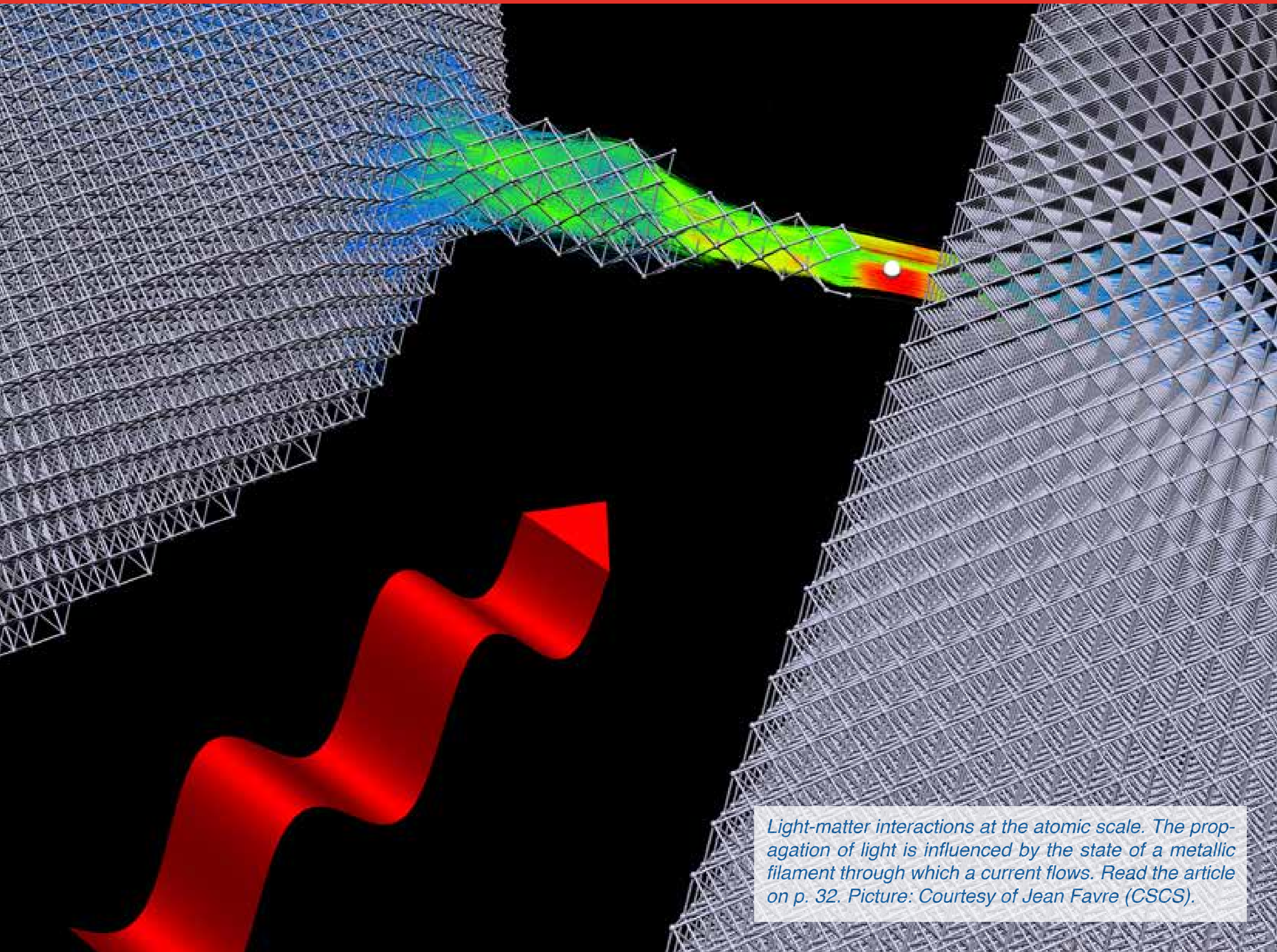
⟨S|P|S⟩ swiss physical society

Nr. 76, Juli 2025

# SPG Mitteilungen
# Communications de la SSP



*Light-matter interactions at the atomic scale. The propagation of light is influenced by the state of a metallic filament through which a current flows. Read the article on p. 32. Picture: Courtesy of Jean Favre (CSCS).*

ÖPG

## JOINT ANNUAL MEETING
of the
Austrian and Swiss Physical Society
18 - 22 August 2025, Universität Wien

⟨S|P|S⟩ swiss physical society

Symposium: 100 Years of Quantum Physics, p. 12; Preliminary Program: p. 14

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member of the scnat swiss academy of sciences

satw technology for society

# Editorial

## Successful Outreach Activities of the SPS

*Christof Fattinger, Bernhard Braunecker*

The efforts of a national physics society are very diverse and nowadays go far beyond the main task of a professional association, namely to ensure the sustainable exchange of knowledge between its members. Thanks to modern computer possibilities, more and more findings in fundamental physics are reaching technical maturity in a much shorter time than in the past. It is therefore an increasingly important task for the SPS to intensify its outreach activities in order to highlight the importance of basic physical knowledge in almost all areas of the natural sciences. In addition to physicists, the target groups are also representatives of politics, academia and relevant industries, who need to be informed at first hand about the results of modern physics in ensuring the continued prosperity of the economy.

The latest issue no. 75 of the *SPG Mitteilungen* illustrates this in an exemplary and emphatic manner, where two extraordinary articles comment on the 2024 Nobel Prizes in Physics and Chemistry by experts who point out the close interaction between computer science and biophysical research from an insider's perspective [1].

Both articles were very well received not only by SPS-members, but also by colleagues from chemistry, molecular biology and pharmaceutical societies. It was impressively demonstrated to everyone that the already great importance of molecular biology will be significantly increased through the use of modern information technologies, such as high-performance computing and AI, by providing researchers and developers with novel analysis, modeling and simulation tools. In this context, it is important to point out that the capacities of the IT systems required for some of the new computer applications are enormous.

1 Nobelprize for Physics 2024: Author Tobi Delbrück; Nobelprize für Chemistry 2024: Authors Johan Åqvist, Cell and molecular biology, University Uppsala, Member of the Royal Swedish Academy of Sciences, and Hubert Kettenberger, Head of Computational Protein Engineering, Roche Pharma Research and Early Development (pRED), Roche Diagnostics GmbH, Penzberg [1]

Methods for predicting and designing protein structures based on deep learning require large amounts of experimental training data, the vast majority of which comes from X-ray crystallography at synchrotron sources (followed by cryo-electron microscopy, which has made great technological progress in recent years) [1]. Remarkably, more than one in 20 (5.5 % according to *https://www.rcsb.org/stats*) X-ray structures were obtained using the Swiss Light Source (SLS) at the Paul Scherrer Institute in Villigen, Switzerland [3]. The SLS has thus made a significant contribution to the experimental database that led to the 2024 Nobel Prize in Chemistry [1]. The planned upgrade to SLS 2.0, which is scheduled to go into operation in 2026 [3], will ensure Switzerland's long-term presence in an important area of life sciences research.

With the help of AI, researchers are now able to predict the structure of virtually all the 200 million proteins that have been identified in organisms [1]. This number is significantly higher (about 1'000-fold) than the number of experimental 3D protein structures (~ 200 000) in the Protein Data Bank [2] that have been solved by biophysical methods in structural biology [1]. To be able to reliably predict protein structures directly from the amino acid sequence by computational methods is a major achievement, which will have a lasting impact on the future of the life science industries relevant to Switzerland.

[1] Johan Åqvist and Hubert Kettenberger, Computational Protein Design and Protein Structure Prediction, *SPG Mitteilungen* **75**, 20–25, *https://sps.ch/de/articles/nobel_prizes*
[2] Bernstein, F. C. et al., The protein data bank: A computer-based archival file for macromolecular structures. *Arch. Biochem. Biophys.* **185**, 584–591 (1978).
[3] Philip Willmott, SLS 2.0 – The upgrade of the Swiss Light Source. *SPG Mitteilungen* **72**, 18–25 (2024), *https://sps.ch/de/articles/milestones_in_physics*.

### From waves to particles: Schrödinger and Heitler in Zurich

2025 marks the centenary of quantum mechanics. The fruitful interaction between both physicists Gregor Wentzel and Wolfgang Pauli was described in *SPG Mitteilungen* Nr. 75 on p. 39 by the historian Irina Morell from the Library Naturwissenschaften of the University Zurich [1 2]. Now in a second and again fascinating to read article the interchange of two other heavyweights of quantum science with connection to Zurich is presented, Erwin Schrödinger and Walter Heitler [3]. This nicely leads to our joint annual conference with our Austrian collegues (p. 12 ff.), where the role of Schrödinger is also one of the highlights.

1 *https://www.zb.uzh.ch/en/zuerich/was-die-welt-im-innersten-zusammenhaelt-zuerich-und-die-geburt-der-quantenmechanik*

2 *https://sps.ch/de/articles/various_articles*

3 *https://www.zb.uzh.ch/en/zwischen-wellen-und-teilchen-schroedinger-und-heitler-in-zuerich*

### How AI and quantum technology are transforming pharmaceutical research in Switzerland

In line with these editorial remarks were the presentations at the SATW annual congress on 27 May 2025 at the FHNW in Muttenz. The focus was the role of Artificial Intelligence and Quantum Technologies with respect to life science, and here especially to the pharmaceutical, medical and food industry [4]. More details can be found on p. 57.

4 *https://www.technik-und-wissen.ch/ki-und-quantencomputing-werden-die-arzneimittelentwicklung-veraendern*

# Gemeinsame Jahrestagung in Wien, 18. - 22. August 2025 - Réunion annuelle commune à Vienne, 18 - 22 août 2025

**Vorwort**

Traditionsgemäß wird im 2025 die Jahrestagung der SPG wieder gemeinsam mit den Kollegen der Österreichischen Physikalischen Gesellschaft (ÖPG) organisert. Sie findet im Hauptgebäude der Universität Wien, Universitätsring 1, 1010 Wien, statt. Weitere Organisationspartner sind u.a. das *Schweizerische Institut für Teilchenphysik* (CHIPP), der *SFB BeyondC*, und die *Association of ERC Grantees* (AERG).

Neben der bewährten Mischung aus Plenarvorträgen, Fachsitzungen und Händlerausstellung steht diesmal ein öffentliches Symposium anlässlich *100 Jahre Quantenphysik* (S. 12) auf dem Programm. Weitere Programmpunkte sind z.B. der Energietag, zwei öffentliche Abendvorträge und das vierte *Frauen in der Physik Karriere-Symposium*.
Zusätzlich können sich die Teilnehmer wie gewohnt für das traditionelle Konferenzabendessen anmelden (Teilnehmerzahl beschränkt).

Im Folgenden finden Sie die Vereinsinformationen für die SPG Mitglieder sowie die vorläufige Programmübersicht. Das vollständige Programm und weitere Tagungsinformationen werden, sobald verfügbar, von der SPG- bzw. der Konferenzwebseite abrufbar sein.

Wir hoffen auf eine rege Beteiligung an der diesjährigen Tagung und freuen uns auf Ihren Besuch.

**Avant-propos**

Fidèle à la tradition, la réunion annuelle de la SSP se tiendra cette année de manière conjointe avec nos collegues de la Société Autrichienne de Physique (ÖPG) à Vienne. La réunion se tiendra dans le bâtiment principal de l'université de Vienne, situé à l'Universitätsring 1, 1010 Wien, avec la participation de l'*Institut Suisse pour la Physique des Particules* (CHIPP), du *SFB BeyondC* et l'*Association of ERC Grantees* (AERG).

En plus, des conférences plénières, des sessions dédiées aux domaines spécifiques et des stands d'exposants, nous organisons en cette année internationale des sciences et technologies quantiques un symposium public sur le *Centenaire de la physique quantique* (p. 12). Notre réunion accueillera par ailleurs la Journée Energie, deux conférences publiques, et pour la quatrième fois le *Symposium sur la carrière des femmes en physique*.
Les participants sont aussi invités à s'inscrire au traditionnel dîner de la conférence (attention, nombre de places limité).

Vous trouverez dans ces pages les informations s'adressant aux membres de la SSP ainsi qu'un aperçu du programme préliminaire. Le programme complet et toutes les informations utiles sur la conférence seront disponibles prochainement sur les pages web de la SSP et de la conférence.

Nous nous réjouissons de votre participation.

## Generalversammlung 2025 - Assemblée Générale 2025

***Montag 18. August 2025, 18:00h, Hörsaal 30 - Lundi 18 août 2025, 18:00h, salle 30***

| | **Traktanden** | **Ordre du jour** |
|---|---|---|
| 1. | Protokoll der Generalversammlung vom 09. September 2024 | Procès-verbal de l'assemblée générale du 9 septembre 2024 |
| 2. | Bericht der Präsidentin | Rapport de la présidente |
| 3. | Rechnung 2024, Revisorenbericht | Bilan 2024, rapport des vérificateurs des comptes |
| 4. | Wahlen | Elections |
| 5. | Projekte | Projets |
| 6. | Diverses | Divers |

## Preisverleihungen - Cérémonies de remise des prix

**SPG Preise, ÖPG Preise, Charpak-Ritz Preis**
**Prix de la SSP, prix de l'ÖPG, prix Charpak-Ritz**

***Dienstag 19. August 2025, 11:00h, Großer Festsaal - Mardi 19 août 2025, 11:00h, Großer Festsaal***

**Preise für die besten Poster**
**Prix des meilleurs posters**

***Freitag 22. August 2025, 12:30h, Großer Festsaal - Vendredi 22 août 2025, 12:30h, Großer Festsaal***

# Protokoll der Generalversammlung vom 09. September 2024
# Protocole de l'assemblée générale du 9 septembre 2024

**Agenda**

1. Approval of the Minutes of the Extraordinary General Assembly held online on 26 February 2024
2. 2023 Finances and Auditors Report
3. Report from the President
4. Elections
5. Projects and Activities of Sections
6. Varia

The president, Prof. Teresa Montaruli, opens the General Assembly 2024 at 13:00. She welcomes all participants to the SPS Annual Meeting and thanks ETH Zürich for using its infrastructure.

### 1. Approval of the Minutes of the Extraordinary General Assembly held online on 26 February 2024

The protocol of the last General Assembly has been published in the *SPG Mitteilungen* Nr. 73 on p. 5/6. New votes were announced and discussed in the last extraordinary GA on founding the Energy and Sustainability section and the Diversity, Equity and Inclusion (DEI) Commission and on electing their chairs. In addition, Medical Physics is not covered by the Biophysics, Soft Matter and Medical Physics section anymore, but rather by the Applied Physics section. The section has therefore been renamed "Biophysics and Soft Matter". This sets the focus better on these two topics and aims to increase attention from the industry and better connection to it.

The majority of the present members approve the Minutes.

### 2. 2023 Finances and Auditors Report

The Society's treasurer, Dr. Dirk Hegemann, presents the 2023 financial report (see also page 8 of the *SPG Mitteilungen* Nr. 73). Prof. Dr. Claude Monney and Dr. Pierangelo Gröning, the auditors of this report, have approved the numbers and their statement can be found on page 9. A minor net loss of 3160.69 CHF is accounted for. The treasurer explains that the financial situation of the SPS can be considered as healthy with a remaining asset of 145604.58 CHF. Most of all, the assets of SPS are used to support physics in many fields, with a total of 205918.40 CHF in 2023 (expenses), mainly balanced by membership fees and SCNAT credits (income). Furthermore, the SPS has a new accountant, Andreas Brandstetter (ETHZ), following François Erkadoo, who served the SPS for many years. Since it is his last term, the treasurer thanks the SPS and all members for their trust.

A question from the audience about the legal status of the SPS is answered by explaining that the SPS is a non-profit association located in Basel.

The annual financial report is approved unanimously by the General Assembly.

### 3. Report from the President

As an introduction, the president mentions that the SPS was founded in 1908 and is a member of the Swiss Academy of Sciences (SCNAT), the Swiss Academy of Technical Sciences (SATW), and the European Physical Society (EPS). Moreover, the SPS cooperates with the Société de Physique Française (SPF) for the Charpak-Ritz Prize and other events as well as with the Österreichische Physikalische Gesellschaft (ÖPG) for the biannual joint meeting and other matters.

The president reports that the number of members of our Society remains at 1094 members with 83 new members in 2023, including 19 honorary and 24 associated members (companies, university/research institutes, student associations), 10 sections, and 1 new commission. Two new honorary members were elected at the 2023 General Assembly (Dr. Bernhard Braunecker and Prof. Ruth Durrer).

The society covers many activities including its annual meetings, workshops, early career physicists' events, reaching out to primary and secondary education, publications, awards, public outreach and more.

The SPS organisation, based on its written bylaws, is summarised in the SPS web pages and the board members are detailed on p. 2 of every *SPG Mitteilungen*.

### 4. Elections

Several members of the board have reached the end of their term. First, the president thanks the former vice-president, Prof. Johan Chang, who ends his term after being active for a total of two years as vice-president and two years as president. She also thanks Prof. Lukas Gallmann for his 6-year-long activities as SPS Secretary. Finally, the treasurer, Dr. Dirk Hegemann, is acknowledged for serving his 6-years term. Votes to replace these three positions are performed requiring a majority.

Election of new Board members:

- Vice president: Prof. Michel Calame * (Empa)
- Secretary: Prof. Christoph Aegerter * (UZH)
- Treasurer: Dr. Sebastian Siol * (Empa)

Furthermore, the election of nine new section chairs is conducted:

- Condensed matter: Dr. Daniel Mazzone (PSI)
- Applied Physics (incl. Medical Physics): Dr. Fabio Avino * (EPFL) and Prof. Mike Seidel (EPFL/PSI/CERN)
- Theoretical Physics: Prof. Julian Sonner (UNIGE)
- Atomic Physics and Quantum Optics: Prof. Rachel Grange (ETHZ)
- Education and Promotion of Physics: Dr. Maria Alice Gasparini (Collège Rousseau and UNIGE)
- Biophysics and Soft Matter: Prof. Sahand Rahi (EPFL)
- History and Philosophy of Physics: Prof. Christian Wüthrich * (UNIGE) and Prof. Jérôme Baudry (EPFL)
- Energy and Sustainability: Dr. Stephan Wirths * (Hitachi Energy).

All candidates are elected unanimously. All future chairs indicated with * are present in person and briefly introduce themselves. For the others, a bio is shown by the president.

Continuation of chairs into the new term (2025-2026):

- Prof. Lesya Shchutska (TASK)
- Dr. Gernot Scheerer (Education and Outreach)
- Dr. Christof Fattinger (Biophysics and Soft Matter)

All chairs are prolonged in their roles unanimously.

As a new SCNAT delegate, Philippe Jetzer (UZH) has been selected (without requiring an election).

**5. Projects and Activities in Sections**

The many publications (*SPG Mitteilungen*, monthly Newsletter, LinkedIn, and *SPS Focus*) are highlighted. The third release of the SPS Focus series with a tentative title "From Classical Computing to Quantum Computing" will be published soon. Furthermore, the numerous activities within supported programs (Teacher training, International Physics Tournament, Pro IYPT-CH, Swiss Physics Olympiad, Schweizer Jugend forscht, Physik im Advent, Science Education and Industry, Women in Physics, Young Talent Day, Young Physicist Forum, and international collaborations) are briefly mentioned and appreciated, considering the support by SCNAT.

The new section "Energy & Sustainability" started this year to identify an interested community and experts and establish connections with the EPS Energy Group, ÖPG Energy Section, Energy and Environment (SATW) and will be central in a future *SPS Focus* publication. An extension of the section name has been proposed to include the environment. Therefore, a vote by the GA is needed to decide on "Energy, Sustainability & Environment (ESE)" or "Energy & Sustainability (E&S)". The president explains that the new focus of the section is now mainly on energy and sustainability, while activities concerning the environment are also related to energy and sustainability. The scope of the section remains unaffected by its naming.

The voting result is in favor of the change of the name to *Energy, Sustainability & Environment* (ESE) with 21 votes, while 8 votes are against (1 abstain).

The Extraordinary GA on 26 February 2024 voted in favor of opening the Commission on Diversity, Equity and Inclusion (DEI) chaired by Philipp Schmidt-Wellenburg (PSI). The 3rd Women in Physics (WiP 2024) career symposium will be held at the Annual Meeting on 10 September, from now on a SPS sustained activity including a mentoring program.

The Biophysics and Soft Matter section has been rescoped to focus on these two topics, while Medical Physics has been moved to Applied Physics.

Opening this year's Annual Meeting, a Historical Symposium on *Louis de Broglie: 100 Years of Wave-Particle Duality* is organized. It is also the start of a series of events being prepared for the International Year of Quantum Science 2025 (IYQ2025). Further activities of the working group on quantum science are noted, organizing the IYQ2025, led by Johan Chang.

Finally, the vote on the name change of the SPS section "Education and Promotion of Physics" to "Education and Outreach", as suggested by Andreas Müller is conducted. The aim is to unify the name as it is used in German ("Bildung und Öffentlichkeitsarbeit"), French ("Education et promotion de la physique") and English language ("Education and Outreach"). Andreas Müller gives additional explanations. The addition "in Physics" is not used in all languages (only for the French version) since it is a subsection of SPS (i.e. of Physics) anyway.

The new section name is agreed on by 33 votes (with 3 votes against).

**6. Varia**

The president thanks ETH Zürich, its Physics Department and the local organizing team again for hosting the Annual Meeting, and for the generous support of SCNAT, SATW, and the sponsors. Moreover, the SPS administrative secretary, the former vice-president Johan Chang and the former chairs of the SPS sections are acknowledged.

Contribution from the audience: "Announcement of conferences would be appreciated."
Answer: Most of the physics-related conferences can already be found in the Newsletter, however, some might have been overseen. Anyone is invited to announce conferences of interest to the Newsletter via Dr. Margherita Boselli.

The president closes the meeting at 14:08.

# Statistik - Statistique

## Neue Mitglieder 2024 - Nouveaux membres en 2024

Abreu Elsa, Agostini Sandro, Angeloni Tancredi Thai, Aramesh Morteza, Aßmus Nils, Avino Fabio, Bainglass Edan, Barbato Pasquale, Barillier Erin, Baudry Jérôme, Baumgärtner Alexander, Birch Harvey John, Bonacci Miki, Brunner Santiago, Burmistrov Leonid, Byloff Johanna, Bzdušek Tomáš, Capu Roxana, Chassot Frédéric, Das Sahana, Davarpanah Shideh, Dörrschuck Michael, Édes Lili, Eichenberger Michael Alexander, Fedrigucci Andrea, Finco Giovanni, Flückiger Karin, Franck Christian, Geerds Birte Christine, Ghimouz Abderrahmane, Gómez Torres José, Gonzalez Filipov Daniel, Grange Rachel, Grünewald Wouter, Härringer Nico, Hasik Juraj, Heidt Alexander, Hernández José Abraham, Hong Xunyang, Hua Nelson, Huang Wenhao, Hunkeler Livia Anigna, Isa Lucio, Islam Manisha, Karić Ajla, Kehrer Tobias, Kellner Jost, Kong Mengdi, Kourkoulou Katerina, Kuttner Tristan, Lani Giovanna, Laxhuber Kathrin, Lee Wei Chuang, Leuthold Tamara, Locher Florian, MacBride Sean, Macdermid Zia, Maini Lucrezia, Makkar Shubhangi, McNamara Keegan, Minotakis Michail, Mondal Angana, Morf Joël, Mousavi Seyyed Jabbar, Müller Ella, Muranaka Tomoko, Museur Flavien, Muster Augustin, Nadolny Tobias, Nocerino Elisabetta, Nordborg Henrik, Nordlander Johanna, Pan Changji, Paulish Nataliya, Pearce Daniel, Penning Björn, Pijnenburg Martin, Potts Heidi, Pozdeeva Anna, Rademaker Louk, Reber Tobias, Rehmann Joel, Reiche Sven, Reindl Mira, Righetti Luca, Romerio Viola, Rusi El Hassani Amine, Sabatti Alessandra, Samalan Amrutha, Scheidegger Simon, Schuler Bruno, Segner Lea, Siklitskaya Aleksandra, Simeth Wolfgang Josef, Siol Sebastian, Siri Cécilia, Soares-Santos Marcelle, Sonner Julian, Southam Astrid, Steiger Ueli, Stepp Willi, Stoffer Peter, Swiatek Maciej, Theiler Christian, Tzschaschel Christian, Umesh Keerthana, Ussling Frederic, Valdez Garduno Nestor Miguel, Valetov Eremey Vladimirovich, Veneziano Matteo, Viebig Niklas, Vörös Janos, Wang Chizhou, Wei Yuan, Windhab Victor, Wirths Stephan, Wüthrich Christian, Zenhäusern Patrick, Zhang Zhijia

## Ehrenmitglieder - Membres d'honneur

Prof. Kathrin Altwegg-von Burg (2020)
Prof. Hans Beck (2010)
Dr. J. Georg Bednorz (2011)
Prof. Maurice Bourquin (2018)
Dr. Bernhard Braunecker (2023)
Prof. Ruth Durrer (2023)
Prof. Jean-Pierre Eckmann (2011)
Prof. Ralph Eichler (2020)
Prof. Jürg Fröhlich (2011)
Prof. Hermann Grunder (2001)
Prof. Martin C. E. Huber (2011)
Prof. Piero Martinoli (2016)
Prof. Hans Rudolf Ott (2005)
Prof. Felicitas Pauss (2022)
Prof. Louis Schlapbach (2010)
Prof. Herwig Schopper (2015)
Prof. Norbert Straumann (2016)
Prof. Friedrich K. Thielemann (2021)

## Assoziierte Mitglieder - Membres associés

*A) Firmen*

- ABB Schweiz AG, 5405 Baden
- COMSOL Multiphysics GmbH, 8005 Zürich
- Eidgenössisches Institut für Geistiges Eigentum, 3003 Bern
- Hitachi Energy Switzerland AG, 5405 Baden-Dättwil
- IBM Research GmbH, Forschungslabor, 8803 Rüschlikon
- ID Quantique, 1227 Acacias - Genève
- METAS, 3003 Bern-Wabern
- Sensirion AG, 8712 Stäfa

*B) Universitäten, Forschungseinrichtungen*

- Albert-Einstein-Center for Fundamental Physics, Universität Bern, 3012 Bern
- Swiss Plasma Center (SPC), EPFL, 1015 Lausanne
- Département de Physique, Université de Fribourg, 1700 Fribourg
- Departement Physik, Universität Basel, 4056 Basel
- Departement Physik, ETH Zürich, 8093 Zürich
- EMPA, 8600 Dübendorf
- Paul Scherrer Institut, 5332 Villigen PSI
- Physik-Institut, Universität Zürich, 8057 Zürich
- Section de Physique, Université de Genève, 1211 Genève 4
- Institut et Section de Physique, EPFL, 1015 Lausanne

*C) Studentenfachvereine*

- AEP - Association des Etudiant(e)s en Physique, Université de Genève, 1211 Genève 4
- Fachschaft Physik und Astronomie, Universität Bern, 3012 Bern
- Fachschaft Physique, Université de Fribourg, 1700 Fribourg
- Fachverein Physik der Universität Zürich (FPU), 8057 Zürich
- Fachgruppe Physik Universität Basel, 4056 Basel
- Les Irrotationnels, EPFL, 1015 Lausanne
- Verein der Mathematik- und Physikstudierenden an der ETH Zürich (VMP), 8092 Zürich

## Verteilung der Mitgliedskategorien - Répartition des catégories de membres (31.12.2024)

| | |
|---|---:|
| Ordentliche Mitglieder | 607 |
| Doktoranden | 104 |
| Studenten | 32 |
| Doppelmitglieder DPG, ÖPG, APS oder VSMP | 141 |
| Doppelmitglieder PGZ | 83 |
| Mitglieder auf Lebenszeit | 94 |
| Assoziierte Mitglieder | 26 |
| Bibliotheksmitglieder | 2 |
| Ehrenmitglieder | 18 |
| Beitragsfreie (Korrespondenz) | 5 |
| **Total** | **1112** |

# Jahresrechnung 2024 - Bilan annuel 2024

| Bilanz per 31.12.2024 | | |
|---|---|---|
| | **Aktiven** | **Passiven** |
| **Umlaufsvermögen** | | |
| Konto Postfinance | 132572,86 | |
| Konto UBS | 23601,17 | |
| Debitoren - Mitglieder | 2260,00 | |
| Debitoren – SCNAT / SATW u.a.m. | 65486,58 | |
| **Anlagevermögen** | | |
| Beteiligung EP Letters | 15840,00 | |
| Mobilien | 1,00 | |
| **Fremdkapital** | | |
| Mobiliar | | 1,00 |
| Mitglieder Lebenszeit | | 75908,25 |
| Transitorische Passiven | | 20704,20 |
| **Eigenkapital** | | |
| Verfügbares Vermögen | | 145604,58 |
| **Total Aktiven / Passiven** | **239761,61** | **242218,03** |
| **Verlust** | **2456,42** | |
| **Kontrollsumme** | **242218,03** | **242218,03** |
| Verfügbares Vermögen per 31.12.2024 nach Verlustzuweisung | | 143148,16 |

| Erfolgsrechnung per 31.12.2024 | | | |
|---|---|---|---|
| | **Aufwand** | | **Ertrag** |
| **Gesellschaftsaufwand** | | **Gesellschaftsertrag** | |
| EPS - Membership | 10199,32 | Mitgliederbeiträge | 113.198,16 |
| SCNAT - Membership | 7301,00 | Inserate / Flyerbeilagen SPG Mitteilungen | 5.170,00 |
| SATW – Mitgliederbeitrag | 1750,00 | Aussteller | 9.065,00 |
| **SCNAT und SATW Verpflichtungskredite** | | **SCNAT und SATW Verpflichtungskredite** | |
| SPG-Jahrestagung | 17065,10 | SPG-Jahrestagung (SCNAT) | 15000,00 |
| Schweizer Physik Olympiade | 4000,00 | Schweizer Physik Olympiade | 3000,00 |
| Übrige Tagungen SPG/SCNAT | 1919,83 | Übrige Tagungen SPG/SCNAT | 2000,00 |
| SPG Young Physicists Forum | 3500,00 | SPG Young Physicists Forum | 3500,00 |
| Lehrerfortbildungsevent 2014 ff | 6400,00 | Lehrerfortbildungsevent 2014 ff | 7500,00 |
| International Physics Tournament | 4000,00 | International Physics Tournament | 4000,00 |
| SPG Bulletin/Tagungsband (SCNAT) | 4300,00 | SPG Bulletin/Tagungsband (SCNAT) | 4000,00 |
| Periodika (SPG Mitteilungen, Druckkosten) | 29952,63 | Periodika (SPG Mitteilungen, Druckkosten) | 8000,00 |
| Internationale Zusammenarbeit | 4302,18 | Internationale Zusammenarbeit | 4000,00 |
| Schweizer Jugend forscht (SJF) Physikarbeiten | 2000,00 | Schweizer Jugend forscht (SJF) Physikarbeiten | 1000,00 |
| Reisekosten Nachwuchs | 667,23 | Reisekosten Nachwuchs | 2000,00 |
| Swiss Young Phys. Tournament | 5000,00 | Swiss Young Phys. Tournament | 5000,00 |
| Women in Physics Career Symposium | 4000,00 | Women in Physics Career Symposium | 4000,00 |
| Science Education and Industry | 5000,00 | Science Education and Industry | 5000,00 |
| **Betriebsaufwand** | | | |
| Löhne | 31655,76 | | |
| Sozialleistungen, berufliche Vorsorge, Versicherung | 22679,92 | | |
| Übrige Druckkosten | 4788,80 | | |
| Porti / Telefonspesen / WWW- und PC-Spesen | 270,80 | | |
| Versand (Porti Massensendungen) | 5367,07 | | |
| Unkosten | 4854,65 | | |
| Büromaterial | 3632,35 | | |
| Bankspesen | 20,00 | | |
| Debitorenverluste Mitglieder | 2120,00 | | |
| Debitorenverlust SCNAT/SATW u.a.m. | 2512,94 | | |
| Buchhaltungs- und Sekretariatsaufwand extern | 8630,00 | | |
| **Total Aufwand / Ertrag** | **197889,58** | | **195433,16** |
| **Verlust** | | | **2456,42** |
| **Kontrollsumme** | **197889,58** | | **197889,58** |

swiss physical society

**Revisorenbericht zur Jahresrechnung 2024**

Die Jahresrechnung 2024 der SPG wurde von den unterzeichneten Revisoren geprüft und mit den Belegen in Übereinstimmung befunden.
Die Revisoren empfehlen der Generalversammlung der SPG, die Jahresrechnung zu genehmigen und den Kassier mit bestem Dank für die gute Rechnungsführung zu entlasten.

