hamburg

Quantum mechanics is widely accepted as the correct approach to understanding elementary particles. However, a classical model can provide improved results, including quantitative ones, where QM cannot. Take inertial mass, for example. Here, the classical model is physically more meaningful and produces accurate results, unlike the Higgs model. Another example of the limits of QM is the inadequate definition of the Planck constant, 'h', which leads to measurement deviations. In the history of QM, these deviations have been explained by the introduction of vacuum polarization. However, this is not necessary if 'h' is defined as derived from the model. This also circumvents the inherent problems of vacuum polarization/energy.

For details: [www.ag-physics.org/rmass](http://www.ag-physics.org/rmass)

## T 101: Searches/BSM VI

Time: Friday 9:00–10:30

Location: KH 02.018

T 101.1 Fri 9:00 KH 02.018

**Search for  $X \rightarrow H\gamma$  production in  $b\bar{b}\tau\tau$  final states at the CMS experiment** — •MORITZ MOLCH<sup>1</sup>, ULRICH HUSEMANN<sup>2</sup>, NIKITA SHADSKIY<sup>1</sup>, NICOLÒ TREVISANI<sup>1</sup>, and ROGER WOLF<sup>1</sup> — <sup>1</sup>Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — <sup>2</sup>Deutsches Elektronen-Synchrotron (DESY), Hamburg

Extensions of the Standard Model (SM), like the Next-to-Minimal Supersymmetric Standard Model (NMSSM), introduce additional Higgs bosons in addition to the SM Higgs boson H. This talk presents a search for the resonant decay of a heavier scalar particle X into a lighter resonance Y and H at the CMS experiment, using data from the LHC Run 3. The analysis considers final states, in which either the Y or the H boson decays into a pair of bottom quarks, and the other one into a pair of  $\tau$  leptons. Backgrounds from jets which are misidentified as hadronic  $\tau$  lepton decays ( $\tau_h$ ) pose a challenge in this search as they are difficult to model in simulation. Therefore, data-driven techniques are used to control these backgrounds. For signal extraction, a parametric deep neural network is used, which enables the treatment of all signal hypotheses with a single

neural network at once. Expected upper limits on the signal cross sections times branching fractions are presented to quantify the sensitivity of this search in the parameter space spanned by the unknown masses of the X and Y bosons.

T 101.2 Fri 9:15 KH 02.018

**Studies towards a search for heavy resonances  $X \rightarrow YH \rightarrow t\bar{t}b\bar{b}$  in the single-lepton final state with CMS** — •SYED SAJAL HASAN, MATTEO BONANOMI, MATHIS FRAHM, JOHANNES HALLER, LARA SOPHIE MARKUS, and MATTHIAS SCHRÖDER — Institut für Experimentalphysik, Universität Hamburg

Many theories of physics beyond the Standard Model (SM) predict additional heavy particles, such as new scalars in extended Higgs sectors. In this study, we explore a generic scenario in which a heavy resonance X decays into a lighter new particle Y and a SM-like Higgs boson (H),  $X \rightarrow YH$ , followed by  $Y \rightarrow t\bar{t}$  and  $H \rightarrow b\bar{b}$  decays. This cascade topology has not yet been probed at the LHC. The analysis uses simulated CMS data at a centre-of-mass energy of 13.6 TeV and targets events with a single isolated lepton and multiple jets. Candidate events are selected based on jet and b-tagged-jet multiplicities, and a neural network

classifier is employed to enhance the separation between signal and SM backgrounds. Expected exclusion limits are presented as a function of the masses of X and Y for the signal production cross-section.

T 101.3 Fri 9:30 KH 02.018

**Probing Dark Matter via the mono-Higgs signature in the  $\tau^+\tau^-$  final state with the ATLAS detector** — •ATHUL DEV SUDHAKAR PONNU and STAN LAI — II. Physikalisches Institut, Georg-August-Universität Göttingen

This analysis searches for physics beyond the Standard Model using the mono-Higgs signature, in which a Higgs boson decaying to a pair of tau leptons ( $H \rightarrow \tau^+\tau^-$ ) recoils against significant missing transverse momentum ( $E_T^{\text{miss}}$ ). This event topology provides a sensitive and direct probe of the dark-matter sector. The results can be interpreted within the framework of the Two Higgs Doublet Model extended by a pseudoscalar mediator (2HDM +  $a$ ), considering both Type-I and Type-II Yukawa coupling scenarios.

The analysis focuses on the  $\tau_{\text{had}}\tau_{\text{had}}$  and  $\tau_{\text{lep}}\tau_{\text{had}}$  final states using  $\sqrt{s} = 13.6$  TeV collision data. Monte Carlo samples of  $t\bar{t}$ , single-top, diboson,  $W/Z$ +jets, and Higgs processes are used to model the Standard Model backgrounds, while dedicated signal samples spanning multiple mass hypotheses are employed to assess sensitivity to new physics. The early stages of the study, including data-MC agreement checks and multivariate analysis training, are presented in this talk.

T 101.4 Fri 9:45 KH 02.018

**Search for an Intermediate-Mass Higgs Boson in the  $\tau + \tau$  Channel with Run 2 Data** — •LUKA VOMBERG<sup>1</sup>, CHRISTIAN GREFF<sup>2</sup>, PHILIP BECHTLE<sup>1</sup>, and KLAUS DESCH<sup>1</sup> — <sup>1</sup>Physikalisches Institut Bonn, Käthe-Kümmel-Str. — <sup>2</sup>1, Esplanade des Particules, Meyrin, Switzerland

A search for additional Higgs bosons decaying to  $\tau + \tau$  in the intermediate mass range, as motivated by extended Higgs sector models such as the 2HDM, is presented. The analysis targets the  $\tau_{\text{had}} + \tau_{\text{had}}$  and  $\tau_{\text{lep}} + \tau_{\text{had}}$  final states and considers both ggF and VBF production modes. Limits are derived on the production cross-section times branching ratio, following a model-independent approach.

This is the first ATLAS analysis probing the 80 GeV to 200 GeV mass range in the  $\tau\tau$  final state using full Run 2 data, complementing existing high-mass searches. This analysis is a re-interpretation of the standard model  $H \rightarrow \tau\tau$  cross section measurement.

Preparations for a follow up analysis using run 3 data are ongoing, with the primary focus on improving suppression of the dominant  $Z \rightarrow \tau\tau$  background

using spin sensitive observables to increase sensitivity in the low-mass region, as well as including effects of interference near the Z-pole.

T 101.5 Fri 10:00 KH 02.018

**Exploring boosted top quark decays using Run 3 data collected by the CMS experiment** — •JOHANNA MATTHIESEN<sup>1</sup>, JOHANNES HALLER<sup>1</sup>, ROMAN KOGLER<sup>2</sup>, and DANIEL SAVOIU<sup>1</sup> — <sup>1</sup>Institut für Experimentalphysik, Universität Hamburg — <sup>2</sup>DESY, Hamburg

Highly energetic top quarks produced in proton-proton collisions at the LHC can result in decay products that are highly collimated, appearing as a single large-radius jet in the CMS detector. These jets exhibit a distinctive internal substructure, enabling discrimination between top quark jets and those arising from other QCD processes. This boosted topology offers a unique opportunity to probe for new heavy particles decaying into top-antitop quark pairs. This presentation provides first insights from the ongoing data taking at the LHC, focusing on the top-antitop quark mass spectrum as a potential window to new physics phenomena with a focus on heavy  $Z'$  bosons. The analysis strategy as well as first results will be presented.

T 101.6 Fri 10:15 KH 02.018

**Anomaly detection for multi-jet resonances.** — •CHITRAKSHEE YEDE, LOUIS MOUREAUX, GREGOR KASIECZKA, and TORE VON SCHWARTZ — University of Hamburg, Hamburg, Germany

The search for physics beyond the standard model is one of the main focuses in high-energy physics. Conventional searches at the LHC, though comprehensive, have not yet shown signs for new physics. Machine learning based anomaly detection has emerged as a powerful tool to widen the discovery horizon, offering a model-agnostic path as a way to enhance the sensitivity of generic searches as compared to those targeting specific signal models. CATHODE (Classifying Anomalies THrough Outer Density Estimation), one of these methods, is a two-step method that combines a data driven background estimation with a classifier flagging potential signal. To date, most studies have mainly focused on dijet resonances. In this work, we explore signals with multiple decays modes, leading to a more challenging detection scenario. We present the first application of CATHODE to multi-jet resonances, which enhance the sensitivity beyond the dijet regime and increase the robustness of weakly supervised anomaly detection, thereby broadening its applicability.

## T 102: Axions/ALPs III

Time: Friday 9:00–10:30

Location: KH 02.019

T 102.1 Fri 9:00 KH 02.019

**X-ray Telescopes for Axion Searches** — •FRANCISCO RODRÍGUEZ CANDÓN — Fakultät für Physik, TU Dortmund, Otto-Hahn-Str. 4, 44221 Dortmund, Germany

X-ray telescopes have become powerful tools in the search for weakly interacting slim particles (WISPs), in particular QCD axions and axion-like particles (ALPs). Through the Primakoff effect, astrophysical magnetic fields can induce axion-photon conversion, giving X-ray observatories unique sensitivity over a broad axion-mass range. This talk reviews recent progress in ALPs searches with NASA's NuSTAR, the first and currently only focusing hard X-ray space telescope. First, observations of the starburst galaxy M82 yield stringent constraints on heavy decaying ALPs in the 30-500 keV range, probing axion-photon couplings in previously unexplored regions of parameter space. Second, NuSTAR observations of the red supergiant Betelgeuse set new and competitive limits on axion-nucleon couplings for masses below the neV, exploiting axion production via nuclear transitions in stellar interiors. Together, these results improve upon earlier astrophysical bounds and motivate future X-ray space missions such as Athena and AXIS, which are expected to extend sensitivity to even fainter axion signatures.

T 102.2 Fri 9:15 KH 02.019

**Axion searches with LOFAR** — •MERLE GIZINSKI and DOMINIK J. SCHWARZ — Fakultät für Physik, Universität Bielefeld, 33613 Bielefeld

The axion is a promising candidate for cold dark matter, originating as a solution to the strong CP problem. The search for axions in neutron star magnetospheres provides a promising opportunity for detection and is complementary to existing laboratory experiments. The plasma surrounding of a neutron star and its strong magnetic field provide the environment for an axion to convert into a photon. This conversion results in a characteristic, sharp radio line, which may be detectable in the spectrum of the neutron star. The observed frequency of the line is directly linked to the axion mass. Since frequencies below 250 MHz are very hard to access in lab experiments and thus have not been tested, LOFAR (10–240 MHz) provides an unique opportunity to constrain the axion to photon coupling in the axion mass range  $0.04 - 0.99 \mu\text{eV}$ .

T 102.3 Fri 9:30 KH 02.019

**Tuning structure of a dielectric haloscope for axion dark matter detection, MADMAX** — •DOMINIK BERGERMANN for the MADMAX-Collaboration — III. Physikalisches Institut A, RWTH Aachen University

Axions are promising candidates for cold dark matter and the absence of CP violation in strong interaction. The **M**agnetized **D**isk and **M**irror **A**xion **e**xperiment is a future dielectric haloscope experiment targeting axion dark matter in a mass range of 40 to 400  $\mu\text{eV}$ . It consists of multiple, consecutive and movable dielectric discs to amplify the weak microwave signal of axion photon conversion in a strong magnetic field.

Covering this range with a single experimental setup, while simultaneously being able to finetune the resonance on potential signals, necessitates repositioning the experimental hardware continuously and automatically. The disc positions as parameter-space can be tuned to produce desired signal shapes, with reliably achieving sub 10  $\mu\text{m}$  accuracy as the prime challenge. All respective hardware is required to be compatible with the high magnetic field strengths, vacuum and cryogenic temperatures.

This talk presents the piezo-motor driven MADMAX disc assembly and its control system, with the first results on disc positioning accuracy.

T 102.4 Fri 9:45 KH 02.019

**MADMAX Open Booster 300 Receiver Chain and Power Calibration** — •ALAN ALIYALI for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg, Deutschland

Originally proposed to solve the strong CP problem of QCD, the axion is also a prominent candidate for cold dark matter. Using the axion-to-photon conversion inside a magnetic field, the **M**agnetized **D**isk and **M**irror **A**xion **e**xperiment aims to probe the axion mass range of 40 to 400  $\mu\text{eV}$ , corresponding to microwaves in the 10 to 100 GHz range. MADMAX makes use of a so-called booster, a series of dielectric disks placed in front of a metallic mirror, to resonantly enhance the expected axion signal over a frequency range adjustable via the spacing of the disks.

The Open Booster 300 is a booster configuration consisting of an aluminum mirror and three sapphire discs, all with a 300 mm diameter. In this configura-

tion, the axion induced current excites gaussian modes that gets measured by a corrugated horn antenna. The resulting signal is amplified and filtered by a low-noise receiver chain, down-converted using heterodyne detection, and digitized by an ADC performing real-time FFTs from which power spectra are recorded.

Accurate measurements of the signal requires precise characterization of the entire receiver chain. In this presentation we show how the receiver chain is calibrated using the Y-factor method to determine the frequency dependent gain and noise temperature.

T 102.5 Fri 10:00 KH 02.019

**3D simulations of a dielectric haloscope for axion dark matter detection, MADMAX** — •SEBASTIAN BALTSCHUN for the MADMAX-Collaboration — III. Physikalisches Institut A, RWTH Aachen University

Axions are promising candidates for cold dark matter and the absence of CP violation in strong interaction. The MAgnetized Disc and Mirror Axion eXperiment is a planned dielectric haloscope experiment targeting axion dark matter in a mass range of 40 to 400 micro eV. It consists of multiple, consecutive and movable dielectric discs to amplify the weak microwave signal of axion photon conversion in a strong magnetic field.

This talk discusses the 3D simulation used to calculate the amplification factor of a certain disk configuration and differences between a narrowband scan and a broadband scan, two different strategies towards positioning disks.

T 102.6 Fri 10:15 KH 02.019

**Development of a radiopure GridPix detector for BabyIAXO** — •JOHANNA VON OY, KLAUS DESCH, JOCHEN KAMINSKI, and TOBIAS SCHIFFER — Physikalisches Institut der Universität Bonn

BabyIAXO is the intermediate stage experiment of the International AXion Observatory (IAXO), a next generation helioscope for the search for axions. BabyIAXO is planned to be built at DESY in Hamburg, and its components are currently under construction. Helioscopes consist of a magnet, where solar axions can convert into X-ray photons, optics to focus the X-rays and detectors to detect them.

Due to the existing stringent limits on the axion-photon coupling, the probability of an axion-induced X-ray reaching the detector is low. Therefore, all detectors built for IAXO and BabyIAXO have to have a low intrinsic background and be combined with active and passive shielding.

A detector technology that is suitable to detect X-rays in the energy range of different solar axion models is a GridPix detector. It is a gas-filled detector with an aluminium grid on top of a pixelated readout chip, which can detect individual electrons produced by particles in the gas. This detector can be constructed in a relatively radiopure form as most of its components can be made out of very pure copper, Teflon and Kapton.

The detector is currently in the assembly and commissioning phase, with the radiopure components having been produced last year. This talk will focus on the developments and steps necessary to reach the background levels required for BabyIAXO.

## T 103: Search for Dark Matter IV

Time: Friday 9:00–10:15

Location: AM 00.014

T 103.1 Fri 9:00 AM 00.014

**Simulations of the MainzTPC2 to observe the Migdal effect** — •PETER GY-ORGY, ALEXANDER DEISTING, CHRISTOPHER HILS, JOHANNES MERZ, UWE OBERLACK, and CONSTANTIN SZYSZKA — Johannes Gutenberg-Universität Mainz, Institut für Physik & Exzellenzcluster PRISMA+

The MainzTPC2 is a small-scale dual-phase xenon time projection chamber (TPC), destined to make a measurement that could prove the Migdal effect for Xe atoms. The Migdal effect manifests in the form of an additional electron recoil signature paired with the typical nuclear recoil signal that an elastic scatter e.g. a neutron or WIMP produces. For large dual-phase TPCs — like XENONnT, XLZD — this effect would decrease their detection threshold, extending their sensitivity to lower dark matter masses.

To ensure the success of the experiment, a detailed simulation must be made of the MainzTPC2. This requires extensive modeling and simulations in GEANT4, including neutron scattering, detector effects, optical physics, position reconstruction, and a Migdal signal model.

The measurement itself is expected to take place at the CN facility at LNL, Italy, in the form of neutrons from a beam undergoing an elastic backscatter off the TPC into a secondary scintillator detector. As such, beam characteristics and neutron flight paths must also be modeled. The use of data quality cuts such as time-of-flight and neutron multi-scatter is expected to reduce the background sufficiently to obtain a clear population of Migdal events in their region of interest. This presentation will summarize results from this simulation process.

T 103.2 Fri 9:15 AM 00.014

**Results of a Cryogenic Multi-Channel  $4\pi$  Veto Module in the CRESST Experiment** — •ÁFRICA GONZÁLEZ PEDRAZA for the CRESST-Collaboration — Technical University of Munich, Garching

CRESST is a cryogenic experiment searching for sub-GeV dark matter via direct scattering off a target crystal's nucleus. The resulting energy transfer causes a nuclear recoil that increases the target's temperature, measured by a Transition-Edge Sensor (TES) enabling energy thresholds of O(10 eV).

Currently, one of the main sensitivity limitations is an unexpected rise in the event rate below 200 eV, known as the Low-Energy Excess (LEE). One of the leading hypotheses attributes the LEE to mechanical stress stored at material interfaces. To investigate the holder-induced stress component, CRESST employs a dedicated three-channel module that integrates an instrumented holder and a beaker-shaped, large-coverage light detector in addition to the standard CRESST detector configuration.

To precisely characterize the detector response to sub-keV nuclear recoils, the signature of dark matter, CRESST is transitioning to a novel calibration method based on thermal neutron capture, which has the additional advantage of not increasing the backgrounds outside the dedicated calibration campaigns.

This talk presents the latest results from the CRESST beaker module operated at LNGS on the LEE and demonstrates that low-energy nuclear-recoil calibration is achievable in CRESST sapphire detectors.

T 103.3 Fri 9:30 AM 00.014

**Fast Template-Based Inference via Conditional Normalizing Flows for XENONnT** — •JOHANNES MERZ for the XENON-Collaboration — Institut für Physik & Exzellenzcluster PRISMA<sup>++</sup>, Johannes Gutenberg-Universität Mainz

Template-based likelihood analysis is a cornerstone of the inference in the XENONnT experiment. It's limited in computational efficiency and flexibility by its reliance on histogram based templates. In this talk, we present a fast inference approach that replaces traditional templates with continuous, differentiable models based on conditional normalizing flows. The models provide an accurate representation of detector response distributions while enabling efficient likelihood evaluation. This significantly accelerates and simplifies parameter inference across the parameter spaces. Our results demonstrate that normalizing flow based templates offer a scalable and efficient alternative to classical template methods for XENONnT.

T 103.4 Fri 9:45 AM 00.014

**Status of large-area cryogenic microcalorimeter (LAMCAL) development for DELight** — •LENA HAUSWALD<sup>1</sup>, CHRISTIAN JEUP<sup>1</sup>, FRIEDRICH WAGNER<sup>1</sup>, and SEBASTIAN KEMPT<sup>1,2</sup> — <sup>1</sup>Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology (KIT), Germany. — <sup>2</sup>Institute for Data Processing and Electronics, Karlsruhe Institute of Technology (KIT), Germany.

The Direct Search Experiment for Light Dark Matter (DELight) is a pioneering initiative aimed at probing light dark matter (LDM). By utilizing superfluid <sup>4</sup>He as target material, DELight will enable the exploration of weakly interacting DM candidates with masses notably below 100 MeV/c<sup>2</sup>. To achieve the required detector sensitivity for resolving the various signal channels of the superfluid, both in terms of time and energy resolution, DELight focuses on the development of large-area cryogenic microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology.

In contrast to state-of-the-art MMCs, each LAMCAL will be operated as athermal phonon detector. Here, the energy of athermal phonons generated by an energy deposit and propagating ballistically within the absorber is converted into a temperature rise of the paramagnetic temperature sensor via Al-based superconducting phonon collectors. Consequently, the signal rise time is governed by the phonon collection time, while the absorber heat capacity becomes negligible to first order, enabling excellent energy resolution. This contribution presents the current status of LAMCAL development for DELight, highlighting their potential and the challenges encountered to date.

T 103.5 Fri 10:00 AM 00.014

**Signal Processing and Machine Learning for Light Dark Matter Detection in DELight** — •DOWLING WONG for the DELight-Collaboration — KIT, Karlsruhe, DE

The parameter space for dark matter below a few hundred MeV remains largely unexplored, motivating detectors with ultra-low energy thresholds. The DELight experiment aims to directly detect light dark matter using superfluid helium-4 instrumented with about 60 large-area microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology. Each LAMCAL achieves an

eV-scale energy resolution, yielding a nuclear-recoil threshold around 10 eV. To further lower the threshold, robust and noise-aware reconstruction across the multi-channel readout is essential. I present a unified signal-processing and machine-learning framework developed for DELight. At the waveform level, we implement optimal filtering and principal component analysis estimators tuned to measured pulse shapes with noise spectra captured under preliminary operating conditions in the DELight LAMCALS. With physics-informed features, we develop a transformer-based attention architecture that captures inter-channel

correlations to improve event reconstruction, while exploring data-driven filters to suppress non-stationary system noise and enhance sensitivity near threshold. I will discuss the architecture of the reconstruction pipeline and its performance on simulated and calibration R&D data, with a focus on trigger efficiency in offline scans. This work is supported by the Heidelberg Karlsruhe Strategic Partnership (HEiKA STAR), with personnel funded by the Alexander von Humboldt Foundation.

## T 104: Neutrino Astronomy V

Time: Friday 9:00–10:30

Location: KS H C

T 104.1 Fri 9:00 KS H C

**Searching for Periodic Neutrino Emission from Pulsars with KM3NeT** — •ROBERT PETRI, THOMAS EBERL, and RODRIGO GRACIA-RUIZ for the KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP) Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany  
Neutrino observatories such as KM3NeT enable exploratory searches in the time domain. In this feasibility study, we investigate whether the count rates of the photo-sensors, induced by optical background and potentially by low-energy neutrinos in the GeV range, can be used to probe periodic neutrino emission through precise timing alone. Following up on recent suggestions for neutrino emission scenarios, we investigate promising pulsars and develop an analysis pipeline. The pipeline includes a barycentric time correction and focuses on a Fast Fourier Transform approach to search for a count rate excess with the pulsar spin frequency. The contribution demonstrates the potential and limitations of periodicity searches and evaluates the sensitivity of KM3NeT to derive meaningful constraints on temporally modulated neutrino sources.