*Die Revisoren der SPG:*

Prof. Dr. Claude Monney

Dr. Pierangelo Gröning

Dübendorf, 21.03.2025

*SPG Buchhaltung, Departement Physik, Klingelbergstrasse 82, CH-4056 Basel*
*Email : sps@unibas.ch*

# Neue Ehrenmitglieder - Nouveaux membres d'honneur

Der Vorstand hat dieses Jahr zwei Vorschläge für neue Ehrenmitglieder erhalten. Die Ernennung findet im Rahmen der Generalversammlung am 18. August 2025 statt.
Le comité a reçu deux propositions pour des nouveaux membres d'honneur cette année. La nomination aura lieu le 18 août 2025 lors de l'Assemblée Générale.

**Christophe Rossel**

Dr. Christophe Rossel is an emeritus condensed matter physicist at IBM Research in Zurich. He served the physics community in various executive positions at national and international level. He is former president of the Swiss Physical Society (SPS) and of the European Physical Society (EPS), as well as an Executive Board member of the Swiss Academy of Sciences (SCNAT). His scientific expertise is mainly in superconductivity and magnetism, semiconductors and advanced functional materials, thin films and nanoelectronics. He is author or co-author of over 200 peer-reviewed scientific publications.

Ch. Rossel studied physics at the University of Neuchâtel in the early 1970s. He then spent a year at the Temple University in Philadelphia, focusing on optics and low-temperature physics, before starting a PhD on superconductivity at the University of Geneva as one of the first PhD students of Prof. Øystein Fischer. He earned his PhD in Physics in 1981 with a work entitled “Propriétés des densités de courant critique dans les phases de Chevrel”. He stayed two more years as postdoc in Geneva following up research on magnetic-field-induced-superconductivity in Chevrel Phases, before moving to the University of California, San Diego, working from 1983 to 1987 as faculty member on strongly correlated systems and heavy fermion superconductors.

In 1987, Ch. Rossel returned to Switzerland at the IBM Research – Zurich Laboratory, where he stayed until retirement in 2014 as an Emeritus Research Staff Member. It was surely an exciting time to start at IBM Zurich, just after the Nobel Prize discovery there by Georg Bednorz and Karl Alex Müller of high-temperature superconductivity in ceramics. Ch. Rossel contributed very actively on the pioneering studies on high-temperature superconductors, notably on the Yttrium barium copper oxide (YBCO). His research on magnetic relaxation in YBCO thin films provided insights into flux dynamics and vortex pinning mechanisms, which are crucial for the development of superconducting devices. He also explored the collective flux pinning behaviour in these films, contributing to the understanding of their electrical transport properties.

Towards the end of the 1990s, Ch. Rossel worked on torsion cantilever as magnetic torque sensor, before extending into the realm of nanotechnology, where he investigated the properties of thin films in various materials systems. The most cited paper he co-authored is from 2000 on reproducible switching effect in thin oxide films for memory applications. A work he followed up in 2001 by studying the electrical current distribution across a capacitor-like structure during bistable switching. While in a 2011 study, he co-authored research on resistance switching at the nanometre scale in amorphous carbon, demonstrating its potential as a candidate for non-volatile memory applications. These and related studies actually led to several patents for improved memory devices.

Beyond his research, Ch. Rossel has held significant leadership roles in scientific organisations. He served as the President of the Swiss Physical Society (SPS) from 2008 to 2012, where he played a pivotal role in promoting physics in Switzerland and fostering collaboration among physicists. During his term, the SPS celebrated its 100th anniversary in 2008, based on research done by his predecessor Tibor Gyalog, reflecting on a century of contributions to the field of physics.

Ch. Rossel was also the President of the European Physical Society (EPS) from 2015 to 2017. The EPS is a learned society and umbrella organization with 42 national physical member societies. Since 2021 he is chair of the working group “Physics and Industry” of IUPAP, the International Union of Pure and Applied Physics.

During his tenure, he emphasized the importance of scientific collaboration across Europe and advocated for the promotion of young talents and the role of physics in addressing global challenges. His leadership in the EPS underscored his commitment to advancing the field of physics on an international scale. Among other engagements, Ch. Rossel was also a member of the High-Level Advisory Group 'Open Science Policy Platform' (OSPP) established in 2016 by the EU Commission.

Last but not least, Ch. Rossel has been an active member of the Swiss Academy of Sciences (SCNAT) and the Swiss Academy of Technical Sciences (SATW), further demonstrating his dedication to the advancement of science and technology in Switzerland. He was an appreciated member of Executive Board of SCNAT from 2018 to 2023, where he accompanied in particular the development of the Platform Mathematics, Astronomy and Physics (MAP), the elaboration of the community roadmaps for research infrastructures and the start of the Swiss Quantum Initiative.

The following laudatio is proposed: *The Swiss Physical Society awards honorary membership to Dr. Christophe Rossel for his very successful and inspiring scientific career and his leadership for the advancement of physics in Switzerland and in Europe.*

**Leonid Rivkin**

Leonid "Lenny" Rivkin was born in Odessa in 1954 and pursued his early studies in physics in Novosibirsk. In the mid 1970s, he emigrated from the Soviet Union to the United States with his family as part of an emigration program enabled by international diplomatic and humanitarian efforts. Once in the U.S., Lenny continued his academic journey at Harvard University, earning an AB in Physics in 1978. He then obtained his PhD in Physics from the California Institute of Technology in 1985. His early career included pivotal roles at the Stanford Linear Accelerator Center (SLAC), where he contributed to the design and commissioning of damping rings for linear colliders, and at CERN, where he was involved in the commissioning of the LEP Injector.

In 1989, Lenny moved to Switzerland to join the Paul Scherrer Institute, where he became a central figure in the design, construction, and commissioning of the Swiss Light Source (SLS). His leadership continued as Head of the Accelerator Development and Operation Division (2002 – 2006) and later as Head of the Department of Large Research Facilities. From 2017 to 2020, he served as Deputy Director of PSI, and since 2020, he has been the Senior Executive Advisor to the PSI Director.

From 2006 until his retirement in 2019, Lenny served as Professor and Chair of Accelerator Physics at the École Polytechnique Fédérale de Lausanne (EPFL). Due to the close links with CERN and PSI, two institutions with several accelerator facilities at the forefront of the state of the art in this field, this is an outstanding position for accelerator physics in Europe. CERN focuses on particle collider physics at the highest energies, and PSI is engaged in a broad program of particle physics at the intensity frontier, material science, biology and medical applications of accelerators. The programs at the two labs are fully complementary and the combined R&D program in accelerator physics at the two institutions covers practically all areas of modern accelerator design. Leonid Rivkin used these opportunities and promoted R&D projects in a wide range of areas, for example Free Electron Laser physics, cancer therapy with proton beam and beam dynamics advancements for particle colliders at LHC or for the FCC study, leading the CHART Collaboration.

In his role as a Professor for Accelerator Physics he supervised 40 PhD students and 10 Master students.

Lenny's influence extends beyond national borders. He has held prominent positions on several international advisory committees, including:

- Chair of the CERN Scientific Policy Committee (2020 – 2022)
- Chair of the MAX IV Machine Advisory Committee, Lund, Sweden
- Chair of the DESY Machine Advisory Committee, Hamburg, Germany (2003 – 2010)
- Member of the International Linear Collider Machine Advisory Committee (2005 – 2007)
- Chair of the SOLEIL Project Machine Advisory Committee (2001 – 2006)
- Chair of the Accelerator Review Panel, Science & Technology Facilities Council (STFC), UK
- Chair of the Advisory Committee, Accelerator Research and Development (ARD) Initiative, Helmholtz Association of German Research Centers
- Member of Working Group 14 (WG14) on Accelerator Science with the International Union of Pure and Applied Physics (IUPAP)

His leadership in these roles has been pivotal in shaping the future of accelerator-based research and fostering international collaborations.

Within the Swiss Physical Society, Prof. Rivkin served as Co-Chair of the Applied Physics Section, where he actively promoted the application of physics in industrial contexts, strengthening the ties between scientific research and practical applications.

*Leonid Rivkin is elected Honorary Member of the Swiss Physical Society in recognition of his pioneering work in accelerator physics, his key contributions to the development of large-scale accelerator facilities at CERN and PSI, and his enduring commitment to education and the scientific community.*

# Public Symposium: 100 Years of Quantum Physics

INTERNATIONAL YEAR OF Quantum Science and Technology

The years 1920 - 1930 are regarded as an important decade in modern physics, in which every year epoch-making discoveries in quantum physics occurred. This prompted UNESCO to proclaim 2025 as the Year of Quantum Science and Technologies (IYQ).

After last year's symposium on *Louis de Broglie - 100 years of wave-particle dualism*, we continue the tradition at this year's Joint Annual Meeting with the colleagues of the Austrian Physical Society (ÖPG) in Vienna. One of the foci will be the scientific work of Wolfgang Pauli and Erwin Schrödinger in the years around 1925. Both physicists were born in Austria, but spent parts of their careers as professors of Physics in Zurich.

This symposium will take place on 18 August 2025 in the afternoon, and is free of charge, no registration needed.

Below we print the abstracts of the talks.

| Time | 100 Years of Quantum Physics<br>Abstracts |
|---|---|
| 14:00<br>–<br>14:45 | **The Tangled Tale of Entanglement: New Discoveries from Schrödinger's Research Notes**<br><br>*Christoph Lehner, Max-Planck-Institut für Wissenschaftsgeschichte Berlin*<br><br>Today, entanglement is commonly accepted as the most striking and characteristic phenomenon of quantum mechanics. But this realization was slow to emerge, in the early years of quantum mechanics, entanglement was just seen as a normal statistical correlation. Only with Einstein, Podolsky and Rosen's "Can quantum mechanical description of reality be considered complete?"(1935) and Schrödinger's "Die gegenwärtige Situation in der Quantenmechanik" (1936) did the phenomenon come into focus as a central and puzzling feature of quantum mechanics. However, not much has been known about the prehistory of these papers. Jos Uffink and me were able to trace the development of both Einstein's and Schrödinger's thought, using Schrödinger's correspondence and especially his extensive research notes. We especially found that they both got important input from Leo Szilard, who proposed in 1931 a thought experiment that is a direct precursor to the EPR experiment and a quantum mechanical state that is essentially identical to the EPR state. |
| 14:45<br>–<br>15:30 | **Scenes from the Quantum Century: From Curious Hippies to Novel Tests of Bell's Inequality**<br><br>*David Kaiser, Department of Physics, MIT*<br><br>The hundredth anniversary of quantum mechanics in 2025 offers opportunities to consider the history of quantum theory and ask how some of our core ideas were introduced, debated, tested, and ultimately accepted. One of the most central conceptual ingredients of quantum theory is entanglement, nowadays so important to the burgeoning field of quantum information science and technology. Yet the history of quantum entanglement---and of physicists' efforts to understand whether entanglement is a robust feature of the world rather than merely an intriguing hypothesis---has been far from straightforward. In this talk I will describe how a colorful group of physicists during the 1970s wrestled with entanglement and with John Bell's now-famous inequality, exploring the subtle interplay between quantum nonlocality and relativity amid the California counterculture scene. More recently, retracing the history of efforts to conduct experimental tests of Bell's inequality helped to catalyze novel tests, which have aimed to close a series of loopholes, including the recent "Cosmic Bell" experiments. These experiments provided compelling evidence for quantum entanglement while constraining certain classes of alternative models – which exploit a particularly subtle loophole – more thoroughly than ever before. |
| 15:30<br>–<br>16:00 | ***Coffee Break*** |
| 16:00<br>–<br>16:45 | **Philosophy of Quantum Mechanics Beyond the Measurement Problem**<br><br>*Alyssa Ney, LMU München*<br><br>One hundred years after Heisenberg's discovery of quantum mechanics, there is still no consensus over even basic facts about its interpretation. One reason for this impasse can be traced to a disagreement in the first place about the role of the observer in quantum physics. Since the development of the Copenhagen interpretation in 1927, observers and measurements have been central elements in orthodox presentations of quantum mechanics. And yet in the philosophy of physics, there is a persistent narrative that such interpretations face a "measurement problem," that references to observers or measurements should not be included in presentations of our fundamental physical theories, but rather such phenomena should be regarded as emergent from more fundamental ontologies described by the quantum wave function or other parameters. This paper proposes a way of reconciling this disagreement by developing the ideas of John Archibald Wheeler. It finds particular inspiration in the reaction of Wheeler, over several decades, to the interpretation of his doctoral student, Hugh Everett, which later became the many worlds interpretation. |
| 16:45<br>–<br>17:30 | **Wolfgang Pauli's and Erwin Schrödinger's Insights<br>from the Perspective of a Modern Quantum Technologist**<br><br>*Beatrix Hiesmayr, Universität Wien*<br><br>This lecture examines the scientific insights of Wolfgang Pauli and Erwin Schrödinger—two outstanding yet very different personalities—from the perspective of current research. It addresses both their ideas, which are now considered universally accepted knowledge, and their misconceptions. A particular focus is placed on how the scientific discourse distinguishes between "right" and "wrong" and how the daily life of researchers has changed compared to the past. |
| 17:30 | ***END*** |

# Public Lectures

This year we have scheduled two public lectures in the program of the Joint Annual Meeting. The first one takes place on Monday 18 August at the main building of the University of Vienna and features ***Thomas Feurer***, Managing Director of the Eurpoean XFEL. He will describe the state of the art of free electron lasers to produce coherent X-Ray radiation. This allows to perform exciting new experiments to study matter under extreme conditions of temperature and pressure.

The second lecture takes place on Tuesday 19 August at the Austrian Academy of Sciences (ÖAW). ***Claus Beisbart***, Institut für Philosophie, Universität Bern, and former head of the SPS section *History and Philosophy of Physics* describes the role that AI methods will also play in physics in the future. Of course, they cannot generate deep physical understanding, but to see them only as a pure aid falls short, as they are being developed more and more powerfully. The talk will also address how this tool can be optimally handled in science also from a ethical point of view

Both talks can be visited free of charge, no registration needed.

Below we print the abstracts of both talks.

| Time | Public Lecture 1 (Monday) |
|---|---|
| 19:00 - 20:15 | **The European X-ray free electron laser**<br><br>*Thomas Feurer, European XFEL GmbH, Holzkoppel 4, DE-22869 Schenefeld*<br><br>X-ray Free Electron Lasers (XFELs) have greatly enhanced our ability to observe transient nuclear and electronic motions in real time at atomic resolution, thereby deepening our fundamental understanding of matter across different disciplines. Moreover, XFELs offer several significant advantages in High Energy Density (HED) science, which deals with matter under extreme conditions of temperature and pressure. For instance, XFELs can probe structure and ionization dynamics in warm dense matter, a regime between solid and plasma states, investigate material response to ultra-high pressures, help refine models of radiation transport at extreme conditions, and recreate and study conditions inside gas giants or white dwarfs.<br>Most XFELs today generate pulses that consist of amplified noise, leading to significant shot-to-shot fluctuations. While these pulses exhibit high transverse coherence, their longitudinal coherence remains very low. In this talk, I will present two methods for controlling longitudinal coherence and demonstrate their application in X-ray spectroscopy. Such experiments are made possible only by the resulting exceptional spectral brilliance of XFEL sources. Specifically, I will discuss a nuclear clock transition in one of the scandium isotopes. By controlling the nonlinear phase-space dynamics of ultrashort electron bunches, undulators can be made to emit pulses as short as attoseconds. Such pulses are ideal for probing electron dynamics on their natural timescales. In this presentation, I will highlight applications where attosecond pulses are used to create transient population inversion in inner-shell electrons. Lastly, I will discuss several applications of XFELs in the area of high energy density science. For example, I will present the first experimental evidence of liquid carbon, formed by shock-compressing graphite with a high-energy laser and probing it transiently using ultrashort XFEL pulses. Additionally, I will show the first experimental observation of plasma compression driven by relativistic currents in a cylindrical geometry; this effect was predicted over two decades ago but never confirmed until now. These experiments underscore the transformative impact of XFELs on advancing inertial fusion energy research. |
| 20:15 | ***END*** |

| Time | Public Lecture 2 (Tuesday) |
|---|---|
| 19:00 - 20:15 | **Physical understanding in times of AI. A philosophical analysis**<br><br>*Claus Beisbart, Universität Bern*<br><br>These days, AI applications, particularly neural networks, are all the rage in physics and beyond. Undoubtedly, they can be powerful in classification and prediction tasks. However, can AI provide physicists with scientific understanding? Some authors have been skeptical and suggested that big-data-oriented science remains shallow because AI remains a black box to humans. Others, by contrast, have taken a more optimistic stance and pointed to examples in which AI has seemingly been instrumental to human understanding. This talk aims to reconcile these different views. I start with systematic reflections on understanding in physics. To account for the skeptical voices, I argue that AI can be trained with fairly little domain knowledge, and that tools that predict something to be the case are typically not known to contain explanatory information, which means that they are not suited for explanatory understanding. However, in some situations, there can be reasons to think that AI applications become sensitive to explanatory relevant variables, and a closer investigation of a network or a bunch of runs of a simulation program can often reveal explanatory information. Accordingly, the impact of AI tools on scientific understanding depends crucially on what people know and how they use AI. To show the power of AI for understanding, the talk systematically carves out inferences that lead to more understanding. |
| 20:15 | ***END*** |

# Vorläufige Programmübersicht - Aperçu du programme préliminaire

Das vollständige Programm mit den Abstracts erscheint demnächst und wird auf der Konferenzwebseite und der SPG Webseite (www.sps.ch) publiziert.

Hinweise:

- Je Beitrag ist nur der präsentierende Autor aufgeführt.
- Die Postersitzung findet am Mittwoch von 16:00 - 19:00 (mit Apéro) statt.
- (p) = Plenarsprecher, (k) = Keynote, (i) = eingeladene Sprecher

**Das Programm am Montag 18. August ist von der Konferenzgebühr ausgenommen. Eine Anmeldung ist nur für die anderen Tage erforderlich.**

Le programme final complet avec les résumés paraîtra prochainement et sera également publié sur le site de la conférence et de la SSP (www.sps.ch).

Indications:

- seul le nom de l'auteur présentant la contribution a été indiqué.
- la session poster aura lieu le mercredi de 16:00 à 19:00 (avec apéro).
- (p) = orateur de la session plénière, (i) = orateur invité

**Le programme du lundi 18 août est exempt des frais de la conférence. Il est seulement nécessaire de s'inscrire pour les autres journées.**

## Energy Day

### *Monday, 18.08.2025, Room Großer Festsaal*

| Time | ID | ENERGY DAY<br>*Chair: Tomoko Muranaka, EPFL; Stephan Wirths, Hitachi Energy* |
|---|---|---|
| 09:00 | 1 | **Renewable energy production and sustainable material design**<br>*Anna Fontcuberta i Morral (p)* |
| 09:45 | 2 | **Efficiency in Computing and Energy Conversions**<br>*Bruno Michel (i)* |
| 10:30 | | ***Coffee Break*** |
| | | *Chair: Robert Hauser, FH Kärnten; Christoph Reichl, AIT* |
| 11:00 | 3 | **Energy Efficient HPC in the Exascale Era**<br>*Siegfried Höfinger (i)* |
| 11:30 | 4 | **High-performance computers: Compact systems with relatively high power densities in the order of around 100 kW/cabinet**<br>*Valentin Hirschbrich (i)* |
| 12:00 | 5 | ***Panel Discussion***<br>*Moderation: Herbert Störi* |
| 12:30 | | ***END; Lunch*** |

## Public Symposium: 100 Years of Quantum Physics & Public Lecture

### *Monday, 18.08.2025, Room Großer Festsaal*

| Time | ID | 100 YEARS OF QUNATUM PHYSICS<br>*Chair: Franz Sachslehner, Universität Wien* |
|---|---|---|
| 14:00 | 11 | **The Tangled Tale of Entanglement: New Discoveries from Schrödinger's Research Notes**<br>*Christoph Lehner (p)* |
| | | *Chair: Jérôme Baudry, EPF Lausanne* |
| 14:45 | 12 | **Scenes from the Quantum Century: From Curious Hippies to Novel Tests of Bell's Inequality**<br>*David Kaiser (p)* |
| 15:30 | | ***Coffee Break*** |
| | | *Chair: Christian Wüthrich, Université de Genève* |
| 16:00 | 13 | **Philosophy of Quantum Mechanics Beyond the Measurement Problem**<br>*Alyssa Ney (p)* |

| Time | ID | *Chair: Franz Sachslehner, Universität Wien* |
|---|---|---|
| 16:45 | 14 | **Wolfgang Pauli's and Erwin Schrödinger's Insights from the Perspective of a Modern Quantum Technology**<br>*Beatrix Hiesmayr (p)* |
| 17:30 | | ***END, Welcome Reception*** |
| 18:00 | | ***General Assemblies of ÖPG * and SPS **** |
| | | PUBLIC LECTURE<br>*Chair: Michel Calame, Empa & Universität Basel* |
| 19:00 | 15 | **The European X-Ray Free Electron Laser**<br>*Thomas Feurer (p)* |
| 20:15 | | ***END*** |

* ÖPG: Room HS 31, ** SPS: Room HS 30

## Women in Physics Career Symposium

THIS EVENT IS SUPPORTED BY SPS, ÖPG, UNIVERSITÄT ZÜRICH, PSI VILLIGEN, SCNAT, UNIVERSITÉ DE GENÈVE, SFB BEYONDC AND SOROPTIMISTINNEN WIEN-BELVEDERE.

### *Monday, 18.08.2025, Room Senatssaal*

| Time | ID | WOMEN IN PHYSICS CAREER SYMPOSIUM |
|---|---|---|
| 12:30 | | ***Fingerfood for participants of the symposium*** |
| | | *Chair: Philipp Schmidt-Wellenburg, PSI Villigen* |
| 13:15 | 21 | **ESO engagement in Equity, Diversity and Inclusion**<br>*Francesca Primas (p)* |
| | | *Chair: Ille Gebeshuber, TU Wien* |
| 14:00 | 22 | Career Talk 1:*Beatrix Hiesmayr (i)* |
| 14:30 | 23 | Career Talk 2: *Kimberly Modic (i)* |
| 15:00 | 24 | *Interactive Career Workshop with Francesca Primas* |
| 15:30 | | ***Coffee Break*** |
| | | *Chair: Tobias Golling, Université de Genève* |
| 16:00 | | *Workshop continued* |
| 17:00 | 25 | Career Talk 3: *Anna Spindelberger (i)* |
| 17:30 | 26 | Career Talk 4: *Rachel Grange (i)* |
| 18:00 | | ***END*** |
| 18:00 | | ***General Assemblies of ÖPG * and SPS **** |
| 19:00 | | ***Public Lecture*** |

## Plenary Session

### Tuesday, 19.08.2025, Room Großer Festsaal

| Time | ID | Official Conference Opening |
|---|---|---|
| 08:50 | | **Welcome note**<br>*NN* |
| | | **Plenary Session I**<br>*Chair: NN* |
| 09:00 | 31 | **The Next 100 Years of Quantum Mechanics**<br>*Caslav Brukner (p)* |
| | | *Chair: Rachel Grange, ETH Zürich* |
| 09:45 | 32 | **Spin Qubits in Semiconductors for Scalable Quantum Computers**<br>*Daniel Loss (p)* |
| 10:30 | | ***Coffee Break*** |
| 11:00 | | ***Award Ceremony*** |
| | | *Chair: NN* |
| 12:00 | 33 | **Quantum Threats and Opportunities for Secure Communication**<br>*Nicolas Sangouard (i)* |
| | | *Chair: NN* |
| 12:30 | 34 | **Winner of the SexI Award**<br>*NN* |
| 13:00 | | ***Lunch*** |
| 14:00 | | ***Topical Sessions*** |
| 18:00 | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |

### Tuesday, 19.08.2025, ÖAW Festsaal

| Time | ID | Public Lecture<br>*Chair: Christian Wüthrich, Université de Genève* |
|---|---|---|
| 19:00 | 35 | **Physical understanding in the times of AI. A philosophical analysis.**<br>*Claus Beisbart (p)* |
| 20:15 | | ***END*** |

### Wednesday, 20.08.2025, Room Großer Festsaal

| Time | ID | Plenary Session II<br>*Chair: NN* |
|---|---|---|
| 09:00 | 36 | **When Crystals Flow: The Emergence of Supersolid Quantum States**<br>*Francesca Ferlaino (p)* |
| | | *Chair: NN* |
| 09:45 | 37 | **A mechanical qubit**<br>*Yiwen Chu (p)* |
| 10:30 | | ***Coffee Break*** |
| | | **ERC Symposium**<br>*Chair: NN* |
| 11:00 | 38 | **Models and methods in the study of high-temperature superconductivity**<br>*Jaksa Vucicevic (i)* |
| 11:30 | 39 | **Title not yet available**<br>*Dragan Mihailović (i)* |
| 12:00 | 40 | **The Quantum Twisting Microscope: Visualizing Waves in Quantum Matter**<br>*Shahal Ilani (i)* |
| 12:30 | | ***Lunch*** |

| Time | ID | Plenary Session III<br>*Chair: NN* |
|---|---|---|
| 14:00 | 41 | **The laser in quantum science**<br>*Serge Haroche (p)* |
| 14:45 | 42 | **Quantum science in condensed matter in the mid-European area**<br>*Panel Discussion* |
| 15:45 | | ***Exhibitor Presentation Session*** |
| 16:00 | | ***Postersession with Apéritif*** |
| 19:00 | | ***END*** |

### Thursday, 21.08.2025, Room Großer Festsaal

| Time | ID | Plenary Session IV<br>*Chair: NN* |
|---|---|---|
| 09:00 | 43 | **Status of the anomalous magnetic moment of the muon**<br>*Martin Hoferichter (p)* |
| | | *Chair: NN* |
| 09:45 | 44 | **Trapped-ion quantum computing at Infineon**<br>*Clemens Rössler (p)* |
| 10:30 | | ***Coffee Break*** |
| | | *Chair: NN* |
| 11:00 | 45 | **Broadband integrated photonics with planarized terahertz quantum cascade lasers**<br>*Urban Senica (i)* |
| | | *Chair: NN* |
| 11:30 | 46 | **Engineering Andreev band structures in multi-terminal Josephson junctions**<br>*Marco Coraiola (i)* |
| | | *Chair: NN* |
| 12:00 | 47 | **Electrical and Optical Manifestation of Flat Bands in 2D Semiconductors**<br>*Gabriele Pasquale (i)* |
| 12:30 | | ***Lunch*** |
| 14:00 | | ***Topical Sessions*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

### Friday, 22.08.2025, Room Großer Festsaal

| Time | ID | Plenary Session V<br>*Chair: NN* |
|---|---|---|
| 09:00 | 48 | **Using cellular phase transitions to understand cancer**<br>*Roberto Cerbino (p)* |
| | | *Chair: Ulrike Diebold, TU Wien* |
| 09:45 | 49 | **Towards Quantum Computing with Spins on Surfaces**<br>*Andreas Heinrich (p)* |
| 10:30 | | ***Coffee Break*** |
| | | *Chair: NN* |
| 11:00 | 50 | **A matter of time, gravity and galaxies**<br>*Sveva Castello (i)* |
| | | *Chair: NN* |
| 11:30 | 51 | **Oscillating rings, IPT 2025**<br>*Tamás Simon (i)* |
| | | *Chair: NN* |
| 12:00 | 52 | **Title not yet available**<br>*Claas Abert (i)* |

| | | |
|---|---|---|
| 12:30 | | *Poster Awards and Closing Ceremony* |
| 12:45 | | *End; Lunch* |
| 14:00 | | *Topical Sessions* |
| 16:00 | | *CONFERENCE END* |

## History and Philosophy of Physics

### *Tuesday, 19.08.2025, Room Erika Weinzierl Saal*

| Time | ID | History and Philosophy of Physics<br>*Chair: Bruno Besser, ÖAW Graz, Christian Wüthrich, Université de Genève, Jérôme Baudry, EPF Lausanne* |
|---|---|---|
| 14:00 | 61 | **A Medieval Planetary Diagram in the University Library Graz, Austria**<br>*Sonja Draxler* |
| 14:15 | 62 | **Erwin Schrödinger's explanation of abnormal audibility of artillery explosions**<br>*Heinz Krenn* |
| 14:30 | 63 | **Bohr's Complementarity in the Age of Quantum Information: Bridging Epistemology and Quantum Foundations**<br>*Marina Passaro* |
| 14:45 | 64 | **Ignored because of prejudices? The late discovery of the Aharonov-Bohm effect from a historical-philosophical perspective**<br>*Guy Hetzroni* |
| 15:00 | 65 | **The Atomic Clock Program at Neuchâtel (1952-1967)**<br>*Ion Mihailescu* |
| 15:15 | 66 | **Localisation of Particles in Quantum Field Theory**<br>*Alexander Niederklapfer* |
| 15:30 | | *END; Coffee Break* |

## Physics and School

### *Tuesday, 19.08.2025, Room Elise Richter Saal*

| Time | ID | Physics and School I<br>*Chair: Alexander Strahl, Universität Salzburg* |
|---|---|---|
| 14:00 | 71 A-E | **Preisträgervorträge der ABA-Preisträgerinnen und -Preisträger der ÖPG 2025**<br>*NN* |
| 14:50 | 72 | **Vorstellung des IYPT Tournament**<br>*NN* |
| 15:05 | 73 | **Vorstellung der Physikolympiade**<br>*NN* |
| 15:20 | | |
| 15:30 | | *Coffee Break* |
| | | Physics and School II<br>*Chair: Alexander Strahl, Universität Salzburg* |
| 16:00 | 74 | **Understanding of Nature of Science and Dealing with Errors**<br>*Rahel Schmid (i)* |
| 16:30 | 75 | **Schrödinger's cat in basic physics instruction - Sketch of a learning path for the Swiss Gymnasium**<br>*Hans Peter Dreyer* |
| 16:45 | 76 | **PPLUS: Project-based Physics Lab for Undergraduate Students**<br>*Andreas Eggenberger* |
| 17:00 | 77 | **Making physics matter - Strategies for science communication**<br>*Henrik Siboni* |
| 17:15 | 78 | **PLANCKS Austria: Competing, Connecting, and Changing Physics Education**<br>*Christian Binder* |
| 17:30 | 79 | **Empowering Youth Through Physics by Three Innovative Approaches in Hands-On School Outreach: Iridescent Chocolate, Iridescent Kombucha Vegan Leather and Complex Mycelium Shapes**<br>*Ille C. Gebeshuber* |
| 17:45 | | *END* |
| | | *Transfer to ÖAW*<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | *Public Lecture* |

## Progress in Material Sciences – from Lab to Industry

*(Physics in Industry)*

### *Thursday, 21.08.2025, Room HS 30*

| Time | ID | Progress in Material Sciences – from Lab to Industry<br>*Chair: Gian Salis, IBM Rüschlikon, Peter Korczak, ÖPG* |
|---|---|---|
| 14:00 | 81 | **Diamond thin films – from lab to industry**<br>*Doris Steinmüller-Nethl (i)* |
| 14:20 | 82 | **Thin film coatings – adressing modern industry challenges**<br>*Georgios Christides (i)* |
| 14:40 | 83 | **High-k SiC power MOSFETs for the next generation of E-mobility power modules**<br>*Stephan Wirths (i)* |
| 15:00 | 84 | **Elucidating the diffision of hydrogen in Zn coatings for the steel industry**<br>*Andreas Kretschmer* |
| 15:20 | | |
| 15:30 | | *Coffee Break* |
| | | *Chair: Christian Teissl, FabLab. Tirol* |
| 16:00 | 85 | **A brain-inspired computing approach – the role of material science**<br>*Wooseok Choi (i)* |
| 16:20 | 86 | **The world of refractory metals molybdenum and tungsten – linking basic research and industrial applications**<br>*Arno Plankensteiner (i)* |
| 16:40 | 87 | **Printed Piezoelectric Transducers as Highly Integrated Nanogenerators for Harvesting Deformation, Motion and Vibration Energy**<br>*Barbara Stadlober (i)* |
| 17:00 | 88 | **GaN – much more than a semiconductor**<br>*Clemens Ostermaier (i)* |
| 17:20 | 89 | **Advances in green manufacturing of Li-ion batteries for scalable eco-friendly production**<br>*Marcus Jahn (i)* |
| 17:40 | | *Discussion* |
| 18:00 | | *END* |
| | | *Transfer to Dinner* |
| 19:00 | | *Conference Dinner* |

## Condensed Matter

**THIS SESSION HAS BEEN ORGANISED IN THE FRAME OF THE INITIATIVE CONDENSED MATTER IN CENTRAL EUROPE.**

### *Tuesday, 19.08.2025, Room HS 31*

| Time | ID | KOND I: Magnetism I<br>*Chair: NN* |
|---|---|---|
| 14:00 | 101 | **Magnetoresistance in Antiferromagnets**<br>*Karel Vyborny (k)* |
| 14:30 | 102 | **Chiral nanomagnetism induced by 3D nanopatterning**<br>*Amalio Fernandez-Pacheco (i)* |
| 15:00 | 103 | **Doping-controlled magnetic and optical effects in $EuCd_2X_2$**<br>*David Santos-Cottin* |
| 15:15 | | |
| 15:30 | | ***Coffee Break*** |
| | | **KOND II: Magnetism II**<br>*Chair: NN* |
| 16:00 | 105 | **Magnetic anisotropy and symmetry of unconventional antiferromagnets**<br>*Mirta Herak (k)* |
| 16:30 | 106 | **At the Frontier of Altermagnetism: Unraveling MnTe's Dual-Channel Photoresponse to Polarized Light**<br>*Juraj Krempasky (i)* |
| 17:00 | 107 | **Altermagnet / Superconductor / Altermagnet Tunneling Junction**<br>*František Herman (i)* |
| 17:30 | 108 | **Anomalous temperature dependence of local magnetic fields in altermagnetic MnTe**<br>*Jonas A. Krieger* |
| 17:45 | 109 | **Percolative metallic state with Kondo-like behavior in manganites $Ca_{1-x}Gd_xMnO_3$**<br>*Matija Culo* |
| 18:00 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

### *Tuesday, 19.08.2025, Room HS 33*

| Time | ID | KOND III: Quantum Dots & 2D Materials I<br>*Chair: NN* |
|---|---|---|
| 14:00 | 111 | **Gate defined electron and hole quantum dots in bilayer graphene**<br>*Luca Banszerus (k)* |
| 14:30 | 112 | **Shaped pulses enable robust quantum dot coherent control**<br>*Vikas Remesh (i)* |
| 15:00 | 113 | **Strong magnon-spin coupling between layered van der Waals antiferromagnet CrSBr and paramagnetic ion crystal GdW10**<br>*David García Pons* |
| 15:15 | 114 | **Pore shape selection in hexagonal boron nitride (hBN) with electron beam induced chemical effects**<br>*Umair Javed* |
| 15:30 | | ***Coffee Break*** |
| | | **KOND IV: 2D Materials II**<br>*Chair: NN* |
| 16:00 | 121 | **Multifrequency Excitation and High Dynamic Range Tunneling Spectroscopy**<br>*Fabian Natterer (k)* |
| 16:30 | 122 | **Atom diffraction through a free-standing 2D crystal**<br>*Toma Susi (i)* |
| 17:00 | 123 | **Bi-modal response in Graphene Nanoribbon Devices**<br>*Christian Teichert (i)* |
| 17:30 | 124 | **Charge Density Wave Ground State in the Intercalated Graphite $CaC_6$**<br>*P. Đurkas Grozić* |
| 17:45 | 125 | **Quantum confinement effects in rhombohedral and hexagonal graphite nanoribbons**<br>*Konrád Kandrai* |
| 18:00 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

### *Tuesday, 19.08.2025, Room HS 7*

| Time | ID | KOND V: Correlated Materials I<br>*Chair: NN* |
|---|---|---|
| 14:00 | 131 | **Exact method for polarons with arbitrary nonlinear electron-phonon interaction: description of quantum paraelectric by double-well "Jahn-Teller" type potential.**<br>*Andrey Mishchenko (i)* |
| 14:30 | 132 | **Novel States of Matter with Site- and Orbital-Selectivity as an Alternative to 'Charge Disproportionation' in Correlated Materials**<br>*Gheorghe Lucian Pascut (i)* |
| 15:00 | 133 | **O(3) Conformal Field Theory from a Truncated Quantum Rotor on the Fuzzy Sphere**<br>*Arjun Dey* |
| 15:15 | 134 | **Charge transport in two-dimensional system with massive and massless Mexican-hat-like bands**<br>*Zoran Rukelj* |
| 15:30 | | ***Coffee Break*** |
| | | **KOND VI: Superconductivity I**<br>*Chair: NN* |
| 16:00 | 141 | **Nanomechanical cat states in NEM-based quantum processing**<br>*Danko Radić (k)* |
| 16:30 | 142 | **Cuprates, Pnictides, and Sulfosalts: Lessons in Functional Materials**<br>*Denis Karl Sunko (i)* |
| 17:00 | 143 | **Discovery of Charge Order and a Dome-Shaped Superconducting Phase Diagram in the Kagome System $LaRu_3Si_2$**<br>*Zurab Guguchia (i)* |
| 17:30 | 144 | **Accidental cancellation of out-of-plane hopping amplitudes and breakdown of Drude behavior as the origin of anomalous c-axis resistivity of $Sr_2RuO_4$**<br>*Sophie Beck* |
| 17:45 | 145 | **A dynamical vertex approximation perspective on superconductivity in infinite-layer nickelates**<br>*Viktor Christiansson* |
| 18:00 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

### Thursday, 21.08.2025, Room HS 31

| Time | ID | KOND VII: Magnetism III<br>*Chair: NN* |
|---|---|---|
| 11:00 | 151 | **Topological magnetism of centrosymmetric skyrmion hosts**<br>*Matjaž Gomilšek (k)* |
| 11:30 | 152 | **Topological meron-antimeron domain walls and skyrmions in a low-symmetry system**<br>*Levente Rózsa (i)* |
| 12:00 | 153 | **Long-range propagating paramagnons**<br>*Sebastian Knauer* |
| 12:15 | 154 | **Realization of Inverse-Design Magnonic Logic Gates**<br>*Fabian Majcen* |
| 12:30 | | ***Lunch*** |
| | | **KOND VIII: Magnetism IV**<br>*Chair: NN* |
| 14:00 | 161 | **Spectroscopy of coupled magnetic and electric resonances**<br>*Dávid Szaller (k)* |
| 14:30 | 162 | **Unraveling the magnetic order in kagome magnet $Co_3Sn_2S_2$**<br>*Yona Soh (i)* |
| 15:00 | 163 | **Magnetic excitations across strain-engineered metal-insulator transition of $SrCrO_3$**<br>*Izabela Biało* |
| 15:15 | | |
| 15:30 | | ***Coffee Break*** |
| | | **KOND IX: 2D Materials III**<br>*Chair: NN* |
| 16:00 | 171 | **Rhombohedral graphite as the simplest platform for exploring strong correlations in topological electron systems**<br>*Peter Nemes-Incze (k)* |
| 16:30 | 172 | **Unconventional temperature evolution of quantum oscillations in topological insulator $BiSbTe_2S$**<br>*Mario Novak (i)* |
| 17:00 | 173 | **Electronic, and Magnetic Properties of Intercalated 2H-$NbS_2$ and 2H-$TaS_2$**<br>*Gaurav Pransu* |
| 17:15 | 174 | **Spin Bridges and Transport Barriers: Contrasting Electronic Effects of Co and Ni Intercalation in 2H-$NbS_2$**<br>*Petar Popčević* |
| 17:30 | 175 | **Enhanced electron-phonon coupling in few-layer $MoTe_2$ from micro-ARPES**<br>*Thomas P. van Waas* |
| 17:45 | 176 | **Control of antiferromagnetism in $La_{0.8}Sr_{0.2}MnO_3$ ultrathin films driven by interfacial chemical potential mismatch**<br>*Carlos Antonio Fernandes Vaz* |
| 18:00 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

### Thursday, 21.08.2025, Room HS 33

| Time | ID | KOND X: Semiconductors<br>*Chair: NN* |
|---|---|---|
| 11:00 | 181 | **Perovskites for photovoltaics: growth and stability characterization**<br>*Nada Mrkyvkova (k)* |
| 11:30 | 182 | **Observation of entangled electron-zone boundary phonon states with transient spectroscopic ellipsometry**<br>*Kurt Hingerl* |
| 11:45 | 183 | **Characterization of Excitons for bulk Black Phosphorus**<br>*Juan Felipe Pulgarin Mosquera* |
| 12:00 | 184 | **Magnetic co-doping in $Al_xGa_{1-x}N$: An emission Mössbauer spectroscopy study**<br>*Rajdeep Adhikari* |
| 12:15 | 185 | **Epitaxial control of silicon color centers for quantum applications at telecom wavelengths**<br>*Johannes Aberl* |
| 12:30 | | ***Lunch*** |
| | | **KOND XI: Superconductivity II**<br>*Chair: NN* |
| 14:00 | 191 | **Dual ground states in $Ce_3PtIn_{11}$ - Coexistence of Magnetism and Superconductivity**<br>*Jeroen Custers (i)* |
| 14:30 | 192 | **Differentiation of Site-Sensitive Symmetry Breakings**<br>*Johan Chang (i)* |
| 15:00 | 193 | **Transverse magnetic susceptibility reveals gigantic magnetic anisotropy in $UTe_2$ at high fields**<br>*Valeska Zambra* |
| 15:15 | 194 | **Stripe order in cuprates: a new perspective from high magnetic field scattering experiments**<br>*Leonardo Martinelli* |
| 15:30 | | ***Coffee Break*** |
| | | **KOND XII: Superconductivity III**<br>*Chair: NN* |
| 16:00 | 201 | **Magnetism and superconducting pairing in spin-state crossover nickelates**<br>*Jiří Chaloupka (k)* |
| 16:30 | 202 | **Effects of the in-plane stress on stripe order in $La_{1.875}Ba_{0.125}CuO_4$ - insights from NMR**<br>*Mihael S. Grbic (i)* |
| 17:00 | 203 | **Persistence of Small Polarons into the Superconducting Phase of $Ba_{1-x}K_xBiO_3$**<br>*Nicholas Plumb (i)* |
| 17:30 | 204 | **Quantum-Corrected Drude–Lorentz Model of Optical Conductivity in Disordered Superconducting Films**<br>*Pavol Neilinger* |
| 17:45 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

### Friday, 22.08.2025, Room 31

| Time | ID | KOND XIV: 2D Materials IV & Topology<br>*Chair: NN* |
|---|---|---|
| 11:00 | 211 | **Spintronics in 2D: Graphene and Beyond in van der Waals Heterostructures**<br>*Martin Gmitra (k)* |
| 11:30 | 212 | **Oxidized $MoS_2$ based memristors**<br>*Katharina Burgholzer (i)* |
| 12:00 | 213 | **Topological superconductivity studied from first principles**<br>*Laszlo Szunyogh (i)* |
| 12:30 | | ***Poster Awards and Closing Ceremony*** |
| 12:45 | | ***Lunch*** |

| Time | ID | KOND XV: Magnetism V<br>*Chair: NN* |
|---|---|---|
| 14:00 | 221 | **Magnetization processes and emergent magnetic excitations of the double spin ladder Cu-CPA**<br>*Tina Arh (i)* |
| 14:30 | 222 | **Long-living magnons at the quantum limit**<br>*Rostyslav Serha (i)* |
| 15:00 | 223 | **Steerable current-driven emission of spin waves in magnetic vortex pairs**<br>*Sabri Koraltan (i)* |
| 15:30 | 224 | **Optical detection of magnon in bulk α-MnTe**<br>*Jan Dzian* |
| 15:45 | 225 | **Tuneable spin-wave dynamics in nanoscale YIG magnonic crystals**<br>*Khrystyna Levchenko* |
| 16:00 | | ***END*** |

### *Friday, 22.08.2025, Room 33*

| Time | ID | KOND XVI: Correlated Materials II<br>*Chair: NN* |
|---|---|---|
| 11:00 | 231 | **THz dynamics of quantum materials, also under pressure**<br>*Elsa Abreu (k)* |
| 11:30 | 232 | **Influence of magnetic field on the band structure of $EuCd_2X_2$ (X=P, As, Sb)**<br>*Serena Nasrallah* |
| 11:45 | 233 | **Soft x-ray photoelectron spectroscopy of $Mn_2P$**<br>*Yuki Utsumi Boucher* |
| 12:00 | 234 | **Time-resolved terahertz spectroscopy in high electric and magnetic fields**<br>*Bence Szász* |
| 12:15 | 235 | **Competing Valence-Bond-Solid Ground States of the Spin-1/2 Heisenberg Antiferromagnet on the Star Lattice**<br>*Pratyay Ghosh* |
| 12:30 | | ***Poster Awards and Closing Ceremony*** |
| 12:45 | | ***Lunch*** |
| | | **KOND XVII: Correlated Materials III**<br>*Chair: NN* |
| 14:00 | 241 | **Symmetry and Complexity in Condensed Matter: Two Nonsymmorphic Tales**<br>*Aline Ramires (k)* |
| 14:30 | 242 | **Do we really need symmetry functions to understand micro-structure and phase transitions?**<br>*Carina Karner* |
| 14:45 | 243 | **Order Informed Sampling in the Physical Sciences**<br>*Christian Binder* |
| 15:00 | 244 | **Electronic structure and superconductivity in nickelates and cuprates: insights from DMFT and DΓA**<br>*Eric Jacob* |
| 15:15 | 245 | **Controlling Plasmonic Catalysis via Strong Coupling with Electromagnetic Resonators**<br>*Christian Schäfer* |
| 15:30 | 246 | **Steady state currents defy non-Hermitian many-body localization**<br>*Pietro Brighi* |
| 15:45 | 247 | **Analytical treatment of π-ton vertex corrections to optical conductivity**<br>*Juraj Krsnik* |
| 16:00 | | ***END*** |

### *Friday, 22.08.2025, Room Erika Weinzierl Saal*

| Time | ID | KOND XIII: Functional Materials<br>*Chair: NN* |
|---|---|---|
| 14:00 | 251 | **Photoinduced phase transitions into hidden states**<br>*Igor Vaskivskyi (k)* |
| 14:30 | 252 | **Topological Flat Bands for Metallic Thermoelectrics**<br>*Andrej Pustogow (i)* |
| 15:00 | 253 | **Insights into the flexibility of the DMOF-1 Metal-Organic Framework upon azobenzene isomerization revealed by terahertz (THz) and infrared (IR) spectroscopy**<br>*Peter Hartmann (i)* |
| 15:30 | 254 | **Optical conductivity of layered topological semimetal $TaNiTe_5$**<br>*Jakov Budić* |
| 15:45 | 255 | **Influence of Antisite Defects on Multiferroic Functionalities in $LaFeO_3$ Perovskite Oxides.**<br>*Souren Majani* |
| 16:00 | | ***END*** |

| ID | KOND Poster |
|---|---|
| 261 | **Spontaneous voltage and persistent electric current from rectification of ambient electronic noise in cuprate/manganite interface**<br>*Subhrangsu Sarkar* |
| 262 | **Bridging Quantum Scars and Classical Localization: Spin Transport Anomalies in Low-Dimensional Systems**<br>*Satar Almazyoudawi* |
| 263 | **Generalized Josephson effect with arbitrary periodicity in qunatum magnets.**<br>*Anshuman Tripathi* |
| 264 | **Static and Dynamic Magnetic Response of van der Waals Antiferromagnets**<br>*Ignac Fejes* |
| 265 | **Multiple CDW phase transitions in quasi-1D $RNiC_2$ compounds (R = rare earth metal)**<br>*Marta Roman* |
| 266 | **Extended s-wave pairing from an emergent Feshbach resonance in bilayer nickelate superconductors**<br>*Pietro Borchia* |
| 267 | **Tuning magnetic exchange interactions in two-dimensional van der Waals magnets**<br>*Jyothi Bhasu Anjali* |
| 268 | **Non-trivial Berry phase and anomalous Hall effect in layered $ZrTe_5$**<br>*Sophia Hollweger* |
| 269 | **Magnetic field-induced phases in BoNO: an extensive NMR study of a model S=1 Haldane chain**<br>*Ivan Jakovac* |
| 270 | **Ultrafast Vortex Velocities in Superconducting $MgB_2$ Films**<br>*Clemens Schmid* |
| 271 | **Impact of ambient hydrocarbon contamination on scanning tunneling microscopy and spectroscopy of graphite**<br>*György Kálvin* |
| 272 | **Γ-point magnons in antiferromagnetic α-MnTe**<br>*Stáňa Tázlarů* |
| 273 | **Colossal magnetoresistance effect and spin-dependent variable-range hopping in the charge ordered phase of overdoped $La_{1-x}Ca_xMnO_3$ manganites**<br>*Emil Tafra* |
| 274 | **Optical Properties of Metallic Carbon Nanotubes: New Insights for Plasmonic Predictions**<br>*Domitille Baux Remini* |
| 275 | **Atomic-resolution investigation of 2D hematene**<br>*Jana Dzibelova* |

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|---|---|
| 276 | **Field-dependent Magneto-optical Kerr Effect Spectra of $EuCd_2As_2$**<br>*Michal Hubert* |
| 277 | **Wide-Field MOKE Imaging of Domains in Altermagnetic MnTe**<br>*Filip Chudoba* |
| 278 | **Magneto-optical detection of malaria in rotating magnetic field**<br>*Gergely Babcsán* |
| 279 | **Modification of the electronic properties of MBE-grown $NbSe_2$ on oxide substrates**<br>*Ryan Thompson* |
| 280 | **Identifying Fulde–Ferrell–Larkin–Ovchinnikov Supercon-ductivity via Magnetotropic Response**<br>*Gulnaz Rakhmanova* |
| 281 | **Elimination of substrate-induced ferromagnetic resonance linewidth broadening in the epitaxial system YIG–GGG by microstructuring**<br>*David Schmoll* |
| 282 | **Investigating Strain-Dependent Magnetoresistance and Metal-Insulator Transition in LCMO Films at Cryogenic Tem-peratures Using Near-Field Techniques**<br>*Giuliano Esposito* |
| 283 | **Broken Symmetries and Ordered Electrons: Probing Charge Order in $CsV_3Sb_5$ Using Ultrasonic Pulse-echo Techniques.**<br>*German Cancino* |
| 284 | **Mapping stacking domains in rhombohedral graphite via conductive atomic force microscopy**<br>*Dóra Varga* |
| 285 | **Time-Domain THz Mueller Matrix Ellipsometry on Low Sym-metry Crystals**<br>*Premysl Marsik* |
| 286 | **Machine Learning for Quantum Many-Body Physics: Effi-cient Representation of Vertex Functions**<br>*Sebastian Hepp* |
| 287 | **Temperature dependence of the DC conductivity in aniso-tropic 3D Dirac semimetals**<br>*Patrik Papac* |
| 288 | **Kohler's Rule in the Strange Metal Regime of Cuprates**<br>*Luka Aksamovic* |
| 289 | **Progress in the studies of electronic and magnetic proper-ties of layered $MPX_3$ materials (M: transition metal, X: chal-cogen)**<br>*Yuriy Dedkov* |
| 290 | **Proximity effects in the graphene-$Co_3Sn_2S_2$ interface**<br>*Elena Voloshina* |
| 291 | **Electronic correlation and magnetic interactions in $PrNiO_2$**<br>*Xunyang Hong* |
| 292 | **Unconventional magnetic states in geometrically frustrated rare-earth heptatantalates**<br>*Kevin Jaksetič* |
| 293 | **Magnetism of doped Murunskite**<br>*Jana Mužević* |
| 294 | **Multiferroic Behavior in $BiFeO_3$ and $Bi_{1-x}Ho_xFeO_3$: Synergy Between Theory and Experiment**<br>*Maria Čebela* |
| 295 | **Hidden covalent insulator and spin excitations in $SrRu_2O_6$**<br>*Diana Csontosova* |
| 296 | **Control of antiferromagnetic domains in $La_{0.55}Sr_{0.45}MnO_3$ ul-trathin films**<br>*Carlos Antonio Fernandes Vaz* |

## Nuclear, Particle and Astrophysics (FAKT - TASK)

This session has been organised in collaboration with CHIPP.

### *Tuesday, 19.08.2025, Room Großer Festsaal*

| Time | ID | **FAKT - TASK I: EDM**<br>*Chair: NN* |
|---|---|---|
| 14:00 | 301 | **A Search for the Electric Dipole Moment of the Muon using the Frozen Spin Technique**<br>*Johannes Alexander Jaeger* |
| 14:15 | 302 | **Introducing the n2EDM experiment**<br>*Gian Luca Caratsch* |
| 14:30 | 303 | **An optically pumped magnetometer array used for a fundamental physics experiment**<br>*Lea Segner* |
| 14:45 | 304 | **A $^{199}$Hg Co-Magnetometer System for the n2EDM Ex-periment at PSI**<br>*Nikolaus von Schickh* |
| 15:00 | 305 | **Development of the superconducting injection channels for the muEDM experiment at PSI**<br>*Pranas Juknevicius* |
| 15:15 | 306 | **Deep-learning event reconstruction for the Cheren-kov Telescope Array Observatory with CTLearn**<br>*Bastien Lacave* |
| 15:30 | | ***Coffee Break*** |
| | | **FAKT - TASK II: Exotic Atoms I**<br>*Chair: NN* |
| 16:00 | 311 | **Precision Spectroscopy of Low-Lying States in Mu-onic Boron with MMC Detectors**<br>*Aziza Zendour* |
| 16:15 | 312 | **Muonic atom spectroscopy of U-238 for the extrac-tion of nuclear properties**<br>*Anastasia Doinaki* |
| 16:30 | 313 | **On the formation of molecules containing positro-nium**<br>*Alina Weiser* |
| 16:45 | 314 | **GRASIAN: Towards the first demonstration of grav-itational quantum states of atoms.**<br>*Carina Killian* |
| 17:00 | 315 | **Antihydrogen formation in the ASACUSA-Cusp ex-periment**<br>*Marcus Bumbar* |
| 17:15 | 316 | **From a Rabi- to a Ramsey-type apparatus for anti-hydrogen hyperfine spectroscopy**<br>*Martin Simon* |
| 17:30 | 317 | **LEMING - Cold muonium for atomic physics and gravity**<br>*Francesco Lancellotti* |
| 17:45 | 318 | **Detecting eV electrons at sub-kelvin temperatures for the LEMING experiment**<br>*Damian Goeldi* |
| 18:00 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

### *Tuesday, 19.08.2025, Room Senatssaal*

| Time | ID | **FAKT - TASK III: Neutrino**<br>*Chair: NN* |
|---|---|---|
| 14:00 | 321 | **Status of DUNE Near Detector ND-LAr**<br>*Saba Parsa* |
| 14:15 | 322 | **The liquid argon TPC at the DUNE Near Detector**<br>*Jan Kunzmann* |

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|---|---|---|
| 14:30 | 323 | **Upgrade detector for the neutrino oscillation experiment T2K experiment near site**<br>*Federico Sanchez Nieto* |
| 14:45 | 324 | **The neutrinoless double beta decay experiment LEGEND**<br>*Gloria Senatore* |
| 15:00 | 325 | **Energy Reconstruction for LHC Neutrinos at FASER**<br>*Jeremy Atkinson* |
| 15:15 | 326 | **Status of the Coherent Elastic Neutrino-Nucleus Scattering experiment NUCLEUS**<br>*Jens Burkhart* |
| 15:30 | | ***Coffee Break*** |
| | | **FAKT - TASK IV: Dark Matter**<br>*Chair: NN* |
| 16:00 | 331 | **Superconducting quantum bits as quasiparticle sensors**<br>*Felix Wagner (i)* |
| 16:15 | 332 | **Dark state pair-production in underground accelerators and their detection**<br>*Maximilian Fahrecker* |
| 16:30 | 333 | **Sensitivity of Dark Matter and Neutrino Experiments for Searches of Cosmic-Ray Boosted Dark Matter**<br>*Richard Diurba* |
| 16:45 | 334 | **Towards a theory of dissipative Dark Matter I: the Born limit**<br>*Garance Lankester-Broche* |
| 17:00 | 335 | **Recent results of the XENONnT Dark Matter experiment**<br>*Luisa Hötzsch* |
| 17:15 | 336 | **COSINUS: Searching for Dark Matter with Cryogenic NaI Detectors**<br>*Mariano Cababie* |
| 17:30 | 337 | **Status of the CRESST-III Experiment**<br>*Dominik Fuchs* |
| 17:45 | 338 | **Search for TeV Heavy Neutral Leptons with the ATLAS experiment**<br>*Lucas Mollier* |
| 18:00 | 339 | **Xenoscope: a vertical demonstrator for the next-generation liquid xenon observatory**<br>*Sana Ouahada* |
| 18:15 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

### *Thursday, 21.08.2025, Room HS 30*

| Time | ID | **FAKT - TASK V: Theory**<br>*Chair: NN* |
|---|---|---|
| 11:00 | 341 | **Title not yet available**<br>*Florian Hechenberger* |
| 11:15 | 342 | **Tensor meson contributions to the muon g-2 from holographic models of QCD**<br>*Jonas Mager* |
| 11:30 | 343 | **Dispersive evaluation of spin-2 resonances in the Hadronic Light-by-Light contribution to the muon g-2**<br>*Emilis Kaziukenas* |
| 11:45 | 344 | **LACTEL: a cosmic-ray detector in the Lac Léman**<br>*Ettore Zaffaroni* |
| 12:00 | 345 | **Search for dark matter with CTAO**<br>*Seraphine Marti* |
| 12:15 | 346 | **Latest results from the DAMPE experiment**<br>*Manbing Li* |
| 12:30 | | ***Lunch*** |

### *Thursday, 21.08.2025, Room Großer Festsaal*

| Time | ID | **FAKT - TASK VI: Detectors**<br>*Chair: NN* |
|---|---|---|
| 14:00 | 351 | **Validation of the design of the TEPX system for the Phase-2 CMS Inner Tracker**<br>*Filip Bilandzija* |
| 14:15 | 352 | **The Calibr-A-Ton: a novel method for calorimeter energy calibration**<br>*Jona Motta* |
| 14:30 | 353 | **The high-speed opto-electrical conversion system for the readout of the ATLAS ITk Pixel upgrade**<br>*Silke Möbius* |
| 14:45 | 354 | **The Mu3e Vertex Detector: From Module Qualification to First Beam**<br>*Thomas Christian Senger* |
| 15:00 | 355 | **Calibration of the LHCb magnetic field map**<br>*Aravindhan Venkateswaran* |
| 15:15 | 356 | **qBounce: a Ramsey-type Gravitational Resonance spectrometer – Results and Outlook**<br>*Joachim Bosina* |
| 15:30 | | ***Coffee Break*** |
| | | **FAKT - TASK VII: Theory**<br>*Chair: NN* |
| 16:00 | 361 | **Exotic hadron spectroscopy with functional methods**<br>*Gernot Eichmann* |
| 16:15 | 362 | **Sampling lattice field theories with diffusion models**<br>*Thomas Ranner* |
| 16:30 | 363 | **The (3+1)D dilute Glasma in the early stage of relativistic heavy-ion collisions**<br>*Kayran Schmidt* |
| 16:45 | 364 | **Jet energy loss in the nonequilibrium quark-gluon plasma during the initial stages in heavy-ion collisions**<br>*Florian Lindenbauer* |
| 17:00 | 365 | **Automated calculation of non-global soft functions**<br>*Rudi Rahn* |
| 17:15 | 366 | **Determination of the strong coupling from electron-positron event shapes**<br>*Andre Hoang* |
| 17:30 | 367 | **Geons as gravity balls**<br>*Axel Maas* |
| 17:45 | 368 | **Quantum gravity in static spherically symmetric spacetime**<br>*Ali Riahinia* |
| 18:00 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