T 104.2 Fri 9:15 KS H C

**Simulation Studies for Characterization of a Calibration Device for the IceCube Upgrade** — •SELINA RUDOLPH for the IceCube-Collaboration — Technical University of Munich (TUM)

The IceCube neutrino observatory at the geographic South Pole has officially begun its Upgrade campaign after successfully operating for over ten years. In addition to the existing 86 strings instrumented with over 5,000 photosensors, the IceCube Collaboration will deploy seven new strings. The Upgrade focuses on improving the lower-energy regime and sensitivity to neutrino oscillation parameters, as well as enhancing the recalibration of the gigaton glacial ice detector medium. One of the instruments deployed in the campaign is the Precision Optical Calibration Module (POCAM), which was developed and assembled at Technical University of Munich (TUM). Over 20 next-generation POCAMs will be utilized to further reduce existing detector systematics. This talk provides an overview of the simulation efforts, specifically for a series of special operations carried out during the installation. These Monte Carlo simulation studies are conducted to predict the POCAM's ability to characterize certain ice parameters, which are crucial for calibration and analysis studies.

T 104.3 Fri 9:30 KS H C

**Improving tau neutrino reconstruction and identification with the IceCube Upgrade** — •DESPOINA MOUSADI for the IceCube-Collaboration — Deutsches Elektronen Synchrotron (DESY) Zeuthen — Friedrich-Alexander-Universität (FAU) Erlangen-Nürnberg

The IceCube Neutrino Observatory is a 1km<sup>3</sup> neutrino detector located at the South Pole. It consists of optical modules which can detect Cherenkov light from charged neutrino interaction products in the Antarctic ice. Measuring the flavor composition of astrophysical neutrinos on Earth can give significant insight in their production mechanisms. However, even though tau neutrinos exhibit a unique double cascade (\*double bang\*) signature which cannot be attributed to the other two neutrino flavors, identifying these signatures remains the most challenging, with only few such events confidently identified so far. This is mainly due to the contrast between the large distance between sensors and the usually short tau decay length, but is also in part caused by limitations in modeling of the surrounding ice and reconstruction algorithm. Starting its operation in 2026, the IceCube Upgrade will provide new possibilities to improve tau neutrino reconstruction and identification, with more densely packed multi-PMT modules containing calibration devices which enable the creation of artificial \*double bang\* events. Such events can serve as benchmarks for validation of ice models and reconstruction methods, paving the way for improved tau neutrino identification and for better understanding of the underlying physics.

T 104.4 Fri 9:45 KS H C

**Search for the DSNB in JUNO: Development of new Methods for Background Event Identification** — •MATTHIAS MAYER, ULRIKE FAHRENDHOLZ, SHIJIAO GAO, MEISHU LU, LOTHAR OBERAUER, STEFAN SCHÖNERT, and ARMIN SIEBERT — School of Natural Science, TU München, James-Franck-Str. 1, 85748 Garching b. München

The diffuse supernova neutrino background (DSNB) describes the constant flux of neutrinos from past core-collapse supernovae over the entire visible universe. The Jiangmen Underground Neutrino Observatory (JUNO), a 20 kton liquid scintillator detector currently plans to observe the DSNB through the inverse beta decay (IBD) detection channel. While other  $\nu_e$  sources will cause irreducible IBD background, we aim to use various pulse-shape discrimination (PSD) techniques to reduce non-IBD backgrounds such as muon-induced fast neutrons and NC interactions of atmospheric neutrinos. For this talk, we compare the performance of different PSD techniques for the DSNB search and discuss our recent measurements towards the energy dependence of the neutron fluorescence time profile in the JUNO scintillator. Given the current release of JUNO's first physics results and detector performance, we will also include a preliminary analysis using JUNO real data for background estimation in the region of interest (ROI) of DSNB. Besides, we will give an outlook into our upcoming publication discussing the JUNO detection potential for different DSNB models. This work has been supported by the Cluster of Excellence ORIGINS as well as the DFG Collaborative Research Center "NDM" (SFB1258) and the DFG Research Units 2319 and 5519.

T 104.5 Fri 10:00 KS H C

**Background estimation for CC-Supernova neutrino searches in JUNO** — •TOBIAS KRAMER, THILO BIRKENFELD, ACHIM STAHL, and CHRISTOPHER WIEBUSCH — III. Physikalisches Institut B, RWTH Aachen

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator detector, which started data taking in August 2025. Its large target mass is well-suited for Core-Collapse Supernova (CC-SN) neutrino detection. Our goal is to identify individual CC-SN bursts up to nearby extragalactic distances, since galactic CC-SNe are rare events; the only CC-SN observed via neutrinos was almost 40 years ago in 1987. The search for distant CC-SNe requires optimized background suppression in the relevant supernova neutrino energy range, where the main detection channel is the inverse beta decay (IBD). In this talk, a general strategy for background estimation and suppression, and its impact on the distant CC-SNe search in JUNO, is discussed.

T 104.6 Fri 10:15 KS H C

**Expanding Stochastic Acceleration in the AGN Corona** — •MARC HUBERT<sup>1,2</sup>, BJÖRN EICHMANN<sup>1,2</sup>, and JULIA BECKER TJUS<sup>1,2,3</sup> — <sup>1</sup>Theoretical Physics IV: Plasma Astroparticle Physics, Ruhr University Bochum, Germany — <sup>2</sup>RAPP Center, Bochum, Germany — <sup>3</sup>Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

In the field of astroparticle physics, understanding the mechanisms responsible for the acceleration of charged particles in astrophysical environments is of central interest. The so-called Fermi-II process describes stochastic acceleration in turbulent magnetic fields. Previous studies have presented a semianalytical solution of the isotropic steady-state momentum-diffusion equation that includes continuous and catastrophic momentum changes for weak magnetic turbulence constrained to a finite range. Within this framework, the solution is valid only in the momentum interval in which interactions with the turbulence occur. In my master thesis, I aim to extend this framework to lower momenta and to investigate how pre-acceleration processes, e.g. magnetic reconnection, affect the resulting particle spectra. Furthermore, I apply the extended model to the AGN corona in NGC 1068 and examine the compatibility of the predicted neutrino flux with current observations. In this talk, I present first results, including the extension to lower momenta and the influence of pre-acceleration processes.



## T 105: Methods in Astroparticle Physics V

Time: Friday 9:00–10:30

Location: KS 00.004

T 105.1 Fri 9:00 KS 00.004

**Neutron Detection with Gadolinium-loaded water based liquid scintillator** — •AMALA AUGUSTHY, NOAH GOEHLKE, JOHANN MARTYN, PHILIPP KERN, and MICHAEL WURM — JGU Mainz

ANNIE is an accelerator neutrino experiment at the Booster Neutrino Beam at Fermilab. It is a 26-ton Gadolinium-loaded water Cherenkov detector designed to measure CC interaction cross-sections and neutron multiplicity. In addition, ANNIE serves as a testbed for novel detector technologies amongst which is Water-based Liquid Scintillator (WbLS). WbLS is a novel detection medium that allows the simultaneous detection of scintillation and Cherenkov light. To test the detection capabilities with WbLS, a 366 L cylindrical vessel, filled with Gadolinium (Gd) loaded WbLS, dubbed SANDI was deployed in ANNIE in fall 2024. The energy carried away by final-state neutrons is a major source of systematic uncertainty in long baseline neutrino oscillation experiments, hence it is very important to tag neutrons efficiently. To investigate neutron detection efficiency in Gd-WbLS, an AmBe source was deployed. Extracting the neutron detection efficiency requires a well-tuned Monte Carlo simulation. This talk presents an overview of the ongoing Monte Carlo tuning efforts aimed at quantifying the neutron detection efficiency in Gd-loaded WbLS.

T 105.2 Fri 9:15 KS 00.004

**A high-precision nuclear recoil calibration facility at the TU Wien TRIGA reactor** — •ANDREAS ERHART — Technische Universität München, München, Deutschland

Cryogenic calorimeters are a key technology for experiments aiming to measure coherent neutrino-nucleus scattering at the low-energy frontier or to directly search for sub-GeV dark matter particles. A detailed understanding of the detector response at the 100 eV scale is hereby indispensable. The CRAB collaboration has developed a novel, direct and model-independent calibration method based on nuclear recoils induced by the radiative capture of thermal neutrons. Following a successful feasibility study at TU München, where CRAB achieved the first observation of a monoenergetic peak at 112.5 eV from  $^{182}\text{W}$  recoils and the observation of two  $^{27}\text{Al}$  nuclear recoil peaks at 575 eV and 1145 eV, respectively, the project now enters its high-precision phase.

For this purpose, a dedicated calibration facility has been established at the TU Wien TRIGA reactor, providing a pure, low-intensity thermal neutron beam to the target detectors mounted inside a wet dilution refrigerator. Stable cryostat operation on a month-scale and excellent detector energy resolution below 5 eV have since been demonstrated. These results enable high-statistics calibration measurements of various detector materials such as  $\text{CaWO}_4$ ,  $\text{Al}_2\text{O}_3$ , germanium and silicon in the near future, and open the prospect of an extensive associated physics program.

T 105.3 Fri 9:30 KS 00.004

**Implementation of a Bi-Po Coincidence Cherenkov Source for Hybrid Calibration in JUNO** — •MANUEL BÖHLES<sup>1</sup>, MARCEL BÜCHNER<sup>1</sup>, TIM CHARISSÉ<sup>1</sup>, ARSHAK JAFAR<sup>1</sup>, MEISHU LU<sup>2</sup>, JOHANN MARTYN<sup>1</sup>, OLIVER PILARCZYK<sup>1</sup>, HANS STEIGER<sup>2</sup>, and MICHAEL WURM<sup>1</sup> — <sup>1</sup>Johannes Gutenberg University Mainz, Institute for Physics, 55128 Mainz, Germany — <sup>2</sup>Technical University of Munich, School of Natural Sciences, 85748 Garching, Germany

Hybrid Cherenkov/scintillation analyses in the JUNO experiment require dedicated calibration tools to improve event identification and background suppression. A precise characterization of Cherenkov light and its separation from scintillation light is essential for enhancing the sensitivity to rare event searches. A compact Cherenkov calibration source based on MeV-scale beta electrons and a delayed coincidence trigger has been designed and realized. The source is loaded with Th-228, providing Bi-Po-212 decay sequences with a well-defined time correlation. The prompt beta decay produces Cherenkov light, while the subsequent alpha decay generates a scintillation signal in a fast plastic scintillator, enabling efficient event tagging. Laboratory tests are underway, and deployment in the OSIRIS pre-detector is planned prior to JUNO calibration campaigns. These measurements will support hybrid Cherenkov/scintillation analyses in JUNO with enhanced sensitivity to solar neutrinos, searches for the Diffuse Supernova Neutrino Background (DSNB), and potential future neutrinoless double beta decay ( $0\nu\beta\beta$ ) studies. The development is funded by the DFG Research Unit "JUNO" (FOR 5519).

T 105.4 Fri 9:45 KS 00.004

**Calibration and Long-term Monitoring for IceCube Upgrade mDOMs without Artificial Light Sources** — •CAROLIN KLEIN and SUMMER BLOT — DESY, Zeuthen, Germany

Since 2011, the IceCube Neutrino Observatory has yielded important results in neutrino astronomy and neutrino physics. The IceCube Upgrade expands this detector. A higher photomultiplier (PMT) density decreases the energy threshold of the experiment, enabling more detailed studies of atmospheric neutrino oscillations at the GeV scale. Current calibration routines of the multi-PMT digital optical module (mDOM) included in the IceCube Upgrade require artificial light produced by LEDs. In this talk, calibration methods without such light sources are presented, enabling calibration even in the case of an LED dysfunction. The calibration of the PMT gain and mainboard electronics is instead performed using dark noise, mainly induced by radioactive decays in the glass components of the module. The dark noise based methods can also be used in-situ for long-term monitoring of the calibrated properties during detector up-time. A long-term monitoring test stand based on these approaches was setup and operated in a laboratory. The goal is to assess the stability of calibration constants and mDOM performance over time in a well-controlled laboratory environment. In this talk, the first results of these measurements will be presented.

T 105.5 Fri 10:00 KS 00.004

**The IceAct PiRATE: A Realtime Snow Accumulation Monitoring and Telescope Calibration System** — •LARS HEUERMANN, OLIVER BOSCH, CEM GÜER, JAN NICKLAUS, ANDREAS NÖLL, JOCHEN STEINMANN, CHRISTOPHER WIEBUSCH, and SIMON ZIERKE — RWTH Aachen - III. physikalisches Institut B, Aachen, Germany

IceAct is an array of Imaging Air Cherenkov Telescopes located on the ice-surface of the IceCube Neutrino Observatory. It aims to calibrate IceTop and the in-ice detector, improve cosmic-ray composition studies, and potentially enhance IceCube's veto capability for atmospheric neutrinos. The telescope design is optimized to be cost-efficient and to operate reliably in the harsh environmental conditions of the South Pole. This is achieved by a Fresnel-lens-based optics and a camera with 61 SiPMs, resulting in a total field of view of 12 degrees per telescope. For stable operation, it is also important to monitor the changing environmental conditions. The Raspberry Pi-based Real-time snow Accumulation monitoring and Telescope calibration Enhancement (PiRATE) has been developed for this purpose. It features a nanosecond LED light pulser for in-situ camera calibration and a CCD-camera-based snow monitoring system, mounted inside the telescope. The PiRATE is designed to operate at extreme cold temperatures and with minimized emission of electromagnetic interference in the radio band. This talk will present the current status of the PiRATE, report on integration, function, and performance tests, as well as give an outlook on the future deployment at the South Pole.

T 105.6 Fri 10:15 KS 00.004

**Optical calibration of the ice stratigraphy logger in the IceCube Upgrade** — •ANDREI CHUBAROV, ANNA EIMER, and MARTIN RONGEN for the IceCube-Collaboration — Erlangen Center for Astroparticle Physics (ECAP)

The IceCube Neutrino Observatory, deployed in the Antarctic glacier, detects atmospheric and astrophysical neutrinos using Cherenkov radiation from secondary charged particles. Limited knowledge of the ice optical properties is currently the dominant systematic for many analyses. The recently deployed IceCube Upgrade includes several new types of calibration modules, enabling additional measurements of the optical properties of the ice. The LOMlogger is such a device, which measured the backscattered light from a collimated light source to analyse the ice stratigraphy in two Upgrade drill holes. This new data covers 150m below the previously explored ice depths and serves as a technology demonstrator for potential large-scale stratigraphy logging in IceCube-Gen2.

In this talk, laboratory characterizations of the light source employed by the LOMlogger will be presented. This includes the pulsed intensity and the angular profile of the laser beam emitted into the ice.

## T 106: Gamma Astronomy III

Time: Friday 9:00–10:15

Location: KS 00.005

T 106.1 Fri 9:00 KS 00.005

**Unsupervised Machine Learning for Muon Ring Classification in Imaging Atmospheric Cherenkov Telescopes** — •GIOVANNI COZZOLONGO<sup>1</sup>, ALISON MITCHELL<sup>1</sup>, and SAMUEL SPENCER<sup>2</sup> — <sup>1</sup>ECAP, FAU Erlangen-Nürnberg — <sup>2</sup>CTAO SDMC, Zeuthen, Germany

Muons from extensive air showers create ring-like patterns in Imaging Atmospheric Cherenkov Telescopes (IACTs). These ring images encode valuable information about muon properties such as energy and direction, making them important for studying the physics of muons in air showers. However, automated identification of muon events remains challenging, particularly for partial rings and mixed events containing both muon rings and air shower components. We present an unsupervised deep learning approach to classify muon events in H.E.S.S. CT5 data using clustering techniques to automatically separate events into categories like complete muon rings, partial rings, mixed events, and standard air showers. This represents one of the first deep learning applications to the analysis of muons in IACT data, offering significant advantages over manual classification and analytical methods that focus primarily on identifying complete rings.

T 106.2 Fri 9:15 KS 00.005

**Exploring goodness of fit methods to improve gamma-hadron separation for the CTA Observatory** — •JAYENDRA PUNDARIKAKSHA KAVIPURAPU<sup>1,2</sup>, GEORG SCHWEFER<sup>1,2</sup>, and JAMES ANTHONY HINTON<sup>1</sup> — <sup>1</sup>Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117, Heidelberg, Germany — <sup>2</sup>Fakultät für Physik und Astronomie, Universität Heidelberg, Im Neuenheimer Feld 226, 69120, Heidelberg, Germany

Background rejection of hadrons is one of the limiting factors for the performance of IACTs. Unfortunately, hadron showers look similar in telescope cameras, even if they produce broader images. A promising approach to differentiate between them is to implement goodness-of-fit measures based on the per-pixel charge probability distribution. In this talk, we explore these goodness-of-fit metrics exploiting the differences between the reconstructed and predicted charges. We do this using methods from likelihood-free inference and simulations of the Cherenkov Telescope Array Observatory, allowing us to create classification criteria to differentiate shower observations

T 106.3 Fri 9:30 KS 00.005

**Analysis of Condition Monitoring Data for the Large Sized Telescope** — •LUCA DAVIDE DI BELLA and TRISTAN GRADETZKE — TU Dortmund University  
The Cherenkov Telescope Array Observatory (CTAO) is the next generation high energy gamma ray observatory. It reaches higher sensitivities than current instruments, between several GeV to hundreds of TeV by facilitating different types of telescopes in the array, which differ mainly in their size. The LST-1 is the first prototype of a Large Sized Telescope of the array, sensitive to the lower energies. It is currently finishing commissioning at the CTAO-North array site, located at

the Roque de los Muchachos Observatory (ORM) on La Palma.

As Imaging Air Cherenkov Telescope (IACT) measurement time is limited by dark hours, maintenance is essential to ensure smooth operation and maximize the uptime. In order to find problems in structural dynamics of the telescope, condition monitoring and predictive maintenance can be performed using sensors placed across the structure. In the years since start of operations, different kinds of sensors have been installed, including linear displacement sensors, vibration sensors and so-called load pins. Methods of data acquisition and a preliminary analysis of recent data from these sensors is presented.

T 106.4 Fri 9:45 KS 00.005

**Characterization of ANTARES Photomultiplier Tubes for Sustainable Reuse in SWGO** — •SAUJANYA DUBALE, ALISON MITCHELL, and OLEG KALEKIN — Erlangen Centre for Astroparticle Physics, Friedrich Alexander Universität Erlangen-Nürnberg, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany  
Modern astroparticle physics experiments face growing pressure to balance scientific performance with cost and sustainability. In this contribution, we explore the possibility of reusing photomultiplier tubes (PMTs) that were previously operated in the ANTARES neutrino telescope for use in the future Southern Wide-field Gamma-ray Observatory (SWGO). A dedicated laboratory setup has been constructed to study the long-term operability and general performance behaviour of these PMTs after extended use deep in the Mediterranean sea, including their quantum efficiency. The aim is to evaluate whether these PMTs remain suitable for use in next-generation Water Cherenkov Detectors. By investigating reuse as a viable option, this work addresses both economic and environmental considerations and supports more sustainable detector development strategies.

T 106.5 Fri 10:00 KS 00.005

**Probing Energy-dependent Morphology in the Pulsar Wind Nebula HESS J1303-631** — •MAXIMILIAN BOHLE, ALISON MITCHELL, and KATHARINA EGG — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany  
Pulsar Wind Nebulae (PWN) exhibit complex morphologies that are often known to be energy-dependent. These morphological variations across energy bands can provide useful insights into the underlying physical mechanisms. In this work, detailed morphological studies of the very-high-energy gamma-ray source HESS J1303-631 are presented, using H.E.S.S. data analysed with the open source software gammapy. Previous studies based on more limited data found the source to be significantly energy-dependent. This energy-dependent nature is probed in more detail by analysing over 20 years of data for several energy ranges and therefore quantifying its morphological energy-dependency. HESS J1303-631 is found to be consistently elongated and highly extended, yet the results suggest that HESS J1303-631 exhibits a weaker energy dependence than previously reported.

## T 107: Invited Overview Talks V

Time: Friday 11:00–12:30

Location: AudiMax

**Invited Overview Talk** T 107.1 Fri 11:00 AudiMax  
**Beyond the Main Detectors: An Overview of Smaller Experiments at the LHC** — •FELIX KLING — Universität Bonn, 53113 Bonn, Germany

While the Large Hadron Collider (LHC) is best known for its large multipurpose experiments — ATLAS, CMS, LHCb, and ALICE — it also hosts a diverse set of smaller experiments that complement its physics program. These include LHCf and TOTEM, which focus on forward QCD measurements and hadronic interactions; FASER and SND@LHC, which perform neutrino measurements and search for physics beyond the Standard Model; as well as MilliQan and MoEDAL, designed to search for particles with anomalous electromagnetic charges. In this talk, I will provide an overview of these smaller LHC experiments and present their recent results. I will also discuss ongoing and proposed initiatives for additional small experiments during the remaining LHC running and at future collider facilities.

**Invited Overview Talk** T 107.2 Fri 11:30 AudiMax  
**Pimp my ride: Overhauling the ATLAS and CMS experiments to ride the High Luminosity Highway at the LHC** — •STEFAN MAIER — Karlsruhe Institute of Technology, Germany

The upcoming high-luminosity upgrade of the Large Hadron Collider (HL-LHC) will provide a unique opportunity to significantly extend the physics research program of the general-purpose experiments ATLAS and CMS. With its harsh environment, operation at the HL-LHC will bring experimental and instrumental challenges such as increased radiation levels and particle collisions per bunch crossing. In order to fully exploit the physics potential, the ATLAS

and CMS collaborations are upgrading their detector systems—both physically and conceptually. These versatile improvements are summarized in the Phase-2 Upgrades. While some subsystems will be partially enhanced with new electronics, others, such as the tracking systems, will be fully replaced or will complement the current detector systems, like the new timing layers.

This talk rides you through the detector upgrades of both experiments and highlights a selection of subdetector systems that do not just get a new paint job but pursue novel detection and readout concepts.