### *Thursday, 21.08.2025, Room Senatssaal*

| Time | ID | **FAKT - TASK VIII: High Energy I, Higgs**<br>*Chair: NN* |
|---|---|---|
| 11:00 | 371 | **Search for Higgs boson pairs production in the bbtautau final state with the CMS detector using LHC Run3 data**<br>*Jona Motta* |
| 11:15 | 372 | **Search for pair production of Higgs bosons in the bbbb final state with the ATLAS detector**<br>*Una Alberti* |
| 11:30 | 373 | **Search for New Physics in the ttbar+MET final state with the ATLAS experiment**<br>*Daniele Dal Santo* |
| 11:45 | 374 | **A novel, model-independent approach to missing transverse energy determination in ATLAS**<br>*Marianna Głażewska* |

| | | |
|---|---|---|
| 12:00 | 375 | **Blueprint to a Numerical Collider**<br>*Valentin Hirschi* |
| 12:15 | 376 | **Search for ggHbb in the resolved final state with the CMS experiment**<br>*Giovanni Celotto* |
| 12:30 | | ***Lunch*** |
| | | **FAKT - TASK IX: High Energy II + R&D**<br>*Chair: NN* |
| 14:00 | 381 | **Search for the $B_c^+ \to \tau^+ \nu_\tau$ decay at LHCb**<br>*Rita De Sousa Ataide Da Silva* |
| 14:15 | 382 | **Technology challenges to realize future HEP experiments: From ECFA Detector Roadmap to DRD collaborations**<br>*Thomas Bergauer* |
| 14:30 | 383 | **Geometric and Optical Characterization of Double-Row Microlens SiPMs for LHCb SciFi Tracker Upgrade II**<br>*Jou An Chen* |
| 14:45 | 384 | **Silicon Carbide Radiation Detector R&D for High Energy Physics and Beyond**<br>*Sebastian Onder* |
| 15:00 | 385 | **Nonfactorizable Effects in Semileptonic Top Quark Decays**<br>*Bernd Carmann* |
| 15:15 | 386 | **Measurement of BR$(B_{(s)} \to K_S K_S)$with Run 2 LHCb data**<br>*Kerim Guseinov* |
| 15:30 | | ***Coffee Break*** |
| | | **FAKT - TASK X: Flavour Physics**<br>*Chair: NN* |
| 16:00 | 391 | **Search for violation of leptonic universality in Semileptonic Hyperon Decays in LHCb**<br>*Alexandre Brea Rodríguez* |
| 16:15 | 392 | **Study of the weakly decaying charmed baryons $X_{c+}$ and $X_{c0}$ with 89/fb of Belle II data**<br>*Nikolaus Schneider* |
| 16:30 | 393 | **Observation of the $K^+ \to \pi^+ + \nu\bar{\nu}$ decay at the NA62 experiment**<br>*Xiafei Chang* |
| 16:45 | 394 | **Measurement of the branching fraction ratio $\mathcal{B}(B^0 \to \omega K\pi)/\mathcal{B}(B^0 \to J/\psi K\pi)$ at LHCb**<br>*Pasquale Andreola* |
| 17:00 | 395 | **Measurement of $y_{CP}$ using 2024 Run 3 data at LHCb**<br>*Dimitrios Kaminaris* |
| 17:15 | 396 | **Search for the $B^+ \to \mu^+\mu^-\mu^+\nu$ decay at LHCb**<br>*Pierre Mayencourt* |
| 17:30 | 397 | **Search for the rare $K_S \to \mu^+\mu^-$ decay using Run 3 data at LHCb**<br>*Luis Miguel Garcia Martin* |
| 17:45 | 398 | **Search for the $B_s^0 \to \mu^+\mu^-\gamma$ decay with photon conversions.**<br>*Raphael van Laak* |
| 18:00 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

### *Friday, 22.08.2025, Room Senatssaal*

| Time | ID | **FAKT - TASK XI: Exotic Atoms II**<br>*Chair: NN* |
|---|---|---|
| 11:00 | 401 | **The time-resolved Migdal Effect**<br>*Stefan Nellen Mondragón* |
| 11:15 | 402 | **LEMING - towards muonium interferometry**<br>*Robert Waddy* |
| 11:30 | 403 | **Development of new superfluid helium-based muonium sources for the LEMING experiment**<br>*Elizaveta Dourassova* |
| 11:45 | 404 | **Antiproton-Nucleus Annihilations at Low Energies**<br>*Viktoria Kraxberger* |
| 12:00 | 405 | **Development and future prospects of a gamma-spectroscopy array for measurement of (n,xng) cross-section measurements at CERN $n_{TOF}$**<br>*Michael Bacak* |
| 12:15 | 406 | **Geant4 Characterization of the High Altitude Scintillator Detector AMORE**<br>*Sergey K. Ermakov* |
| 12:30 | | ***Poster Awards and Closing Ceremony*** |
| 12:45 | | ***Lunch*** |
| | | **FAKT - TASK XII: High Energy III**<br>*Chair: NN* |
| 14:00 | 411 | **Neutrino measurements with the FASER electronic detector at the LHC**<br>*Charlotte Cavanagh* |
| 14:15 | 412 | **Higgs Beyond the Standard Model: Probing Bosonic Resonant Decays to Hadronic VV$\tau\tau$ at CMS**<br>*Fanqiang Meng* |
| 14:30 | 413 | **FASERCal: Probing High-Energy Neutrinos at FASER in the HL-LHC Era**<br>*Anna Mascellani* |
| 14:45 | 414 | **Search for Neutrino Interaction Signature on SND@LHC with Machine Learning**<br>*Zhibin Yang* |
| 15:00 | 415 | **Charmed Baryon Physics at Belle II and Measurement of $\Xi_c$ Branching Fractions**<br>*Cristhian Ricaurte* |
| 15:15 | 416 | **Proton irradiation of a SciFi module to the dose profile expected in LHCb Upgrade 2**<br>*Gauri Napoletano* |
| 15:30 | | ***END*** |

| ID | **FAKT - TASK Poster** |
|---|---|
| 431 | **SiPM development for LHCb SciFi Upgrade II**<br>*Federico Ronchetti* |
| 432 | **Study of Signal-to-Background Discrimination in the muEDM experiment using Geant4**<br>*David Höhl* |
| 433 | **Measurement of the differential branching fraction of $B^+ \to K^+\pi^+\pi^-\mu^+\mu^-$**<br>*Anni Kauniskangas* |
| 434 | **Low energy antimatter at the Stefan Meyer Institute**<br>*Ross Sheldon* |
| 435 | **The Spectroscopy Beamline of the ASACUSA Antihydrogen Experiment**<br>*Matti Cerwenka* |
| 436 | **Cesium Magnetometry for the n2EDM Experiment**<br>*Luz Sanchez-Real Zielniewicz* |
| 437 | **Study of Exclusive Dimuon Photoproduction in Ultraperipheral Pb–Pb Collisions at $\sqrt{s_{nn}}$ = 5.02 TeV with the CMS Detector**<br>*Eslam Shokr* |
| 438 | **Machine learning a fixed-point action for the O(3) non-linear sigma-model**<br>*Liane Backfried* |
| 439 | **Cryogenic tracking detectors for the LEMING experiment**<br>*Rebecca Gartner* |
| 440 | **Decay of the Vortex neutron**<br>*Rahul Singh* |
| 441 | **A visualization of the relativistic Terrell-Penrose effect**<br>*Victoria Helm* |

## Gravitational Waves

### Thursday, 21.08.2025, Room Erika Weinzierl Saal

| Time | ID | Gravitational Waves I<br>*Chair: Philippe Jetzer, Universität Zürich* |
|---|---|---|
| 14:00 | 461 | **Overview of Austrian and Swiss GW communities**<br>*Gianluca Inguglia, Steven Schramm* |
| 14:20 | 462 | **Challenges and opportunities of the Einstein Telescope**<br>*Ulyana Dupletsa* |
| 14:40 | 463 | **Preparing for computing at the Einstein Telescope**<br>*Steven Schramm* |
| 15:00 | 464 | **Anomaly Detection of Gravitational Waves at the Einstein Telescope**<br>*Gianluca Inguglia* |
| 15:20 | | |
| 15:30 | | ***Coffee Break*** |
| | | Gravitational Waves II<br>*Chair: Gianluca Inguglia, ÖAW* |
| 16:00 | 465 | **An Algorithmic Approach to the Cauchy Problem for the Einstein Field Equations**<br>*Arthur Fischer* |
| 16:20 | 466 | **Identification and parameter estimation of gravitational-wave signals from extreme-mass-ratio inspirals with LISA**<br>*Stefan Strub* |
| 16:40 | 467 | **Deep source separation meets deep source inference: Toward a unified learning pipeline for high-dimensional gravitational-wave data**<br>*Niklas Houba* |
| 17:00 | 468 | **Exploring nanoHz gravitational waves with pulsar timing arrays**<br>*Michele Vallisneri* |
| 17:20 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:30 | | ***Conference Dinner*** |

## Accelerator Science and Technology

### Tuesday, 19.08.2025, Room Erika Weinzierl Saal

| Time | ID | Accelerator Science and Technology<br>*Chair: Mike Seidel, PSI Villigen* |
|---|---|---|
| 16:00 | 481 | **Superconducting-Magnet R&D for the Future Circular Collider at the PSI MagDev Laboratory**<br>*Bernhard Auchmann* |
| 16:15 | 482 | **Towards multi-scale modelling of $Nb_3Sn$ cable for accelerator magnets**<br>*Joep Van den Eijnden* |
| 16:30 | 483 | **Quench Protection based on Smart Insulation for the Final Cooling Solenoid of the Muon Collider**<br>*Matteo Crescenti* |
| 16:45 | 484 | **Update on Beam Halo Removal Studies for HL-LHC**<br>*Milica Rakic* |
| 17:00 | 485 | **Accelerating Mixed Ion Beams for Treatment Monitoring Research**<br>*Matthias Kausel* |
| 17:15 | 486 | **Beamline optimisation for High Intensity Muon Beams at PSI using heterogeneous island models**<br>*Eremey Valetov* |
| 17:30 | 487 | **The Upgrade of the Swiss Light Source and Characterization of its Beam Optics**<br>*Jesus Avila Pulido* |
| 17:45 | 488 | **Implementation of the Synchrotron Radiation Integrals in Xsuite**<br>*Simon Buijsman* |
| 18:00 | 489 | **Energy-efficient ERL-based accelerators from a beam dynamics perspective**<br>*Lode Vanhecke* |
| 18:15 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

## Energy, Sustainability and Environment

### Tuesday, 19.08.2025, Room HS 30

| Time | ID | Energy, Sustainability and Environment<br>*Chair: Robert Hauser, FH Kärnten; Christoph Reichl, AIT* |
|---|---|---|
| 16:00 | 501 | **Nature-Inspired Nanopores for Osmotic Energy Conversion**<br>*Yunfei Teng (i)* |
| 16:30 | 502 | **The Vienna Environmental Research Accelerator (VERA) for applications in Earth and Environmental sciences**<br>*Karin Hain* |
| 16:45 | 503 | **High-Power, Low-Noise Mid-Infrared Optical Frequency Combs for Precision Spectroscopy**<br>*Vito Fabian Pecile* |
| 17:00 | 504 | **Data-Driven Fault Detection in PV Plants Based on IV Curve Analysis and Artificially Generated Fault Scenarios**<br>*Felix Korbelius* |
| 17:15 | 505 | **Enhancing Heat Pump Installation Through Frequency-Based Acoustic Directivity Information: An Open Database Initiative**<br>*Luisa Stöckl* |
| 17:30 | 506 | **Decentralized heat pump solutions and their safety concepts for natural refrigerants in multi-family houses**<br>*Stephan Preisinger* |
| 17:45 | 507 | **IEA HPT Annex 61 – Integration of Heat Pumps in Positive Energy Districts**<br>*Christoph Reichl* |
| 18:00 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

| ID | Energy, Sustainability and Environment Poster |
|---|---|
| 521 | **Automatic focusing system for laser thermal annealing setup: toward effective wafer back contact annealing.**<br>*Martin Buessler* |
| 522 | **Upgrade of the proton induced x-ray emission setup at the Vienna Environmental Research Accelerator (VERA)**<br>*Leopold Unterweger* |
| 523 | **Extended aerosol optical depth (AOD) time series analysis in an alpine valley: a comparative study from 2007 to 2023**<br>*Jochen Wagner* |
| 524 | **IEA HPT Annex 63 - Placement Impact on Heat Pump Acoustics - Overview and Austrias Contribution to the Network**<br>*Christoph Reichl* |

## Applied Physics

### *Tuesday, 19.08.2025, Room Elise Richter Saal*

| Time | ID | **Applied Physics I**<br>*Chair: Fabio Avino, EPF Lausanne* |
|---|---|---|
| 14:00 | 551 | **$^{44}$Ti – A new Trace Isotope for Astrophysics**<br>*David Krebs* |
| 14:15 | 552 | **$M^2$ as a Quantitative Measure of Beam Quality**<br>*Filipp Lausch* |
| 14:30 | 553 | **Production and characterization of an isotopic Np spike for mass spectrometry**<br>*Karin Hain* |
| 14:45 | 554 | **Dark Field MOKE as a laboratory- based characterization tool for complex 3D magnetic nanostructures**<br>*Jakub Jurczyk* |
| 15:00 | 555 | **Ultrashort Picosecond Ion Pulse Generation by Laser-Stimulated Desorption**<br>*Alexander Redl* |
| 15:15 | 556 | **Femtosecond two-photon-absorption laser-induced-fluorescence in fusion-relevant hydrogen plasmas**<br>*Michael Goddijn* |
| 15:30 | | ***Coffee Break*** |
| | | **Applied Physics II**<br>*Chair: Fabio Avino, EPF Lausanne* |
| 16:00 | 561 | **Nanoscaled Spin-Wave Frequency Selective Limiter (FSL) and Delay Line for 5G Technology**<br>*Kristýna Davídková* |
| 16:15 | 562 | **Novel InAs/AlSb interband detectors**<br>*Stefania Isceri* |
| 16:30 | 563 | **Wavefront correction over large fields of view via cone tomography**<br>*Juan David Munoz Bolanos* |
| 16:45 | 564 | **Towards Monte Carlo based Full Spectrum Modeling of Airborne Gamma-Ray Spectrometry Systems**<br>*David Breitenmoser (i)* |
| 17:15 | 565 | **ILIAMS-assisted accelerator mass spectrometry measurements of long-lived radionuclides produced in nuclear fusion environment**<br>*Carlos Vivo-Vilches* |
| 17:30 | 566 | **Impact of divertor leg length on plasma-wall interaction in the TCV boundary plasma using self-consistent, global turbulence simulations**<br>*Sergio Garcia Herreros* |
| 17:45 | 567 | **Design of a Fast Reciprocating Diagnostic to Characterize the Boundary Plasma in the Tokamak à Configuration Variable**<br>*Alysée Khan* |
| 18:00 | 568 | **Trajectoids: Rolling stones downhill.**<br>*Jean-Pierre Eckmann* |
| 18:15 | | ***END*** |
| | | ***Transfer to ÖAW***<br>*Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

| ID | **Applied Physics Poster** |
|---|---|
| 581 | **Influence of impurity injection location on a tokamak plasma performance**<br>*Riccardo Morgan* |
| 582 | **Interpretation of Neutral Pressure Measurements and Design of a Novel Pressure Diagnostic Array for the TCV Tokamak through Monte Carlo Modelling with MolFlow**<br>*Benjamin Brown* |
| 583 | **Design of 3D Printed Tips for Advanced Magnetic Force Microscopy**<br>*Dominik Schramm* |
| 584 | **Action Spectroscopy of He-Tagged, Anionic Coinage Metal Clusters**<br>*Martin Schmidt* |
| 585 | **Development of a quasi-optical high-magnetic-field millimeter-wave spectrometer**<br>*Levente Hegyessy* |
| 586 | **Updates on CREScent: High-Precision Electron Spectroscopy using Cyclotron Radiation Emissions**<br>*Alberto Jose Saavedra Garcia* |

## Atomic Physics and Quantum Optics

### *Thursday, 21.08.2025, Room Elise Richter Saal*

| Time | ID | **Atomic Physics and Quantum Optics I**<br>*Chair: NN* |
|---|---|---|
| 14:00 | 601 | **Low Temperature Quantum Sensing with Single Nitrogen-Vacancy Centers in Diamond**<br>*Jodok Happacher (i)* |
| 14:30 | 602 | **Quantum synchronization of twin limit-cycle oscillators**<br>*Tobias Kehrer* |
| 14:45 | 603 | **Rapid and Robust Hyperfine Qudit Gates in Trapped Neutral Atoms**<br>*Johannes Krondorfer* |
| 15:00 | 604 | **Detection of Spin System Dynamics in Transmission Electron Microscope**<br>*Antonin Jaros* |
| 15:15 | 605 | **Spectroscopy of Multilevel Disordered Atomic Clouds**<br>*Aleksei Konovalov* |
| 15:30 | | ***Coffee Break*** |
| | | **Atomic Physics and Quantum Optics II**<br>*Chair: NN* |
| 16:00 | 611 | **A minimalistic mirrorless laser**<br>*Helmut Ritsch* |
| 16:30 | 612 | **Progress in matter-wave interference of mesoscopic metal nanoparticles**<br>*Richard Ferstl* |
| 16:45 | 613 | **Enhanced Polarization-Based Dark-Field Microscopy via Controlled Beam Decollimation**<br>*Fabian Maier* |
| 17:00 | 614 | **Source technologies for matter-wave interferometry with large metal clusters**<br>*Severin Sindelar* |
| 17:15 | 615 | **Driving Electron Spin Resonance with the Non-Radiative Near-Field of a Modulated Electron Beam**<br>*Matthias Kolb* |
| 17:30 | 616 | **Impact of Intensity Fluctuations on the Second-Order Coherence of High-Harmonic Emission**<br>*Rafael T. Winkler* |
| 17:45 | 617 | **Deep ultraviolet laser light for cluster interferometry**<br>*Hannah Foltas* |
| 18:00 | 618 | **Violating Wigner Inequalities**<br>*Maximilian Rottensteiner* |
| 18:15 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

### Friday, 22.08.2025, Room Elise Richter Saal

| Time | ID | Atomic Physics and Quantum Optics III<br>*Chair: NN* |
|---|---|---|
| 14:00 | 621 | **Electron-Photon Entanglement**<br>*Alexander Preimesberger* |
| 14:15 | 622 | **A cavity-microscope for micrometer-scale control of atom-photon interactions.**<br>*Ekaterina Fedotova* |
| 14:30 | 623 | **Restoring thermalization in long-range quantum magnets with staggered magnetic fields**<br>*Lucas Winter* |
| 14:45 | 624 | **Subradiance and superradiant long-range excitation transport among quantum emitter ensembles in a waveguide**<br>*Martin Fasser* |
| 15:00 | 625 | **Hybrid Atom-Optomechanical System in the Quantum Regime**<br>*Gian-Luca Schmid* |
| 15:15 | 626 | **Modeling the quantum dynamics of optomechanical self-organization of a condensate in a cavity, we discover interesting transient phenomena such as Dicke squeezing of atomic momentum and quantum enhanced SU(1,1) interferometry.**<br>*Ivor Kresic* |
| 15:30 | 627 | **Laser-Induced Quenching of the $^{229}$Th nuclear clock isomer in $CaF_2$**<br>*Fabian Schaden* |
| 15:45 | 628 | **Optical Coherent Feedback Control of a Mechanical Oscillator**<br>*Manel Bosch Aguilera* |
| 16:00 | | ***END*** |

| ID | Atomic Physics and Quantum Optics Poster |
|---|---|
| 641 | **Non-Hermitian Dynamics and Nonreciprocity of two Optically Coupled Nanoparticles**<br>*Murad Abuzarli* |
| 642 | **A quantum processor with non-local interactions and programmable connectivity**<br>*Johannes Schabbauer* |
| 643 | **Vibrationally Induced Molecular Magnetism**<br>*Johannes Krondorfer* |
| 644 | **Bistable and oscillating phases in ordered atomic arrays**<br>*Simon Panyella Pedersen* |
| 645 | **Towards quantum metrology with ultracold Cesium**<br>*Maximilian Lerchbaumer* |
| 646 | **Free expansion of charged nanoparticles via electrostatic compensation**<br>*David Steiner* |
| 647 | **NQR Spectroscopy of $^{229}$Th:$CaF_2$ crystals**<br>*Michael Bartokos* |
| 648 | **Towards two photon excitation of $^{229}$Th nuclei in $CaF_2$ crystals**<br>*Ira Morawetz* |
| 649 | **Scalable high-bandwidth quantum network platform with a room temperature quantum memory and a quantum dot single photon source.**<br>*Suyash Gaikwad* |
| 650 | **Collective cavity scattering by arrays of nanoparticles**<br>*Iurie Coroli* |

## Coherent Optical Metrology Beyond Electric-Dipole-Allowed Transitions

This session has been organised in collaboration with the
**SFB COMB.AT**

### Friday, 22.08.2025, Room Erika Weinzierl Saal

| Time | ID | Coherent Optical Metrology Beyond Electric-Dipole-Allowed Transitions (COMB.AT)<br>*Chair:* |
|---|---|---|
| 11:00 | 671 | **Theory of angular momentum transfer from light to molecules**<br>*Mikhail Maslov* |
| 11:15 | 672 | **Optical Vortex–Induced Orbital Angular Momentum Transfer in Ro-Vibrational Spectroscopy**<br>*Georgios Koutentakis* |
| 11:30 | 673 | **The R-Index metric for evaluating OAM Content and mode purity in optical fields**<br>*Monika Bahl* |
| 11:45 | 674 | **Technical Developments of Multi-Pulse CPA for Nonlinear Spectroscopy**<br>*Vinzenz Stummer* |
| 12:00 | | ***END*** |
| 12:30 | | ***Poster Awards and Closing Ceremony*** |

| ID | COMB.AT Poster |
|---|---|
| 681 | **Shaped light in spectroscopy: how using light carrying OAM can enhance molecular spectroscopy**<br>*Timo Gaßen* |
| 682 | **Towards the measurement of orbital angular momentum-enabled transitions in molecules**<br>*Tom Jungnickel* |
| 683 | **Bottom-up Analysis of Ro-Vibrational Helical Dichroism**<br>*Mateja Hrast* |
| 684 | **Coherent Optical Metrology Beyond Electric-Dipole-Allowed Transitions (COMB.AT)**<br>*Mikhail Lemeshko* |

## Surfaces, Interfaces and Thin Films

### Tuesday, 19.08.2025, Room HS 23

| Time | ID | Surfaces, Interfaces and Thin Films I<br>*Chair: Anna Niggas, TU Wien* |
|---|---|---|
| 14:00 | 701 | **Angle-Selective Infrared Reflection Absorption Spectroscopy on Oxide Surfaces**<br>*David Rath (i)* |
| 14:30 | 702 | **Atomically-resolved surface structure: The prerequisite for understanding surfaces at the atomic level**<br>*Ulrike Diebold* |
| 14:45 | 703 | **Valence Band states of copper phthalocyanines on Ag(111): hybridised states or spin splitting?**<br>*Francesco Presel* |
| 15:00 | 704 | **The surface structure of $Al_2O_3$(0001)**<br>*Jan Balajka* |
| 15:15 | 705 | **Stabilization of the polar spinel $MgAl_2O_4$(001) surface by an Al-rich reconstruction**<br>*David Kugler* |
| 15:30 | | ***Coffee Break*** |

| Time | ID | **Surfaces, Interfaces and Thin Films II** *Chair: Margareta Wagner, TU Wien* |
|---|---|---|
| 16:00 | 711 | **Charging, metalation and tautomerization of 2H-Phthalocyanine on ultrathin MgO films** *Martin Sterrer* |
| 16:15 | 712 | **Atomic-Scale Insights into Copper Cluster Growth on Tunable Magnesium Oxide Thin Films on Ag(100)** *Maximilian Laßhofer* |
| 16:30 | 713 | **Atomic-scale surface chemistry of $CaSiO_3$: interaction with water and carbon dioxide** *Giada Franceschi* |
| 16:45 | 714 | **Characterization of $CO_2$ adsorption configurations on $In_2O_3(111)$** *Sarah Tobisch* |
| 17:00 | 715 | **A Multi-Technique Approach to Characterize Responsive Nanostructures** *Sumea Klokic* |
| 17:15 | 716 | **Surface Resonant Raman Scattering from Cu(110)** *Sarang Bhasme* |
| 17:30 | 717 | **Multi-technique characterization and stabilization of single-atom catalysts: $Rh_1/TiO_2(110)$** *Faith Lewis* |
| 17:45 | 718 | **Thermal Stability of Platinum Adatoms on $Fe_2O_3(1\bar{1}02)$** *Ali Rafsanjani-Abbasi* |
| 18:00 | | ***END*** |
| | | ***Transfer to ÖAW*** *Doktor-Ignaz-Seipel-Platz 2, 1010 Wien* |
| 19:00 | | ***Public Lecture*** |

### *Thursday, 21.08.2025, Room HS 23*

| Time | ID | **Surfaces, Interfaces and Thin Films III** *Chair: Martin Sterrer, Universität Graz* |
|---|---|---|
| 11:00 | 721 | **Angle-resolved ion-induced electron emission spectroscopy from surfaces** *Anna Niggas (i)* |
| 11:30 | 722 | **Artificial Intelligence for Surface-Sensitive Materials Characterization: A Transformer for High-Throughput Quantitative X-ray Photoelectron Spectroscopy** *Florian Simperl* |
| 11:45 | 723 | **The Response of a High-Sensitivity Quartz Crystal Microbalance to MeV Ion Irradiation** *Martina Fellinger* |
| 12:00 | 724 | **Oscillator-Model-Based Analysis of Ellipsometric Spectra in Combinatorial Unary and Binary Material Samples** *Máté Podráczki* |
| 12:15 | | |
| 12:30 | | ***Lunch*** |
| | | **Surfaces, Interfaces and Thin Films IV** *Chair: Giada Franceschi, TU Wien* |
| 14:00 | 731 | **Revealing Solar Wind Erosion of Lunar Regolith through High-Precision Experiments and 3D Modeling** *Johannes Brötzner* |
| 14:15 | 732 | **Quantification of nanoparticle adhesion using atomic force microscopy** *Markus Kratzer* |
| 14:30 | 733 | **Ion adsorption at charged interfaces: visualization and quantification of ion-specific effects and water structure** *Markus Valtiner* |
| 14:45 | 734 | **How is the hydrophobic force modified by an oscillation frequency in saline conditions?** *Chiara Wagner* |
| 15:00 | 735 | **Laser-Induced Phase Transformations at the Ti/SiC Interface: Microstructural and Chemical Insights** *Elahe Akbari* |
| 15:15 | | |
| 15:30 | | ***Coffee Break*** |
| | | **Surfaces, Interfaces and Thin Films V** *Chair: Jan Balajka, TU Wien* |
| 16:00 | 741 | **$SrCrO_3/LaCrO_3$ Superlattices: Transport, Magnetic and Structural Properties** *Simon Jöhr* |
| 16:15 | 742 | **A complex temperature-dependent Rashba spin splitting in ferroelectric topological crystalline insulator** *Tetiana Zakusylo* |
| 16:30 | 743 | **Modulation of room temperature ferromagnetism in talc via iron-implantation.** *Muhammad Zubair Khan* |
| 16:45 | 744 | **Skyrmion formation mechanisms and pinning in Ir/Co/Pt multilayers** *Reshma Peremadathil Pradeep* |
| 17:00 | 745 | **Surface effects in infinite-layer nickelates** *Leonard Verhoff* |
| 17:15 | 746 | **Designing and Understanding Cuprate-Analog Superconductivity: Electronic Structure Engineering and Lattice Dynamics in Nickelate Systems** *Wenfeng Wu* |
| 17:30 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

| ID | **Surfaces, Interfaces and Thin Films Poster** |
|---|---|
| 751 | **Forces between hydrophobic surfaces: solvent influence** *Luis N. Ponce-Gonzalez* |
| 752 | **PEEM and LEED insights into the growth of ultrathin CoPc and F16CuPc films on Ag(100) surfaces** *Robert Heller* |
| 753 | **Spatially resolving the cone of reaction for a single molecule** *Matthew Timm* |
| 754 | **Automatic data acquisition and magnetic field compensation in LEED I(V)** *Florian Dörr* |
| 755 | **AFM Study of Lipid Monolayer Modulation Factors** *Wisnu Sudjarwo* |
| 756 | **Computational modeling of ice on silver iodide** *Andrea Conti* |
| 757 | **Revealing the character of coordination bonding in two-dimensional MOFs by photoemission tomography** *Dominik Brandstetter* |
| 758 | **Surface roughness characterization of biobased nanostructured coatings and nanocomposites** *Maximilian Alexander Molnar* |
| 759 | **Simulating solid-liquid interfaces with machine-learned force fields** *Andreas Kretschmer* |
| 760 | **Dielectric relaxation in scanning tunneling microscopy** *Stefan Müllegger* |
| 761 | **On-Surface Synthesis of two-dimensional Metal-Organic Frameworks: Structural Assembly, Electronic Properties and Transmetallation** *Olga Resel* |

## Physics at Neutron and Synchrotron Sources

### Tuesday, 19.08.2025, Room HS 30

| Time | ID | PHYSICS AT NEUTRON AND SYNCHROTRON SOURCES<br>*Chair: Herwig Michor, TU Wien* |
|---|---|---|
| 14:00 | 781 | **Ramsey GRS (Gravitational Resonance Spectroscopy) with the qBounce setup**<br>*Florian Lachaume* |
| 14:15 | 782 | **Nano- and Mesoporous Structure Formation Probed with In Situ/In Operando Small and Wide-Angle X-Ray Scattering Analysis during Electrodeposition**<br>*Heinz Amenitsch* |
| 14:30 | 783 | **Phase-Contrast Microtomography Applications in Life Sciences at the BEATS Beamline of the SESAME Synchrotron**<br>*Fareeha Hameed* |
| 15:00 | 784 | **Study on FeO Nanocubes combining X-ray Scattering Techniques with Various Complementary Characterisation Techniques**<br>*Rainer T. Lechner* |
| 15:00 | 785 | **Where are the metals? Analysis of elemental distributions in moss leaflets using synchrotron X-ray experiments**<br>*Matthias Weinberger* |
| 15:15 | 786 | **Conglomerate screening of 1,1'-binaphthalene by thin film preparation**<br>*Roland Resel* |
| 15:30 | | ***END; Coffee Break*** |
| 19:00 | | ***Public Lecture*** |

| ID | PHYSICS AT NEUTRON AND SYNCHROTRON SOURCES POSTER |
|---|---|
| 791 | **Deep X-ray Lithography for material science: latest results**<br>*Benedetta Marmiroli* |
| 792 | **Elastic and inelastic neutron scattering studies of magnetism in the heavy fermion system $YbPt_5B_2$**<br>*Herwig Michor* |
| 793 | **The PERC Beamstop**<br>*Johannes Schilberg* |
| 794 | **Upgrading qBounce: Toward New Frontiers in Quantum State Measurements**<br>*Christoph Grüner* |
| 795 | **Exploring Magnetic Field Effects on Quantum States of Ultracold Neutrons in the qBounce Experiment**<br>*Daniel Aziz* |

## Quantum Information and Quantum Computing

THIS SESSION HAS BEEN ORGANISED IN COLLABORATION WITH THE SFB BEYONDC.