**Invited Overview Talk** T 107.3 Fri 12:00 AudiMax  
**Overview of the solar model and LUNANOVA** — •DANIEL BEMMERER — Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

The standard solar model describes the physics of the solar interior. Input parameters include the solar elemental composition, the total energy radiated from the sun, and microphysics such as nuclear reactions and radiation transport. The model can be validated observing the fluxes of neutrinos produced in the solar core and the sound waves at the solar surface. There were two main challenges to the model. First, the solar neutrino problem, which was solved by the discovery of neutrino flavour oscillations. Second, the solar abundance puzzle, caused by discrepant data on the solar composition. In order to solve this puzzle, we will build a new laboratory, LUNANOVA, and measure the rates of several neutrino-producing reactions in the sun. The new data will break the degeneracy between abundances and radiation transport, enable to use the sun as a calibrated particle source, and decisively improve the models of solar-like stars in general.

## History of Physics Division Fachverband Geschichte der Physik (GP)

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## Overview of Invited Talks and Sessions

(Lecture hall KH 02.019)

### Plenary Talk of the History of Physics Division

PV II Mon 11:00–11:45 AudiMax **Why the Invention of the World Wide Web was no Coincidence: Scientific Culture and Technological Innovation at CERN, 1972-1991 — •BARBARA HOF**

### Invited Talks

GP 1.3 Mon 15:00–15:30 KH 02.019 **Flucht oder Tod – das Schicksal verfolgter Mitglieder der DPG im Nationalsozialismus — •STEFAN L. WOLFF**

GP 4.1 Tue 16:15–17:15 KH 02.019 **Scientific Instruments and the Evolution of Experimental Volcanology: Insights from Mount Etna — •VALENTINA ROBERTI**

### Sessions

|            |     |             |           |                                                           |
|------------|-----|-------------|-----------|-----------------------------------------------------------|
| GP 1.1–1.3 | Mon | 13:45–15:30 | KH 02.019 | <b>Opening Session: History of Physics within the DPG</b> |
| GP 2.1–2.4 | Mon | 16:15–18:15 | KH 02.019 | <b>History of Theoretical Physics</b>                     |
| GP 3.1–3.2 | Tue | 11:00–12:00 | KH 02.019 | <b>Particles in Practice</b>                              |
| GP 4.1–4.3 | Tue | 16:15–18:15 | KH 02.019 | <b>Instruments and Measurement</b>                        |
| GP 5       | Tue | 18:30–19:30 | KH 02.019 | <b>Members' Assembly</b>                                  |
| GP 6.1–6.3 | Wed | 11:00–12:30 | KH 02.019 | <b>Physics and People</b>                                 |
| GP 7.1–7.4 | Wed | 13:45–15:45 | KH 02.019 | <b>Practices and Experiments</b>                          |

### Members' Assembly of the History of Physics Division

Tuesday 19:00–20:00 Room KH 02.019

### Dinner for Early Career Scholars

Monday 19:00

Contact: Dr. Julia Bloemer (julia-bloemer@uni-flensburg.de)

### Joint Dinner of the History of Physics Division

Tuesday after General Assembly

## Sessions

– Invited and Contributed Talks –

### GP 1: Opening Session: History of Physics within the DPG

Time: Monday 13:45–15:30

Location: KH 02.019

#### Welcome to Conference

GP 1.1 Mon 14:00 KH 02.019

**Das Archiv der DPG - Rückblick, Gegenwart und Ausblick** — •RALF HAHN — DPG Archive, Berlin, Germany

Das Archiv der DPG feiert im April 2026 sein dreißigjähriges Bestehen. Es wird ein Überblick auf den damaligen Zustand in der Gründungsphase gegeben sowie die weitere Entwicklung bis zum heutigen Tage skizziert. Illustriert werden die Ausführungen durch zahlreiche Abbildungen herausragender Archivalien, die für die Geschichte der DPG eine besondere Bedeutung haben.

GP 1.2 Mon 14:30 KH 02.019

**Physikgeschichte für Physiker. Erfahrungen aus dem Quantenjahr** — •ARNE SCHIRRMACHER — Humboldt-Universität, Berlin, Germany

Wie jede Forschungsrichtung wendet sich auch die Physikgeschichte in der Regel an jene, die sich damit professionell beschäftigen. Entsprechend findet die Diskussion zur aktuellen Forschung in eigenen Zeitschriften, auf dedizierte Konferenzen und in speziellen Netzwerken statt. Physikhistorische Fachverbände innerhalb von Physikalischen Gesellschaften verstehen es aber zudem als ihre Aufgabe, die Geschichte der Physik auch den vielen aktiven Physikerinnen und Physikern zu vermitteln, etwas, das zu Jubiläumszeiten auch besonders erwünscht

und nachgefragt ist, nicht zuletzt im zurückliegenden Quantenjahr. Ein summarischer Rückblick auf die historischen Aktivitäten innerhalb der DPG zum Quantenjahr diskutiert Erfahrungen und stellt die Frage, welche Bedeutung die Physikgeschichte für Physikerinnen und Physiker sowie Physikstudierende haben kann und welche Chancen sich hier eröffnen.

#### Invited Talk

GP 1.3 Mon 15:00 KH 02.019

**Flucht oder Tod – das Schicksal verfolgter Mitglieder der DPG im Nationalsozialismus** — •STEFAN L. WOLFF — Deutsches Museum, Munich, Germany (Träger der DPG-Ehrennadel 2025)

Seit dem Berufsbeamtengesetz vom April 1933 verloren viele Wissenschaftler aufgrund ihrer Herkunft oder politischen Haltung ihre Anstellung und einige von ihnen auch ihr Leben. Die aktuell zur Verfügung stehenden Datenbanken und Archivzugänge wie etwa zu den Unterlagen der Entschädigungsämter ermöglichen uns, die hiervon betroffenen Personen systematisch und vollständiger als bisher zu erfassen. Darüber hinaus erlaubt uns dies in manchen Fällen, Kontakte zu den Nachfahren herzustellen. Neben der Rekonstruktion der Biographien beinhaltet dieses Projekt die Anbringung von Gedenktafeln bzw. das Setzen von "Stolpersteinen" am letzten Wohnort der Opfer. Von den Ergebnissen dieser Spurensuche soll berichtet werden.

### GP 2: History of Theoretical Physics

Time: Monday 16:15–18:15

Location: KH 02.019

GP 2.1 Mon 16:15 KH 02.019

**The Young Bohr on the "Statistical": A Prelude to Quantum Indeterminacy** — •HAJIME INABA — Meiji University, Tokyo, Japan — Niels Bohr Archive, University of Copenhagen, Denmark

This paper examines how and what Niels Bohr learned about the statistical approach in science during the 1900s, thereby illuminating his intellectual development during his student days. Despite the innovative work of James Clerk Maxwell and Josiah Willard Gibbs in the late nineteenth century, the word "statistical" still seems to have sounded peculiar in the context of physics at the beginning of the twentieth century. When Bohr enrolled at the University of Copenhagen in 1903, statistics, as discussed by Harald Westergaard, mainly concerned mass phenomena such as population, economy, and insurance. *Theory of Observation* by Thorvald Thiele, under whom Bohr studied mathematics, offered a mathematical theory of observational error illustrated by examples from population statistics. Harald Høffding, with whom Bohr had long been familiar, also discussed the relation between statistical laws and human behavior. In the context of physics, Bohr's doctoral dissertation on the theory of electrons in metals (1911) explicitly adopted Gibbs' theory of statistical mechanics. Bohr probably encountered it through a paper by Peter Debye, who emphasized the universality of Gibbs' method in that it depended only on the statistical properties of the constituents. This paper thus provides a backdrop for highlighting Bohr's later conception of the "statistical," which came to encompass indeterminacy in quantum mechanics.

GP 2.2 Mon 16:45 KH 02.019

**From Virtual to Real. The Epistemological Relevance of Virtual Entities in (the Early History of) Quantum Field Theory** — •MARKUS EHBERGER — Deutsches Museum, München

The ontological, representational and epistemological status of virtual particles is still debated in the philosophy of physics. In the corresponding literature, the concept is nearly exclusively studied through its modern formulation. In this contribution, I will take a historically informed perspective on the virtual particle's role in scientific reasoning. By means of historical examples, I will identify an argumentative structure which utilizes the virtual particle concept - or concepts which we can reconstruct as lying in its historical trajectory. Such arguments are now part of scientific practice for nearly 100 years and, applying them, physicists took and take the ontological step from the virtual to the real. I will further argue that the appeal of reasoning with virtual particles and their prominence in the didactic literature is partially due to the storylines which could not be told without them. It is the narrative structure of the physical arguments and the virtual particle's role in them - both historically and contemporary -, which contributes to the concept's success.

GP 2.3 Mon 17:15 KH 02.019

**On Textbooks and their Contexts during the Renaissance of General Relativity** — •BERNADETTE LESSEL — Philosophisches Institut, Universität Bonn

The Renaissance of General Relativity refers to the period from roughly 1955 to 1975, during which the field experienced significant institutional growth and conceptual advancements. The institutional growth came in the shape of the establishment of several research centers, each typically led by a senior principal investigator (PI) guiding a group of postdoctoral researchers and doctoral students, as is well documented in the work of Roberto Lalli, Jürgen Renn, and Alexander Blum. These centers acted as intellectual schools, where knowledge of general relativity was passed on to students, which was however channeled through the lens of the PI's particular research focus. A manifestation of this was the surge of publications of school-specific textbooks on general relativity. This talk examines the textbooks produced by three influential schools, analyzing how they reflect their unique research environments and their impact on subsequent generations of relativists: 1) The Hamburg group around Pascual Jordan, who aimed at an extension of general relativity to incorporate a variable gravitational constant. 2) The Paris group led by mathematician André Lichnerowicz, whose interest was the initial value problem in general relativity. 3) The Syracuse group around Peter Bergmann, who transitioned from unified field theory -collaborating initially with Albert Einstein- to concentrating on quantum gravity.

GP 2.4 Mon 17:45 KH 02.019

**Foundations of quantum mechanics and the Milan School (1950s–1960s): conceptual issues and historical perspectives** — •LUISA LOVISETTI and MARCO GILIBERTI — Department of Physics "Aldo Pontremoli", University of Milan, Milan, Italy

The Department of Physics at the University of Milan developed an early and distinctive interest in the conceptual and formal development of quantum mechanics, reflected in both its teaching programme and research activities. As early as the A.Y. 1926–27, lectures on matrix and wave mechanics were delivered by A. Pontremoli, making Milan one of the first Italian universities to introduce quantum mechanics into its curriculum. From the late 1950s onward, at a time when the pragmatic "Shut up and calculate" attitude was becoming increasingly dominant, a group of Milan-based physicists engaged deeply with foundational issues, contributing to the international debate on the foundations of quantum theory. A central role in this effort was played by G.M. Prosperi and his 1962 paper *Quantum Theory of Measurement and Ergodicity Conditions* (co-authored with A. Daneri and A. Loinger), which addressed the measurement problem within the conceptual framework developed by P. Jordan and G. Ludwig. The paper

sparked a wide debate among leading physicists and also attracted significant attention from historians and philosophers of quantum theory. Drawing on the 1962 paper and subsequent responses, this presentation aims to illustrate a fun-

damental step of the historical development of the Milan School's foundational research and to explore its impact on the broader history of quantum mechanics.

### GP 3: Particles in Practice

Time: Tuesday 11:00–12:00

Location: KH 02.019

GP 3.1 Tue 11:00 KH 02.019

**Particle Dance: On the Experimental Intertwining of Brownian Motion and Elementary Charge in the Early 20th Century** — •JULIA BLOEMER — Europa-Universität Flensburg, Germany

The experiments with the oil-drop apparatus are celebrated for their precise determination of the elementary charge and are famously associated with the 1923 Nobel Prize in Physics awarded to Robert A. Millikan. Yet, the historical record reveals a much more complex picture. The same apparatus was simultaneously used by Millikan's doctoral student Harvey Fletcher to investigate another physical phenomenon, Brownian motion, and to determine a different constant, Avogadro's number. Brownian motion, the thermal and jittery movement of small particles, was treated as a disturbance in one line of inquiry – elementary charge – and became the very object of measurement in the other. This raises fundamental questions about experimental practice: How did taking Brownian motion into account change experimentation with the oil drop apparatus, as well as the subsequent data analysis and theoretical discussions? The results of this analysis will improve not only our understanding of a canonical experiment in the history of physics, but also of the process of control and stabilisation in experiments.

GP 3.2 Tue 11:30 KH 02.019

**Der Kernphysiker Karl-Heinz Höcker und sein Beitrag zur Uranmaschine** — •ROLAND SADLER — Universität Stuttgart, Historisches Institut

Karl-Heinz Höcker ist vor allem deshalb interessant, weil er gemeinsam mit Werner Heisenberg und Carl Friedrich von Weizsäcker an der Entwicklung der theoretischen Grundlagen der Uranmaschine beteiligt war. Nach seinem Studium wurde Karl-Heinz Höcker der erste Doktorand von Carl-Friedrich von Weizsäcker. Er promovierte bereits 1940 mit dem kernphysikalischen Thema Wirkungsquerschnitte der Reaktionen zwischen Neutronen und Deutronen. Aus diesem Jahr gibt es ebenfalls Forschungsberichte mit einem technischen Anklang: Berechnung der Energieerzeugung in der Uranmaschine und später Über den Wärmetransport aus der Uranmaschine. Das zeigt, dass bei Karl-Heinz Höcker in Forschung und Lehre von Anfang an Physik und Technik nahe beisammen lagen. Nach seinem Wehrdienst wechselte er Ende 1942 an das Institut für Theoretische Physik der Reichsuniversität Straßburg. Hier war er Assistent von Carl Friedrich von Weizsäcker. Karl-Heinz Höcker arbeitete weitgehend unabhängig weiter an Themen zur Uranmaschine. 1943 zeigte er, dass ein räumliches Gitter aus Atomwürfeln in schweren Wässern einen höheren Neutronenvermehrungsfaktor ergibt, als eine Anordnung aus Platten. Dieses Würfelgitter wurde dem letzten Großversuch 1945 in Haigerloch zugrunde gelegt. Dieser Vortrag gibt einen ersten Überblick, von den Arbeiten, die Karl-Heinz Höcker für die Uranmaschine geleistet hat.

### GP 4: Instruments and Measurement

Time: Tuesday 16:15–18:15

Location: KH 02.019

#### Invited Talk

GP 4.1 Tue 16:15 KH 02.019

**Scientific Instruments and the Evolution of Experimental Volcanology: Insights from Mount Etna** — •VALENTINA ROBERTI — Department of Humanities, University of Catania, Italy

This contribution examines the emergence of volcanology as an experimental science through an analysis of the scientific instruments employed in research on Mount Etna. Beginning with Giovanni Alfonso Borelli's investigations of the 1669 eruption, scholars progressively incorporated new methods and instruments into the study of volcanic activity. The development of volcanology as an autonomous field, however, was neither linear nor uniform; rather, it was initially shaped by the interaction of different disciplines, such as physics, chemistry, and later geology and mineralogy, as well as by the intrinsic complexity of volcanic phenomena. The analysis is situated within the cultural and academic context of Catania, starting with the university reform of 1779, which introduced the first scientific chairs and promoted the acquisition and commissioning of instruments from both local craftsmen and leading European ateliers. Particular attention is devoted to selected case studies drawn from the cabinets of natural history, physics, and chemistry, whose instruments embodied disciplinary advances and were simultaneously employed in the investigation of Mount Etna. Surviving artefacts provide tangible evidence of the convergence of research and teaching practices that contributed to the institutionalization of volcanology at the University of Catania. These findings have directly informed a broader initiative aimed at enhancing the university's historical scientific heritage, including the temporary exhibition *Lo studio dell'Etna tra strumenti e rappresentazioni* (*The Study of Mount Etna Between Instruments and Representations*), held at the Museo della Fabbrica, Department of Humanities, from 10 March to 30 April 2025.

GP 4.2 Tue 17:15 KH 02.019

**Stereoscopic Rangefinders: in the Borderlands Between Physics and Physiology** — •ANDREAS JUNK — Europa-Universität Flensburg

The development of the stereoscopic rangefinder is the strange story of an improvement of precision in range determination by introducing a notoriously unprecise element: an observer. After the identification and introduction of the personal equation in astronomy in the first half of the 19th century it was clear,

that the human factor cannot possibly be removed from any measurement made by a human operator. The resolution in that particular case was to find methods to remove the human error by mathematical means. The subsequent idea of precision measurement, which were initiated based on the findings of Bessel in astronomy, was to an extent to not let an operator have an influence in any precise measurement, i.e. to remove the operator from the measurement.

In the last decade of the 19th century the newly developed rangefinders were pushing the limits of precision engineering but they were facing very basal problems regarding the uncertainty of the measurement. The geometrical principles of physics and engineering indicated, that the error to be expected in distance measurement couldn't be ruled out by precise manufacturing or an improved design of the instrument. The development of the stereoscopic telemeter was not only an attempt to overcome this particular problem, it added insult to injury by re-introducing the human operator, whose daily experiences gave the grounds to improve the measurements at large distances.

GP 4.3 Tue 17:45 KH 02.019

**Development, optimization, distribution, installation and repair of early Bruker Fourier transform infrared spectrometers** — •PROF. DR. KLAUS HENTSCHEL — Head of the Section for History of Science & Technology, University of Stuttgart

Roughly 50 years ago, the Karlsruhe & Ettlingen-based company of Bruker Optics introduced its first Fourier-transform infrared spectro-meter IFS 113v. An interdisciplinary working group at the University of Stuttgart, consisting of physicists still working with similar kinds of Fourier-transform instruments and a historian of science & instrumentation, collaborated with the Bruker Optics company which gave free access to its archives. A website is produced informing interested users about the history of Fourier-transform technology, the history of Bruker Optics and technical details of FT interferometers including beam-splitters and mirrors, detectors, typical sources etc. Furthermore, 4 members of the Bruker team were interviewed who were active in the early years and had participated in Bruker instrument development and improvement, management, sales, installation and repair. All of this will be presented in an openly accessible webpage, to be released in the spring of 2026. Samples of this webpage will be presented and discussed.

### GP 5: Members' Assembly

Time: Tuesday 18:30–19:30

Location: KH 02.019

Invitation and agenda will be sent out separately.

## GP 6: Physics and People

Time: Wednesday 11:00–12:30

Location: KH 02.019

GP 6.1 Wed 11:00 KH 02.019

**Physik-Dissertationen von Chinesinnen und Chinesen an deutschen Hochschulen zwischen 1939 und 1945** — •XIAN WU — TU Bergakademie Freiberg, Freiberg, Germany

Die Geschichte des Auslandsstudiums von Chinesinnen und Chinesen geht auf das 19. Jahrhundert zurück. 1907 erhielt Fuji Li als der erste in Europa und zugleich der erste in einer Naturwissenschaft promovierte Chinesen mit einem Thema zur experimentellen Spektroskopie am Physikalischen Institut der Universität Bonn. In der ersten Hälfte des 20. Jahrhunderts war Deutschland nach den USA das zweitbeliebteste Land für diejenigen Chinesinnen und Chinesen, die einen Doktorgrad in einer naturwissenschaftlichen oder technischen Disziplin anstrebten.

Zwischen 1939 und 1945, als der Nationalismus die allgemeine Stimmung in Deutschland prägte und die Beziehung zwischen China und Deutschland ab 1941 aufgrund des Zweiten Weltkriegs einen Tiefpunkt erreichte, studierten immerhin zahlreiche Chinesinnen und Chinesen an deutschen Hochschulen in verschiedenen Disziplinen. Darunter schrieben mehr als zehn Studierende ihre Doktorarbeiten auf den Gebieten der Physik.

Wer sind diese Doktoranden? Worum geht es bei ihren Dissertationen? Wo wurden die Arbeiten durchgeführt und von wem wurden sie betreut? In diesem Vortrag wird ein Überblick über diese Aspekte dargelegt, was bisher von Wissenschaftshistorikern ungenügend beachtet wurde.

GP 6.2 Wed 11:30 KH 02.019

**Quantitative Analyse der Darstellung von Frauen in Physik- und Astronomie-Journals (1950–1999)** — •COLLEEN SEIDEL — Bergische Universität Wuppertal, Wuppertal, Deutschland

Die zweite Hälfte des 20. Jahrhunderts war eine Zeit des Umbruchs: Frauen drangen langsam in die männlich dominierten Naturwissenschaften vor, während

gleichzeitig die Wissenschaftsgeschichte begann, ihre Beiträge systematisch aufzuarbeiten. Doch wie spiegeln sich diese Entwicklungen in den Publikationen der Disziplinen selbst wider?

In meiner Forschung untersuche ich quantitativ, wie Frauen in Physik- und Astronomie-Journals von wissenschaftlichen Gesellschaften aus Westeuropa und den USA in der zweiten Hälfte des 20. Jahrhunderts dargestellt wurden. Zum einen nutze ich eine Keyword-basierte Volltextanalyse, um die Inhalte der Journals nach bestimmten Begriffen zu durchsuchen, die im Zusammenhang mit Physikerinnen, Astronominnen und Geschlechtervorstellungen stehen. Zum anderen analysiere ich die Autor:innenschaft der Journals, um hier die Entwicklungen in der Partizipation von Frauen in den Disziplinen nachvollziehen zu können. Meine Ergebnisse kontextualisiere ich durch die Entwicklungen in der Frauen-/Genderforschung sowie der Physik-, Astronomie- und Wissenschaftsgeschichte.

GP 6.3 Wed 12:00 KH 02.019

**Women physicists and technicians in the Paperclip Program** — •JOHANNES-GEERT HAGMANN — Deutsches Museum, Munich, Germany

At the end of World War II, national interest programs for the evacuation and immigration of specialist scientist from Germany, Austria and other countries to the USA were born. These initiatives were designated by the names of Project Paperclip, Project 63 and Defense Scientist Immigration Program (DEFSIP). They operated over a time period of more than 20 years from 1945 to the end of the 1960s. While a significant body of historical literature has described these programs in their globality, the role of the small cohort of women scientists and technicians has so far been overlooked. In this contribution, we reconstruct and highlight selected biographies of women physicists and technicians in the Paperclip program, adding to a transnational historical perspective of migration of scientists from Europe to the USA in the early Cold War period.

## GP 7: Practices and Experiments

Time: Wednesday 13:45–15:45

Location: KH 02.019

GP 7.1 Wed 13:45 KH 02.019

**Materielle Kultur der Thermodynamik: Werkstattbericht aus dem Ausstellungsprojekt „Energie – Dampf“** — •ECKHARD WALLIS — Deutsches Museum, München, Deutschland

Im Zuge der Generalsanierung des Deutschen Museums wird die Kraftmaschinenausstellung bis 2028 zur thematisch breiteren Ausstellung „Energie – Dampf“ umgestaltet. So soll auch der ehemalige Raum „Moderne Dampfmaschinen“ zukünftig eine allgemeinere Perspektive auf thermodynamische Prozesse einnehmen. Die physikalischen Prinzipien von Dampfmaschinen, so die Kernbotschaft, haben nichts an Aktualität verloren. Kreisprozesse und Phasenübergänge sind bis heute elementar für das Verständnis von Kältemaschinen und Wärmepumpen, aber auch von Kraftwerken und Dampfturbinen. Historische Artefakte bilden eine tragende Säule des Ausstellungsnarrativs. Der Vortrag gibt einen Einblick in den aktuellen Planungsstand und reflektiert insbesondere die Frage, welchen Mehrwert der Einbezug der materiellen Kultur für die Vermittlung thermodynamischer Prinzipien bietet.

GP 7.2 Wed 14:15 KH 02.019

**Experiments on the Propagation of Light: Taqi al-Din al-Rasid and His Source Ibn al-Haytham** — •SENA AYDIN — Istanbul Medeniyet University Institute for the History of Science, Istanbul, Turkey

Taqi al-Din al-Rasid (d. 1585) is regarded as the leading figure of optical science in the classical Ottoman period. Containing forty-nine experimental setups, his book on optics may be considered an experimental manual. One of its principal sources is Ibn al-Haytham (d. 1040), who, by combining physical and mathematical methods in the history of science, established the method of experimental verification. In doing so, he brought about a major transformation in optical studies and fundamentally changed how natural philosophers produced scientific knowledge. The experiments of Taqi al-Din on the propagation of light include observations such as the perception of objects by the eye along straight lines; the formation of a conical structure by light as it travels between the eye and the object; the observation that light spreads in a straight direction through smoky air; the spherical propagation of light from every point of a luminous source toward all opposite directions; and the creation of secondary lights as rays from primary sources reflect off surfaces. This study aims to present examples of replicas of experiments of Taqi al-Din on the propagation of light, produced within the framework of our project, and to analyze these experiments in comparison with those of his primary source, Ibn al-Haytham.

GP 7.3 Wed 14:45 KH 02.019

**Between geometry and physics: revisiting Torricelli's Opera geometrica (1644) as a foundational framework for early modern mechanics** — •RAFFAELE PISANO — HOPAST team, IEMN, Department of Physics, University of Lille, France

My talk revisits the physical-mathematical foundations of Evangelista Torricelli's Opera geometrica (1644) within the context of seventeenth-century mechanics and geometry. Marking the 380th anniversary of the work, it draws on the historical-scientific analysis developed in *Homage to Evangelista Torricelli's Opera Geometrica (1644–2024)* (Springer, 2024), which presents a critical transcription of the original text alongside interpretative essays. Torricelli stands at a crucial transition between classical Archimedean geometry and early modern infinitesimal methods, deeply shaped by Galilean mechanics. Like Cavalieri, he relied on geometrical proportions rather than algebraic equations and worked without an explicit notion of limit. Yet Torricelli advanced beyond the geometry of indivisibles by seeking the logical and physical structure underlying geometrical reasoning. His mathematics is inseparable from physical-mechanical meaning, especially in problems concerning motion, statics, and the determination of areas and volumes of curvilinear solids. For example, Torricelli's proofs on finite volume of the solido acutissimo, illustrating early infinitesimal reasoning at the boundary between geometry and mechanics, and his analysis of the logarithmic spiral, revealing a refined conception of geometrical motion. The Opera geometrica is examined as a synthesis of geometry, infinitesimals, and mechanics.

GP 7.4 Wed 15:15 KH 02.019

**Practising with the Lucernal Microscope** — •PETER HEERING<sup>1</sup> and TRIENKE VAN DER SPEK<sup>2</sup> — <sup>1</sup>Europa-Universität Flensburg, Institut für Physik und ihre Didaktik und Geschichte — <sup>2</sup>Teylers Museum Haarlem

The lucernal microscope, a projection microscope that uses the newly developed Argand lamp as a light source, was developed at the end of the 18th century, particularly George Adams sen. and jun. are key persons in this respect. The instrument was marketed as an improvement of the solar microscope and has two key advantages. Due to the use of an artificial light source, the device can be used both during the day and, above all, at night. Furthermore, use of the device is not dependent on weather conditions, meaning that, unlike a solar microscope, it can be used for demonstrations at any time.

Martinus van Marum ordered a lucernal microscope together with a substantial set of specimens from George Adams in 1788. This instrument still exists

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>in Teylers Museum Haarlem where we started to use both the instruments and the specimens for projections. In our presentation, we are discussing the experiences made in working with the instrument. Moreover, we will also discuss</p> | <p>in particular the findings with respect to the sliders - this seems to be particularly relevant as these objects are frequently neglected in the discussion of 18th century microscopes.</p> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|



## Working Group on Equal Opportunities Arbeitskreis Chancengleichheit (AKC)

Agnes Sandner  
Sprecherin des AKC  
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### Overview of Invited Talks and Sessions

(Lecture hall KH 01.011)

#### Invited Talks

|         |     |             |           |                                                                                                                                           |
|---------|-----|-------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------|
| AKC 1.1 | Thu | 11:15–11:45 | KH 01.011 | <b>Visibility, invisibility and hypervisibility of women in quantum technologies —</b><br>MARTINA ERLEMANN, ANDREA BOSSMANN, •TAMAR GROSZ |
| AKC 1.2 | Thu | 11:45–12:15 | KH 01.011 | <b>Leadership, Cooperation and Conflicts in Physics: Research Leaders' Perspectives</b><br>— •MAIKE REIMER                                |
| AKC 1.3 | Thu | 12:15–12:45 | KH 01.011 | <b>From Taboo to Transformation: Addressing Gender-Based Violence in Academia</b><br>— •ANJA WIEDE                                        |

#### Sessions

|             |     |             |           |                               |
|-------------|-----|-------------|-----------|-------------------------------|
| AKC 1.1–1.3 | Thu | 11:00–12:45 | KH 01.011 | <b>AKC</b>                    |
| AKC 2       | Thu | 13:00–13:45 | KH 01.011 | <b>Women in Physics Lunch</b> |

## Sessions

– Invited Talks –

### AKC 1: AKC

Time: Thursday 11:00–12:45

Location: KH 01.011

#### Begrüßung durch Agnes Sandner, Sprecherin des AKC

**Invited Talk** AKC 1.1 Thu 11:15 KH 01.011  
**Visibility, invisibility and hypervisibility of women in quantum technologies**  
 — MARTINA ERLEMANN, ANDREA BOSSMANN, and •TAMAR GROSZ — Fachbereich Physik, Freie Universität Berlin, Deutschland

Quantum technologies are widely recognized as key technologies of the future. With their broad range of applications, they have the potential to address major societal challenges and contribute to the sustainable, future-oriented development of society. However, equal participation of highly qualified women in quantum technologies has not yet been achieved. Women remain significantly underrepresented in STEM fields that lead to careers in research and development within quantum technologies, such as physics, computer science, and certain branches of engineering. Additionally, high-achieving women in quantum technologies often receive less visibility than their male counterparts. This lack of visibility is evident both within the scientific community, in the form of fewer awards, recognitions, or leadership appointments, and externally, in public discourse, industry, politics, and the media. At the same time, women in these fields are hypervisible because of being part of a minority, which however doesn't lead to recognition, but rather to a higher level of being exposed and scrutinized. Here we will discuss the effects of these competing types of visibility and preliminary findings of our BMBF-funded research project WomenInQuantumTech: In/visibility of Women in Quantum Technologies - Development of effective strategies for better participation.

**Invited Talk** AKC 1.2 Thu 11:45 KH 01.011  
**Leadership, Cooperation and Conflicts in Physics: Research Leaders' Perspectives** — •MAIKE REIMER — Bayerisches Staatsinstitut für Hochschulforschung und Hochschulplanung (IHF), Arnulfstraße 56, 80335 München  
 "Can Germany rein in its academic bullying problem?" This question was recently raised prominently in a nature article. Anecdotal evidence as well as systematic surveys among researchers indeed paint a bleak picture of research leadership and institutional structures for conflict prevention and management in research settings in Germany and its German-speaking neighbouring states.

However, the perspectives and voices of senior researchers are conspicuously absent from this discourse. Therefore, in collaboration with the DPG, we conducted 11 interviews and a survey among all members with leadership experience, about one crucial aspect and challenge of leadership: dealing with conflicts in their research teams. Here, we will present results from the full report on the frequency, kind, antecedents and consequences of conflicts and the ways they were resolved with or without institutional support. In addition, we investigate gender specific patterns in conflict experience. We hope to contribute to a more nuanced discussion and ultimately an improvement in research institutions conflict management structures.

**Invited Talk** AKC 1.3 Thu 12:15 KH 01.011  
**From Taboo to Transformation: Addressing Gender-Based Violence in Academia** — •ANJA WIEDE — TU Dresden, Dresden, Germany

Gender-based violence in academia is not a side issue but part of how power and inequality are reproduced within universities. According to recent UniSAFE findings, around 62% of respondents have encountered at least one form of such violence since joining their institution. Psychological violence and sexual harassment are particularly common, while reporting remains rare.

This lecture treats sexualised discrimination and violence not as individual misbehaviour or desire, but as a way power is exercised through everyday academic relations. It examines how universities with their status hierarchies, insecure employment paths, male-centred norms, and self-image as progressive spaces, create conditions in which these forms of harm are downplayed, rendered invisible, or dealt with inadequately. These structural features interact with individual tendencies of perpetrators, making violence both possible and easy to hide.

The lecture explores why such violence persists despite equality and diversity rhetoric and how gender-based violence operates as a form of power abuse in academic systems. Participants will gain concrete insights into the structural and cultural conditions that enable these dynamics, and they will be invited to reflect on their own institutional contexts. The session offers practical ideas for creating safer academic environments from strengthening accountability and reporting structures to developing everyday practices that confront power imbalances.

### AKC 2: Women in Physics Lunch

Time: Thursday 13:00–13:45

Location: KH 01.011

**Female physicists of all career stages are cordially invited to join our meet-and-greet networking lunch or snack. Diverse and all kinds of interested colleagues are also welcome!**

## Working Group on Energy Arbeitskreis Energie (AKE)

Karl-Friedrich Ziegahn  
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### Overview of Invited Talks and Sessions

(Lecture hall KH 01.022)

#### Invited Talks

|         |     |             |           |                                                                                                                                                                                                                                                                                                    |
|---------|-----|-------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AKE 1.1 | Tue | 11:00–11:30 | KH 01.022 | <b>Unterwasserpumpspeicher in den Braunkohletagebauen des Rheinischen Reviers – die Lösung zur bezahlbaren Grundlastenergieversorgung der deutschen Industrie</b><br>— •HORST SCHMIDT-BÖCKING, H. RISSE, G. LUTHER, U. SCHÖLER, J. SCHWISTER, L. MÜLLER, T. BENDER, A. GARG, H. LAMBERTZ, M. DÜREN |
|---------|-----|-------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

#### Sessions

|             |     |             |           |                                                                      |
|-------------|-----|-------------|-----------|----------------------------------------------------------------------|
| AKE 1.1–1.4 | Tue | 11:00–12:15 | KH 01.022 | <b>Innovative Contributions for the Energy System Transformation</b> |
|-------------|-----|-------------|-----------|----------------------------------------------------------------------|

## Sessions

– Invited and Contributed Talks –

## AKE 1: Innovative Contributions for the Energy System Transformation

Time: Tuesday 11:00–12:15

Location: KH 01.022

## Invited Talk

AKE 1.1 Tue 11:00 KH 01.022

**Unterwasserpumpspeicher in den Braunkohletagebauen des Rheinischen Reviers – die Lösung zur bezahlbaren Grundlastenergieversorgung der deutschen Industrie** — •HORST SCHMIDT-BÖCKING<sup>1</sup>, H. RISSE<sup>2</sup>, G. LUTHER<sup>3</sup>, U. SCHÖLER<sup>4</sup>, J. SCHWISTER<sup>5</sup>, L. MÜLLER<sup>6</sup>, T. BENDER<sup>6</sup>, A. GARG<sup>6</sup>, H. LAMBERTZ<sup>7</sup> und M. DÜREN<sup>8</sup> — <sup>1</sup>Institut für Kernphysik, Goethe Universität Frankfurt — <sup>2</sup>RWTH Aachen — <sup>3</sup>Universität des Saarlandes, Saarbrücken — <sup>4</sup>Früher Ruhr-gas Essen — <sup>5</sup>Techn. Beigeordneter a.D. Stadt Kerpen — <sup>6</sup>University of Applied Sciences, Mainz — <sup>7</sup>Kreistagsabgeordneter im Rhein-Erft-Kreis — <sup>8</sup>Justus-Liebig-Universität Gießen

Die Energiewende in Deutschland kann gelingen, wenn man der Industrie zu jeder Zeit auch in Flauten bezahlbare elektrische Energie in ausreichender Menge zur Verfügung steht und die Überschüsse insbesondere aus PV am Tage verwertet werden können. Dazu braucht man sehr große Energiespeicher. Zur Zeit scheint man das Kurzzeit-Speicherproblem fast nur mit elektrochemischen Speichern lösen zu wollen. Die bewährte Technologie von Pumpspeichern wird kaum im Betracht gezogen, da es angeblich keine Möglichkeiten mehr gäbe, in Deutschland wegen fehlender Topographie und geltenden Umweltauflagen solche Speicher in ausreichender Größe zu errichten.

In den mehr als 400 m tiefen Braunkohletagebauen kann man riesige Pumpspeicher (sogenannte Unterwasserpumpspeicher) errichten, die so groß sind, dass sie selbst zu Kosten von weniger als 6 Cent/kWh die Grundlastversorgung für die Industrie sichern können. Dort könnten „unsichtbare“ Unterwasserpumpspeicher erbaut werden, von weit mehr als 100 GWh Speicherkapazität (ein Zyklus), die man sofort ohne Flutung des Sees in Betrieb nehmen kann. Deutschland besitzt heute ca. 38 GWh Pumpspeicher und weniger als 3 GWh ins Stromnetz integrierte elektrochemische Speicher. Der Ausbau an elektrochemischen Speichern (vor allem Li-Ionenbatterien) wird stark zu nehmen. Diese Speicher werden aber vor allem im privaten Bereich und in der Mobilität (unter 100 kWh) und im mittleren Speicherbereich (< 300 MWh) zum Einsatz kommen und werden ohne Zweifel wichtige Speicherkomponenten in der Energiewende sein. Sie unersetzbar, da sie extrem hohe Leistungen (etliche 10 GW) bereitstellen können.

Im Vortrag wird das Funktions- und Aufbauprinzip dieser Speicher vorgestellt und deren Wirtschaftlichkeit im Vergleich zu anderen Speicherkonzepten beschrieben.

AKE 1.2 Tue 11:30 KH 01.022

**Multiphysics Simulation of 1D MEA in a PEM fuel cell** — •ZAHRA HARATI-ZAVEH and JAN LOHBREIER — Technische Hochschule Nürnberg Georg Simon Ohm

**Abstract:** The membrane electrode assembly (MEA) is the key functional unit of low-temperature polymer electrolyte membrane (PEM) fuel cells. It includes a proton-conducting membrane positioned between catalyst layers where hydrogen and oxygen react electrochemically. Gas diffusion layers support this structure by supplying reactants, removing products, and providing electron transport, creating a tightly integrated system in which electrochemical, thermal, and mass-transport processes are closely linked. Water has a significant impact on MEA performance. Ionomer conductivity requires adequate hydration, nevertheless too much liquid water may block gas pathways and delay reactions. Understanding how humidity and transport conditions impact the equilibrium between hydration, gas access, and electrochemical activity is therefore necessary for stable operation. This work focuses on a detailed nonisothermal model used to study how inlet gas relative humidity affects the performance of a hydrogen-fueled PEM MEA. The model incorporates gas-phase species trans-

port, water diffusion and sorption in the ionomer, and the hydration-dependent variation of proton conductivity. Heat generation from electrochemical reactions and Joule heating is included to resolve temperature gradients that develop during operation, coupling thermal effects directly to water content and reaction kinetics. Hydrogen crossover through the membrane is represented to capture cross-diffusion.

AKE 1.3 Tue 11:45 KH 01.022

**Comparison of Surrogate Models Trained with Small Data Sets for a Thermoelectric Energy Harvester** — •EUGEN VAMBOLT<sup>1</sup>, NIKLAS PÖPEL<sup>1</sup>, JOHANNES WIECZOREK<sup>2</sup>, MAHLA MOAZAMIGUDARZI<sup>2</sup>, JOHANNES ROTHMAYR<sup>2</sup>, and JAN LOHBREIER<sup>1</sup> — <sup>1</sup>Technische Hochschule Nürnberg Georg Simon Ohm — <sup>2</sup>Fraunhofer Institute for Integrated Circuits (IIS) Nürnberg

Energy harvesting technologies can be used to cover the energy consumption of wireless sensor nodes. This enables the use of sensor nodes in locations without a wired power supply. It also eliminates the need to charge or replace batteries, which can quickly become an economic obstacle when a large number of sensors are installed. For energy harvesting technologies to work, there must be a sufficient energy source near the sensor node. For example, temperature differences are essential for the use of thermoelectric generators (TEG) so that electrical energy can be harvested. Locations where such temperature differences can be found typically occur on supply lines or on machines that generate waste heat. The size of the required energy harvesting system depends on the energy consumption of the sensor node and the amount of available ambient energy. The design of a TEG can be optimized for a specific application to meet the energy requirements of the sensor node. To do this, a sensitivity analysis is performed to determine the factors that have the greatest influence on, for example, performance. A surrogate model is usually used in this step, as a large number of predictions have to be calculated. In this thesis, three approaches for surrogate models are investigated and compared with each other.

AKE 1.4 Tue 12:00 KH 01.022

**The Inclusive Investigation of Defect Thermodynamics for Cl-Ion Battery Materials using Grand Canonical Diagrams** — •JOHANNES DÖHN<sup>1</sup> and AXEL GROSS<sup>1,2</sup> — <sup>1</sup>Institute of Theoretical Chemistry, Ulm University, Germany — <sup>2</sup>Helmholtz Institute Ulm, Germany

In our contribution we use the example of chloride perovskites to discuss the crucial role of defect thermodynamics for electrode and solid electrolyte materials in Cl-ion batteries. In this regard, the energetic relation between the pristine compound, the formation of defects and the conversion into other materials under varying electrochemical conditions is of great importance, though still underexplored.

Here, we suggest an analysis based on grand canonical approaches which is frequently applied using the concepts of ab initio thermodynamics or the computational hydrogen electrode. Grand canonical diagrams contain in a compact form information on the relative stability of the pristine and defective materials as well as potential decomposition products at varying potentials and loadings. Thus they can help to predict whether topotactic or conversion reactions are to be expected during chlorination/dechlorination. Furthermore, relevant properties as the open circuit voltage or the electrochemical stability window can be read off directly from the diagrams.

We demonstrate that this inclusive investigation of all relevant thermodynamic properties presented here enables a comprehensive and intuitive access to the elucidation of materials properties which can hardly be gained otherwise.

## Working Group "Young DPG" Arbeitskreis junge DPG (AKjDPG)

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### Overview of Invited Talks and Sessions

(Lecture hall AM 00.014)

#### Tutorial

|            |     |             |           |                                                                                                                                                |
|------------|-----|-------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------|
| AKjDPG 1.1 | Sun | 14:00–15:00 | AM 00.014 | <b>Quantising Gravity: The Path from General Relativity to Loop Quantum Gravity</b> — •KRISTINA GIESEL                                         |
| AKjDPG 1.2 | Sun | 15:00–16:00 | AM 00.014 | <b>Jets 101: Reconstruction, Calibration, and Substructure at the LHC</b> — •CHRIS MALENA DELITZSCH                                            |
| AKjDPG 1.3 | Sun | 16:00–17:00 | AM 00.014 | <b>Probing hot and dense QCD matter with dileptons</b> — •ANTON ANDRONIC                                                                       |
| AKjDPG 2.1 | Sun | 17:30–19:00 | AM 00.014 | <b>Resource-Aware Deep Learning: Tracking Energy Consumption in Scientific AI Applications</b> — •KEVIN SCHMITZ, ANNO KNIERIM, RAPHAEL FISCHER |

#### Physicists beyond Academia

|            |     |             |           |                                                                                               |
|------------|-----|-------------|-----------|-----------------------------------------------------------------------------------------------|
| AKjDPG 3.1 | Tue | 13:00–13:25 | AM 00.014 | <b>From a career in academia to cutting-edge research in industry</b> — •ACHIM SCHÖLL         |
| AKjDPG 4.1 | Tue | 19:00–19:25 | AM 00.014 | <b>from a nuclear physicist to a nuclear instrumentation architect</b> — •BANU OEZEL TASHENOV |
| AKjDPG 4.2 | Tue | 19:25–19:50 | AM 00.014 | <b>From ATLAS to Banking</b> — •ELIAS RÜTTINGER                                               |
| AKjDPG 4.3 | Tue | 19:50–20:15 | AM 00.014 | <b>Podium discussion with the three speakers</b> — •MICHAEL LUPBERGER                         |

#### Sessions

|                |     |             |           |                                                                                          |
|----------------|-----|-------------|-----------|------------------------------------------------------------------------------------------|
| AKjDPG 1.1–1.3 | Sun | 14:00–17:00 | AM 00.014 | <b>jDPG Tutorials</b>                                                                    |
| AKjDPG 2.1–2.1 | Sun | 17:30–19:00 | AM 00.014 | <b>jDPG/AKPIK Programmierworkshop (joint session AKjDPG/AKPIK)</b>                       |
| AKjDPG 3.1–3.1 | Tue | 13:00–13:25 | AM 00.014 | <b>yHEP/jDPG Physicists Beyond Academia I</b>                                            |
| AKjDPG 4.1–4.3 | Tue | 19:00–21:00 | AM 00.014 | <b>yHEP/jDPG Physicists Beyond Academia II</b>                                           |
| AKjDPG 5.1–5.4 | Wed | 13:45–15:45 | KH 00.011 | <b>Artificial Intelligence in Scientific Publishing (joint session AGI/AKjDPG/AKPIK)</b> |

## Sessions

– Invited Talks, Tutorials, and Discussions –

### AKjDPG 1: jDPG Tutorials

Time: Sunday 14:00–17:00

Location: AM 00.014

**Tutorial** AKjDPG 1.1 Sun 14:00 AM 00.014

**Quantising Gravity: The Path from General Relativity to Loop Quantum Gravity** — •KRISTINA GIESEL — FAU Erlangen-Nürnberg, Department Physik, Lehrstuhl für Quantengravitation, Staudtstr. 7B, 91058 Erlangen — FAU Erlangen-Nürnberg, ECAP, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen

This talk provides a brief introduction to the central concepts and basic ideas of loop quantum gravity (LQG). Starting from general relativity, the conceptual and technical challenges that arise when applying quantisation to gravity are discussed, highlighting the essential differences to quantum mechanics and the standard model of particle physics. Within the framework of LQG, these concepts lead to the Quantum Einstein Equations, which encode the dynamics of LQG at the quantum level. Selected applications of the Quantum Einstein Equations to cosmology and black holes are presented and their physical implications are discussed.