### Thursday, 21.08.2025, Room HS 7

| Time | ID | QUANTUM INFORMATION AND QUANTUM COMPUTING I: QUANTUM THERMODYNAMICS<br>*Chair: NN* |
|---|---|---|
| 14:00 | 801 | **Precision is not limited by the second law of thermodynamics**<br>*Florian Meier* |
| 14:15 | 802 | **Quantum Master Equations in the Presence of Continuous Measurement and Feedback: Theory and Applications**<br>*Pharnam Bakhshinezhad* |
| 14:30 | 803 | **Optimal Landauer Erasure in Finite-Time Thermodynamics**<br>*Alberto Rolandi* |
| 14:45 | 804 | **Quantum geometry: new paradigm in topological quantum matter and quantum information science**<br>*Alexander Kruchkov* |
| 15:00 | 805 | **Information Thermodynamics of Agents**<br>*Lukas J. Fiderer* |
| 15:15 | 806 | **On the second law of thermodynamics in isolated quantum systems**<br>*Tom Rivlin* |
| 15:30 | | ***Coffee Break*** |
| | | QUANTUM INFORMATION AND QUANTUM COMPUTING II: QUANTUM INFORMATION THEORY<br>*Chair: NN* |
| 16:00 | 811 | **High-dimensional entanglement witnessed by correlations in arbitrary bases**<br>*Nicky Kai Hong Li* |
| 16:15 | 812 | **A Framework for the Security Analysis of Practical High-Dimensional QKD Setups**<br>*Florian Kanitschar* |
| 16:30 | 813 | **Bypassing Losses in Quantum Optics: A Robust Measurement Design**<br>*Mohammad Mehboudi* |
| 16:45 | 814 | **Estimating entanglement monotones of non-pure spin-squeezed states**<br>*Julia Mathe* |
| 17:00 | 815 | **The Impact of Architecture and Cost Function on Dissipative Quantum Neural Networks**<br>*Tobias Christoph Sutter* |
| 17:15 | 816 | **Generalized Parity Measurements and Efficient Large Multi-component Cat State Preparation with Quantum Signal Processing**<br>*Sina Zeytinoglu* |
| 17:30 | 817 | **Quantum entanglement in Wigner functions**<br>*Shuheng Liu* |
| 17:45 | 818 | **Exact Steering Bound for Two-Qubit Werner States**<br>*Martin J. Renner* |
| 18:00 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

### Friday, 22.08.2025, Room HS 7

| Time | ID | QUANTUM INFORMATION AND QUANTUM COMPUTING III: QUANTUM FOUNDATIONS AND INFORMATION<br>*Chair: NN* |
|---|---|---|
| 11:00 | 821 | **How to implement a causal measurement scheme for quantum fields?**<br>*Jan Mandrysch* |
| 11:15 | 822 | **On the Planckian time of thermalization**<br>*Paolo Abiuso* |
| 11:30 | 823 | **Events and their Localisation are Relative to a Lab**<br>*Lin-Qing Chen* |
| 11:45 | 824 | **Stabilizer-based entanglement and secure key distillation**<br>*Christopher Popp* |
| 12:00 | 825 | **Optimising quantum tomography with classical post-processing**<br>*Andrea Caprotti* |
| 12:15 | | |
| 12:30 | | ***Poster Awards and Closing Ceremony*** |
| 12:45 | | ***Lunch*** |

| Time | ID | Quantum Information and Quantum Computing IV: Experiment<br>*Chair: NN* |
|---|---|---|
| 14:00 | 831 | **High finesse microcavities for quantum science and technology**<br>*Philipp Koller* |
| 14:15 | 832 | **Experimental certification of high-dimensional entanglement with randomized measurements**<br>*Giuseppe Vitagliano* |
| 14:30 | 833 | **Entropic costs of the quantum-to-classical transition in a microscopic clock**<br>*Paul Erker* |
| 14:45 | 834 | **Robust generation of multiphoton states from quantum dots**<br>*Vikas Remesh* |
| 15:00 | 835 | **Quantum network node based on trapped ions coupled to a cavity**<br>*Sudhan Bhadad* |
| 15:15 | 836 | **Experimentally probing Landauer's principle in the quantum many-body regime**<br>*Stefan Aimet* |
| 15:30 | 837 | **High-Dimensional Time-Bin Entanglement for Quantum Key Distribution**<br>*Dorian Schiffer* |
| 15:45 | 838 | **Experimental data re-uploading with provable enhanced learning capabilities**<br>*Martin Mauser* |
| 16:00 | | ***END*** |

| ID | Quantum Information and Quantum Computing Poster |
|---|---|
| 841 | **Subjective nature of path information in quantum mechanics**<br>*Xinhe Jiang* |
| 842 | **The Cumulant Expansion Approach: the Good, the Bad and the Ugly**<br>*Johannes Kerber* |
| 843 | **Random Numbers from Cosmic Microwave Background for Bell test**<br>*Amin Babazadeh* |
| 844 | **Uncertainty relations and entanglement with finite Fourier transformed variables.**<br>*Dimpi Thakuria* |
| 845 | **Approaching the mechanical ground state in an inductively coupled electromechanical system**<br>*Bhargava Thyagarajan* |
| 846 | **Towards a Quantum Network Node: Trapped Calcium Ions Coupled to a High-Finesse Optical Cavity**<br>*Mehdi Rizvandi* |
| 847 | **Adding and removing systems in quantum reference frames**<br>*Bruna Sahdo* |
| 848 | **A new view on Quantum Computers**<br>*Christoph Grüner* |
| 849 | **Detecting genuine multipartite entanglement in multi-qubit devices with restricted measurements**<br>*Nicky Kai Hong Li* |
| 850 | **Security Analysis and Implementation of Finite-Size Multi-User CV-QKD with Discrete Modulation**<br>*Florian Kanitschar* |
| 851 | **Robust quantum memory in a trapped-ion quantum network node with an optical cavity**<br>*James Bate* |
| 852 | **Josephson Gravimeter - Gravity Sensing by Quantum Tunneling in Superconducting Circuit**<br>*Martin Zemlicka* |

## Correlated Quantum Materials and Solid State Quantum Systems

This session has been organised in collaboration with the **SFB Q-M&S**

***Thursday, 21.08.2025, Room HS 27***

| Time | ID | Correlated Quantum Materials and Solid State Quantum Systems<br>*Chair: NN* |
|---|---|---|
| 16:00 | 871 | **Correlated Quantum Materials and Solid State Quantum Systems**<br>*Silke Paschen* |
| 16:15 | 872 | **Enhanced entanglement in the pseudogap**<br>*Frederic Bippus* |
| 16:30 | 873 | **Quantum Fisher information in quantum critical $Ce_3Pd_{20}Si_6$**<br>*Federico Mazza* |
| 16:45 | 874 | **High-entropy magnetism of murunskite**<br>*Priyanka Reddy* |
| 17:00 | 875 | **Disentangling Coherent Phonons from Propagation Effects in the Terahertz Kerr Response of Bulk $LaAlO_3$**<br>*Chao Shen* |
| 17:15 | 876 | **Magnetotropic Susceptibility in α-$RuCl_3$: Insights into Bond-Dependent Exchange Interactions and Frustrated Magnetism**<br>*Hamza Nasir* |
| 17:30 | 877 | **Low-noise quantum dots in ultra-thin cap Ge/SiGe heterostructures for applications in hybrid semiconducting-superconducting devices.**<br>*Maksim Borovkov* |
| 17:45 | | *Discussion* |
| 18:00 | | ***END*** |
| | | ***Transfer to Dinner*** |
| 19:00 | | ***Conference Dinner*** |

| ID | Correlated Quantum Materials and Solid State Quantum Systems Poster |
|---|---|
| 881 | **Signatures of Weyl-Kondo physics in $Ce_3Bi_4Pd_3$**<br>*Monika Luznik* |
| 882 | **Emergent topological phase from quantum criticality in $CeRu_4Sn_6$**<br>*Diana Kirschbaum* |
| 883 | **Functional renormalization group study of the two-dimensional Su–Schrieffer–Heeger-Hubbard model**<br>*Francesco Domizio* |
| 884 | **Tuning the Weyl-Kondo semimetal $Ce_3Bi_4Pd_3$ via stoichiometry**<br>*Nikolas Reumann* |
| 885 | **Investigation of the quantum critical compound $Ce_3Pd_{20}Si_6$ through thermal conductivity**<br>*Gwenvredig Le Roy* |
| 886 | **Scrutinizing quantum effects on the classical modeling of $BaCo_2(AsO_4)_2$ with the magnetotropic susceptibility**<br>*Shiva Safari* |
| 887 | **MBE growth of heavy-fermion thin films**<br>*Lukas Fischer* |
| 888 | **Microwave conductivity of a strange metal heavy fermion compound**<br>*Thanh Duc Phan* |

## Biophysics and Soft Matter

### *Friday, 22.08.2025, Room HS 30*

| Time | ID | BIOPHYSICS AND SOFT MATTER I: BIOPHYSICS<br>*Chair: Christof Fattinger* |
|---|---|---|
| 11:00 | 901 | **A generic mechanism for force-modulated adsorption of E. coli**<br>*Erik Reimhult* |
| 11:30 | 902 | **Understanding Fracture in Physically Crosslinked Hydrogels**<br>*Kerstin G. Blank* |
| 11:45 | 903 | **Effect of 2D confinement and substrate properties on bacterial self-organization at surfaces**<br>*Vincent Hickl* |
| 12:00 | 904 | **Synthesis and flow behaviour of polymer-grafted nanopores**<br>*Giacomo Chizzola* |
| 12:15 | 905 | **Electro-Acoustic Spinning for the Characterization of Individual Cells**<br>*Tayebeh Saghaei* |
| 12:30 | | ***Poster Awards and Closing Ceremony*** |
| 12:45 | | ***Lunch*** |
| | | BIOPHYSICS AND SOFT MATTER II:<br>LIGHT AND BIOPHYSICS<br>*Chair: Rainer Leitgeb, Med. Universität Wien* |
| 14:00 | 911 | **New contrasts for holographic microscopy for novel applications in biotechnology and environmental monitoring**<br>*Peter D. J. van Oostrum* |
| 14:15 | 912 | **Investigation of dynamic tissue properties using optical coherence tomography**<br>*Bernhard Baumann* |
| 14:30 | 913 | **Light scattering angular dependency in brain tissues determined by wide-field polarimetric and time-of-flight measurements.**<br>*André Stefanov* |
| 14:45 | 914 | **How do Graphium butterflies manipulate colors by using protein?**<br>*Limin Wang* |
| 15:00 | 915 | **Formation of biophotonic gyroid nanostructures in the butterfly Parides sesostris**<br>*Anna-Lee Jessop* |
| 15:15 | 916 | **Mutanofactin affects interactions of mucin-coated surfaces and Streptococcus mutans**<br>*Konstantin Nikolaus Beitl* |
| 15:30 | | ***END*** |

| ID | BIOPHYSICS AND SOFT MATTER POSTER |
|---|---|
| 931 | **Optical Performance of Cylindrical and Tapered Fly Rhabdomeres Using a Cascaded Waveguide Approach**<br>*Mahdi Khodadadi Karahroudi* |
| 932 | **Atomic Force Microscopy (AFM) Analysis of Cellular Mechanics Following Measles Vaccine Virus Infection**<br>*Alexander Einschütz López* |
| 933 | **Understanding Biological Material Mechanics Through Energy Dissipation**<br>*Jose Luis Toca-Herrera* |
| 934 | **Rheo-microscopy of Soft Materials**<br>*Eva Hudec* |
| 935 | **Non-Universality of Jamming in Cellular Monolayers**<br>*Jasmin Di Franco* |
| 936 | **Rheomicroscopy of hydrogels across the yielding transitions**<br>*Sakshi Khandelwal* |
| 937 | **Cell response to curvature gradients**<br>*Parvathy Anoop* |
| 938 | **Multimodal single-cell real-time imaging of phage-induced bacterial lysis**<br>*Ivana Matoušová Víšová* |
| 939 | **Cavitation on metallic implants induced by alternating magnetic fields disrupts bacterial biofilms but damages osteoblast-like cells**<br>*Konstantin Nikolaus Beitl* |

## Young Minds

### *Friday, 22.08.2025, Room HS 23*

| Time | ID | YOUNG MINDS<br>*Chair: NN* |
|---|---|---|
| 14:00 | 991 | **Title not yet available**<br>*Markus Wallerberger (i)* |
| 14:30 | 992 | **ÖPG Student Award**<br>*NN* |
| 14:45 | 993 | **ÖPG Student Award**<br>*NN* |
| 15:00 | 994 | **ÖPG Student Award**<br>*NN* |
| 15:15 | | ***END*** |

## Further Meetings and Events

| TIME | ROOM | MEETING |
|---|---|---|
| **Monday, 18.08., 08:30** | **HS 30** | SPS Board Meeting (Non-Public) |
| **Monday, 18.08., 18:00** | **HS 30** | SPS General Assembly |
| **Monday, 18.08., 08:30** | **HS 31** | ÖPG Board Meeting (Non-Public) |
| **Monday, 18.08., 18:00** | **HS 31** | ÖPG General Assembly |
| **Tuesday, 19.08., 15:30** | **HS 29** | NESY Fachausschusstreffen |
| **Wednesday, 20.08., 20:00** | | Young Minds Get-Together<br>*Further information will follow.* |
| **Thursday, 21.08., 12:00** | **HS 27** | SFB BeyondC Business Meeting |
| **Friday, 22.08., 16:30** | | Lab Tours<br>*Further information will follow.* |

# The winners of the SPS Awards 2025 have been selected

The SPS Award committee, chaired by Prof. Hugo Zbinden, selected the winners for 2025. The high level of all submitted works proves the scientific qualification of the younger generation of physicists in Switzerland. In combination with the high number of nominations it was therefore not at all easy to make a decision.

The seven winners are as follows:

**SPS Award in General Physics**, sponsored by *ABB Schweiz AG*:
**Sveva Castello** (Université de Genève), for *realising how measurable effects of time distortion can resolve the degeneracy between alternative theories of the observed expansion of our universe.*

**SPS Award in Condensed Matter Physics**, sponsored by *IBM Research GmbH*:
**Gabriele Pasquale** (EPFL, Harvard) for his *groundbreaking studies on the electronic structure of flat-band materials.*

**SPS Award with relation to Metrology**, sponsored by *Metas*:
**David Breitenmoser** (ETHZ, PSI Villigen) for the *development of a more precise and faster spectrum modeling for airborne gamma-ray spectrometry systems*.

**SPS Award in Computational Physics**, sponsored by *COMSOL Multiphysics GmbH*:
**Urban Senica** (ETHZ, Harvard) for his work on *Broadband integrated photonics with planarized terahertz quantum cascade lasers*.

**SPS Award with relation to Energy Technology**, sponsored by *Hitachi Energy Switzerland AG*:
**Yunfei Teng** (EPFL) for his work on *developing nature-inspired stalactite nanopores for energy conversion and harvesting applications.*

**SPS Award in the field of Sensing, Detection and Monitoring**, sponsored by *Sensirion AG*:
**Jodok Happacher** (Universität Basel) for his *contributions to the understanding and control of single nitrogen-vacancy centers in diamond for quantum sensing applications.*

**SPS Award in Quantum Science and Technology**, sponsored by *ID Quantique*:
**Marco Coraiola** (IBM Rüschlikon) for his *contributions to multiterminal Josephson junction physics.*

The winners will each give a talk on their work at the Joint Annual Meeting in Vienna. More details on the winners and their work will be also presented in the next issue of the *SPG Mitteilungen*.

# What happened to *Helvetica Physica Acta*?

*Gian Michele Graf, ETH Zürich; Thomas Jung, PSI Villigen*

As the older members of the Swiss Physical Society (SPS) surely remember, from 1928 till 1999 the society published a journal, called ***Helvetica Physica Acta*** [1], that encompassed virtually all disciplines in physics and also served purposes similar to those the ***SPG Mitteilungen*** presently does. Less widely known, but undeservedly so, is that the journal has a successor, called the ***Annales Henri Poincaré*** [2], in the governance of which the SPS plays a prominent role, up to this day and, if it so wishes, for many years to come.

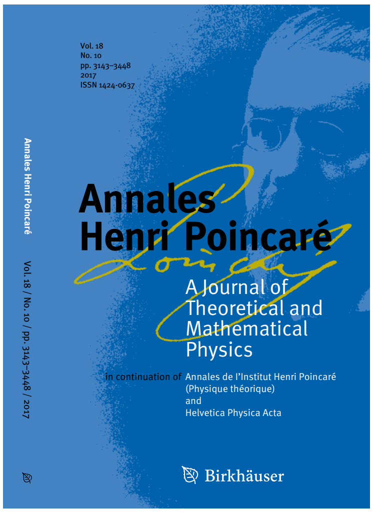

But let's take things in order. During several decades, *Helvetica Physica Acta (HPA)* was a well-known journal. Among its authors you will find almost all Swiss winners of the Nobel Prize in Physics of the 20$^{th}$ century, such as G. Binnig, F. Bloch, K. A. Müller, W. Pauli, A. Piccard, H. Rohrer, but also other prominent names, such as M. Fierz, T. M. Rice, P. Scherrer, N. Straumann, E. C. G. Stueckelberg, and F. Zwicky. Like other national scientific journals, the journal lost submissions, subscriptions, and income, as the scientific community gradually moved to journals with higher international visibility. This also correlated with the emergence of 'Letter' journals separating the role of society journals and reporting journals. *Physical Review Letters*, for example, had been created as a kind of experiment in 1958. In line with the worries of the SPS council to run into a deficit, the then thriving mathematical physics community in Switzerland, in particular W. Amrein, J.-P. Eckmann and, not least, W. Hunziker managed to gain some visibility for *HPA* in the international mathematical physics community, which published an increasing share of articles. As an emphasis of the new scientific focus, the journal title received the subheading "*Physica Theorica*" about 1996. This, however, did only retard, but not save the journal from the threat of reaching the non-profit line sometime later in the 90's. Triggered by W. Hunziker, different rescue plans had been discussed. Peter Oelhafen, then SPS President, and Thomas Jung, then Treasurer of the SPS, travelled to Rome, to discuss the option of a merger with *Nuovo Cimento B*, the theoretical physics journal of the Società Italiana di Fisica. After an interview with the Editor-in-Chief and an analysis of the articles published, the prospects of a joint venture were not considered worthwhile. Not too long after, another

1 still available at https://www.e-periodica.ch/digbib/volumes?UID=hpa-001

2 https://link.springer.com/journal/23

initiative of W. Hunziker, W. Amrein and V. Rivasseau and B. Duplantier was brought forward to the SPS in the form of the proposed collaboration with the journal "*Annales de l'Institut Henri Poincaré, Physique Théorique*" *(AIHP)*. The mission of that institute was, and still is, that of running international programs in mathematics and physics, as well as a number of journals.

*AIHP* was looking for a more international authorship and readership. It also boasted a glorious past, featuring authors like A. Einstein, E. Schrödinger, L. de Broglie, A. Sommerfeld, W. Pauli, P. Dirac, V. Fock, among others, and was likewise facing a less promising future. Representatives for that journal, such as B. Duplantier and V. Rivasseau, met with their Swiss colleagues and evaluated the merger between the two journals. The collaboration was also considered worthwhile as *AIHP* was of higher standing in the field, but at the same time less widely distributed due to the fact that some articles still appeared in French. The project materialized after some negotiations between the proprietors (with T. Jung then president of SPS) and with potential publishers (and Birkhäuser finally chosen). All that gave birth in the *Annales Henri Poincaré (AHP)*, which saw the light at the beginning of the year 2000. While the journal's main focus is in the area of Mathematical Physics, it also accepts papers in Mathematics and Theoretical Physics, if relevant to the area first named. Notably the HPA published its last edition in 1999 – all its content can be downloaded free of charge from the archives – a service initiated also by the SPS.




According to the AHP Statutes, that were approved along, the governing body, called Executive Committee (EC), consists of four delegates, with each Proprietor appointing two of them. The capital of the journal is managed by the EC and is "used for operations and for development of the journal, or for related scientific activities." The EC appoints the Editor-In-Chief (and conducts the search for a new one when needed) who in turn selects the Editorial Board. The EC also chooses the Publisher, pending confirmation by the Proprietors.

Since its inception, the journal has been directed by three Editors-In-Chief: Vincent Rivasseau (2000 - 2012), Krzysztof Gawedzki (2012 - 2018), and Claude-Alain Pillet (2018 -). Pillet, who is Swiss, yet based in France, best exemplifies the joint nature of the endeavour. All three brought the journal on a path of steady growth, be it in terms of numbers of published papers, of their quality, of the topical breadth of the journal as a whole, and of the geographic distribution of the authorship. It can be safely argued that the journal *Annales H. Poincaré* ranks second in its field. As a scant proof to that claim, the journal recently published two articles by E. Witten, one in 2022 and one in 2024. Notably the journal resumed remarkable international recognition and status in comparison to competing scientific journals. This provides an achievement that remains to be a grand goal for the EPJ and the Europhysics Letters, the other two journals with links to the SPS.

That success was above all made possible by the three successive Editors-In-Chief, who were willing to sacrifice a large part of their professional time in order to serve science and their scientific community. For each submitted paper, they decide *prima facie* whether it is off-topic or does not meet minimal quality standards, in which case it gets rejected without refereeing process. Moreover the Editor-In-Chief constantly reshapes the Editorial Board, replacing members who become less active, or sections which so do, with new ones. Thanks should also be extended to the countless referees, whose thoughtful criticisms quite often allows to decisively improve the quality of the papers accepted for publication. By the end of the whole process, roughly one out of three submitted papers gets published. All this contributes to the standing of the journal in the community.

In line with the Statutes ("The Journal is intended as a service to the scientific community") the capital is partially, yet steadily, used in support of the Mathematical Physics community in a broad but not indefinite sense of those words. The journal has become one of the main (if not the main) sponsor of the last two editions of the International Congress of Mathematical Physics, which took place in Switzerland (2021) and France (2024); it will be one again for the next edition (Vietnam, 2027).

It is the task of the Executive Committee to take care of the relations with the Publisher, which through some acquisitions has now factually become Springer Nature. While the relations between the parties are long-standing and most cordial at the personal level, the distance between their strategic goals is unfortunately growing. The Executive Committee puts science and the interests of the scientific community upfront, whereas the legitimate economic interests of the Publisher puts the former ones at risk of suffering at least collateral damage. While there are not-for-profit publishers, that are deemed to be valid alternatives to commercial ones, neither model is – by design alone – able to secure the genuine interests of the scientific community. Indeed, not-for-profit publishers still incur in operating costs that are charged to Proprietor, while for sure generating no perks for the community. It thus remains the task of the Executive Committee to weigh interests and to maximize the future options of the journal.

The immediate cause for this short article, as well as its timing, may be traced to some misunderstanding by some, yet definitely not all, members of the Board of SPS in relation with the tasks of the Executive Board and more generally about the governance of the *Annales H. Poincaré*. The present delegates (T. Jung since 2000) and G. M. Graf (since 2009) were asked to resign on short notice, so as to give way to a more rapid rotation. While complying with that wish and making every effort in proposing willing substitutes, the delegates remain wary of what the proposed kind of rotation will hold for the future of the journal.

# Progress in Physics (108)

## Atomic-Scale Electronics and Photonics for Sustainable AI Technologies and Beyond

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### Introduction

Artificial intelligence (AI) is shaping modern societies at unprecedented scales – and pace. State-of-the-art semiconductor technologies increasingly struggle to keep up with their seven decade long thrive and can thus only provide temporary solutions to the AI-generated global-scale computational challenges. The latter are dominated by exponentially growing data generation, traffic, and processing needs arising from generative AI platforms, crypto-currencies, and the Internet-of-Things (IoT), a world-wide network of autonomous systems interconnected via the Web, to name a few examples. The major persisting computational – and ecological – bottlenecks of AI come (i) from the currently prevailing von Neumann architecture of the underlying hardware where memory, storage, and information processing rely on physically separated units, which necessitates permanent, extremely energy-hungry data shuttles, and (ii) from the exploding training overheads of generative tools, e.g., large language models (LLM). As a result, the global energy demand of computation is foreseen to approach the total production of our planet – within a decade [Mehonic2022]. This trend is not sustainable: Alternative AI solutions are therefore imperatively and instantly needed.

The computing approaches of the human brain provide important insights and clear pathways to address these challenges through adaptive, multifunctional units (our neurons and synapses), the seamless collocation of information processing and storage, low-energy operation, and adaptive learning rules [Zidan2018]. Memristors [Strukov2008], which are atomic- to nanometer-scale devices, can emulate the aforementioned biological features through modulations of their electrical conductance at competitively low energy costs and versatile time scales. Thus, they can act in artificial neural networks (ANNs) both as multifunctional synapses [Weilenmann2024] and neurons [Kumar2022], as illustrated in Figure 1. Moreover, they can be arranged into high-density and fully interconnected matrix-like structures, called crossbar arrays [Xia2019], and monolithically integrated with existing semiconductor platforms [Cai2019]. Such architectures can implement simplistic and powerful learning rules, inspired by the functionality of the human brain, and demanding arithmetic operations even in single time-steps due to their physical characteristics and interconnectivity.

In this paper we provide insight into our ongoing work that has explored the physical boundaries of memristor operation in the space, time, and energy domains. Our studies have revealed the ultimate, single-atom scaling limit [Cheng2019], multilevel conductance tunability [Portner2021], and ultra-fast switching [Csontos2023] of these devices. Operation down to the femtojoule energy level has been demonstrated, outperforming the energy-efficiency of individual neurons in the human brain [Schmid2024]. Accordingly, in our latest works we showed that several key functions of modern AI algorithms can be emulated using a single nanometer-scale device operated at the lowest possible power [Lewerenz2024, Portner2024, Weilenmann2024]. Beyond the above breakthroughs implemented in the electronic domain, the functionalities of our single devices have been vastly extended by the chip-scale integration of electronic and photonic degrees of freedom [Emboras2018]. These achievements are key enablers for next-generation brain-inspired computational and communication platforms, where low-energy operation is granted by memory/processing collocation, adaptability, increased functional complexity and reduced time-complexity from the single device- to the system-level.

### Memristor: a versatile alternative to the CMOS transistor

Memristors are two-terminal solid-state devices exhibiting tunable conductance. The device layout typically consists

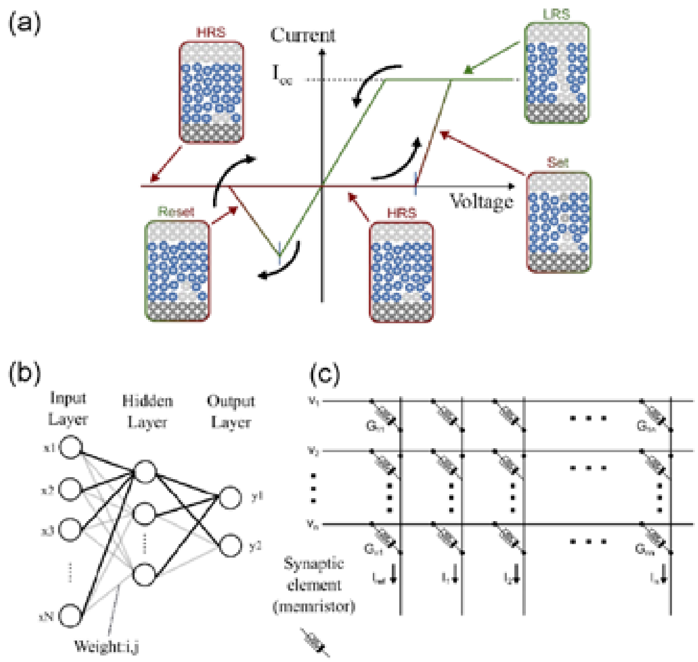


*Figure 1: Operation cycle of a non-volatile filamentary memristor and its application in the synaptic layers of artificial neural networks (ANN). (a) Typical hysteretic current-voltage characteristics and the associated structural changes in the metal (grey) – insulator (blue) – metal (grey) structure. (b) Schematics of an ANN. The circles (solid lines) represent neurons (synaptic weights). (c) Illustration of a memristor crossbar array implementing a fully connected synaptic layer. Memristors sit at each cross point.*

of two metallic electrodes terminating an insulating layer, as shown in Figure 1a. Under the influence of external electrical, thermal, or optical stimuli, various electrochemical processes may take place in the insulator, such as oxidation/reduction reactions and ionic/atomic transport. These often result in the formation of nanoscale conducting regions, so-called filaments, capable of bridging the metallic terminals through the insulating layer. The atoms contributing to the conducting filament may be sourced from an active electrode, such as Ag or Cu (electrochemical metallization - ECM) or, alternatively, from the generation of oxygen vacancies at metal-oxide interfaces (valence change mechanism - VCM) [Waser2009]. As will be discussed in the following, the controllability and scalability of such conducting filaments down to the ultimate, single-atom level play a fundamental role also in low-energy and high dynamic range memristor operation.

While the operation of memristors based on atomic- to nanometer-scale conducting filaments depends on ionic rearrangements, that of conventional complementary metal-oxide-semiconductor (CMOS) transistors relies on the formation of an electronic conducting channel at their metal-oxide interface. In particular, memristors exhibit more conductance (resistance) states for computation and data storage than transistors, extending over a >10 orders of magnitude wide window. These key features are enabled by their unique conduction phenomena, which range from (i) electron tunneling through (ii) the contribution of individual atomic orbitals of a single-atom junction, (iii) discrete conductance steps arising from the atom-by-atom growth of oxide layers to (iv) diffusive conductance in nanometer-scale disordered conductors. Among them, the ultimately available resistance states can be conveniently tailored to the desired application by materials engineering.