**Tutorial** AKjDPG 1.2 Sun 15:00 AM 00.014

**Jets 101: Reconstruction, Calibration, and Substructure at the LHC** — •CHRIS MALENA DELITZSCH — TU Dortmund, Dortmund, Germany

Jets are collimated, high-energy streams of particles that act as proxies for the production of quarks and gluons at short distances. They are ubiquitous at hadron colliders such as the Large Hadron Collider. Jet production and evolution are governed by the parton distribution functions, the strong coupling constant  $\alpha_s$ , and the rules of Quantum Chromodynamics.

Whether you are new to jet physics or looking to refresh key concepts, this tutorial provides a crash course on the essential tools needed to work with jets at the LHC. Understanding jets is central to many measurements and searches for new physics, and this tutorial offers the foundation needed to explore this rich and evolving field. An introduction is given to jet reconstruction in the ATLAS and CMS experiments, together with the complex calibration chain required before jets can be used in physics analyses. In addition, jet-substructure techniques are presented, which play an important role at the LHC because heavy particles such as e.g. the  $W/Z$  bosons or the top quark are frequently produced with large Lorentz boosts, causing their hadronic decay products to become collimated into single jets.

**Tutorial** AKjDPG 1.3 Sun 16:00 AM 00.014

**Probing hot and dense QCD matter with dileptons** — •ANTON ANDRONIC — University of Münster

I will introduce the dileptons as probes of the hot and dense QCD matter created in heavy-ion collisions and will explain the challenges of the measurement through examples in several experiments. The planned measurements in ALICE and CBM will also be discussed.

### AKjDPG 2: jDPG/AKPIK Programmierworkshop (joint session AKjDPG/AKPIK)

Time: Sunday 17:30–19:00

Location: AM 00.014

**Tutorial** AKjDPG 2.1 Sun 17:30 AM 00.014

**Resource-Aware Deep Learning: Tracking Energy Consumption in Scientific AI Applications** — •KEVIN SCHMITZ<sup>1</sup>, ANNO KNIERIM<sup>1</sup>, and RAPHAEL FISCHER<sup>2</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>Lamarr Institute for ML & AI, Dortmund, Germany

Deep learning has become an indispensable tool across physics and astronomy, yet its growing computational demands increasingly raise questions about energy efficiency and sustainability. This tutorial introduces physicists to the principles of resource-aware deep learning, focusing on practically quantifying, understanding, and optimizing the energy consumption of deep learning models. We begin by outlining different approaches for tracking model power usage, ranging from static estimation methods to dynamic profiling tools validated against ground-truth measurements, and demonstrate how these concepts are implemented in practice using the Lamarr Energy Tracker, developed at the Lamarr Institute for Machine Learning and Artificial Intelligence, for straightforward monitoring of GPU and CPU utilization during training or inference. Finally, we show how resource metrics can be visualized together with reconstruction accuracy using an example from radio interferometric imaging, where super-resolution neural networks reconstruct astrophysical sources from sparse visibility data. The session provides conceptual foundations and practical guidance for integrating sustainability into scientific machine learning workflows, empowering researchers to balance predictive performance with environmental responsibility.

### AKjDPG 3: yHEP/jDPG Physicists Beyond Academia I

Time: Tuesday 13:00–13:25

Location: AM 00.014

**Invited Talk** AKjDPG 3.1 Tue 13:00 AM 00.014

**From a career in academia to cutting-edge research in industry** — •ACHIM SCHÖLL — Carl Zeiss SMT GmbH Rudolf-Eber-Strasse 2 73447 Oberkochen; Germany

In this talk, I will share my journey from a career in academia to my current role as a research scientist in EUV lithography at ZEISS SMT. I will discuss the challenges and opportunities encountered during this transition and how my background has shaped my work in a cutting-edge technology industry. Additionally, I will emphasize how physicists can thrive in diverse career paths beyond traditional academic roles and the impact they can have in a dynamic industrial environment.

### AKjDPG 4: yHEP/jDPG Physicists Beyond Academia II

Time: Tuesday 19:00–21:00

Location: AM 00.014

**Invited Talk** AKjDPG 4.1 Tue 19:00 AM 00.014

**from a nuclear physicist to a nuclear instrumentation architect** — •BANU OEZEL TASHENOV — Framatome GmbH, Erlangen, Germany

In this invited talk, I will introduce my professional journey as a nuclear physicist, highlighting the key stages of my education, career development, and transition into my current role in industry.

I will outline my education and early research experience in experimental nuclear physics, highlighting how this training influenced my analytical thinking and problem-solving approach.

The talk will then focus on my professional experience beyond academia, including my work at Framatome GmbH, where I currently serve as a Nuclear Instrumentation Architect. I will describe the mission of the company, the nature of our work, ongoing projects, my current responsibilities, and how physics-based thinking contributes to real-world applications and technological innovation.

This presentation aims to provide an overview of my personal and professional path, while offering perspective on career development for nuclear physicists working at the interface of science, technology, and industry.

**Invited Talk**AKjDPG 4.2 Tue 19:25 AM 00.014

**From ATLAS to Banking** — •ELIAS RÜTTINGER — Deutsche Kreditbank AG

Although many physicists do not plan it initially, their professional paths often lead outside academic research. This talk traces my transition from high-energy physics into the banking sector, with a focus on applied data science at Deutsche Kreditbank (DKB). After completing a PhD, I first worked at a project management organization for the German Federal Ministry for Economic Affairs and Climate Action (BMWi), evaluating industrial research projects. I then joined DKB in risk controlling, where I worked on analytical tasks and Monte Carlo simulations for practical risk assessment. In a subsequent step, my work shifted toward fraud prevention, where I now develop machine-learning models for operational use. The talk illustrates how methods familiar from physics – such as modeling, statistics, and software development – can be transferred to a regulated, industry-driven environment and create tangible impact.

**Invited Talk**AKjDPG 4.3 Tue 19:50 AM 00.014

**Podium discussion with the three speakers** — •MICHAEL LUPBERGER — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — yHEP

A podium discussion follows the presentations of the three speakers. They are all former physicists from our field now working outside academia. The audience is welcome to ask questions, in particular regarding e.g. career path, skills learned in physics usable in the commercial sector, working atmosphere, decision-making for leaving academia and much more. I will moderate the discussion and co-chair the presentations of the speakers.

**get together with Beer & Brezel**

**AKjDPG 5: Artificial Intelligence in Scientific Publishing (joint session AGI/AKjDPG/AKPIK)**

Time: Wednesday 13:45–15:45

Location: KH 00.011

See AGI 3 for details of this session.



Working Group on Physics, Modern IT and Artificial Intelligence

Arbeitskreis Physik, moderne Informationstechnologie und Künstliche Intelligenz

(AKPIK)

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Overview of Invited Talks and Sessions

(Lecture halls KS 00.003 and KS H C)

Invited Talks

|           |     |             |        |                                                                                                                              |
|-----------|-----|-------------|--------|------------------------------------------------------------------------------------------------------------------------------|
| AKPIK 3.1 | Tue | 11:00–11:30 | KS H C | <b>Large Language Models for Research Data Access</b> — •JUTTA SCHNABEL                                                      |
| AKPIK 3.2 | Tue | 11:30–12:00 | KS H C | <b>Deep Learning-Based Imaging of MeerKAT Observations</b> — •KEVIN SCHMITZ                                                  |
| AKPIK 3.3 | Tue | 12:00–12:30 | KS H C | <b>Towards FAIR fundamental physics: PUNCH4NFDI approach</b> — •VICTORIA TOKAREVA, IVAN KNEŽEVIĆ, HARRY ENKE, ANDREAS HAUNGS |

Sessions

|               |     |             |           |                                                                                          |
|---------------|-----|-------------|-----------|------------------------------------------------------------------------------------------|
| AKPIK 1.1–1.1 | Sun | 17:30–19:00 | AM 00.014 | <b>jDPG/AKPIK Programmierworkshop (joint session AKjDPG/AKPIK)</b>                       |
| AKPIK 2.1–2.8 | Mon | 16:00–18:00 | KS 00.003 | <b>Parallel Talks</b>                                                                    |
| AKPIK 3.1–3.3 | Tue | 11:00–12:30 | KS H C    | <b>Invited Talks</b>                                                                     |
| AKPIK 4.1–4.4 | Wed | 13:45–15:45 | KH 00.011 | <b>Artificial Intelligence in Scientific Publishing (joint session AGI/AKjDPG/AKPIK)</b> |

## Sessions

– Invited Talks, Tutorials, Discussions, and Contributed Talks –

### AKPIK 1: jDPG/AKPIK Programmierworkshop (joint session AKjDPG/AKPIK)

Time: Sunday 17:30–19:00

Location: AM 00.014

See AKjDPG 2 for details of this session.

### AKPIK 2: Parallel Talks

Time: Monday 16:00–18:00

Location: KS 00.003

AKPIK 2.1 Mon 16:00 KS 00.003

**Metadata Analysis for the Square Kilometre Array Max Planck Institute Telescope** — •FELIX WERSIG and LUCA DAVIDE DI BELLA — TU Dortmund University

The Square Kilometre Array Max Planck Institute (SKAMPI) telescope has been operating since 2019 at the Karoo Radio Astronomy Reserve, collecting metadata from the receiver, the antenna control unit and the MeerKAT weather sensors for many observations under diverse conditions. Searching for unusual patterns in the metadata could be a key method for assessing data quality and identifying maintenance needs.

The SKAMPI telescope is designed as a 15 m prototype dish for MeerKAT+ and the SKA-Mid component of the Square Kilometre Array Observatory. The SKA-Mid component is going to consist of 197 parabolic dishes incorporating the MeerKAT+ radio telescope. Its layout will consist of a ~1 m central core and antennas radiating out from it up to a diameter of 150 km.

Ensuring that a large fraction of the antennas remain operational at all times is a key challenge given the large number of antennas and extensive distances present in the planned layout. Leveraging the large dataset collected by the SKAMPI telescope, a preliminary tool for quick analysis of the collected metadata from a dish is presented.

AKPIK 2.2 Mon 16:15 KS 00.003

**Calibration in radio interferometer simulations using pyvisgen** — •SADIAH AZEEM<sup>1</sup>, KEVIN SCHMITZ<sup>1,2</sup>, ANNO KNIERIM<sup>1,2</sup>, and CHRISTIAN ARAUNER<sup>1,2</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>Lamarr Institute for Machine Learning and Artificial Intelligence, Dortmund, Germany

Modern physics experiments greatly benefit from the ability to reproduce entire measurement processes through realistic simulations. In radio interferometry, such simulations enable testing of calibration and data analysis pipelines and allow estimation of the discovery potential for faint astrophysical sources. `pyvisgen` is a Python framework designed to generate radio interferometric visibilities based on the radio interferometer measurement equation (RIME) and is a part of the `radionets-project`, which uses deep learning based methods for radio interferometric imaging. Realistic simulations must include instrumental and atmospheric effects that corrupt the measured visibilities such as antenna gains and tropospheric delays. They also provide the ground truth needed to test and evaluate calibration methods. This talk will outline how to generate RIME-consistent corrupted visibilities and apply them to the development of calibration methods.

AKPIK 2.3 Mon 16:30 KS 00.003

**Simulating Protoplanetary Disks as Training Data for Neural Network based Reconstruction of Radio Interferometer Measurements** — •TOM GROSS<sup>1,2</sup>, KEVIN SCHMITZ<sup>1,2</sup>, CHRISTIAN ARAUNER<sup>1,2</sup>, and ANNO KNIERIM<sup>1,2</sup> — <sup>1</sup>TU Dortmund University — <sup>2</sup>Lamarr Institute for Machine Learning and Artificial Intelligence

Understanding the evolution of planetary systems is an important research field in modern astronomy. Planets form through accretion processes of dust and gas in protoplanetary disks around young stars.

The thermal radiation of the disks is measurable in the radio spectrum using radio interferometers. These enable the observation of small structures but only measure samples of an incomplete Fourier space. This intrinsic limitation results in noisy images, unsuitable for physical analyses.

The `radionets-project` uses a modern deep-learning framework to reconstruct the missing information. To enhance the scientific interpretation of the reconstructions, the training data needs to represent realistic source distributions. The software `FARGO3D` simulates the distribution of dust and gas in a protoplanetary disk using a hydrodynamical model. From these distributions, the thermal radiation can be simulated using Monte Carlo methods. This presentation shows the results of the simulations and how they are integrated into the data pipeline for the deep-learning based reconstruction.

AKPIK 2.4 Mon 16:45 KS 00.003

**ParaO: In situ reproducible workflows through user-centric design** — MARTIN ERDMANN, •BENJAMIN FISCHER, and FELIX ZINN — III. Physikalisches Institut A, RWTH Aachen University

In High Energy Physics (HEP) and other fields, data analyses require many different steps to produce a final result. As such, it is sensible to leverage workflow tools to codify these complex structures of tasks and their dependencies. Of course, such intricate analyses are not created ad hoc; rather, their development is a lengthy and iterative process.

Here, ParaO's design empowers users to rapidly grow and readily adapt their work while avoiding verbose boilerplate. For example, integrating a new parameter or dependency in the middle of a ten-step workflow needs just a single line of code. There, ParaO automatically propagates the resulting knock-on effects, such as changed implicit parameterization of later tasks—unlike Luigi, which requires a more manual treatment.

Thus, ParaO enables in situ usage of workflows and their benefits, such as bookkeeping and reproducibility, even in early and chaotic stages of development. We demonstrate ParaO's principles and features in the context of a comprehensive top-Higgs analysis.

AKPIK 2.5 Mon 17:00 KS 00.003

**Cleaning MOJAVE observations with neural networks** — •CHRISTIAN ARAUNER<sup>1,2</sup>, KEVIN SCHMITZ<sup>1,2</sup>, ANNO KNIERIM<sup>1,2</sup>, and TOM GROSS<sup>1,2</sup> — <sup>1</sup>TU Dortmund University — <sup>2</sup>Lamarr Institute for Machine Learning and Artificial Intelligence

Radio interferometry enables observations of astronomical objects with high angular resolution. However, the inherent incompleteness of the  $(u, v)$ -plane sampling leads to significant noise and artifacts in the reconstructed images. Existing state-of-the-art cleaning algorithms effectively mitigate these effects but are computationally demanding, not easily reproducible and not readily scalable to the data volumes anticipated from next-generation radio telescopes. As a promising alternative, neural network-based approaches offer the potential to automate and accelerate the image reconstruction process.

The Python package `radionets` implements a deep-learning framework for the reconstruction of calibrated data from radio observations. In this approach, ResNets are used to reconstruct the missing values directly in the  $(u, v)$ -plane. The validity of the neural network-based approach has been shown with simulated data, now it is possible to apply it to real measurements from the MOJAVE program. The observations of the MOJAVE archive are particularly suitable for the development and testing of these neural networks as it comprises a large data set of high-quality data, measured over a long period of time.

In this talk, I will present first observations of the MOJAVE program, reconstructed with `radionets`.

AKPIK 2.6 Mon 17:15 KS 00.003

**Methodological Preparation for Measurements with the DSA-2000: Simulation, Analysis, and Reconstruction Using Neural Networks** — •JONAS GROSSMANN<sup>1</sup>, KEVIN SCHMITZ<sup>1,2</sup>, ANNO KNIERIM<sup>1,2</sup>, CHRISTIAN ARAUNER<sup>1,2</sup>, and TOM GROSS<sup>1,2</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>Lamarr Institute for Machine Learning and Artificial Intelligence, Dortmund, Germany

A new generation of radio telescopes is set to begin operations later this decade. Among these is the Deep Synoptic Array 2000 (DSA-2000), a radio survey interferometer. It comprises 2000 small antennas, each 5 m in diameter, distributed over an area of 160 square kilometres in the Nevada Desert, USA. This configuration is optimised for rapid, high-resolution surveys of the entire northern sky. The DSA-2000 will achieve at least an order of magnitude improvement in angular resolution, enabling the discovery of billions of previously unknown radio sources. The resulting data volumes are unprecedented, surpassing the capabilities of conventional analysis methods and necessitating new approaches for translating interferometric measurements into cleaned images. The

**radionets-project** group at TU Dortmund University aims to develop neural networks that, could automatically reconstruct dirty radio images. Training these networks requires large, realistic datasets. Given that all 2000 antennas cannot operate flawlessly at all times, the goal is to train the networks to deliver stable and reliable reconstructions even when subsets of antennas are inactive. This talk outlines the framework in **radionets-project** required to create the datasets necessary for training these neural networks.

AKPIK 2.7 Mon 17:30 KS 00.003

**Resource Awareness in Deep Learning-based Imaging in Radio Interferometry** — •ANNO KNIERIM<sup>1,2</sup>, KEVIN SCHMITZ<sup>1,2</sup>, CHRISTIAN ARAUNER<sup>1,2</sup>, RAPHAEL FISCHER<sup>1,2</sup>, DOMINIK ELSÄSSER<sup>1,2</sup>, and WOLFGANG RHODE<sup>1,2</sup> — <sup>1</sup>TU Dortmund University, Dortmund, Germany — <sup>2</sup>Lamarr Institute for Machine Learning and Artificial Intelligence, Dortmund, Germany

Recent approaches in radio interferometry aim to improve image cleaning of measurements using machine learning techniques. Reconstructing sources using these novel techniques has the advantage of being agnostic to the initial parameters used in traditional cleaning algorithms.

The **radionets-project** is a multi-software environment developed at TU Dortmund University. The main deep-learning framework, **radionets**, reconstructs calibrated data from radio observations using convolutional neural networks (CNNs). The framework aims to achieve a high dynamic range and produce high-resolution source images.

Due to their high complexity, applying deep learning models sustainably requires balancing predictive performance with resource consumption. The environmental impacts extend well beyond training, as model complexity also affects the efficiency during data simulation and inference. This talk presents ongoing

efforts to track and estimate the environmental impact of our models using CodeCarbon, PyTorch Lightning, and MLFlow.

AKPIK 2.8 Mon 17:45 KS 00.003

**FAIR-Driven Retrospective Metadata Enrichment for KCDC Digital Resources** — •VICTORIA TOKAREVA — Karlsruhe Institute of Technology, Institute for Astroparticle Physics, 76021 Karlsruhe, Germany

The KASCADE Cosmic-Ray Data Centre (KCDC) is an established open data archive in astroparticle physics with more than a decade of experience in long-term data preservation. It aims to apply modern technologies to maximise the accessibility, usability, and scientific value of research data for a broad audience, from professional researchers to students, citizen scientists, and science enthusiasts, while advancing the use of FAIR (Findable, Accessible, Interoperable, Reusable) practices. Operating within a data-intensive high-energy physics environment, we address community-wide challenges such as the large data volumes produced in astroparticle physics and the complexity of formats like ROOT and HDF5, which require domain-specific software and specialised approaches for machine-actionable metadata extraction. To support interdisciplinary discovery and integration into infrastructures such as PUNCH4NFDI, we extend established metadata with additional discovery-oriented elements and references, including domain knowledge historically dispersed in scientific publications. In this contribution, we present an enhanced metadata model for KCDC digital resources featuring expanded use of persistent identifiers and increased semantic connectivity. We also demonstrate how natural language processing and large language models support retrospective metadata enrichment for archival KASCADE datasets.

### AKPIK 3: Invited Talks

Time: Tuesday 11:00–12:30

Location: KS H C

#### Invited Talk

AKPIK 3.1 Tue 11:00 KS H C

**Large Language Models for Research Data Access** — •JUTTA SCHNABEL for the KM3NET-ERLANGEN-Collaboration — ECAP, FAU Erlangen-Nürnberg

In a strive to provide ever more interoperable, complex scientific data to a wide range of users across scientific domains, new approaches to lower the boundaries for the access to research data are called for. To address the collection, reduction and analysis of data, as well as its storage, sharing and finding, Large Language Models (LLMs) offer an intriguing opportunity. They can facilitate the transition in research data management from Big Data to Smart Data by increasing the effectiveness of research workflows and the efficiency of data discovery, curation, and reuse especially in the physics domain. This contribution will introduce the uptake of LLMs for data management as pursued in the Physics-LLM project in ErUMData, starting from the application of LLMs in the KM3NeT collaboration.

#### Invited Talk

AKPIK 3.2 Tue 11:30 KS H C

**Deep Learning-Based Imaging of MeerKAT Observations** — •KEVIN SCHMITZ — TU Dortmund University, Dortmund, Germany — Lamarr Institute for ML & AI, Dortmund, Germany

Modern radio interferometers such as MeerKAT produce vast amounts of data that enable high-resolution imaging of astrophysical sources but also pose significant challenges for image reconstruction. Classical deconvolution algorithms like CLEAN struggle with noise artifacts and limited scalability. The deep-learning framework **radionets** addresses these issues by combining simulated observations with neural-network-based image reconstruction.

Using the Radio Interferometer Measurement Equation (RIME), realistic simulations model signal propagation and systematic effects in the measured data. These synthetic datasets allow convolutional neural networks to be trained under controlled conditions, enabling quantitative studies of image quality, uncertainty estimates, and computational efficiency.

The framework reconstructs sparse data directly in Fourier space before trans-

forming them into clean sky images, achieving higher positional accuracy and flux recovery than standard tools, especially for wide-field observations containing both compact sources and diffuse emission. I will present its application to real MeerKAT observations, compare the results with classical methods, and illustrate how physics-guided machine learning improves data quality and interpretation in radio astronomy.

#### Invited Talk

AKPIK 3.3 Tue 12:00 KS H C

**Towards FAIR fundamental physics: PUNCH4NFDI approach** — •VICTORIA TOKAREVA<sup>1</sup>, IVAN KNEŽEVIĆ<sup>2</sup>, HARRY ENKE<sup>3</sup>, and ANDREAS HAUNGS<sup>1</sup> — <sup>1</sup>Karlsruhe Institute of Technology, Karlsruhe, Germany — <sup>2</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — <sup>3</sup>Leibniz-Institute for Astrophysics, Potsdam, Germany

Research data management is becoming increasingly important in data-intensive fundamental physics, including astroparticle, particle, nuclear and astrophysics. Growing data volumes and complexity, increasing interdisciplinarity, high costs of data acquisition and processing, and rising expectations for open science and AI-ready digital research outputs are driving these communities toward FAIR (Findable, Accessible, Interoperable, Reusable) data management practices. Key efforts in this direction include reuse and practical harmonisation of semantic artefacts such as metadata schemas, thesauri and controlled vocabularies; making explicit expert knowledge embedded in collaboration-internal data transformations, specialised software tools, and internal data formats (e.g., FITS, ROOT, HDF5); and defining minimal requirements for reusable digital research objects. This talk presents the multi-layer metadata model and the concept and the use-case-based implementations of Digital Research Product, developed within the PUNCH4NFDI (Particles, Universe, NuClei and Hadrons for the German National Research Data Infrastructure, punch4nfdi.de) consortium in the context of a modern FAIR Data landscape and as core elements of the PUNCH4NFDI Science Data Platform.

### AKPIK 4: Artificial Intelligence in Scientific Publishing (joint session AGI/AKJDPG/AKPIK)

Time: Wednesday 13:45–15:45

Location: KH 00.011

See AGI 3 for details of this session.

## Working Group on Physics and Disarmament Arbeitsgruppe Physik und Abrüstung (AGA)

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Zur Abrüstung, der Verhinderung der Verbreitung von Massenvernichtungsmitteln und der Beurteilung neuer Waffentechnologien sind naturwissenschaftliche Untersuchungen unverzichtbar. Auch bei der Verifikation von Rüstungskontrollabkommen werden neue Techniken und Verfahren benötigt und eingesetzt. Schwerpunkte in diesem Jahr bilden Themen wie die nukleare Abrüstung, Verifikation bzw. die Detektion von Nuklearanlagen und Materialien, Raketenabwehr und Zerstörung von Nuklearsprengköpfen, neue militärrelevante Technologien wie Drohnen. Die Fachsitzung wird von der DPG gemeinsam mit dem Forschungsverbund Naturwissenschaft, Abrüstung und internationale Sicherheit FONAS durchgeführt. Die 1998 gegründete Arbeitsgruppe Physik und Abrüstung ist für die Organisation verantwortlich. Die Sitzung soll international vorrangige Themen behandeln, Hintergrundwissen vermitteln und Ergebnisse neuerer Forschung darstellen.

### Overview of Invited Talks and Sessions

(Lecture hall KH 00.016)

#### Invited Talks

|         |     |             |           |                                                                                                          |
|---------|-----|-------------|-----------|----------------------------------------------------------------------------------------------------------|
| AGA 1.1 | Wed | 14:00–15:00 | KH 00.016 | <b>How Missile Defence Works. A Look into Technical Details</b> — •MARKUS SCHILLER                       |
| AGA 1.2 | Wed | 15:00–16:00 | KH 00.016 | <b>Technical and Security Aspects of Hypersonic Weapons</b> — •DAVID WRIGHT                              |
| AGA 4.1 | Thu | 11:00–12:00 | KH 00.016 | <b>Quantum Technology Military Applications and Strategic Implications for Defence</b> — •MICHAL KRELINA |
| AGA 4.2 | Thu | 12:00–13:00 | KH 00.016 | <b>Risiko Dual-use-Forschung</b> — •WOLFGANG LIEBERT                                                     |
| AGA 6.1 | Thu | 15:15–16:15 | KH 00.016 | <b>Modeling Nuclear Weapon Effects from Trinity to Nuclear War</b> — •SÉBASTIEN PHILIPPE                 |
| AGA 6.2 | Thu | 16:15–17:15 | KH 00.016 | <b>From Local Impacts to Global Risks: New Science on Nuclear War Consequences</b> — •FRIEDERIKE FRIESS  |

#### An Overview of Physics and Disarmament Research in Germany – Social Event & Poster Session

This session offers an overview of physics research focusing on disarmament issues in Germany. Different research groups will introduce themselves and present brief summaries of their current work. In addition, posters covering a range of related topics will be on display. The session also provides opportunities for discussion and networking with the researchers.

#### Sessions

|              |     |             |           |                                                                                                       |
|--------------|-----|-------------|-----------|-------------------------------------------------------------------------------------------------------|
| AGA 1.1–1.3  | Wed | 14:00–16:30 | KH 00.016 | <b>Missile Defense and Outer Space</b>                                                                |
| AGA 2.1–2.3  | Wed | 17:00–18:30 | KH 00.016 | <b>Nuclear Fuel Cycle</b>                                                                             |
| AGA 3        | Wed | 18:30–19:15 | KH 00.016 | <b>Members' Assembly</b>                                                                              |
| AGA 4.1–4.2  | Thu | 11:00–13:00 | KH 00.016 | <b>Dual-Use Technologies</b>                                                                          |
| AGA 5.1–5.2  | Thu | 14:00–15:00 | KH 00.016 | <b>Safeguards</b>                                                                                     |
| AGA 6.1–6.2  | Thu | 15:15–17:15 | KH 00.016 | <b>Nuclear Weapon Effects</b>                                                                         |
| AGA 7.1–7.10 | Thu | 17:30–18:30 | KH 00.016 | <b>An Overview of Physics and Disarmament Research in Germany – Social Event &amp; Poster Session</b> |
| AGA 8.1–8.3  | Fri | 9:30–11:00  | KH 00.016 | <b>Verification</b>                                                                                   |

#### Members' Assembly of the Working Group on Physics and Disarmament

Mittwoch 18:30–19:15 KH 00.016

- Bericht
- Wahl
- Verschiedenes

## Sessions

– Invited Talks, Contributed Talks, and Posters –

### AGA 1: Missile Defense and Outer Space

Time: Wednesday 14:00–16:30

Location: KH 00.016

**Invited Talk** AGA 1.1 Wed 14:00 KH 00.016

**How Missile Defence Works. A Look into Technical Details** — •MARKUS SCHILLER — ST Analytics München

Missile defence has lived through a renaissance over the past few years. With an increased use of missiles in conflicts since the Second Nagorno-Karabakh War 2020, the defence against missile attacks also became an ever more important issue. This is true not only on the tactical level, but also on the greater strategic stage, as America's plans for a "Golden Dome" vividly illustrate. This presentation will give an overview of conflicts where missiles have played a role, thus pointing out the renewed interest for defence systems, and it will try to offer insights into the physical and technical basics of missile defence systems, to make the problem of missile defence more accessible.

**Invited Talk** AGA 1.2 Wed 15:00 KH 00.016

**Technical and Security Aspects of Hypersonic Weapons** — •DAVID WRIGHT — Laboratory for Nuclear Security and Policy, MIT

Hypersonic weapons travel faster than Mach 5 and use atmospheric forces to glide at low altitudes. Boost-glide vehicles (BGV) use rocket boosters to reach high speeds and then glide without powered. Hypersonic cruise missiles (HCM) are also boosted to high speeds but use a scramjet engine to provide power during part of their atmospheric flight.

Hypersonic weapons have gained considerable attention due to their purported advantages over existing missiles - including short delivery times, high

maneuverability, and invulnerability to defenses which some proponents have said will "revolutionize warfare". However, technical analysis and computer simulations show that the fundamental physics of hypersonic flight severely constrains their performance. Comparison with existing ballistic missiles shows that many claims about the advantages of hypersonic weapons are overstated or incorrect.

This talk will discuss the physics and technology of BGVs and HCMs and their limitations in terms of speed, range, and maneuverability

AGA 1.3 Wed 16:00 KH 00.016

**The Emerging Weaponization of Outer Space and Possible Restraint Measures** — •GÖTZ NEUNECK — Federation of German Scientists

The challenges of a more congested and weaponized space environment are rising due to geopolitical rivalries of space-faring nations. The leading space powers accuse each other of weaponizing space while testing stealthy satellites and rendezvous and proximity operations (RPOs), direct-ascent ground-based interceptors and preparing space-based interceptors. Armed conflict in space and the deliberate destruction of satellites can cause much short-term havoc in the space environment causing long-term consequences for different space constellations. Also nuclear weapons in space can not be ruled-out any longer. The arms control history is full confidence building measures and regulations but lack on implementation. The talk summarizes the threat and discusses possible measures of restraint.

### AGA 2: Nuclear Fuel Cycle

Time: Wednesday 17:00–18:30

Location: KH 00.016

AGA 2.1 Wed 17:00 KH 00.016

**Nuclear archaeology with reprocessing waste: a Bayesian framework for reconstructing reactor operating parameters** — •BENJAMIN JUNG — Peace Research Institute Frankfurt (PRIF), Frankfurt, Germany — Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen, Aachen, Germany

In order to verify declarations of fissile material for nuclear disarmament and non-proliferation regimes, nuclear archaeology seeks to reconstruct a state's history of fissile material production by analysing the isotopic composition of samples of material collected at its nuclear facilities. The novel Bayesian Reprocessing Waste Analysis Method (BRAM) aims to use waste from nuclear reprocessing activities as evidence for nuclear archaeology. Through simulation-based case studies, I demonstrate that this Bayesian framework can identify the type of source reactor and reconstruct important parameters such as burnup, cooling time, initial enrichment and power density. Using experimental data from the SFCOMPO database, I have successfully taken the first steps towards validating the framework by correctly reconstructing the operating parameters of a Magnox-type reactor and a pressurised water reactor (PWR). These results demonstrate the framework's potential and encourage further research and development in preparation for real-world applications.

AGA 2.2 Wed 17:30 KH 00.016

**China's growing plutonium stockpile: Modelling the new CFR-600 reactors** — •LAURA MERTES<sup>1</sup>, JULIEN DE TROULLIQUOT DE LANVERSIN<sup>2</sup>, MATTHIAS ENGLERT<sup>3</sup>, FRIEDERIKE FRIESS<sup>4</sup>, and MALTE GÖTTSCHE<sup>1</sup> — <sup>1</sup>TU Darmstadt, PRIF — <sup>2</sup>The Hong Kong University of Science and Technology — <sup>3</sup>Öko-Institut — <sup>4</sup>BOKU University

China vastly expands the construction of new reactors to reach less dependence on coal. Two of more than 30 reactors under construction are sodium-cooled fast breeder reactors of type CFR-600, that are declared for civilian purposes, and their start of operation seems imminent according to satellite imagery. Fast reactors can be operated to produce more fissile material than they consume and the bred plutonium can be weapons-grade. This leads to proliferation risks typ-

ically associated with fast reactors.

Despite the reactors' importance, there are no publicly available studies on the CFR-600's possible plutonium production rates which are necessary for the assessment of the Chinese nuclear modernization campaign.

We present burnup simulation results on the CFR-600 plutonium production using OpenMC and publicly accessible input data. Due to a lack of available data, that are required for the simulation, we resort to an alternative ansatz and include information of similar reactor types which may share significant similarities to the CFR-600. This procedure as well as the adaption to the Chinese fast breeder reactor involves a broad discussion of the role of uncertainties and not-knowing and the impact on the estimation of the plutonium production.

AGA 2.3 Wed 18:00 KH 00.016

**Safeguards Monitoring in Geological Repositories - Physics, Systematics, Interfaces, and Constraints** — •MATTHIAS ENGLERT — Öko-Institut, Rheinstraße, 95 Darmstadt

We outline a technical framework to integrate safeguards-relevant monitoring into the context of long-term safety for deep geological repositories. The approach maps monitoring measures (e.g., passive seismics, borehole radar, anti-neutrino detection, myon tomography) to Features-Events-Processes (FEP) catalogues and to safety functions (containment, isolation, retardation) across salt, clay, and crystalline host rocks. Using THMC classification and life-cycle phases (operation, closure, post-closure), we identify influence pathways such as direct paths via installation, heat, or mechanical perturbations, and indirect paths such as signal interpretation and scenario screening. The framework supports completeness and consistency checks by grouping by physics principle, intrusiveness, range, or system coupling and describes trade-offs between verification demands and barrier integrity. Preliminary results emphasize standardised tabulation for comparability, explicit treatment of uncertainties, and criteria for selecting complementary techniques. The aim is a transparent, auditable coupling of safeguards information with safety assessment reasoning rather than a new safety methodology.

## AGA 3: Members' Assembly

Time: Wednesday 18:30–19:15

Location: KH 00.016

All members of the Working Group on Physics and Disarmament are invited to participate.

## AGA 4: Dual-Use Technologies

Time: Thursday 11:00–13:00

Location: KH 00.016

## Invited Talk

AGA 4.1 Thu 11:00 KH 00.016

**Quantum Technology Military Applications and Strategic Implications for Defence** — •MICHAL KRELINA — University of Prague

Quantum technologies are emerging as force multipliers for military and intelligence activities by transforming how information is collected, processed, secured and exploited. Near-term applications are most visible in quantum sensing and communications, with implications for navigation and timing in GNSS-denied environments, enhanced submarine and underground detection, improved ISR performance, and highly secure command-and-control links for strategic and high-value assets. These capabilities promise greater resilience and precision, but also challenge existing assumptions about stealth, survivability and situational awareness. Quantum computing, while longer-term, carries profound intelligence implications through its potential to undermine current cryptographic systems, accelerate code-breaking and pattern analysis, and optimise complex military operations and logistics. The uneven pace of quantum adoption across states may generate new asymmetries, compress decision-making timelines and complicate deterrence and escalation dynamics. As quantum technologies converge with AI, cyber and space systems, their military significance will extend beyond individual capabilities to reshape intelligence advantage, operational planning and strategic stability

## Invited Talk

AGA 4.2 Thu 12:00 KH 00.016

**Risiko Dual-use-Forschung** — •WOLFGANG LIEBERT — ISRW, BOKU Wien

Ausgehend von der Frage, um was es geht, wenn von Dual-use die Rede ist, wird die Entwicklung von Dual-use-Forschungskonzepten und ihre aktuelle Renaissance in Europa und Deutschland (zuletzt durch ein Positionspapier des Wissenschaftsrates) dargestellt. Die bislang beachtete Unterscheidung einer zivilen und einer militärischen Wissenschaftskultur soll durch die bewusste Schaffung von Grauzonen und entsprechende Forschungs- und Technologieförderung aufgehoben werden. Diskutiert werden (auch anhand von beispielhaften Entwicklungen) die erwartbaren Folgen — insbesondere für Universitäten und weitere zivile Forschungseinrichtungen. Ein postulierter, aber unreflektierter "Zwang" zur Verteidigungsforschung steht einer anderen Vorstellung von Verantwortungsübernahme in der Wissenschaft gegenüber. Einige Risiken durch Dual-use-Förderstrategien werden diskutiert. Dazu gehören: die schwer revidierbare Verwandlung der Wissenschaftskultur, unerwünschte Folgen für humanitäre und internationale Sicherheit, Herausforderungen für Rüstungskontrolle und Nonproliferation sowie ethische Dilemmata. Dies führt zu weiteren Fragen: Wie könnte eine angemessene individuelle und institutionelle Verantwortungsübernahme aussehen? Kann eine tiefergehende Analyse der wissenschaftlich-technologischen Dynamik den dringlichen Diskurs über Dual-use-Forschung unterstützen?

## AGA 5: Safeguards

Time: Thursday 14:00–15:00

Location: KH 00.016

AGA 5.1 Thu 14:00 KH 00.016

**Assessing safeguards challenges in compact reactors through antineutrino detection** — •SARAH FRIEDRICH, ROBIN MENTEL, YAN-JIE SCHNELLBACH, and ADHITYA SEKHAR — Technische Universität Darmstadt, Germany

Small Modular Reactors (SMRs) and advanced reactor and fuel types promise enhanced nuclear safety and greater operational flexibility, but they may also introduce new challenges to safeguarding efforts. To support the monitoring of SMRs and the detection of nuclear material diversion, we propose employing antineutrinos, which can be detected by a liquid-organic time-projection chamber outside of the reactor building, allowing non-intrusive, continuous, real-time measurements. The objective is to identify undeclared shutdowns, verify declared operational parameters and detect the diversion of nuclear material.

Our research builds on computational reactor simulations performed with OpenMC and Geant4 for a prototype 300-MWth pressurized water SMR, which allows us to investigate a cluster of several SMRs in close proximity to one another. We analyze how the energy spectrum of detected antineutrinos changes over time with a special focus on the spectrum before and after the declared shutdown of one module, where refuelling takes place. In a further step, we investigate whether the number and spectrum of detected antineutrinos can be used to identify undeclared shutdowns of a module.

AGA 5.2 Thu 14:30 KH 00.016

**Developing antineutrino-based safeguards for naval reactors** — •ROBIN TOBIAS MENTEL, SARAH FRIEDRICH, YAN-JIE SCHNELLBACH, and ADHITYA SEKHAR — Technische Universität Darmstadt

In a world with an increasingly chaotic security landscape, the danger of nuclear proliferation is rising. In recent years, a potential proliferation concern has emerged with the planned employment of nuclear propulsion in submarines by Non-Nuclear Weapon States under the NPT. A prominent example of this is the sale of conventionally armed, nuclear-powered attack submarines by the US and the UK to Australia under the AUKUS agreement. Here, it is important to give safeguards inspectors powerful tools for a comprehensive and reliable safeguards regime, capable of detecting a diversion of weapons-grade nuclear material. We present our research on the development and the detailed simulation of antineutrino monitoring of a few nuclear-powered submarines anchored in the base of a consenting host state. To this aim, we will simulate the antineutrino emission from a naval reactor, simulated by OpenMC, and the subsequent detection in a tonne-scale active medium a few meters away, using Geant4. While focusing on the type of nuclear reactors relevant for the AUKUS-class submarines, we will explore the plausible parameter space of nuclear reactors typically employed in other submarines in terms of enrichment fraction (20 to 97%), reactor power (50 to 150 MW<sub>th</sub>), burnup, and reactor geometry, like hexagonal and rectangular symmetry. Finally, we explore ways to implement this technique in the context of safeguards, including detector positioning, sensitivity, and integration times.

## AGA 6: Nuclear Weapon Effects

Time: Thursday 15:15–17:15

Location: KH 00.016

## Invited Talk

AGA 6.1 Thu 15:15 KH 00.016

**Modeling Nuclear Weapon Effects from Trinity to Nuclear War** — •SÉBASTIEN PHILIPPE — University of Wisconsin\*Madison

The Trinity nuclear test of July 16, 1945 marked the first uncontrolled, large-scale release of radioactive material into the atmosphere. In the decades that followed, more than 500 atmospheric nuclear tests produced fallout at local, regional, and global scales, exposing populations worldwide. Yet the spatial and temporal distribution of this fallout remains only partially characterized. This presentation shows how modern tools - combining high-resolution atmospheric transport

models, reanalyzed historical meteorological data, and physics-based nuclear explosion source terms\*enable a new generation of fallout reconstructions. These methods yield hour-by-hour deposition estimates at kilometer-scale resolution, improving assessments of radiological exposure from historical testing, including in regions with sparse or absent monitoring data. The same framework scales directly to contemporary nuclear conflict scenarios. When integrated with population, infrastructure, agricultural, ecological, and other prompt nuclear effects, it enables comprehensive assessments of the physical, environmental, and societal consequences of nuclear war.

## Invited Talk

AGA 6.2 Thu 16:15 KH 00.016

**From Local Impacts to Global Risks: New Science on Nuclear War Consequences** — •FRIEDRIKE FRIESS — BOKU University, Vienna

Heightened geopolitical tensions have renewed attention to the health and environmental consequences of nuclear explosions and war. Reflecting this urgency, WHO has convened a new working group to update its reports on nuclear weapons and health, and the UN Scientific Panel on the Effects of Nuclear War began work last summer, with a comprehensive assessment due by September

2027. Drawing on literature reviews and the authors' participation in the UN panel and respective research, this presentation traces the field's evolution from understanding local impacts to globally integrated monitoring and modeling. We highlight two active areas of research and debate: atmospheric transport of radioactive particles, moving beyond idealized spherical assumptions to more realistic morphologies; and the magnitude of global consequences governed by soot injection from large fires, with implications for climate perturbations and downstream risks to food security and public health.

## AGA 7: An Overview of Physics and Disarmament Research in Germany – Social Event & Poster Session

This session offers an overview of physics research focusing on disarmament issues in Germany. Different research groups will introduce themselves and present brief summaries of their current work. In addition, posters covering a range of related topics will be on display. The session also provides opportunities for discussion and networking with the researchers.

Time: Thursday 17:30–18:30

Location: KH 00.016

AGA 7.1 Thu 17:30 KH 00.016

**Nuclear archaeology with normalizing flows: Learning about past plutonium production from reprocessing waste** — •FABIAN UNRUH<sup>1</sup> and MALTE GÖTTSCHE<sup>1,2</sup> — <sup>1</sup>Peace Research Institute Frankfurt — <sup>2</sup>TU Darmstadt

Plutonium, a material used in nuclear weapons, is produced in nuclear reactors. In reprocessing, plutonium is separated from the fuel rod—a crucial procedure for weaponization—producing highly radioactive waste. Being very informative about operational reactor parameters, an analysis of the waste could be an asset for verifying declarations on plutonium production for an arms control agreement.