Furthermore, conducting channels created by the rearrangement of ions/atoms rather than by electronic effects, as in CMOS technologies, offer major competitive benefits: (i) The ultimate down-scalability to single-atom channel widths is enabled without a need for top-shelf lithographic facilities; (ii) information stored in atomic positions can be inherently robust, as opposed to electronic charges which are always prone to leakage due to quantum mechanical tunneling; thereby (iii) nonvolatile operation, i.e., safely preserving the stored information after disconnecting the power, also becomes possible. Meanwhile, the array-level scalability and CMOS compatibility of the prevailing memristive material systems also allow for the seamless integration of this emerging technology with state-of-the-art digital platforms.

## Atomic-scale memristors: scalability, speed, and energy-efficiency

The resistance state of filamentary memristors can be tuned by relocating only a few atoms at interatomic distances in the active region of the conducting filament. Hence, it is conceivable that this relocation may occur at very short time-scales and at low energy cost. Thereby, the technology holds great promises also in view of high-frequency applications, such as those in the telecommunication domain, where the ever-increasing power consumption is a growing concern.

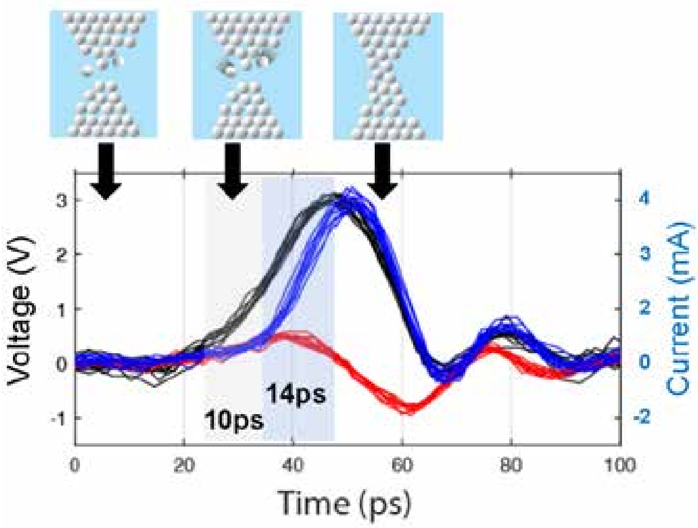


*Figure 2: High-speed resistive switching experiment in a filamentary switching Pt/$Ta_2O_5$/Ta memristor. As illustrated by the schematics on the top, the atomic-scale filament is initialized in a disconnected, high-resistance state. When the voltage (black) is first applied, the current (blue) only exhibits a low-magnitude capacitive response (red), corresponding to the capacitance of the metal/insulator/metal structure. The onset of the resistive switching transition follows the rise of the voltage pulse within 10 ps and completes in another 14 ps. During the falling edge of the voltage pulse, a current proportional to the voltage is observed, which is a hallmark of an Ohmic link.*

In this context, we demonstrated unprecedented resistive switching speeds in memristors incorporating a $Ta_2O_5$ oxide layer deposited between Pt and Ta electrodes. These devices were operated in the single- to few atom switching configurations, as revealed by the detailed analysis of the current-voltage characteristics [Török2023]. An optimized sample design facilitating low parasitic capacitances enabled us to monitor the dynamics of the resistive switching during ultra-short programming voltage pulses. As a result, filament formation times down to the 10 ps time-scale could be measured at picosecond resolution, as explained in Figure 2. Moreover, the dynamics of the slower, thermally activated processes governing the dissolution of the conductive filament upon a reversed bias voltage polarity was also characterized. Thus, the electric-field-induced and diffusion-driven resistive switching mechanisms could be experimentally sorted, which is a prerequisite for the optimization of high-speed cyclic memristor operation [Csontos2023].

To determine the energy cost of the resistive switching, the bias voltage, the resulting device current, and the duration of the switching operation must be taken into account. As the key figure of merit of filamentary resistive switching dynamics – which spans from picoseconds to years in the time domain – the completion of a filamentary bridge requires an exponentially shortened time as the bias voltage is linearly increased, which follows from the activated nature of ionic transport through solid dielectrics. As a result, faster resistive switching operation is energetically more favorable even at the expense of an increased applied bias voltage. This is in contrast with the switching dynamics of CMOS transistors, where a simplistic plate capacitor model predicts a gate-voltage-independent switching energy. Accordingly, our recent nanosecond to picosecond time-scale experiments revealed resistive switching energies in the 1 to 100 fJ regime, surpassing the energy-efficiency of neurons in the human brain [Schmid2024].

## Memristors as artificial synapses and neurons

Thanks to customizable, volatile or non-volatile memory effects arising from the short- and long-term stability of their conducting filaments, memristors can act both as solid-state neurons or synapses, as illustrated in Figure 3. When used as artificial synapses, the strength of the synaptic connection is represented by the device conductance which can be incrementally tuned by successive positive or negative voltage pulses. The permanent nature of such conductance changes facilitates in-memory computing, where the co-localization of the computing and memory functionalities inherently eliminates the aforementioned von Neumann bottleneck. In contrast, memristors used as artificial neuron circuits exploit volatile memory effects: Upon receiving a critical amount of input stimuli, they respond with a short-term, temporary conductance change. By embedding a volatile memristor into a simplistic electronic circuit environment, the transient effect of the latter can be harnessed to implement the (leaky) "integrate and fire" operation of biological neurons at a competitively low footprint and energy consumption [Lewerenz2024].

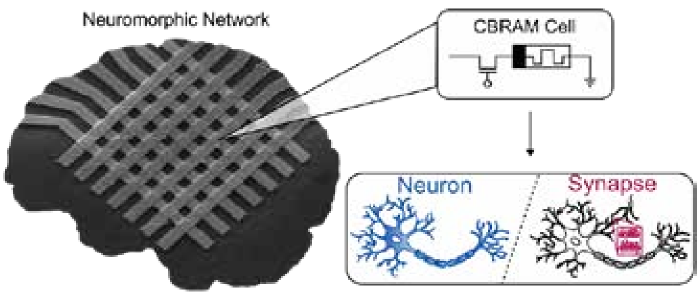


*Figure 3: Illustration of a neuromorphic network consisting of memristors, a.k.a. CBRAM cells, which can be configured to emulate either neuron or synaptic functionalities [Passerini2025].*

Over the last 8 to 10 years, our objective has been to establish a versatile platform where, depending on the actual application, individual devices in high-density memristor arrays can be conveniently and reproducibly reconfigured between such synaptic or neural operation. To achieve this goal, a better control over the formation and stability of the conducting filament is necessary. We found that by alloying the widely applied Ag electrodes with other metallic compounds, such as Sn, a more complex but also more customizable conducting filament structure can be created in $SiO_2$ dielectric layers. In agreement with molecular dynamics calculations and scanning electron microscopy studies, at low concentrations the less mobile Sn atoms form a stable 'backbone' across $SiO_2$, where the originally more mobile Ag atoms can anchor. Depending on the current level at which the conductive filament is formed, different Ag/Sn ratios can be achieved in the filamentary region, resulting in its (de) stabilization at zero voltage bias, favoring (neuronal) synaptic operation [Passerini2023].

## A neuromorphic application of atomic memristors: solving navigation tasks

Autonomous systems – smart devices which can make decisions and act without human involvement – are at the center of the ongoing fourth industrial revolution. Among them, the development of systems capable of navigating complex environments has been transforming major industries such as automotive, aviation, health care, or defense. Current state-of-the-art autonomous navigation platforms rely on billions of CMOS transistors and traditional machine learning algorithms. They are extremely power demanding – and also prone to frequent, potentially hazardous failure. This is in contrast, for example, to the abilities of the honey bee, which performs sophisticated navigation tasks and exhibits social behavior with only one million neurons in its brain.

We recently showed experimentally that the combination of dedicated atomic memristors with cutting-edge neuroscience theories allows for similarly efficient navigation and search operations in hardware [Portner2024]. Particularly, our framework takes advantage of a bio-inspired, three factor learning rule, where the added third factor emulates the functionality of biological dopamine and acts as a reward signal. Such learning rule was implemented on our tunable, analog, and multifunctional atomic memristors rather than by combining CMOS transistors and demanding machine learning algorithms [Portner2024]. Using this framework, we demonstrated how a mouse learns the optimal trajectory through a simple, T-like maze environment, to find a reward in the form of a piece of cheese, as shown in Figure 4.

## Photonic memristors

While neuromorphic systems offer high speed and low power consumption, reaching the capabilities of the human brain requires connecting millions, if not billions, of individ-

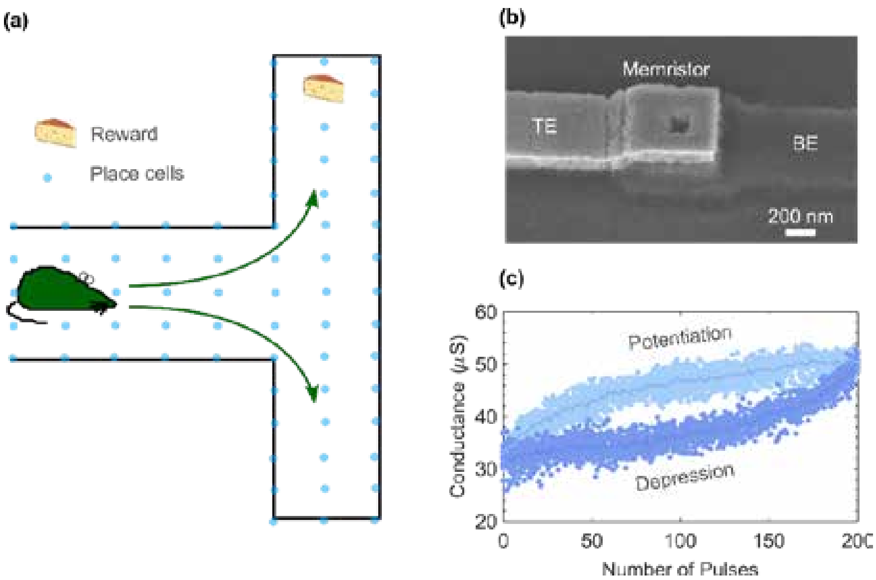


*Figure 4: Memristor-based implementation of a navigation task. (a) Schematic of a reward-based learning experiment: A mouse learns how to go through the desired sequence of actions (moving forward, turning left) to reach a designated location where a reward, a piece of cheese, is deposited. At each discretization point, the animal chooses the action (moving East, West, North, South, or Stop) that eventually brings it to the reward (piece of cheese). This experiment was implemented on hardware (b) and in-software emulated memristors whose conductance can be gradually modulated between a high and low resistance state upon the application of voltage pulses. The corresponding potentiation and depression measurements of these devices are shown in (c).*

ual memristive devices, leading to significant energy losses and performance bottlenecks. Optical communication links present a promising alternative to electrical interconnects, combining fast data transmission with minimal energy use.

An optical communication link typically comprises lasers, modulators, and photodetectors, and can be implemented based on various material systems. Silicon photonics platforms have established themselves as the state-of-the-art for applications requiring high bandwidths of few 10's of GHz [Assefa2012], while plasmonic-organic platforms have achieved speeds of more than 500 GHz [Burla2019]. Yet, their basic building blocks (modulators, photodetectors, and lasers) are bulky compared to the size of electronic components. This is where memristors come into play: When combined with optical signals, they provide an attractive alternative to standard technologies. Indeed, optical memristive effects have recently pushed device miniaturization well beyond previous limits. We advanced this vision by embedding a CBRAM-type memristor into a plasmonic/photonic circuit, and demonstrated that it can serve simultaneously as a modulator, photodetector, and laser source [Emboras2016, Emboras2018, Cheng2022].

Back in 2016, we reported the first memristive plasmonic modulator operating on the atomic scale [Emboras2016]. The device structure and functionality are shown in Figure 5a. A silicon waveguide channels an infra-red (IR) light beam into a narrow slot where it is covered by an insulating layer of amorphous Si (a-Si) that fills the gap between two metal electrodes, silver and platinum. The Ag–a-Si–Pt stack forms a CBRAM cell. The slot converts the incoming optical beam into a surface plasmon (carrier oscillations) that can, under the right conditions, squeeze through the tiniest part of the gap and reach the opposite side of the structure, where it is converted back to a photon beam. The optical transmission of the fabricated device is controlled by a voltage applied to the CBRAM, upon which an Ag filament grows and dissolves between the Ag and Pt electrodes. Depending on whether this filament short circuits the metallic plates or not, IR transmission is turned off or on, respectively. The binary switching mechanism between these two states and the resulting optical transmission therefore rely on the electrically-controlled relocation of a few atoms (≤20), which change the resonance frequency of the plasmonic cavity.

A memristive photodetector based on light-induced relocations of atoms was fabricated as next step [Emboras2018]. It is illustrated in Figure 5b. The realized structure consists of a silicon photonic waveguide butt coupled to a vertical 3-D atomic point contact of Ag-$SiO_2$-Pt material stack. In this combined experimental-theoretical work, we emphasized how a localized optical hot spot can efficiently interact with only a few atoms in a CBRAM cell through photonic/plasmonic couplers and thus modify its fundamental principles of operation, i.e., the current passing through the device.

To complete the photonic toolbox, a memristive, on-chip photon source, as visualized in Figure 5c, was developed [Cheng2022]. Such light sources offer a compact footprint, low power consumption, are operated electrically, and are compatible with standard CMOS fabrication processes. They thus enable high integration densities and energy-efficient operation at reduced cost. Our atomic scale memristive devices emit photons during resistive switching. Light emission occurs within the gap of an Ag/a-$SiO_x$/Pt junction under an applied voltage thanks to the special shape of the electrodes, engineered to form a plasmonic nanoantenna. Our demonstrations triggered a new conceptual paradigm of atomic scale devices combining electrical and optical functionalities within the same nanoscale unit. Thereby, we successfully addressed the challenge of downscaling photon sources, photodetectors, and electro-optical modulators to dimensions comparable to those of electronic components.

Embedding memristive modulators, photodetectors and photon sources directly into neuromorphic hardware could pave the way for high-speed photonic inter-chip links. Furthermore, the light-driven memory effects intrinsic to memristors can be exploited to tune solid-state synapses more precisely and to endow them with additional capabilities—namely, computation and data storage carried out entirely in the optical domain [Emboras2020].

**Outlook**

After developing a versatile memristve toolbox, the next phase of our research is dedicated to system level integration and promoting these technologies in application areas where their utilization has only become possible due to our latest breakthroughs. The integration efforts aim at the design and fabrication of combined CMOS and memristor arrays where memristor-based synapse and neuron arrays can emulate various machine learning tasks, alleviating some of the most demanding software overheads of typical AI tasks. Potential new application areas are mounting in the field of optical communication, where the highest operation speeds, electronic – photonic conversion, as well as low footprint, energy consumption and latency are key requirements.

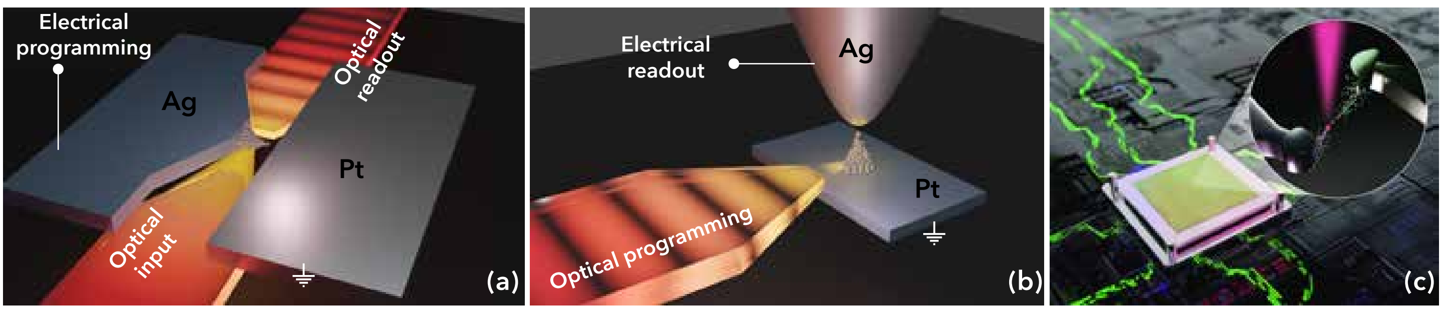


*Figure 5: Photonic memristive platform. (a) Electro-optical modulator [Emboras2016]. (b) Photodetector [Emboras2018]. (c) Photon source [Cheng2022]. Sub-plots (a) and (b) reprinted from [Emboras2020] with the permission of AIP Publishing.*

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# International Year of Quantum Science and Technology

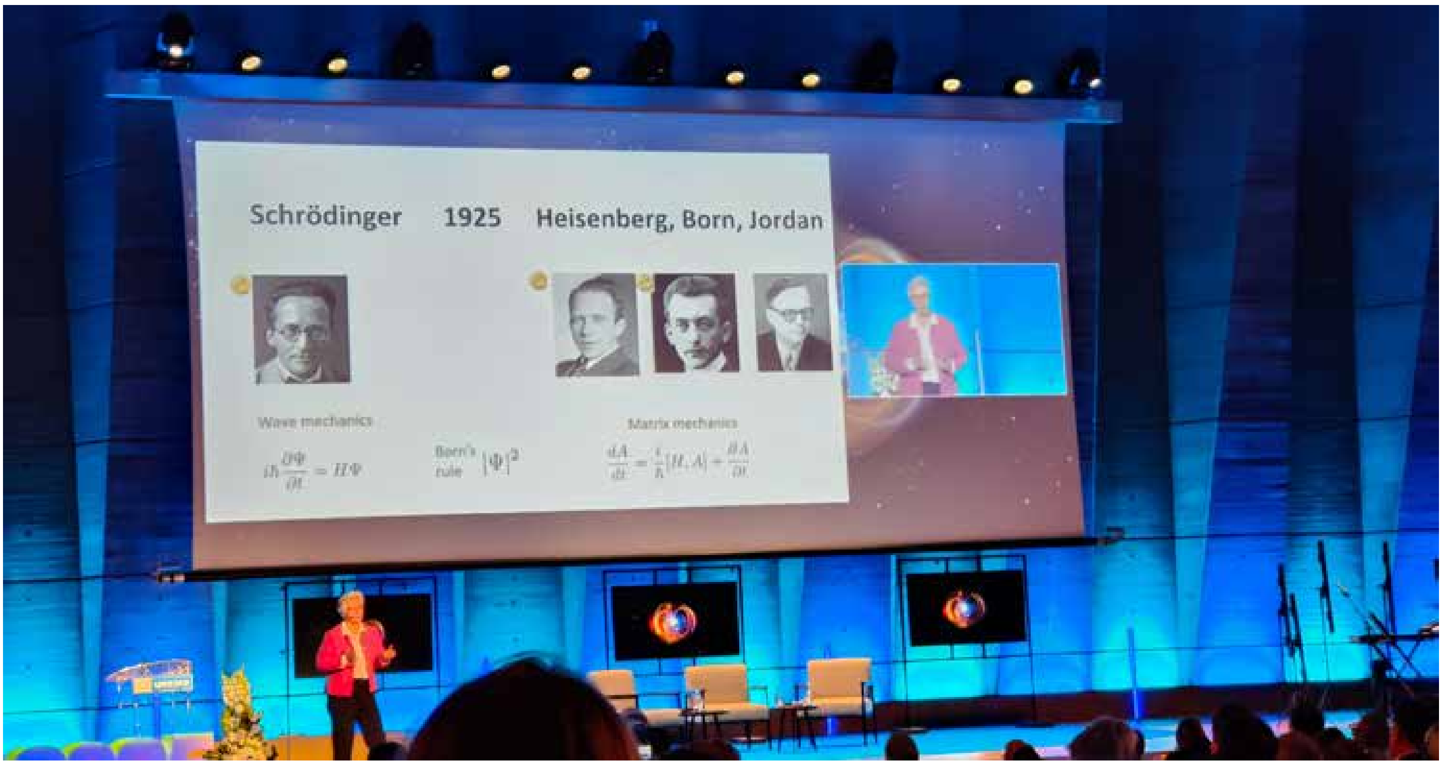
## #QUANTUMYEAR2025, UNESCO, Paris, 4 - 5 February 2025

*Gerd Leuchs, 2024 Optica president*

International years highlighting a particular topic are a great vehicle to alert the public and society of the relevance of this topic. If it is endorsed by **UNESCO** and **United Nations** then it is a rare gem, such as the Year of Light in 2015 celebrating the anniversaries of light related research progress through-out the last thousand years. Short after, preparations started for convincing United Nations to celebrate 100 years of the landmark papers by Werner Heisenberg and Erwin Schrödinger in 2025, in a world-wide effort led by the American Physical Society and with crucial support from Mexico and Ghana. The approval came last summer.

While Max Planck postulated energy to be quantized in 1900, Werner Heisenberg and Erwin Schrödinger created quantum theory, followed soon after by Paul Dirac providing the more general theory which is compatible with Albert Einstein's special relativity theory. The 100th anniversary this year is a splendid opportunity to look back, recapitulate the progress made and share this with the public. Interestingly, the important applications of major break-throughs and inventions and the implications for society are typically not foreseen at the time the break-through is made. In fact, some novel finding can often only in hind sight be determined to be a break-through, once a larger field has developed in response. This year we are celebrating the second quantum revolution **Quantum** 2.0, which is concerned with the properties of single quantum systems, not with statistical ensembles. One of the break-throughs leading to this particular field is the now famous Einstein-Podolsky and Rosen paper of 1935 addressing the weird implications of entanglement for a single potentially multi-partite system. As Anton Zeilinger often pointed out, this paper was cited only a handful of times in the first 30 years after its publication.

The official opening in early February this year in the UNESCO headquarters at Paris was a highlight for all who participated embracing all players in the field from academia to industry, from the publication to the political sector, across the globe and involving almost all age groups. Eminent representatives of the wider field such as William "Bill" Philips and Anne L'Huillier (see big picture) gave inspiring talks for the broad audience representing the whole spectrum of science and humanities. Others emphasized the importance of sustainability and socio-economic aspects – very relevant in our times of change. And last but not least, the one and a half days at Paris provided ample opportunities for networking. We are now looking forward to a firework of events, to outreach activities and to fests of interaction across society during this year.



# Milestones in Physics (29)

## 100 Years of Quantum Mechanics

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*"Heisenberg's type of mechanics has given me new hope and joy in life. To be sure, it does not supply the solution to the riddle, but I believe it is again possible to march forward."* (Wolfgang Pauli)

**Abstract**

The revolutionary discoveries in quantum theory of the year 1925 are recalled. Key ideas that went into Heisenberg's seminal work on matrix mechanics of July 1925 are reviewed in some detail. Dirac's important contributions to the birth of quantum mechanics are hinted at. It is argued that we should and are in fact able to "march forward" in our comprehension of quantum mechanics.

### 1 1925: An 'annus mirabilis'

*'Annus Mirabilis'* is a poem by *John Dryden* published in 1667. It commemorates the year 1666, which, despite the poem's name, was the tragic year of the Plague and the Great Fire of London. The term has also been used to refer to *Isaac Newton's* discoveries in 1665–1666, and to *Albert Einstein's* discoveries of 1905 [1]. Here I use it to refer to the fundamental progress in quantum theory made in 1925, which has inspired the United Nations General Assembly to declare 2025 an "***International Year of Quantum Science and Technology.***"

This contribution reviews some of the key ideas that led to *Heisenberg's* fundamental discovery of matrix mechanics in July 1925 [1], subsequently interpreted and extended in celebrated work by *Dirac* [2]. Readers, who want to understand more deeply how quantum mechanics was created are advised to consult *van der Waerden's* collection [3] of the most important papers written between 1917 and the beginning of 1926, which also contains a lucid introduction written by him. My presentation is influenced by the courses on quantum theory taught by my teachers, *Klaus Hepp*, *Markus Fierz* and *Res Jost* [4] and, later on, by myself and by *Norbert Straumann's* book on quantum mechanics [5]. Remarks by *Alain Connes* in [6] have helped triggering my interest in the history of these developments.

I would argue that, with regard to the quantity and depth of revolutionary progress in understanding how Nature works on the atomic scale, there was no other year in the history of physics comparable to 1925. It is thus natural to begin this essay with a list of the epochal discoveries made during that year, as reflected in the following works.

- 1924/25: *Einstein's* work on ideal quantum gases [7]; prediction of Bose-Einstein condensation in Bose gases; first prediction of a phase transition using quantum statistical mechanics.
- January 1925: *Pauli's* discovery [8] of the (Pauli) exclusion principle and of electron spin as a "*classically not describable two-valuedness of the quantum-theoretical properties of the valence electron,*" as well as of its g-factor, $g_e = 2$; (see also [5, 9]) [2].
- January: Paper by *H. A. Kramers* and *W. Heisenberg* on the scattering of light by atoms [11] following a series of earlier papers on related matters by various authors.
- May: *Kuhn's* paper on what is called the *Thomas-Reiche-Kuhn sum rule*; (see [12] for the original results). This sum rule was instrumental in replacing the Bohr-Sommerfeld quantization condition by a fundamental new one, namely the canonical commutation relations.
- July: *Heisenberg's* revolutionary work [1] marking the discovery of matrix mechanics.
- September: Paper by *Born* and *Jordan* [13] on the mathematical formalism underlying Heisenberg's matrix mechanics and extensions thereof, which they call *Quantum Mechanics* [3].
- October: *Goudsmit* and *Uhlenbeck* [14] interpret Pauli's "two-valuedness" as *spin* (Eigendrehimpuls) of the electron and propose an explanation of $g_e = 2$, which, however, was not tenable.
- November: *Dirac* proposes a crystal-clear mathematical interpretation and completion of Heisenberg's discovery [2].
- November: "Dreimännerarbeit" [15]. Independently of *Dirac*, and shortly after him, *Born*, *Heisenberg* and *Jordan* propose a mathematical formulation of the new quantum mechanics. They develop the quantum theory of angular momentum and sketch extensions of quantum mechanics to systems with infinitely many degrees of freedom.
- January 1926: *Pauli's* derivation of the hydrogen spectrum from the postulates of matrix mechanics [16]. (Since Pauli must have done most of the calculations in this paper late in 1925, and since it provided a convincing confirmation of the correctness of matrix mechanics, I count this paper among the triumphs of 1925.)

As is well known, the year 1926 saw further quite spectacular discoveries in quantum mechanics related to *Schrödinger's* wave mechanics – a great source of powerful mathematical methods leading to important progress in the analysis of concrete physical systems, and, alas, a source of much confusion lasting until the present – and the work of *Dirac* and *Jordan* on quantum electrodynamics and quan-

1 I refer to 'Wikipedia' for further details about the meaning and the use of the term 'annus mirabilis'.

2 Pauli's exclusion principle is fundamental for the *stability of (non-relativistic) matter*, systems of atomic nuclei and electrons, first established by Dyson and Lenard in 1967/68; see [10] and references given there. This property is one of the pillars which condensed matter physics rests upon.

3 The name "quantum mechanics" first appeared in a paper by Max Born, entitled "*Über Quantenmechanik*", Zeitschrift für Physik **26**, 379-395 (1924).

tum optics [4]. For lack of space I will not comment on these developments in any detail. The *Dirac equation*, the prediction of the *positron* and, more generally, of *anti-matter*, and *Dirac's path integral* [21] cannot be reviewed either. But a few sketchy remarks about some of the important further progress in quantum theory will be made at the end of this essay.

If I were asked to rank the discoveries mentioned above my choice would be the following one:

1. Heisenberg's discovery of matrix mechanics of July 1925.
2. Dirac's paper of November 1925, interpreting and extending Heisenberg's discovery.

In the following I try to reproduce the main ideas underlying Heisenberg's paper.

## 2 The basis for Heisenberg's discovery of matrix mechanics

During the years 1923 - 1925, it became increasingly clear that a radical change in the analysis of the structure and the spectra of atoms was indispensable. In the two leading centers, Göttingen (*Born*) and Copenhagen (*Bohr*), discomfort grew about the persistent problems encountered in the description of many-body systems [5] (e.g., the Helium atom and the $H_2$ molecule) within the old *Bohr-Sommerfeld-Epstein* quantum theory.

The way out of this impasse was found by *Heisenberg* in July 1925 and published in a paper entitled "*Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen.*" (Heisenberg was 23 years old when he wrote this paper.) I quote a sentence from the introduction:

> *"[Es scheint] geratener, jene Hoffnung auf eine Beobachtung der bisher unbeobachtbaren Grössen, wie Lage, Umlaufszeit des Elektrons [im Atom], ganz aufzugeben, gleichzeitig also einzuräumen, dass die teilweise Übereinstimmung der genannten Quantenregeln mit der Erfahrung mehr oder weniger zufällig sei, und zu versuchen, eine der klassischen Mechanik analoge quantentheoretische Mechanik auszubilden, in welcher nur Beziehungen zwischen beobachtbaren Grössen vorkommen."*

What earlier results could Heisenberg build upon when he made his epochal discovery? Here are four essential ones.

A. *Rydberg-Ritz combination principle* [17] (1889, 1908)

B. "Quantization" of integrable Hamiltonian systems according to the quantization rules of *Bohr-Sommerfeld-Epstein-(Schwarzschild-)Einstein* [18] (1913 - 1917)

C. Theoretical work on scattering of light by atoms and (its relation to) atomic spectra by *Bohr*, *Heisenberg*, *Kramers*, *Pauli*, *Slater*, *Wentzel* and others, prior to 1925 and in January 1925; see [3]

D. *Thomas-Reiche-Kuhn sum rule* [12]

Inputs C and D will enter our discussion in the next section. It deserves to be mentioned that the basis for Heisenberg's discovery was *atomic spectroscopy*; Planck's formula, which had stimulated much of Einstein's work on quantum theory, and *de Broglie's* discovery of the wave nature of particles did apparently not play an important role in Heisenberg's thinking.

### A. Rydberg-Ritz combination principle

• For every species of atoms, there is a series of energies, $\{E_n\}_{n=1}^{\infty}$, the "*Termschema*" or "*Grotrian diagram*" (which depends on the external electromagnetic field: Zeeman- and Stark effect), where $E_n$ is the energy of an atom in a stationary state, $|n\rangle$, for all $n$, such that the frequency, $\omega_{n,m}$, of light emitted during an atomic transition from state $|n\rangle$ to state $|m\rangle$, with $E_n > E_m$, is given by [6]

$$\omega_{n,m} = \frac{1}{\hbar}(E_n - E_m), \qquad (1)$$

where $\hbar = h/2\pi$, and $h$ is Planck's constant.