In this *nuclear archaeology* approach, the isotopic composition of the waste is analyzed with normalizing flow-based invertible neural networks, which unlike many Deep Learning (DL) techniques output probability density functions rather than point-estimates. The obtained posterior distributions for burnup and time since irradiation can represent multiple modes corresponding to mixtures of waste from several irradiation campaigns. Knowing only true parameter values, but not true posterior distributions, for test data renders validation challenging and requires specific approaches. First, *coverages* of posterior distributions, i.e. the fraction of instances where a confidence region covers the true value, are compared to expectations. Second, clustering algorithms partition multimodal distributions and the probability mass of individual modes is related to the corresponding campaign's share in the total waste. The presented results contribute to developing sound and trustworthy DL techniques for nuclear archaeology.

AGA 7.2 Thu 17:30 KH 00.016

**Analysis of Human Intrusion Scenarios in the context of Site-Marking Concepts for Deep Geological Repositories** — •YANNICK VOGT and FRIEDRIKE FRIESS — Universität für Bodenkultur Wien, Institute of Safety and Risk Sciences, Department of Landscape, Water and Infrastructure, Peter-Jordan-Straße 76, 1190 Vienna, Austria

Scientific consensus suggests the disposal of high-level radioactive waste in deep geological repositories. Such repositories are to be protected against human intrusion. Here, a differentiation can be made between intentional and unintentional intrusion scenarios. Where unintentional intrusion describes intrusion by accident, intentional intrusion scenarios refer to the deliberate locating of a storage site, to recover the resource materials contained within, e.g. plutonium or copper.

Based on a comprehensive literature review, pathways are studied by which a repository might be entered. These pathways include drilling and mining activities, infrastructure projects, archaeological excavations, or military operations. Additional methodological approaches are explored, helping to broaden the horizon of scenario development, such as incorporating thematically related literary works or conducting a creative tabletop workshop.

This work aims to present a comprehensive overview of human intrusion scenarios. The presented results are part of a larger project on site-marking concepts for deep geological repositories.

AGA 7.3 Thu 17:30 KH 00.016

**Advancements in Radionuclide Monitoring with the new German SAUNA Q<sub>b</sub> Systems** — •STEFFEN LUDWIG<sup>1</sup>, SOFIA BRANDER<sup>1</sup>, J. OLE ROSS<sup>2</sup>, SABINE SCHMID<sup>1</sup>, MARTINA KONRAD<sup>1</sup>, ANDREAS ZEHR<sup>1</sup>, ANDREAS BOLLHÖFER<sup>1</sup>, and MORITZ KÜTT<sup>3</sup> — <sup>1</sup>Bundesamt für Strahlenschutz (BfS) — <sup>2</sup>Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) — <sup>3</sup>Hamburg Nuclear Disarmament Laboratory (HaNDL), University of Hamburg

Since 1997, the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization has been monitoring nuclear weapon tests globally through the International Monitoring System. Radionuclide isotopes are produced in characteristic ratios during nuclear fission processes and can be in-

dicators for nuclear explosions. They can even escape from deep underground nuclear tests.

As part of my PhD project in the Atmospheric Radioactivity and Trace Analysis group at BfS and at HaNDL, I will present first data from the new SAUNA Q<sub>b</sub> systems deployed in Freiburg and the Bavarian Forest. These compact systems automatically sample and analyze radionuclides from the atmosphere. Thus, they improve the ability to characterize known radionuclide sources, evaluate Atmospheric Transport and Dispersion Models and identify unknown radionuclide emitters. In particular, traces of Xe-131m, which presumably originate from hospital emissions, will be investigated. Further, I will discuss ideas to combine SAUNA Q<sub>b</sub> data, other radionuclide monitoring data and available emission data to improve source localization within the new European Q<sub>b</sub> network.

AGA 7.4 Thu 17:30 KH 00.016

**Opportunities for Natural-Science and Technical Peace Research** — •JÜRGEN ALTMANN<sup>1</sup>, MATTHIAS ENGLERT<sup>2</sup>, FRIEDRIKE FRIESS<sup>3</sup>, MANUEL KREUTLE<sup>4</sup>, MORITZ KÜTT<sup>5</sup>, CHRISTOPH PISTNER<sup>2</sup>, LUKAS RADEMACHER<sup>6</sup>, and MAX SCHALZ<sup>7</sup> — <sup>1</sup>TU Dortmund University — <sup>2</sup>Öko-Institut Darmstadt — <sup>3</sup>BoKu University Vienna — <sup>4</sup>Forschungszentrum Jülich — <sup>5</sup>University of Hamburg — <sup>6</sup>Peace Research Institute Frankfurt/TU Darmstadt — <sup>7</sup>RWTH Aachen University

FONAS, the Research Association Science, Disarmament and International Security, is the German professional organisation of scientists who conduct peace research based on natural science, engineering, computer science or mathematics. A wide variety of topics is being investigated: consequences of (nuclear) war, escalation potential and strategic stability; monitoring of (military) research and development; assessment of potential new weapon systems; military uses of new technologies under viewpoints of peace and international security and options for preventive arms control; verification technologies for actual and future disarmament, arms control and non-proliferation; proliferation risks from civilian/dual-use technologies. The poster will present examples from present research, with a main focus on research groups in Germany, to raise awareness about such research and to encourage (young) physicists to participate.

AGA 7.5 Thu 17:30 KH 00.016

**nuSENTRY: Safeguards monitoring of future compact reactors using antineutrino detectors** — •YAN-JIE SCHNELLBACH, SARAH FRIEDRICH, ROBIN MENTEL, and ADHITYA SEKHAR — Technische Universität Darmstadt, Darmstadt, Germany

Current developments in the nuclear industry foresee a growth in the number of nuclear power plants, especially driven by a new class of reactor types with < 300 MW<sub>e</sub> power, called Small Modular Reactors (SMRs). The planned decentral deployment of SMRs, combined with technically more integrated and compact designs, present new challenges for safeguards. Antineutrino detectors offer a potential new way of monitoring the fissile material in SMRs. Active reactors produce an unique neutrino fingerprint based on the fissioning isotopes and reactor power. Unlike other radiation, neutrino emissions penetrate any shielding and can therefore allow continuous monitoring at a stand-off distance of up to tens of metres. Furthermore, these detectors are highly sensitive to other radiation, including atmospheric muons and reactor neutrons, allowing further characterisation of facility operations. The nuSENTRY project studies the feasibility of using such a detector to characterise SMRs with antineutrinos and complementary radiation signatures as well as the potential for verifying reactor operations in the naval reactor context. This is done by using OpenMC-based reactor simulation to extrapolate reactor designs to SMR or naval designs, while different detection technologies are compared using GEANT4-based simulations to determine energy resolution and measurement times with respect to sensitivity.



AGA 7.6 Thu 17:30 KH 00.016

**A muon detector concept for non-destructive imaging and material distinction for verification of nuclear items** — •NICOLAS SCHWARZ, YAN-JIE SCHNELLBACH, and SARAH FRIEDRICH — Technische Universität Darmstadt, Darmstadt, Germany

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) aims to ensure the exclusively peaceful civilian use of fissile material and nuclear technology in energy generation and disarmament. They are implemented by state parties and controlled by the International Atomic Energy Agency (IAEA). This contribution presents a conceptual muon detector as a safeguard for the purpose of (re-)verification. Ideally, such detectors could look inside closed compartments, advantageous for radioactive contents that pose a hazard for human safety, when opened. Muography is already established in structure analysis of civil engineering, archeology and geological research of volcanoes. Cosmic muons are naturally emerging as secondary rays in the atmosphere and are therefore suitable probes for passive measurements. They belong to minimum ionizing particles (MIPs) and thus the mean energy loss is a function of the momentum alone in the Bethe region. The proposed detector concept studied in this work is a two-sided hybrid muon detector, that uses a PVT scintillator hodoscope for muon track reconstruction, and a liquid organic TPC for calorimetric energy loss measurement. Simulation-based feasibility studies have been conducted to yield density images and show that a differentiation of heterogeneous materials is possible. A final disposal container will be used as a Spent Nuclear Fuel test subject to apply the insights gained from this analysis.

AGA 7.7 Thu 17:30 KH 00.016

**Forensic Measurements for Nuclear Archaeology** — •LUKAS RADEMACHER — Technical University of Darmstadt, Darmstadt, Germany — Peace Research Institute Frankfurt, Frankfurt am Main, Germany

Reliable verification, conducted using universally accepted tools, is an integral part of lasting efforts towards nuclear disarmament. And the further such efforts progress, the more important it will become that this verification focusses not only on warheads, but also on existing stocks of fissile materials. 'Nuclear Archaeology' is a toolbox providing verification methods for these stocks. One of its most established methods, the 'Isotope Ratio Method' (IRM), revolves around isotopic measurements of samples taken from structural reactor elements, such as a graphite moderator or fuel channel tubes. Specific isotopic ratios in these samples can be used to deduce the neutron fluence in the reactor and create an estimate of the total plutonium production. We present a further development of this established methodology, aiming to strengthen its potential. Breaking down the deduced information about past operation in more detail becomes possible when analyzing several isotopic ratios in parallel. However, this deduction can no longer be performed analytically, and a numerical approach is applied instead. Suitable ratios and deduced operational history information are presented for two example cases. They are based on simulations of two different reactor types, the graphite moderated Trawsfynydd Unit II as well as a generic heavy water moderated CANDU 6 model, showcasing the framework's potential as well as wide applicability.

AGA 7.8 Thu 17:30 KH 00.016

**Research on Nuclear Safeguards and Disarmament at Forschungszentrum Jülich** — •MANUEL KREUTLE<sup>1,2</sup>, THOMAS BOLAND<sup>1,2</sup>, LISA LAUMEN<sup>1</sup>, KIM WESTERICH-FELLNER<sup>1</sup>, NESLIHAN YANIKÖMER<sup>1</sup>, PHILLIP KEGLER<sup>1</sup>, KATHARINA AYMANN<sup>1</sup>, and STEFAN NEUMEIER<sup>1</sup> — <sup>1</sup>Forschungszentrum Jülich, Germany — <sup>2</sup>RWTH Aachen University, Germany

With this poster we want to provide insight to physicists with interest in society and policy on working in interdisciplinary research in the nuclear area. We will give an overview of the physics-related work on nuclear safeguards and disarmament currently conducted in the 'Nuclear Safeguards and Security' division at the Institute for Fusion Energy and Nuclear Waste Management (IFN-2) at Forschungszentrum Jülich. We will present safeguards research projects on muon-based measurements to confirm the presence of nuclear material in storage casks or the absence of undeclared tunnels in a deep geological repository for nuclear waste, the development of digital twins for monitoring nuclear waste management facilities under safeguards, or the creation of a virtual reality (VR) training platform for education and training in nuclear safety and safeguards. We will further discuss work on nuclear disarmament, including practical tabletop and roleplay exercises.

AGA 7.9 Thu 17:30 KH 00.016

**Mentorship program for scientific peace research** — •ROBIN TOBIAS MENTEL<sup>1</sup> and MARTIN BERNHARD KALINOWSKI<sup>2</sup> — <sup>1</sup>Technische Universität Darmstadt — <sup>2</sup>Peace Science Collaboration

This poster presents the AGA's new mentorship program for students and young scientists, aiming to support young researchers to grow their career and skills, while also developing the network of junior and senior people in this complex and multidisciplinary field of physics and disarmament and other topics of science and peace research. The mentorship will help them not just to plan their career, but also develop relevant skills and prepare for job searches and applications. The Frühjahrstagung offers a great opportunity to introduce this initiative to a broad audience. We invite interested students and potential mentors to approach us and contribute to a growing community dedicated to responsible scientific peace and conflict research. This poster will also present the scope of the work and the current initiatives of the AGA. Specifically, we will introduce the research groups that are active in the field of nuclear arms control in Germany. Our goal is to show the diversity of research, ranging from technical verification methods to policy analysis. Further, the poster will outline engagement opportunities for students, early-career researchers, and senior scientists. There are a number of opportunities to become active, including public outreach, participation in interdisciplinary working groups, and contributions to the dialogue between science and society.

AGA 7.10 Thu 17:30 KH 00.016

**Development of a novel antineutrino monitor prototype for nuclear safeguards** — •ADHITYA SEKHAR<sup>1</sup>, NICK THAMM<sup>2</sup>, SARAH FRIEDRICH<sup>1</sup>, ROBIN MENTEL<sup>1</sup>, STEFAN ROTH<sup>2</sup>, and YAN-JIE SCHNELLBACH<sup>1</sup> — <sup>1</sup>Technische Universität Darmstadt — <sup>2</sup>RWTH Aachen University

In recent years there has been growing interest in antineutrino-based nuclear safeguards for monitoring reactor operation and spent fuel containment through the low-MeV antineutrinos emitted in beta-decay of fission fragments. Following previous promising simulations, a prototype for a novel antineutrino detection concept utilising a liquid organic time projection chamber (LOR-TPC) is now being developed. This study presents the initial phase of this project, showcasing investigations into the amplification properties of gaseous tetramethylsilane (TMS). A first test was conducted using a single-wire proportional counter in a ~5mL cylindrical chamber and a <sup>55</sup>Fe source. A second test is being planned using a Thick Gaseous Electron Multiplier (THGEM). The results of these tests will be shown, along with comparisons made to previous measurements of amplification in other standard gases using the same setup, and their implications on the antineutrino monitor prototype development pipeline.

## AGA 8: Verification

Time: Friday 9:30–11:00

Location: KH 00.016

AGA 8.1 Fri 9:30 KH 00.016

**Mimicking Nuclear Warhead Signatures via Shielding of Radioactive Material** — •EMMA LUCKE<sup>1</sup>, CHRISTOPHER FICHTLSCHERER<sup>2</sup>, and MORITZ KÜTT<sup>1,3</sup> — <sup>1</sup>Hamburg Nuclear Disarmament Laboratory, University of Hamburg — <sup>2</sup>Laboratory for Nuclear Security and Policy, Massachusetts Institute of Technology — <sup>3</sup>Program on Science and Global Security, Princeton University

On the road toward reliable gamma spectroscopy-based warhead confirmation systems, ensuring signature uniqueness remains a challenge. If signatures are not unique, this vulnerability could be exploited by presenting hoax objects in place of actual warheads, thereby cheating procedures during nuclear dismantlement. In our previous work we established that combinations of shielded radioactive isotopes can produce gamma emission signatures indistinguishable from those of actual nuclear warheads. However, it remains unclear whether shielded isotope emissions actually offer any advantages over unshielded ones. In addition, earlier results suggest that some shielding configurations may be more effective than others. Our new work focuses on investigating these aspects. We expand the set of considered isotopes to include all long-lived candidates potentially appli-

cable to cheating, which requires new OpenMC shielding simulations at higher photon energies. Additionally, the set of theoretical warhead models is broadened to incorporate further signatures. In a subsequent systematic search for hoax objects within this expanded space, we explore the role of shielding effects in constructing hoax objects that are capable of deceiving gamma spectroscopy based warhead confirmation systems.

AGA 8.2 Fri 10:00 KH 00.016

**Modeling, simulations, database, and GUI: Updates on the Digital Twin for Nuclear Verification Project** — •MANUEL KREUTLE<sup>1</sup>, KATHARINA AYMANN<sup>1</sup>, and IRMGARD NIEMEYER<sup>1,2</sup> — <sup>1</sup>Forschungszentrum Jülich, Germany — <sup>2</sup>International Atomic Energy Agency (IAEA), Vienna, Austria

Nuclear non-proliferation and disarmament efforts are centered around technical verification of related activities. This is true for bilateral agreements (e.g. New START, Open Skies, etc.) as well as multilateral treaties (e.g. NPT, CTBT, etc.). Past, present and potential future verification regimes are complex socio-technical systems that produce increasing amounts of data, nowadays usually in

digital from. In convergence to that, "Digital Twins" have become a popular concept to monitor, predict or plan the behavior of cyber-physical systems. Hence it is just another step to combining the two.

In this talk, we will give an update on the state of a project on digital twins for safeguards in nuclear waste management. We will present a framework of database-enabled systems modeling, validated simulations, and visualization. The related software can produce realistic measurement and inspection data which can be displayed in a graphical user interface (GUI). In its current state it can be utilized to plan and improve monitoring systems, but we will discuss how it can be extended to allow for data processing of incoming real (live) data. We will close with sharing thoughts on how this project can be extended to create digital twins for nuclear verification in general.

AGA 8.3 Fri 10:30 KH 00.016

**MUTOMCA: Muon Tomography for the Re-Verification of Spent Nuclear Fuel Casks** — PAOLO ANDREETTO<sup>1</sup>, KATHARINA AYMANN<sup>2</sup>, MASSIMO BENETTONI<sup>1</sup>, NICOLA BEZ<sup>1</sup>, •THOMAS BOLAND<sup>2</sup>, GERMANO BONOMI<sup>4</sup>, LORENZO CASTELLANI<sup>1</sup>, ENRICO CONTI<sup>1</sup>, JOHAN DACKNER<sup>5</sup>, FRANCO GONELLA<sup>1</sup>, ALTEA LORENZON<sup>1</sup>, FABIO MONTECASSIANO<sup>1</sup>, MARITA MOSCONI<sup>5</sup>,

MENTOR MURTEZI<sup>5</sup>, JULIA NIEDERMEIER<sup>6</sup>, IRMGARD NIEMEYER<sup>2</sup>, JUHA PEKKARINEN<sup>5</sup>, ANDREA RIGONI<sup>1</sup>, DANIELE SCARPA<sup>1</sup>, MAIK STUKE<sup>3</sup>, MATTEO TURCATO<sup>1</sup>, and GIANNI ZUMERLE<sup>1</sup> — <sup>1</sup>INFN Padova and University of Padova, Padova, Italy — <sup>2</sup>Forschungszentrum Jülich GmbH, Jülich, Germany — <sup>3</sup>BGZ Gesellschaft für Zwischenlagerung mbH, Essen, Germany — <sup>4</sup>University of Brescia, Brescia and INFN Pavia, Pavia, Italy — <sup>5</sup>European Commission, Directorate-General for Energy, Luxembourg — <sup>6</sup>Technical University Munich, Garching, Germany

Safeguards inspectors require reliable information to ensure that nuclear material in heavily shielded casks in dry spent fuel storage facilities is not diverted. In the event that all safeguards-related containment and surveillance measures fail, enhanced verification capabilities are needed. The MUTOMCA project aims to address this necessity by exploring muon tomography as a non-destructive assay method for re-verifying spent fuel casks. A detector setup was developed and tested and two algorithms were designed for reconstructing cask contents from muon absorption and scattering data respectively. A field test was performed with two loaded casks. This talk presents the muon detectors, data collection, preliminary results and future prospects.

Working Group on Information

Arbeitsgruppe Information (AGI)

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Overview of Invited Talks and Sessions

(Lecture hall KH 0.011 and KH 0.024)

Invited Talks

|         |     |             |           |                                                                                                                                  |
|---------|-----|-------------|-----------|----------------------------------------------------------------------------------------------------------------------------------|
| AGI 1.1 | Mon | 16:15–16:45 | KH 00.011 | <b>Diamond Open Access: Misconceptions, Systemic Constraints, Potentials</b> —<br>•ULRICH HERB                                   |
| AGI 1.2 | Mon | 16:45–17:15 | KH 00.011 | <b>Green, Gold, Diamond, Platinum, Rhodium etc: SciPost’s stance on modern publishing business models</b> — •JEAN-SÉBASTIEN CAUX |
| AGI 1.3 | Mon | 17:15–17:45 | KH 00.011 | <b>Expanding the Diamond Open Access Publishing Model: on the how’s and why’s</b> — •MARGO BARGHEER                              |
| AGI 3.1 | Wed | 13:45–14:15 | KH 00.011 | <b>Scientific publishing in the era of AI</b> — •DOMINIK ELSÄSSER                                                                |
| AGI 3.2 | Wed | 14:15–14:35 | KH 00.011 | <b>Intelligence and the Art of Scientific Publishing - an Editor’s Perspective</b> —<br>•ANDREAS BUCHLEITNER                     |
| AGI 3.3 | Wed | 14:35–15:05 | KH 00.011 | <b>Prompt or perish - the research life cycle in times of genAI</b> — •SANDRA GEISLER                                            |

Sessions

|             |     |             |           |                                                                                          |
|-------------|-----|-------------|-----------|------------------------------------------------------------------------------------------|
| AGI 1.1–1.4 | Mon | 16:15–18:15 | KH 00.011 | <b>Diamond Open Access – The final step?</b>                                             |
| AGI 2.1–2.1 | Tue | 11:00–11:45 | KH 00.024 | <b>Information Service for Physics</b>                                                   |
| AGI 3.1–3.4 | Wed | 13:45–15:45 | KH 00.011 | <b>Artificial Intelligence in Scientific Publishing (joint session AGI/AKjDPG/AKPIK)</b> |

## Sessions

– Invited Talks, Discussions, and Contributed Talks –

### AGI 1: Diamond Open Access – The final step?

Time: Monday 16:15–18:15

Location: KH 00.011

#### Invited Talk

AGI 1.1 Mon 16:15 KH 00.011

#### Diamond Open Access: Misconceptions, Systemic Constraints, Potentials —

•ULRICH HERB — Saarland University, Saarbrücken

Open Access has expanded considerably: in 2024, about 50% of articles were published openly, mostly via gold and hybrid models. Yet dissatisfaction with APC-based publishing, concerns about inequitable participation, and the limited impact of transformative agreements have shifted attention toward Diamond Open Access (DOA), where neither authors nor readers pay. Although DOA's share doubled from 3% in 2015 to 6% in 2024, it remains marginal and has plateaued since 2021. This contribution examines misconceptions and structural blind spots. DOA is often treated as a coherent model\*scholar-led, non-profit, free of charge\*although these traits do not necessarily coincide. Journals and publishers still act as key quality signals; despite reform efforts, prestige remains decisive, limiting uptake of new or low-visibility DOA venues. The idea that DOA is inherently cheaper is also misleading: studies and practice show substantial costs for editorial work, infrastructure, compliance, quality assurance, coordination, and scaling\*often underestimated in non-profit settings. Sustainability concerns add to this. While niche and community-driven models show that DOA can succeed under specific disciplinary conditions, such cases rarely scale, raising questions about DOA's capacity to drive broader transformation. The talk argues that DOA is valuable but no panacea; without realistic assessments of costs, incentives, and governance, the risk of renewed cycles of hype and disillusionment remains.

#### Invited Talk

AGI 1.2 Mon 16:45 KH 00.011

#### Green, Gold, Diamond, Platinum, Rhodium etc: SciPost's stance on modern publishing business models — •JEAN-SÉBASTIEN CAUX — Institute of Physics, University of Amsterdam

Scientific publishing is currently undergoing a vast transition away from traditional models based on subscriptions to journals from corporate or scientific society-led publishers. Instead, a new ecology of Green, Gold, Diamond, Platinum/Palladium has sprung up from a variety of service providers, dressed in sometimes (deliberately?) obscure business practices. Confusion is rife as to whose interests are being served, and who pays the price.

Within this context, SciPost aims to provide a community-driven solution which puts scientific quality back at the forefront, and offers an alternative busi-

ness model achieving significant cost slashing and aiming to deprecate profit-making in the publishing industry.

This talk will deliver an update on the current status of the reform of publishing in general, and SciPost in particular. It will also share thoughts on experiences gained, and provide perspectives for a successful transition to a healthier scientific publishing future both for scientists and the academic institutions who support and employ them.

#### Invited Talk

AGI 1.3 Mon 17:15 KH 00.011

#### Expanding the Diamond Open Access Publishing Model: on the how's and why's — •MARGO BARGHEER — Niedersächsische Staats- und Universitätsbibliothek Göttingen

While the beneficial aspect of open access, more scientific content freely available for everyone, goes without a doubt, the extractive model of commercially provided open access calls for action. Transformative agreements seem to work too slowly, article processing charges cause budget problems and new injustice. Diamond Open Access as the publishing model without fees for reading or publishing has gained significant traction in the last years. Mostly institutionally provided or community-led with light-weight technology and infrastructures, Diamond Open Access is charged with the expectation to bring a better, fairer and more inclusive system of scholarly communication than the one offered by profit-oriented publishers. The presentation will offer some trends on the growth of Diamond Open Access and show pathways for scientific communities to promote stable and organic growth of Diamond Open Access, thereby moving towards a more self-reliant publication system that serves their disciplinary needs.

#### Discussion

AGI 1.4 Mon 17:45 KH 00.011

**Discussion** — MARGO BARGHEER<sup>1</sup>, JEAN-SÉBASTIEN CAUX<sup>2</sup>, ULRICH HERB<sup>3</sup>, •UWE KAHLERT<sup>4</sup>, and ESTHER TOBSCHALL<sup>5</sup> — <sup>1</sup>Niedersächsische Staats- und Universitätsbibliothek Göttingen — <sup>2</sup>Institute of Physics, University of Amsterdam — <sup>3</sup>Saarland University, Saarbrücken — <sup>4</sup>RWTH Aachen University — <sup>5</sup>TIB Hannover

Is Diamond Open Access the next and maybe final step in the transformation of the scientific publication system? What are the chances and what are potential obstacles? After the speakers have considered (Diamond) Open Access from different perspectives, these questions will now be discussed with them.

### AGI 2: Information Service for Physics

Time: Tuesday 11:00–11:45

Location: KH 00.024

AGI 2.1 Tue 11:00 KH 00.024

#### Introducing FID Physik - a discipline-specific information service for physics

•HOLGER ISRAEL<sup>1</sup>, ESTHER TOBSCHALL<sup>1</sup>, JULIA HOFFMANN<sup>1</sup>, MARKUS M. BECKER<sup>2</sup>, JOHANNA HICKMANN<sup>3</sup>, and LINA BOCKHORN<sup>1</sup> — <sup>1</sup>TIB - Leibniz-Informationszentrum Technik und Naturwissenschaften und Universitätsbibliothek — <sup>2</sup>Leibniz-Institut für Plasmaforschung und Technologie e.V. (INP) — <sup>3</sup>Physikalisch-Technische Bundesanstalt (PTB)

Starting in February 2026, FID Physik, the discipline-specific information service for physics, is going to provide a free, open science -minded information portfolio tailored to meet the needs of cutting-edge physics research. Initially, to start with a well-defined specialised community, FID Physik seeks to support researchers in low-temperature plasma physics. From the outset, however, the

tools and services will be designed to be broadly applicable across physics to progressively expand the target audience.

FID Physik will offer a suite of services to facilitate discovery and retrieval of relevant subject-specific information, most notably a literature search engine based on quality-curated corpus. Complementary tools include support of analysis and comparison of publications via visualisation powered by knowledge graphs and large language models (LLMs) and a consolidated conference overview. Extensive community engagement will ensure alignment with researchers' needs. Stay tuned!

FID Physik is funded by DFG under project number 558452925, via the "Discipline-Specific Information Services" programme, for an initial period of three years.

### AGI 3: Artificial Intelligence in Scientific Publishing (joint session AGI/AKjDPG/AKPIK)

Time: Wednesday 13:45–15:45

Location: KH 00.011

#### Invited Talk

AGI 3.1 Wed 13:45 KH 00.011

#### Scientific publishing in the era of AI — •DOMINIK ELSÄSSER — TU Dortmund, Department of Physics

The dissemination of results to colleagues and to the general public has been an indispensable part of the scientific process for as long as humankind has expanded our treasure of knowledge with scientific methods. The forms and the

means by which this dissemination happens have however been subject to fundamental changes over time. One such change surely was that many fields of physics have moved towards working in large and international collaborations. And a more recent, yet profound change is the emergence of AI systems, which can be used to support many steps of the publication process, but also pose new challenges. In this talk, I will present key steps of the publication process typ-

ically encountered in fundamental physics and adjacent areas, and discuss options, methods, and tools available to the publishing scientist in the era of AI, with a specific focus on modern Large Language Models (LLMs), and on systems based on LLMs. While a focus will be on publication in peer-reviewed journals, there will also be a discussion of other forms of publication.

#### Invited Talk

AGI 3.2 Wed 14:15 KH 00.011

**Intelligence and the Art of Scientific Publishing - an Editor's Perspective** — •ANDREAS BUCHLEITNER — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Artificial intelligence (AI) shatters fundamental rules of the scientific publishing process. It induces a certain level of perplexity and disorientation within the academic realm, on how to react and/or to adapt - at a speed which is dictated from the outside, by a rapidly developing technology, together with the economic traction which comes with it. Different stakeholders of the publication process suggest distinct remedies, certainly guided by their respective perspectives, levels of expertise, and interests. And, clearly, there are highly nonlinear interdependencies between the thus reorganizing publication process, standards of good scientific practice, and the - in many respects highly disputable - incentives which constrain science and, in particular, academic careers. After stating some of the immediate challenges AI poses to the inner workings of the editorial process, the talk will expand upon the above interdependencies, and contemplate the genuine role and responsibility of the scientific community in shaping them.

#### Invited Talk

AGI 3.3 Wed 14:35 KH 00.011

**Prompt or perish - the research life cycle in times of genAI** — •SANDRA GEISLER — RWTH Aachen University, Aachen, Deutschland

Large Language Models (LLMs) are rapidly reshaping how research is conducted and communicated. In this talk we will explore and spark discussions about where generative AI could or already does add value along the research life cycle, as well as the limitations and risks that must be carefully considered. From brainstorming and literature discovery to FAIR-compliant research data management, science communication and the review process, LLMs offer powerful new opportunities for researchers. At the same time, researchers face significant uncertainty, ethical concerns, and policy gaps. Drawing on recent studies and practical examples from our own research projects, this presentation highlights both the promise and the perils of an AI-assisted research life cycle.

#### Discussion

AGI 3.4 Wed 15:05 KH 00.011

**Discussion** — ANDREAS BUCHLEITNER<sup>1</sup>, DOMINIK ELSÄSSER<sup>2</sup>, SANDRA GEISLER<sup>3</sup>, •UWE KAHLERT<sup>3</sup>, SIMON NEUHAUS<sup>4</sup>, and •TIM RUHE<sup>2</sup> — <sup>1</sup>Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — <sup>2</sup>TU Dortmund, Department of Physics — <sup>3</sup>RWTH Aachen University — <sup>4</sup>Bergische Universität Wuppertal

Scientific publishing has long been said to be in crisis. "Publish or perish" is too often the prevailing motto. AI tools can now be used at almost every stage of the process. What risks and perhaps also opportunities does this development present? We will discuss this with the speakers of this session.

## Job Market (JOB)

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During the conference various companies and organisations will present their working fields and career opportunities to all interested participants.

## Overview of Invited Talks and Sessions

(Lecture hall AM 00.014)

### Invited Talks

|         |     |             |           |                                                                                                                                                                                        |
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| JOB 1.1 | Wed | 12:30–13:30 | AM 00.014 | <b>Data-Analytics in der HUK-COBURG – Wie Physiker den Weg in ein datengetriebenes Versicherungsunternehmen mitgestalten</b> — •JANNIK HOFESTÄDT,<br>•ANDREAS GLEIXNER, •GORAN NAKERST |
|---------|-----|-------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

### Sessions

|             |     |             |           |                   |
|-------------|-----|-------------|-----------|-------------------|
| JOB 1.1–1.1 | Wed | 12:30–13:30 | AM 00.014 | <b>Job Market</b> |
|-------------|-----|-------------|-----------|-------------------|

Sessions  
– Invited Talks –

JOB 1: Job Market

Time: Wednesday 12:30–13:30

Location: AM 00.014

**Invited Talk** JOB 1.1 Wed 12:30 AM 00.014  
**Data-Analytics in der HUK-COBURG – Wie Physiker den Weg in ein daten-**  
**getriebenes Versicherungsunternehmen mitgestalten** — •JANNIK HOFESTÄDT,  
•ANDREAS GLEIXNER und •GORAN NAKERST — HUK-COBURG  
Ein Überblick über das Data-Analytics Programm bei der HUK-COBURG mit

Fokus auf die typischen Aufgabenbereiche von Physikern.  
Die Referenten berichten aus ihrem Arbeitsalltag in Forschung und Entwick-  
lung in der Risikomodellierung und Telematik (auf Sensordaten basierende Be-  
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## Exhibition venue

Friedrich-Alexander-Universität Erlangen-Nürnberg

AudiMax – Foyer

Bismarckstraße 1, 91054 Erlangen

## Exhibition opening hours

Tuesday, March 17 10:30 – 18:30

Wednesday, March 18 10:30 – 18:30

Thursday, March 19 10:30 – 18:30

## Stand No.

### CAEN GmbH

10

Brunnenweg 9, 64331 Weiterstadt

*HV/LV, Analog- und Digitalelektronik für Teilchendetektoren.*

### Edwards GmbH

08

Philipp-Hauck-Straße 2, 85622 Feldkirchen

*Vakuumsysteme und Vakuumpumpen.*

### Hamamatsu Photonics Deutschland GmbH

05

Arzbergerstraße 10, 82211 Herrsching

*Components and Sensors.*

### Kashiyama Europe GmbH

07

Münchner Straße 24, 85774 Unterföhring

*Vacuum, rootspumps, oilfreepumps, drypumps, multistagerootspumps, primarypumps, vacuumtechnology, analytical systems, masspec.*

### Netzwerk-Teilchenwelt TU Dresden

12

TU Dresden, Institut für Kern- u. Teilchenphysik, Zellescher Weg 19, 01069 Dresden

[www.teilchenwelt.de](http://www.teilchenwelt.de)

### Punch 4 NFDI

02

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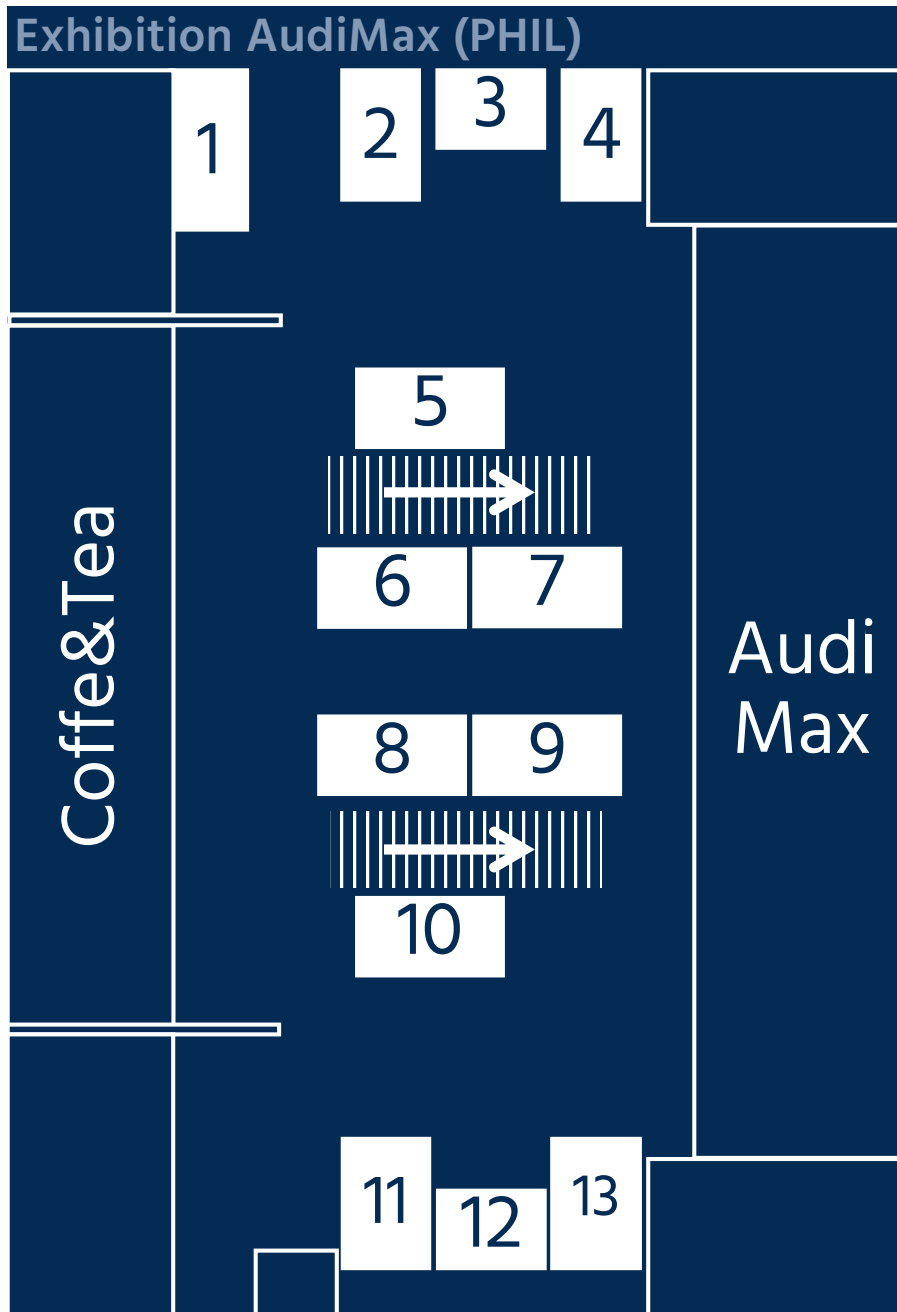
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### Technische Informationsbibliothek Hannover (TIB)

09

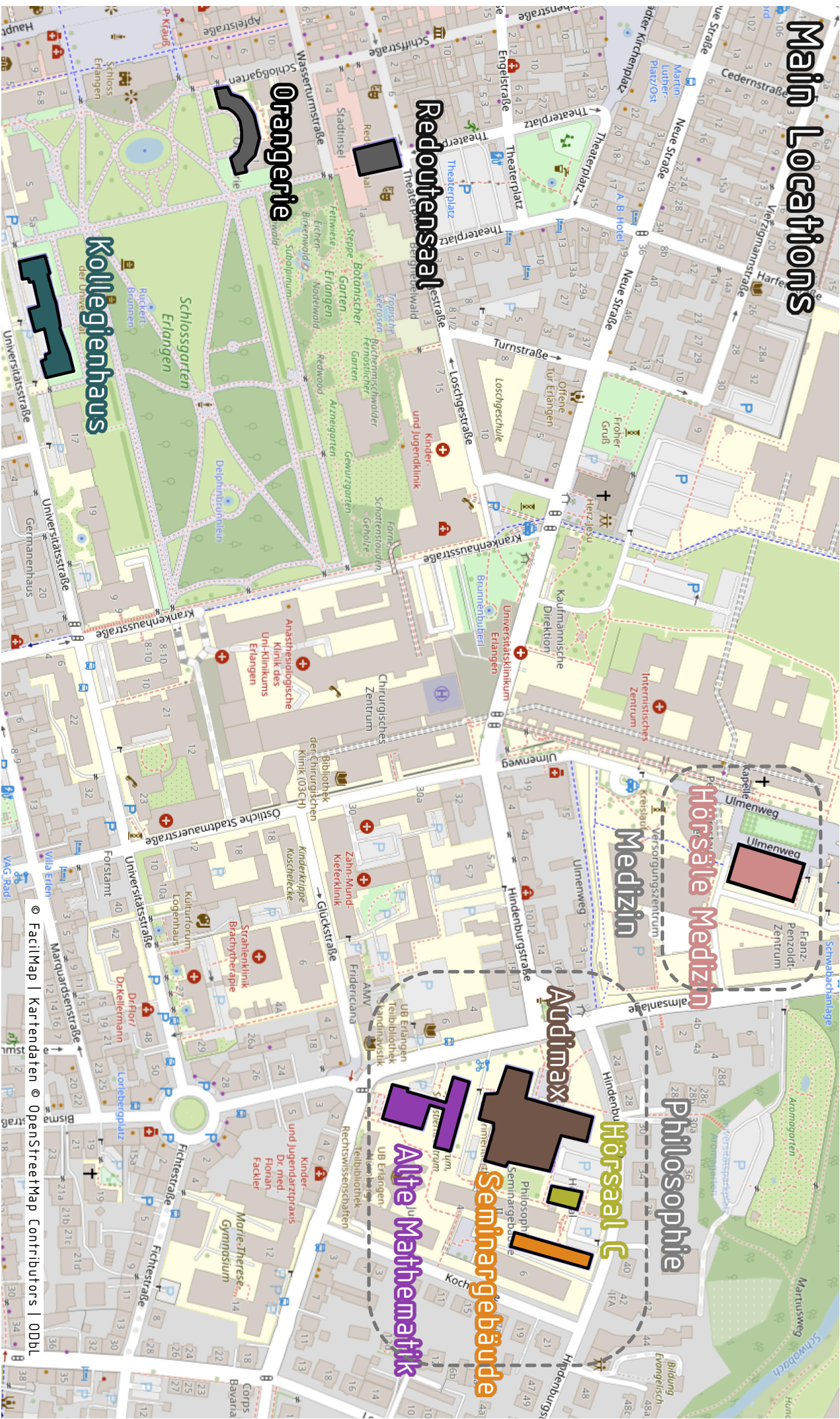
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*Wissenschaftliche Fachliteratur.*





# Main Locations



| Start | Sunday<br>15.03.2026          | Monday<br>16.03.2026                 | Tuesday<br>17.03.2026                                                                                                                                         | Wednesday<br>18.03.2026                                  | Thursday<br>19.03.2026                                                       | Friday<br>20.03.2026          | Start |
|-------|-------------------------------|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------------------------|-------------------------------|-------|
| 9.00  |                               | Registration<br>starting at 8.00h    | Plenary Talk (P)<br>Plasma technologies                                                                                                                       | Plenary Talk (HK)<br>FAIR: Status and perspectives       | Plenary Talk (ST)<br>AI and medical images                                   | Programme of<br>DPG Divisions | 9.00  |
|       |                               | Coffee available<br>at Audimax       |                                                                                                                                                               |                                                          |                                                                              |                               |       |
| 10.00 |                               | Opening Session                      | Plenary Talk (MP)<br>Invariants of topological order                                                                                                          | Plenary Talk (T)<br>Precision physics at LHC             | Plenary Talk (GR)<br>GW Observatory LISA                                     |                               | 10.00 |
|       |                               | Prize Talk:<br>Exotic atoms          | Coffee                                                                                                                                                        | Coffee                                                   | Coffee                                                                       |                               |       |
| 11.00 |                               | Plenary Talk (GP)<br>History of WWW  | Programme of<br>DPG Divisions                                                                                                                                 | Programme of<br>DPG Divisions                            | Programme of<br>DPG Divisions                                                |                               | 11.00 |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |
| 12.00 |                               | Plenary Talk (EP)<br>Exoplanets      |                                                                                                                                                               |                                                          |                                                                              |                               | 12.00 |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |
| 13.00 |                               | Lunch                                | Lunch                                                                                                                                                         | Lunch                                                    | Lunch                                                                        | Closing Session               |       |
|       |                               |                                      | <small>DPG/HEP:<br/>Physics<br/>beyond<br/>Academia!</small>                                                                                                  | Job<br>market                                            |                                                                              |                               | 13.00 |
| 14.00 | jDPG<br>Tutorials             | SMuK-<br>Dissertations-<br>Symposium | DPG Celebration<br>(Festakt)<br>1) Welcome addressees and<br>prize ceremony<br>2) Higgs at present and<br>future colliders<br>3) Modern physics at<br>schools | Programme of<br>DPG divisions                            | Programme of<br>DPG Divisions<br>(incl. Poster session<br>of FV P and FV ST) |                               | 14.00 |
| 15.00 |                               | Programme of<br>DPG Divisions        |                                                                                                                                                               |                                                          |                                                                              |                               | 15.00 |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |
| 16.00 |                               | Coffee                               | Coffee                                                                                                                                                        | Coffee                                                   | Coffee                                                                       |                               | 16.00 |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |
| 17.00 |                               | Programme of<br>DPG Divisions        | Programme of<br>DPG Divisions                                                                                                                                 | Programme of<br>DPG Divisions<br>(incl. Poster Sessions) | Programme of<br>DPG Divisions                                                |                               | 17.00 |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |
| 18.00 | jDPG/ AKPIK<br>Programming WS |                                      |                                                                                                                                                               |                                                          |                                                                              |                               | 18.00 |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |
| 19.00 |                               | Welcome Evening                      | Public Talk:<br>Astropart. physics<br>with gamma rays and<br>neutrinos                                                                                        | Lise Meitner Lecture:<br>GW astronomy                    |                                                                              |                               | 19.00 |
|       |                               |                                      | <small>jDPG/<br/>HEP:<br/>Physics<br/>beyond<br/>Academia!</small>                                                                                            |                                                          |                                                                              |                               |       |
| 20.00 |                               |                                      |                                                                                                                                                               |                                                          | Max von Laue Talk:<br>QCD and the threat of<br>nuclear annihilation          |                               | 20.00 |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |
|       |                               |                                      |                                                                                                                                                               |                                                          |                                                                              |                               |       |