• Certain pairs $(n, m)$ correspond to frequencies $\omega_{n,m}$ that are *not* observed: "*Selection Rules*".

• If $\omega_{n,m}$ and $\omega_{m,k}$ are observed then

$$\omega_{n,k} = \omega_{n,m} + \omega_{m,k} \qquad (2)$$

is observed, too.

Within classical mechanics and electrodynamics, the Rydberg-Ritz combination principle cannot be understood. However, if, in Eq. (1), $n \to \infty$ (i.e., $E_n$ approaches a threshold energy), with $|n-m|$ bounded, the predictions of the Rydberg-Ritz principle are assumed to agree with classical radiation theory; this is Bohr's "*Correspondence Principle*".

### B. Quantization of Integrable Hamiltonian Systems

Consider a classical Hamiltonian system, $S$, with phase space $\Gamma \overset{e.g.}{=} \mathbb{R}^{2f}, T^*M$ (the cotangent bundle of some configuration space $M$), $S^2$, etc. Let $\{\cdot,\cdot\}$ denote the *Poisson bracket* on the space of smooth functions on $\Gamma$.

**Definition:** Let $f = \dim \Gamma/2$; S is said to be *integrable*, if there are $f$ smooth, "independent" functions, $G_1,\ldots, G_f$, on $\Gamma$ in *involution*, i.e., satisfying

$$\{G_i, G_j\} = 0, \ \forall\, i, j,$$

which are *constants of motion*, i.e., $\{H, G_i\} = 0, \forall i,$ where $H$ is the Hamilton function of $S$.

**Theorem** (*Liouville, Jacobi, Arnol'd, Jost,* [20]):
Let $S$ be an integrable Hamiltonian system with phase space $\Gamma = \mathbb{R}^{2f}$ and with the property that the level surfaces of constant $G_1,\ldots, G_f$ are compact. Then $\Gamma$ is foliated by $f$-dimensional tori,

$$\mathbb{T}^f = \mathbb{T}^f(\boldsymbol{G}), \text{ with } \boldsymbol{G} := (G_1, \ldots, G_f) \in \mathbb{R}^f,$$

that are invariant under the Hamiltonian flow generated by $H$ and under the flows generated by the functions $G_1,\ldots,G_f$.

4 It appears that Born always felt that his contributions to discoveries like this one were underappreciated.

5 classically, *non-integrable* Hamiltonian systems.

6 In accordance with Heisenberg's *time-energy uncertainty relation*, relation (1) between the frequency of light emitted in a transition from a stationary state $|n\rangle$ to a state $|m\rangle$ turns out to be only approximate; excited states, $|n\rangle$, other than ground-states and symmetry-protected states, are *unstable*, namely *resonances*, and the corresponding energies $E_n$ are (fuzzy) *resonance energies*; see [19] for a mathematical treatment of these matters.

Every invariant torus $\mathbb{T}^f(\boldsymbol{G})$ can be parametrized by *f angle variables*, $\boldsymbol{\varphi} = (\varphi_1, ..., \varphi_f)$, where $\varphi_i \in [0, 2\pi]$ parameterizes the $i^{th}$ non-contractable cycle of $\mathbb{T}^f(\boldsymbol{G})$, for $i = 1,..., f$. Since the functions $G_i$ are constant on every torus $\mathbb{T}^f(\boldsymbol{G})$ and *independent*, in the sense that their gradients, $dG_1$,..., $dG_f$, are everywhere linearly independent, one can introduce functions, $W_1$,..., $W_f$, called *action variables*, which only depend on $G_1$,..., $G_f$, such that

$$\{W_i, W_j\} = 0, \{W_i, \varphi_j\} = \delta_{ij}, \text{and } \{\varphi_i, \varphi_j\} = 0, \forall\, i, j.$$

The Hamilton function $H$ of $S$ is a function of the action variables alone. In general, the mechanical flow on $\mathbb{T}^f(\boldsymbol{G})$ is *not* periodic but *quasi-periodic* in time $t$, which represents a problem for the original Bohr-Sommerfeld quantization.

### *Generalization of the Bohr-Sommerfeld quantization rules*

The *"allowed orbits"* (stationary states), $|\mathbf{n}\rangle$, of $S$ lie on tori $\mathbb{T}^f(\mathbf{W_n}) \equiv \mathbb{T}^f(\mathbf{G}(\mathbf{W_n}))$, where $\mathbf{W_n}$ satisfies

$$\mathbf{W_n} = (W_1, ..., W_f) = h\,\mathbf{n}, \quad \mathbf{n} = (n_1, ..., n_f) \in \mathbb{Z}^f. \qquad (3)$$

The integers $n_1$,..., $n_f$ are called *quantum numbers*. The corresponding "energy levels" of $S$ are given by

$$E_\mathbf{n} = H(\mathbf{W_n}). \qquad (4)$$

This generalization of the Bohr-Sommerfeld quantization rules is due to *Einstein* (1917) [18], who also pointed out that, according to *Poincaré*, the three-body Coulomb problem is not integrable, which explains why already the Helium atom could not be understood using Bohr-Sommerfeld quantization rules.

Let $X$ be an "*observable*" of $S$, i.e., $X$ is a real-valued smooth function on $\Gamma = \mathbb{R}^{2f}$. In the following we imagine that $S$ contains particles interacting with the electromagnetic field, and that $X$ is, for example, proportional to a component of the total electric dipole moment of $S$. For $\mathbf{W}$ = const., $X = X(\boldsymbol{\varphi}, \mathbf{W})$ is a periodic function of the angle variables $\boldsymbol{\varphi} = (\varphi_1, ..., \varphi_f)$. We expand it in a *Fourier series*,

$$X(\boldsymbol{\varphi}, \mathbf{W}) = \sum_{\mathbf{n} \in \mathbb{Z}^f} \hat{X}_\mathbf{n}(\mathbf{W})\, e^{i\mathbf{n}\cdot\boldsymbol{\varphi}}.$$

The *time evolution* of $X$ can be derived from the time evolution of the angle variables,

$$\dot{\varphi}_j = \{H, \varphi_j\} = \frac{\partial H(\mathbf{W})}{\partial W_j} =: \omega_j(\mathbf{W}),$$
$$\dot{W}_j = \{H, W_j\} \equiv 0, \quad \forall\, j = 1, ..., f.$$

The solutions of these Hamiltonian equations of motion are

$$\mathbf{W} = \text{const.}, \ \boldsymbol{\varphi} = \boldsymbol{\varphi}_0 + \boldsymbol{\omega} \cdot t, \quad \text{with } \boldsymbol{\omega} = \boldsymbol{\omega}(\mathbf{W}).$$

Thus

$$X(t) = \sum_{\mathbf{n} \in \mathbb{Z}^f} \hat{X}_\mathbf{n}(\mathbf{W})\, e^{i(\mathbf{n}\cdot\varphi_0 + [\mathbf{n}\cdot\boldsymbol{\omega}(\mathbf{W})]\cdot t)},$$

We observe that $X(t)$ is a *quasi-periodic* function of time $t$, with frequencies $\omega^{(\mathbf{n})} \equiv \mathbf{n} \cdot \boldsymbol{\omega}$.

If $S$ were a classical Hamiltonian system, and if $X$ were a component of the total electric dipole moment of charges in $S$, then the Maxwell equations would imply that electromagnetic radiation with frequencies $\omega^{(\mathbf{n})}$, $\mathbf{n} \in \mathbb{Z}^f$, would be emitted; (the recoil of the electromagnetic field on the motion of charges in $S$ is neglected here) [7]. For every fixed $\mathbf{W}$, the frequencies $\omega^{(\mathbf{n})} = \omega^{(\mathbf{n})}(\mathbf{W})$ define a representation of the *abelian group* $\mathbb{Z}^f$,

$$\omega^{(\mathbf{n})} + \omega^{(\mathbf{m})} = \omega^{(\mathbf{n}+\mathbf{m})}, \quad \mathbf{n}, \mathbf{m} \in \mathbb{Z}^f.$$

Hence, with some frequency $\omega$, all its harmonics, $n\omega$, $n = 1$, 2,..., would in general be emitted, too! This is *not* observed in Nature and *contradicts* the Rydberg-Ritz principle.

Consider an atom, $S$. In Nature, frequencies of electromagnetic radiation emitted by electrons in $S$ actually represent a *groupoid* (*not* a group), $\mathcal{G}$, consisting of pairs, ($\mathbf{m}$, $\mathbf{n}$), of "*quantum numbers*" labeling "*stationary states*," $|\mathbf{n}\rangle$ and $|\mathbf{m}\rangle$, of $S$; see Eqs. (3) and (4). For ($\mathbf{m}$, $\mathbf{k}$) and ($\mathbf{k}$, $\mathbf{n}$) in $\mathcal{G}$, ($\mathbf{m}$, $\mathbf{k}$) ∘ ($\mathbf{k}$, $\mathbf{n}$) = ($\mathbf{m}$, $\mathbf{n}$) belongs to $\mathcal{G}$, too. (The composition, ($\mathbf{m}$, $\mathbf{k}$) ∘ ($\boldsymbol{\ell}$, $\mathbf{n}$), of ($\mathbf{m}$, $\mathbf{k}$) with ($\boldsymbol{\ell}$, $\mathbf{n}$) is defined if and only if $\mathbf{k} = \boldsymbol{\ell}$.)

The Rydberg-Ritz principle implies that the frequencies

$$\omega_{\mathbf{m},\mathbf{n}} := \frac{1}{\hbar}(E_\mathbf{m} - E_\mathbf{n}) \qquad (5)$$

define a representation of $\mathcal{G}$.

## 3 Heisenberg's breakthrough of July 1925

Let $S$ be a hydrogen atom or a system of harmonic oscillators; $S$ is thus an integrable system. Then $E_\mathbf{n} = H(\mathbf{W} = h\,\mathbf{n})$, see Eq. (4), is the energy of an "*allowed orbit*" (*stationary state*), $|\mathbf{n}\rangle$, of the quantization of $S$; see (3). This yields the correct "*Termschema*" for the spectral lines of hydrogen and of systems of harmonic oscillators and the correct degeneracies of their stationary states. The problem Heisenberg attempts to solve is to develop a *new mechanics* that does *not* depend on $S$ being integrable. He proposes that the new mechanics be formulated exclusively in terms of "*observable quantities*". Given the "*Termschema*" $\{E_n\}_{n=1}^{\infty}$ of some system $S$, he associates a *stationary state*, $|n\rangle$, with every energy $E_n$, for all $n$, and assumes that all the "*observables*," such as the total electric dipole moment of charges in $S$, *only* depend on *pairs* ($m$, $n$) corresponding to observed transitions between stationary states $|m\rangle$ and $|n\rangle$ of $S$.

Thus, when quantizing a classical Hamiltonian system in accordance with the new mechanics, the Fourier coefficients, $\hat{X}_\mathbf{n}(\mathbf{W} = h\,\mathbf{m})$, of a function $X$ on its phase space are to be replaced by what Heisenberg called (number-) "*schemes*", $\hat{X}$, with

$$\hat{X} = (X_{m,n})_{(m,n)\in\mathcal{G}},$$

where $\mathcal{G}$ is the groupoid of pairs of quantum numbers corresponding to observed transitions between stationary states of the quantized system. (Here $\mathbf{n} \in \mathbb{Z}^f$ is replaced by a general index $n \in \mathbb{Z}_+$.)

***Remark***: If $X$ is proportional to the electric dipole moment of $S$ then the entry $X_{m,n}$ in the "scheme" $\hat{X} = (X_{m,n})_{(m,n)\in\mathcal{G}}$ corresponding to $X$ after quantizing $S$ has the property that $|X_{m,n}|^2$ is proportional to the intensity of light with frequency $\omega_{m,n} = \frac{1}{\hbar}(E_m - E_n)$ emitted in the transition from state $|m\rangle$ to state $|n\rangle$. This is suggested by earlier results on atomic

7 This fact was discovered, in theory and experiment, by *Heinrich Hertz*.

spectra alluded to in Input C, Sect. 3. Hence $X_{m,n}$ can be considered to be "*observable*". Heisenberg's schemes were subsequently recognized by *Born* and *Jordan* and by *Dirac* to be *matrices* [13, 2].

Returning to the special case of an integrable Hamiltonian system *S*, Bohr's "*Correspondence Principle*" suggests that, after quantizing *S*,

$$X_{\mathbf{m},\mathbf{m}+\mathbf{n}} \approx \hat{X}_n(\mathbf{W} = h\mathbf{m}), \text{ for } 0 < |\mathbf{n}| \ll |\mathbf{m}|. \quad (6)$$

Since, classically, *X* is a *real* function on the phase space of *S* one has that

$$\hat{X}_{-n}(\mathbf{W}) = \hat{X}_n(\mathbf{W})^*,$$

where $^*$ is complex conjugation. With Eq. (6) this suggests that $X^*_{\mathbf{m},\mathbf{n}} = X_{\mathbf{n},\mathbf{m}}$, i.e., $\hat{X}$ is a hermitian matrix.

If $X^{(1)}$ and $X^{(2)}$ are two classical "observables" of *S* then their product $X^{(1)} \cdot X^{(2)}$ is an "observable," too; (smooth functions on phase space form an abelian algebra). Then

$$(\widehat{X^{(1)} \cdot X^{(2)}})_{\mathbf{n}}(\mathbf{W}) = \sum_{\mathbf{m}\in\mathbb{Z}^f} \hat{X}^{(1)}_{\mathbf{n}-\mathbf{m}}(\mathbf{W}) \cdot \hat{X}^{(2)}_{\mathbf{m}}(\mathbf{W}),$$

i.e. the Fourier coefficients of the product $X^{(1)} \cdot X^{(2)}$ are given by the convolution of the Fourier coefficients of $X^{(1)}$ and $X^{(2)}$. Heisenberg proposes to replace the *convolution product* on the group $\mathbb{Z}^f$ by the product

$$(\hat{X}^{(1)} * \hat{X}^{(2)})_{\mathbf{m},\mathbf{n}} = \sum_{\mathbf{k}} X^{(1)}_{\mathbf{m},\mathbf{k}} \cdot X^{(2)}_{\mathbf{k},\mathbf{n}}, \quad (7)$$

which is the *matrix product* of $\hat{X}^{(1)}$ and $\hat{X}^{(2)}$. Setting **n** = **m** + **p**, **k** = **m** + $\ell$, with |**p**| ≪ |**m**|, |$\ell$| ≪ |**m**|, the matrix product (7) is seen to approach the convolution product, in accordance with Bohr's correspondence principle.

The next problem Heisenberg had to face concerns the *time evolution* of "observables" $\hat{X}$. Supposing that *S* is an integrable system with the property that

$$E_{\mathbf{n}} = H(\mathbf{W} = h\mathbf{n})$$

is the energy of an "*allowed orbit*", $|\mathbf{n}\rangle$, we find that

$$\hbar\,\omega_{\mathbf{m},\mathbf{n}} \overset{(4)}{=} E_{\mathbf{m}} - E_{\mathbf{n}} \approx \nabla H(\mathbf{W} = h\,\mathbf{m}) \cdot h(\mathbf{m}-\mathbf{n}), \quad \text{for } |\mathbf{m}-\mathbf{n}| \ll |\mathbf{m}|. \quad (8)$$

Using the Rydberg-Ritz combination principle, with the frequency condition (8), and Bohr's correspondence principle (6), one arrives at the idea that

$$X_{\mathbf{m},\mathbf{n}}(t) = e^{i\omega_{\mathbf{m},\mathbf{n}}\cdot t} X_{\mathbf{m},\mathbf{n}} = e^{i(E_{\mathbf{m}}t)/\hbar} X_{\mathbf{m},\mathbf{n}} e^{-i(E_{\mathbf{n}}t)/\hbar}. \quad (9)$$

Heisenberg generalizes (9) by replacing the Hamilton function *H* of a classical system *S* by a "*diagonal scheme*" (i.e., a diagonal matrix), $\hat{H} = (H_{m,n})$, the *Hamiltonian* of *S*, given by

$$H_{m,n} = E_m \delta_{m,n},$$

where the quantum number *m* corresponds to the stationary state $|m\rangle$ of energy $E_m$ of the quantization of *S*, and he proposes that the time evolution of a general "observable" $\hat{X} = (X_{m,n})$ be given by

$$X_{m,n}(t) = [e^{i\hat{H}t/\hbar} * X * e^{-i\hat{H}t/\hbar}]_{m,n}. \quad (10)$$

This equation was baptized *Heisenberg equation* by Dirac. Following the philosophy of the young Einstein, namely to formulate a theory entirely in terms of observable quantities [8], Heisenberg now proposes to *ban* the Bohr-Sommerfeld rules for "*allowed (mechanical) orbits*" of integrable systems, as expressed in the conditions

$$\mathbf{W}_{\mathbf{n}} = h\,\mathbf{n}, \quad \mathbf{n} \in \mathbb{Z}^f, \quad E_{\mathbf{n}} = H(\mathbf{W}_{\mathbf{n}}),$$

because classical orbits are not observable (and most systems *S* are not integrable). He finds an appropriate replacement of these rules in the *Thomas-Reiche-Kuhn sum rules*, input D, Sect. 2, which we discuss next.

Let *x* be a component of the position of an electron (mass *M*) in the shell of an atom. By $p = M\dot{x}$ we denote the corresponding component of its momentum. As explained above, Heisenberg replaces x by a matrix $\hat{X} = (X_{m,n})$ and *p* by a matrix $\hat{P} = (P_{m,n})$. He proposes to preserve the classical relation between the position and the momentum, setting $\hat{P} = M\dot{\hat{X}}$. Eq. (10) then implies that

$$P_{m,n} = M\dot{X}_{m,n} = iM\omega_{m,n}X_{m,n},$$
$$\text{with } \omega_{m,n} = \frac{i}{\hbar}(E_m - E_n) = -\omega_{n,m}.$$

Heisenberg considers the commutator

$$-i[\hat{X},\hat{P}]_{n,n} \equiv -i\sum_{m\in\mathbb{Z}_+}(X_{n,m}\cdot P_{m,n} - P_{n,m}\cdot X_{m,n})$$
$$= 2M\sum_{m\in\mathbb{Z}_+}|X_{n,m}|^2\omega_{m,n}. \quad (11)$$

The quantity $|X_{m,n}|^2$ had appeared in calculations of the intensity of the spectral line corresponding to a transition from a state $|n\rangle$ to a state $|m\rangle$. The right side of Eq. (11) is the basic expression appearing in the *Thomas-Reiche-Kuhn sum rule*, which says that *this expression is equal to Planck's constant* $\hbar$. It is straightforward to argue that, for a *harmonic oscillator*, this sum rule is correct.

The classical equation of motion of the harmonic oscillator is $M\ddot{x} = -fx$, where *f* is the spring constant. The frequency of the oscillator is given by $\omega = \sqrt{f/M}$. The solutions of these equations of motion are

$$x_t(\xi) = \xi\cos(\omega t + \theta), \quad \dot{x}_t(\xi) = -\omega\xi\sin(\omega t + \theta),$$

for constants $\xi \geq 0$ and $\theta \in [0,2\pi)$ determined by the initial conditions; (*t* denotes time). The energy of this solution is

$$E(\xi) = \frac{M}{2}\dot{x}_t(\xi)^2 + \frac{M\omega^2}{2}x_t(\xi)^2 = \frac{M\omega^2}{2}\xi^2$$

According to Planck, the energies of *"allowed orbits*" (*stationary states*) are given by $E(\xi_n) \equiv E_n = n\hbar\omega$, $n$ = 0,1, 2,..., (zero-point energy neglected). This follows from the Bohr-Sommerfeld quantization condition

$$\int p \cdot dx = nh,$$

for an "*allowed orbit.*" Thus, for a given *n*,

$$\xi \equiv \xi_n = \sqrt{\frac{2n\hbar}{M\omega}}.$$

Following Heisenberg's ideas, one sets

$$X_{n,n+1} \simeq \hat{x}_1(\xi_n) = \frac{1}{2}\xi_n, \quad X_{n,n-1} \simeq \hat{x}_{-1}(\xi_{n-1}) = \frac{1}{2}\xi_{n-1},$$

8 which Einstein had already abandoned in 1925

($X_{n,m} = 0$, for $|n-m| > 1$) and

$$\omega_{n+1,n} = (n+1)\omega - n\omega = \omega = \omega_{n,n-1} = -\omega_{n-1,n}.$$

It then follows that

$$\begin{aligned} -i[\hat{X},\hat{P}]_{n,n} &= -i[\hat{X}, M\dot{\hat{X}}]_{n,n} = 2M\{|X_{n,n+1}|^2\omega_{n+1,n} + |X_{n,n-1}|^2\omega_{n-1,n}\} \\ &= 2M\omega\frac{1}{4}\{\xi_n^2 - \xi_{n-1}^2\} = \frac{M\omega}{2}\frac{2\hbar}{M\omega}\{n-(n-1)\} \\ &= \hbar\,. \qquad (12) \end{aligned}$$

Next, one would like to determine the matrix elements $[\hat{X},\hat{P}]_{m,n}$ for $m \neq n$. This was first done by Born and Jordan in [13] [9].

## 4 Completing matrix mechanics to quantum mechanics

*Born* and *Jordan* interpret Heisenberg's "*schemes*" as *matrices* and further develop the *mathematical formalism* of *matrix mechanics*. Following Heisenberg, they replace real-valued functions on classical phase space by *hermitian matrices*, they replace Hamilton functions of the form

$$H(p,x) = \frac{p^2}{2M} + V(x)$$

by *Hamilton operators* (Hamiltonians)

$$\hat{H} := \frac{\hat{P}^2}{2M} + V(\hat{X}), \qquad (13)$$

and, following Heisenberg, they demand that the Heisenberg equations of motion for $\hat{X}$ and $\hat{P}$ have the same form as the classical Hamiltonian equations of motion. Thus,

$$\frac{d}{dt}\hat{X} \equiv \dot{\hat{X}} = \frac{i}{\hbar}[\hat{H},\hat{X}] \overset{!}{=} \frac{\hat{P}}{M}, \qquad \dot{\hat{P}} = \frac{i}{\hbar}[\hat{H},\hat{P}] \overset{!}{=} -grad\,V(\hat{X}),$$

for $\hat{H}$ as in (13). It follows that

$$\frac{i}{\hbar}[\hat{H},[\hat{X},\hat{P}]] = [\dot{\hat{X}},\hat{P}] + [\hat{X},\dot{\hat{P}}] = [\frac{\hat{P}}{M},\hat{P}] - [\hat{X}, grad\,V(\hat{X})] = 0.$$

Next,

$$\frac{i}{\hbar}[\hat{H},[\hat{X},\hat{P}]]_{m,n} = \frac{i}{\hbar}(E_m - E_n)[\hat{X},\hat{P}]_{m,n} = i\omega_{m,n}[\hat{X},\hat{P}]_{m,n}.$$

Assuming that $E_m \neq E_n$, for $m \neq n$, it follows that

$$[\hat{X},\hat{P}]_{m,n} = 0\,,\ \text{for } m \neq n \qquad (14)$$

Together with Eq. (12) (Thomas-Reiche-Kuhn sum rule), it follows that

$$[\hat{X},\hat{P}] = i\hbar\,\mathbf{1},$$

which are the *canonical commutation relations*. These relations replace the Bohr-Sommerfeld quantization conditions. With the hermiticity condition and the Heisenberg equations of motion for "observables" they completely determine the *algebraic structure of the non-relativistic quantum mechanics of a system of particles*.

9 When Born asked Pauli whether he was willing to help him work out the mathematical formalism clarifying Heisenberg's discovery and, in particular, determine the off-diagonal elements of the commutator $[\hat{X},\hat{P}]$ Pauli replied as follows: "Yes, I know you are fond of tedious and complicated formalism. You are only going to spoil Heisenberg's physical ideas by your futile mathematics..."

The discovery of quantum mechanics holds a *miracle*: only approximately valid empirical rules (rules A, B and C, Sect. 2) gave birth to a mathematically consistent, perfect physical theory.

## 5 Dirac's contributions to quantum mechanics in 1925

Stimulated by Heisenberg's discovery of July 1925, *Dirac* proposes the following general rules to pass from classical Hamiltonian mechanics to quantum mechanics [2]:

Let $\Gamma$ be the phase space of a Hamiltonian system *S* with Poisson bracket $\{.,.\}$.

- Let *F* be an arbitrary real function on $\Gamma$. In order to quantize *S*, *F* must be replaced by a *hermitian matrix* $\hat{F}$. Specializing to ordinary mechanical systems of particles moving in physical space, then, up to ordering problems, this is accomplished by replacing $F(x,p)$ by $\hat{F} = F(\hat{X},\hat{P})$, with $\hat{X}$ and $\hat{P}$ satisfying the canonical commutation relations.
- The product, $F \cdot G$, of two functions, *F* and *G*, on $\Gamma$ must be replaced by the matrix product, $\hat{F} * \hat{G}$, of the quantizations of *F* and *G*.
- The Poisson bracket, $\{F,G\}$, of *F* and *G* must be replaced by commutator, $\frac{i}{\hbar}[\hat{F},\hat{G}]$, of their quantizations.

Dirac notices that the algebraic structure of the family of quantum-mechanical observables is preserved under similarity transformations,

$$\hat{F} \mapsto T \cdot \hat{F} \cdot T^{-1}, \qquad (15)$$

for an arbitrary invertible matrix *T*. In order to preserve the *hermiticity* of observables under the transformation in (15), one must require *T* to be *unitary*, i.e., $T^* = T^{-1}$.

## 6 Completing quantum mechanics

*"It seems clear that the present quantum mechanics is not in its final form."* (P. A. M. Dirac)

Three further fundamental contributions should be mentioned:

1. *Von Neumann's uniqueness theorem:* The quantization of the phase space $\Gamma = \mathbb{R}^{2f}$, with the (exponentiated) canonical commutation relations, the so-called *Weyl relations*,

$$e^{i(\hat{X},a)} \cdot e^{i(\hat{P},b)} = e^{i\hbar(a\cdot b)}e^{i(\hat{P},b)} \cdot e^{i(\hat{X},a)},$$

imposed, is *unique*. This means that Schrödinger's configuration space representation of the basic observables of quantum mechanics (1926),

$$\hat{P} = \frac{\hbar}{i}\nabla_x\ , \quad \hat{X} = \text{multiplication by } x,$$

can be used without loss of generality.

2. *Dirac's* discovery of the *path integral* [21]. Integration over "*paths*" or "*trajectories*", $\{x(s)\}_{s=0}^{s=t}$, can be used to calculate the matrix elements of the propagator,

$$[e^{-it\hat{H}/\hbar}]_{x,x'} = Z^{-1}\int_{x(0)=x}^{x(t)=x'}\prod_{s=0}^{t}\mathcal{D}x(s)\,exp[-\frac{i}{\hbar}\int_0^t ds\,\mathcal{L}(\dot{x}(s),x(s))],$$

of quantum systems obtained by quantizing Lagrangian mechanical systems. Here $Z$ is a normalization factor, and $\mathcal{L}$ is the Lagrangian.

In 1905, Einstein discovered the *photon* and outlined a theory of the *photoelectric effect*. In 1916, he proposed a theory of (spontaneous and induced) emission and absorption of photons by atoms (*A*- and *B*- coefficients). In this work, *probabilities* first entered quantum theory! It contained a new derivation of *Planck's law of black-body radiation*. However, it did not represent a coherent quantum theory of electrically charged matter interacting with electromagnetic radiation, yet. Shortly after Heisenberg's discovery of matrix mechanics and Dirac's 1925 paper,

3. Dirac and Jordan made the first successful steps in developing a quantum mechanics of electrically charged matter interacting with the *quantized electromagnetic field*.

This signals the beginnings of *quantum electrodynamics* (QED) and of *quantum optics*; (see [22] and references given there).

## Concluding remarks

> *"The constant element in physics, since Newton, is not a configuration or a geometrical form, but a law of dynamics."* (Werner Heisenberg)

It turns out that taking into account the effects of interactions between charged matter and the quantized electromagnetic field is absolutely critical in the quest of a *general quantum-mechanical law of dynamics* enabling one to determine the *stochastic time evolution of states of individual systems* and thus for the development of a logically coherent *theory of measurements* as physical processes that properly expresses the probabilistic predictions for individual measurement outcomes, i.e., for a solution of the so-called *measurement problem*. This problem has been the cause of a lot of confusion about the deeper meaning of quantum mechanics that have lasted from the birth of quantum mechanics until today. A tentative completion of quantum mechanics, including a general law of dynamics and a resolution of the measurement problem, has been proposed in what I have called *ETH-Approach to / ETH-completion* of quantum mechanics; see [23], and references given there.

The reader may expect to find comments on further important topics, such as *interpretations of quantum mechanics*, Schrödinger's discovery of *entanglement* [24] and its diverse consequences and applications in quantum information and condensed matter theory, *hidden variables* [25, 5] (*Kochen-Specker theorem* and *Bell's inequalities*), *developments in quantum information theory and quantum computing*, etc. These topics ought to be discussed in a future contribution.

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# Physics Anecdotes and Personal Recollections (32)

## Remote Sensing in Industrial Metrology

*Bernhard Braunecker*

### Introduction

Data encoding is traditionally applied in industry to stabilize processing, transfer, storage and display of digital data against distortions. Well-known are the adding of redundant bits when transmitting a N-bit word, which allows the receiver to find out which bits have been inadmissibly changed by external influences and have to be corrected.

In this paper we consider encoding strategies being optimized for technical surveying tasks. To this purpose a large binary code word is fixed on the rigid body, which 3D-position and 3D-angular orientation has to be known. The measurement instrument analyses the shift, rotation and frequency changes of the code image (Figure 1).

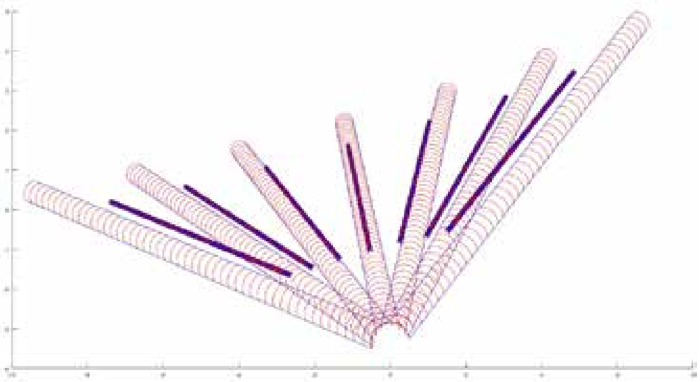

*Figure 1: 3D-motion of a coded stick. Analyzing the codepattern allows to determine the 3D spatial position and 3D-orientation of the stick.*

There are special requirements for the barcode design. First the code should be sufficiently 'nervous', i.e. sensitive to small variations of the object position and orientation. Secondly it should be distortion insensitive for measurements in problematic environmental situations, and third fast decoding algorithms should be available comparable to the well-known Fast-Fourier transformation. Then position and orientation can be precisely determined even if dust and dirt particles contaminate the barcode on the object. Such properties are well known from optical holograms, where contaminated or broken parts still include the full object information, however with reduced resolution.

We explain in the following some use cases of actual industrial relevance: First the digital level, which revolutionized the classical optical surveying technique, followed by an interesting low-cost variant without any focusing mechanisms. The concept of accepting defocused code images is then applied to automatically calibrate optical surveying instruments in the factory and to calibrate in real-time modern micro-machining systems, where femtosecond laser beams are swept over workpieces with sub-micrometer accuracy for material ablation.

### Noise Equivalent Quantity

The impact of system noise on the measurement data has to be minimized in all cases. To this purpose we consider in the following the *Noise equivalent quantity Ne(m)* of the measurement parameters *m*, which are the 3D-position and 3D-orientation values. The goal is to reduce the *Ne(m)* by encoding techniques. A powerful method is to use a barcode with a sharp autocorrelation peak and to correlate the measured 2D-code image data with artificially generated, pseudo-measurement data from a reference model. The model parameters are numerically varied until the cross-correlation between real and virtual measurement data is optimally peaked [1]. Details of this concept are presented in the Appendix.

### Case 1: Digital Level for Geodetic Measurements

To automatically record the height profile of a terrain, a measuring rod of 2 - 4 m length is positioned at distances *z* between 1.5 m to 100 m away from the levelling instrument. The rod barcode (Figure 2) is imaged on a CCD-sensor array, where the distance *z* is obtained from the size of the code image (magnification) and the levelling height *h* from the code's vertical position on the sensor. Since the measurement evaluation is based on the correlation estimator concept (see Appendix), two major problems must be solved by the code design. The first one is that at closer distances only parts of the barcode pattern are visible on the sensor leading to an unfavorable small *L* value in equation (6) of the Appendix, while at larger distances the image of a code element becomes smaller than the pixel width of the sensor which leads to a reduced information density in equation (6). Both effects unfavorably increase the *Ne(h,z)* values and, consequently, lead to a lower accuracy of the measurement data of *h* and *z*. This, however, could be avoided if the code pattern is designed as Fine-code with good correlation properties even for code fragments, which is the situation at closer distances. At larger distances the Fine-code should cluster to a new code, called Coarse-code with fewer elements, but again good correlation properties. This *code-in-code* strategy in geodesy was adapted by Leica from wavelet considerations in image processing.

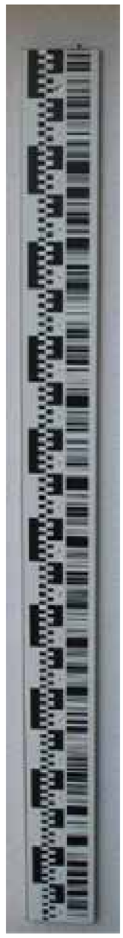

*Figure 2: Level Rod (Classical scaling, left) and Leica barcode (right)*

The method is robust and accurate, and measurement runs with realistic data yield *Ne*($\alpha$) values of about one pixel/100 (rms). Typical industrial applications are to control the mechanical vibrations of bridges and their supporting pillars, the stability of huge cranes in strong winds, the loading of cargo containers, and the exact angular alignment of missiles, mortars and rockets at their launch pads.

1 *SPS Focus* No 3: Chap. 5.1 Physics and Industries, *https://sps.ch/en/publications/sps_focus*

## Case 2: Fix-Focus Digital Level

The power of processing encoded data and their efficient numerical decoding allows to further increase the performance of instruments in daily use. We demonstrated this first by an extension of the digital level eliminating focusing, and secondly by applying the idea to laser micro-machining. To this purpose we split the lens element located in the level's exit pupil in five segments of different optical power (i.e. focal length), adapted to the distances 2.5 m, 4.5 m, 8 m, 16 m and 40 m (Figure 3). Each lens segment includes a prism to shift its received code image to a different position on the 2D sensor. Dependent on the rod distance between 2 m and 100 m one always measures five more or less strongly blurred images of the code rod.

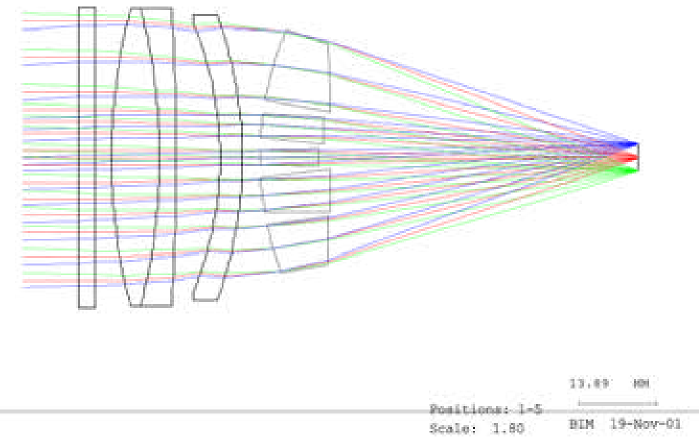


*Figure 3: Digital Level, where the last lens is split in five segments of different focusing power.*

In Figure 4 we see from left to right the code images produced by the five lens segments fix-focused on 16 m, 8 m, 2.5 m, 4.5 m and 40 m. The actual rod distance is indicated in each sub-figure.

The simultaneous recording of five different blurred and different magnified code images allows to cross-correlate the individual code patterns. Even the totally blurred code image at rod distance of 3 m includes enough information to extract height and distance values. The results are astonishingly good (Figure 5): accuracies of about 0.1 mm for the object height, and 1 mm to 4 mm for the object distance have been measured within the application-relevant distance range from 2 m to 18 m [2].

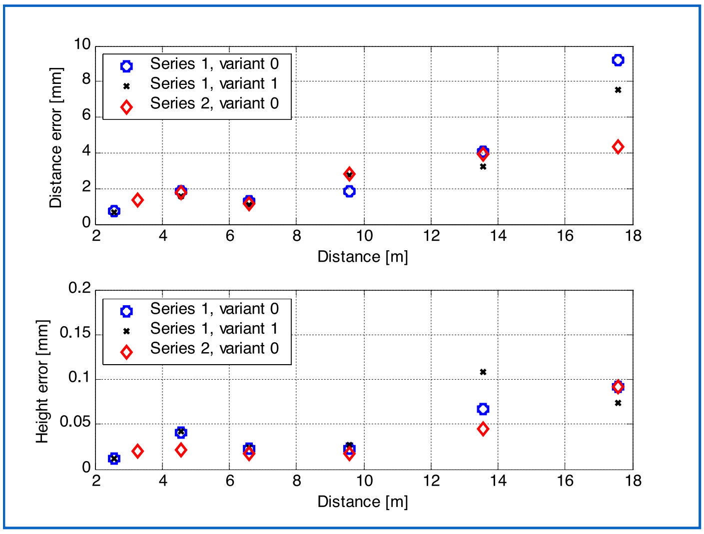


*Figure 5: Results of levelling height h and distance z for different illumination profiles.*

## Case 3: Automatic Calibration of Optical Surveying Instruments

Surveying instruments like levels, theodolites, laser trackers must be precisely calibrated according to international certification standards. An interesting, fast and precise method is that the instrument under test looks inside a specially prepared digital level, focused at infinity and carrying in its focal plane a code plate of different glass thickness segments and barcodes of different size (Figure 7). The four segments correspond to the true focus situation at 1.5 m, 4 m, 10 m and 100 m. The instrument to be calibrated is automatically focused to any distance between 1 and 100 m and the four permanently recorded, but more or less unsharp code images are analyzed to verify the instrument's displayed distance value *z* with respect to its motor drive parameters.

2 United States Patent Gaechter B., Braunecker B. US 6,081,327 A, Jun. 27, 2000 B

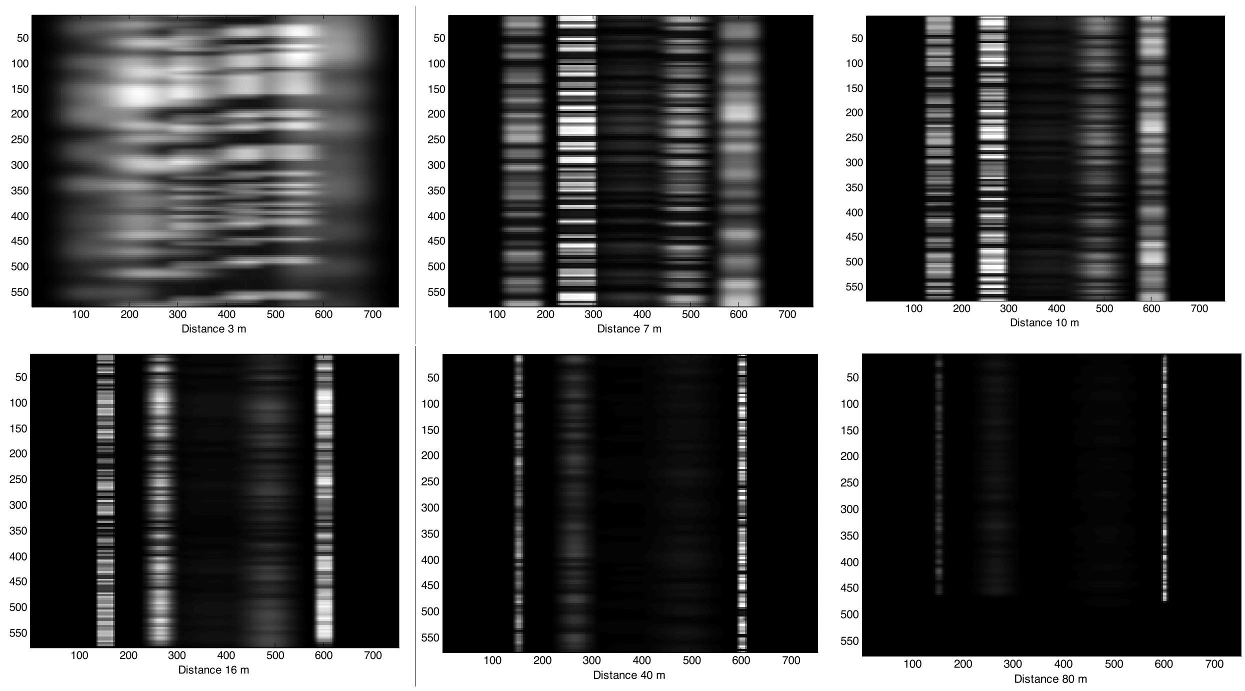


*Figure 4: Five barcode images on the instrument's CCD for different rod distances between 3 and 80 m.*

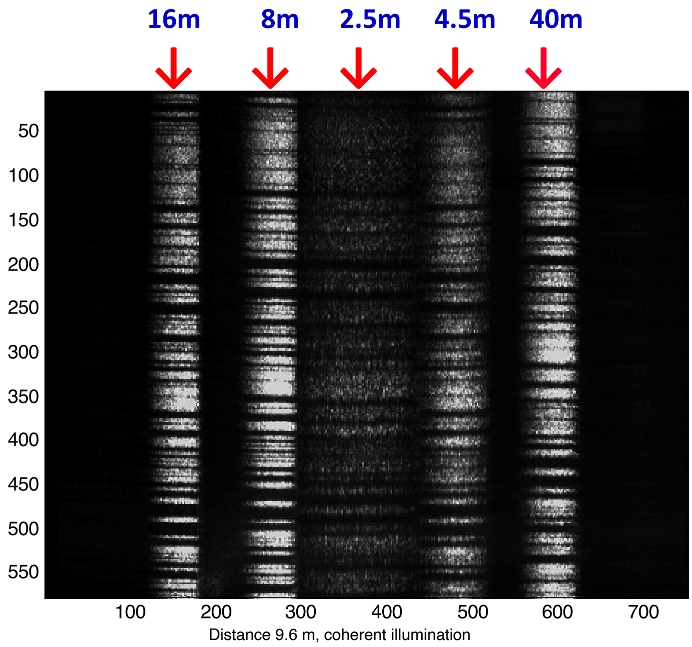


*Figure 6: Rod at 9.6 m and illuminated by laser light. The data encoding concept minimizes the influence of speckle noise on the measurement accuracy.*

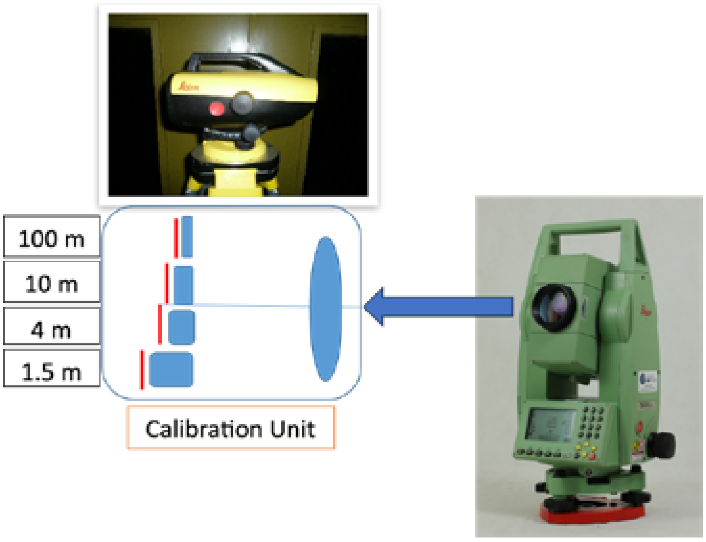


*Figure 7: The theodolite to be calibrated looks into the calibration instrument on four different code patterns, virtually located at 1.5 m, 4 m, 10 m and 100 m.*

### Case 4: In Field Control of Laser Macro/Micro-Machining

Material ablation by lasers is one of the most promising processing methods in industry due to its efficiency, accuracy and flexibility, and due to the fact that optical surface measurement by interferometers can be performed parallel at the same time within the same coordinate system. The whole material treating process takes place in a finite working volume (WV), into which the work piece is loaded by robots. A combination of a fast beam-deflecting unit (*xy*-scanner) and a fast vario-optic directs the laser focus to any point (*x,y,z*) inside the WV with $\mu$m accuracy (Figure 8).

The high pointing accuracy demands require the regular calibration of the motor drives of both optical control units. To this purpose a special target plate (TP) with code patterns of different size is permanently installed close to the bottom of the WV. The first step is to determine the correct position and the azimuthal orientation of the TP relative to the current control data of scanner and vario. To this purpose the

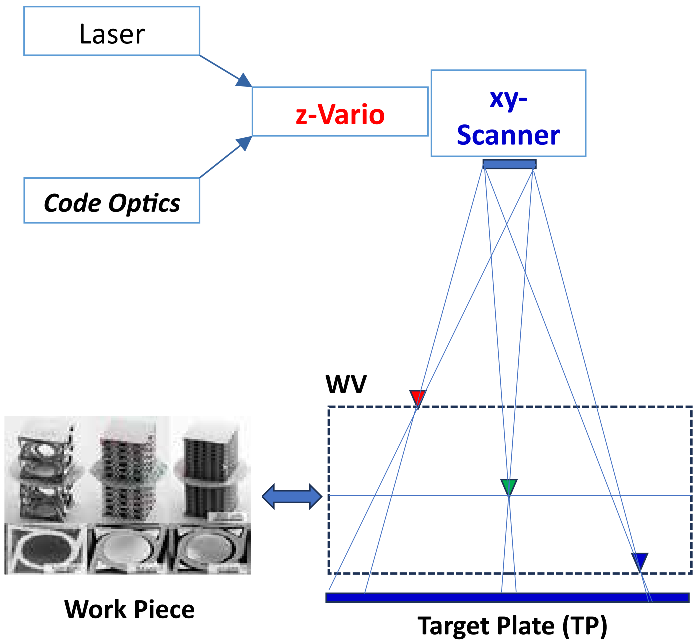


*Figure 8: Target Plate TP with fine, medium and coarse code for WV calibration, together with reflecting spheres for TP installation purposes.*

laser beam with reduced intensity is focused on the TP and swept along a line with known start and end points. (Figure 9a) The beam hits the code elements of a special shark-fin pattern in its left and right branches (blue points). The knowledge of the position of the hitpoints and their mutual distances allows to calculate the *x,y* coordinates of the TP center relative to the scan line and to readjust the TP if necessary. Later in daily work the method is applied to control the relation TP to scanning system, which is necessary after the laser, scanner or vario-optics were changed or after general service work.

The second step concerns the WV calibration in *x,y,z*. When the TP is optically accessible during a work piece change, the laser with reduced intensity is focused by the vario-optic to different *z*-planes within the WV and swept in *x* and *y*. Depending on the *z*-value the laser spot of variable diameter illuminates several codepattern of different size at the TP (Figure 9b). The code pattern are back-imaged through scanner and vario-optic on a sensor. Analysing the blurred code element positions and the size of the illumination profile allows to determine the *x,y,z* coordinates of the true laser focus as function ot the motor drive parameters of scanner and optics.

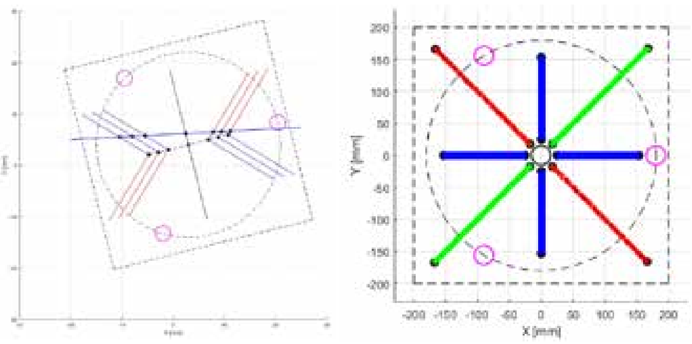

*Figure 9: a) Special code pattern is hit by the laser beam (blue) to re-adjust the Target plate. b) Linear code patterns of different size (small, medium and large) are radially distributed. The pattern of a) is located in the centre of the TP.*

## Summary

The examples show that optical remote sensing is a powerful technique which is widely applicable in industrial practice from the micrometer to the centimeter range. Since in all cases code label images are evaluated, no measurement errors can occur by mechanical contacts. The digital comparison of encoded label data with the model data by estimation algorithms can be easily adapted to many applications. The numerical evaluating of the code position, magnification, magnification chirp, distortion or blur parameters allows to determine the body's 3D position and 3D orientation in a flexible, fast, robust and cost-effective way.

## Appendix

### Improving the Signal to Noise ratio by Data Encoding

The object, a rigid body as the cylindrical rod in Figure 2, is characterized by the parameter set $m$ = {*3D-position, 3D-angular orientation*}. An optical system images the object on a 2D sensor, and the goal is to precisely determine the six parameters, even if the measurement data are corrupted by severe object and system noise. To this purpose one considers the *Noise equivalent quantity Ne(m)* of the measurement data.

The goal is to reduce the *Ne(m)* values by data encoding, thereby applying the so-called method of *correlation estimators* on the measurement data. The noisy image data are $Q(\boldsymbol{x}, m_0) \equiv Q_0(\boldsymbol{x}, m_0) + N(\boldsymbol{x})$, with $\boldsymbol{x} = (x, y)$ the pixel coordinates on the CCD, where parameter $m_0$ describes the true, but unknown geometrical parameter set. $Q_0$ are the ideal, noiseless, but blurred code signals, and $N(\boldsymbol{x})$ denotes the noise intensity at pixel $\boldsymbol{x}$. The measurement signals are normalized:

$$q(\boldsymbol{x}, m_0) \equiv (Q - \langle Q \rangle) / \sqrt{\int (Q - \langle Q \rangle)^2 d\boldsymbol{x}} \equiv q_0(\boldsymbol{x}, m_0) + n(\boldsymbol{x})$$

with $n(\boldsymbol{x}) \equiv N(\boldsymbol{x}) / \sqrt{\int (Q - \langle Q \rangle)^2 d\boldsymbol{x}}$,

where $\langle \; \rangle$ describes the statistical expectation value. The integral over $\boldsymbol{x}$ on the sensor is taken *along* the code pattern axes of length $L$, i.e. between $-L/2$ and $+L/2$. Therefore $L$ counts the number of code elements or sensor pixels.

### Correlation Estimator

The known normalized code reference function is $p(\boldsymbol{x}, m)$, where the start parameter $m$ is chosen to be close to $m_0$, and $m$ is varied for optimum mathematical consistency between $p$ and $q$. One considers the cross-correlation function across all code elements

$$c(\boldsymbol{x}, m, m_0) = \int q(\boldsymbol{x}', m_0) \cdot p(\boldsymbol{x}' + \boldsymbol{x}, m) \, d\boldsymbol{x}' . \quad (1)$$

Since the code pattern $p$ should be designed so that its auto-correlation function is sharply peaked, the goal of the optimization process $m$ to $m_0$ is to *maximize the peak of the cross-correlation function*

$$c_{peak}(\boldsymbol{x} = \boldsymbol{0}, m, m_0) = \int q(\boldsymbol{x}, m_0) \cdot p(\boldsymbol{x}, m) \, d\boldsymbol{x} . \quad (2)$$

One calculates its derivative with respect to $m$

$$c'_{peak} \equiv \delta c_{peak} / \delta m = \int q(\boldsymbol{x}, m_0) \cdot \{\delta p / \delta m\}(\boldsymbol{x}, m) \, d\boldsymbol{x} ,$$

and also its variance. To this purpose one considers

$$c'_{peak} - \langle c'_{peak} \rangle = \int (n - \langle n \rangle) \, p' \, d\boldsymbol{x}$$

where biasfree and uncorrelated pixel noise $\langle n \rangle = 0$ and $\langle n(\boldsymbol{x}') \, n(\boldsymbol{x}'') \rangle = \sigma_n^2 \cdot \delta(\boldsymbol{x}' - \boldsymbol{x}'')$ is assumed. This results in the variance

$$\begin{aligned} \sigma_{c'}^2 &= \langle | c'_{peak} - \langle c'_{peak} \rangle |^2 \rangle \\ &= \int \{ p'(\boldsymbol{x}', m) \, d\boldsymbol{x}' \} \cdot \int \{ p'(\boldsymbol{x}'', m) \langle n(\boldsymbol{x}') \, n(\boldsymbol{x}'') \rangle d\boldsymbol{x}'' \} \\ &= \sigma_n^2 \int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x} . \quad (3) \end{aligned}$$

Next one needs the second derivative of the correlation function $c''_{peak}$, and develops $c'$ at $m = m_0$ to get $c'_{peak}(m) = c'_{peak}(m_0) + \Delta m \cdot c''_{peak}(m_0) = \Delta m \cdot c''_{peak}(m_0)$, since $c'_{peak}(m_0) = 0$.

Then $\Delta m = c'_{peak}(m) / c''_{peak}(m_0)$ and its variance is

$$\begin{aligned} \sigma_m^2 &= \langle \Delta m^2 \rangle = \sigma_{c'}^2 / (c''_{peak})^2 \\ &= \sigma_n^2 \int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x} \, / \, (c''_{peak})^2 \\ &= \sigma_n^2 \int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x} \, / \, (\textstyle\int q(\boldsymbol{x}, m_0) \cdot p''(\boldsymbol{x}, m) \, d\boldsymbol{x})^2 \\ &= \sigma_N^2 / \langle Q \rangle^2 \cdot 1/L \\ &\cdot \int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x}/L \, / \, (\textstyle\int q(\boldsymbol{x}, m_0) \cdot p''(\boldsymbol{x}, m) \, d\boldsymbol{x}/L)^2 \quad (4) \end{aligned}$$

and the *Noise Equivalent value of m is*

$$Ne(m) \equiv \sigma_m = 1/SNR \cdot CF, \quad (5a)$$

using $SNR \equiv \langle Q \rangle / \sigma_N$ and the code improvement factor

$$CF \equiv (1/\sqrt{L}) \cdot \sqrt{\int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x}/L} \; / \int q(\boldsymbol{x}, m_0) \cdot p''(\boldsymbol{x}, m) \, d\boldsymbol{x}/L . \quad (5b)$$

*CF* depends on three factors: the length $L$ of the recorded code pattern on the sensor, i.e. the number of code elements; second on a term with $p'$ which can be interpreted as the *information* density of the blurred codefunction $p$, asking how sensitive the correlation peak reacts on changes of the variation of $m$, and finally on a term with $p''$ describing the sharpness of the code correlation peak $c$, i.e. its curvature $c''$. When designing the code function $p$ the derivatives $p'$ and $p''$ must also be considered to effectively minimize $Ne(m)$ at all measurement situation.

The $Ne(m)$ can be better understood if one assumes $q \approx p$. Then the third term in (5b) reduces to

$$\begin{aligned} &\int q(\boldsymbol{x}, m_0) \cdot p''(\boldsymbol{x}, m) \, d\boldsymbol{x}/L \approx \int p(\boldsymbol{x}, m_0) \cdot p''(\boldsymbol{x}, m) \, d\boldsymbol{x}/L \\ &= \{ p \cdot p'(L/2) - p \cdot p'(-L/2) \} / (L) - \left\{ \int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x}/L \right\} \\ &\approx \left\{ \int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x}/L \right\} \end{aligned}$$

for large $L$, leading to the approximation

$$Ne(m) \approx 1 / \left\{ SNR \cdot \sqrt{L} \cdot \sqrt{\int p'(\boldsymbol{x}, m)^2 \, d\boldsymbol{x}/L} \right\} . \quad (6)$$

In conclusion $Ne(m)$ is minimized by a large *SNR*, by many recorded code elements (large $L$) and by a large *information density* of the code function, i.e. by a code of good 'nervousness'.

# Physique et Société

## Bienvenue au Repair'Lab de l'Université de Genève!

*Céline Lichtensteiger, Iaroslav Gaponenko,*
*Département de Physique de la Matière Quantique (DQMP), Université de Genève*

**Réparer plutôt que jeter**
Réparer plutôt que jeter est un geste qu'on doit faire pour la planète, mais qui peut aussi être ludique et instructif. La réparation prolonge la vie d'un produit et ainsi évite l'énorme gaspillage de ressources et d'énergie engendré par la fabrication et la distribution d'un nouveau produit. Le fait de réparer un appareil nous permet également de mieux comprendre son fonctionnement, d'en optimiser l'utilisation et pourquoi pas d'y apporter des améliorations. Effectuer un diagnostic, c'est utiliser des instruments de mesure et manier des outils pour désassembler et ré-assembler. Oser réparer, c'est oser découvrir, apprendre et perfectionner ses connaissances et son savoir-faire dans les domaines de l'électricité, de l'électronique, de l'informatique ou de la mécanique. Des connaissances et un savoir-faire que nous avons déjà à l'école de Physique – aussi bien dans nos laboratoires de recherche que dans nos ateliers ou nos travaux pratiques – et que nous souhaitons rendre plus visibles et accessibles afin de mieux les transmettre à toutes et tous.

**Notre concept**
Le Repair'Lab est un espace de réparation de matériel électronique et informatique créé au coeur de l'école de Physique, pour pouvoir permettre au personnel et aux étudiants de l'Université de Genève de poser un diagnostic sur un appareil défectueux, et d'apprendre à le réparer soi-même dans un espace convivial avec l'assistance de l'équipe du Repair'Lab.

Vous avez envie de réparer un objet, de comprendre comment un appareil fonctionne, ou juste de bricoler? Passez nous voir pendant nos heures de permanence!

Vous venez avec votre projet, et nous vous accompagnons à chaque étape, de l'établissement du diagnostic à la réparation. Que vous soyez débutant ou déjà expérimenté, nous vous offrons un soutien personnalisé pour vous aider à résoudre vos problèmes techniques de manière autonome ou en collaboration avec notre équipe.

En plus de travailler sur vos propres réparations, vous avez l'opportunité de participer à nos ateliers interactifs. Ces sessions sont conçues pour partager des compétences pratiques, favoriser l'échange de savoirs et encourager un apprentissage collaboratif dans un environnement chaleureux et stimulant.

**Notre public**
Notre initiative s'adresse principalement au personnel et aux étudiants et étudiantes de l'Université, avec un focus initial sur les membres de l'École de Physique. Ce public constitue la première communauté bénéficiaire de notre projet pilote, permettant ainsi de tester et d'ajuster nos services afin de les élargir à d'autres départements et à la communauté universitaire dans son ensemble.

**Notre histoire**
Le projet a été créé en décembre 2023 par Iaroslav Gaponenko et Céline Lichtensteiger, deux chercheurs au Département de la Matière Quantique (DQMP) de l'Université de Genève, avec le soutien de l'équipe durabilité du Rectorat, du DQMP et de la Section de Physique. Leur vision commune a permis de donner naissance à un espace de réparation et de partage des savoirs, ancré dans des valeurs d'éco-responsabilité et de collaboration.

Le projet n'a pas nécessité de gros investissement mais s'appuie plutôt sur de l'énergie humaine positive. Afin de garantir un accompagnement régulier et accessible, Gianluca Folino, étudiant en master de Physique Nucléaire, a été engagé à 20 % pour assurer les permanences trois fois par semaine, entre 12h et 14h.

Le projet bénéficie également de l'implication de plusieurs autres membres clés, parmi lesquels : Florin Buta, chercheur en physique et enseignant et désormais ingénieur applications ; Quentin Berthet, ingénieur et désormais professeur à l'HEPIA ; Loïc Musy, docteur en physique ; Guillaume Rapin, docteur en physique et enseignant ; et Alain Hugentobler, expert en sécurité informatique. Grâce à l'engagement et à la diversité des compétences de chacun, ce projet s'inscrit dans une dynamique collaborative et innovante.

En s'appuyant sur des personnes motivées, même avec peu de ressources, ces initiatives sont possibles et peuvent émerger facilement. N'hésitez pas à nous contacter et à venir nous voir si vous souhaitez nous rencontrer, rejoindre notre équipe, ou lancer une initiative similaire dans votre milieu professionnel. Nous nous réjouissons de vous accueillir lors de nos permanences!

**Notre mission**

Notre mission est de créer un espace dédié à la réparation et à l'apprentissage des techniques de réparation de petits équipements (ordinateurs, générateurs, appareils de mesure, audiovisuel, petit électroménager, etc.). Cet espace permet à chacun de redonner vie à ses appareils défectueux, en offrant un cadre propice à la réparation, mais aussi à l'acquisition de compétences pratiques.

Nous souhaitons également offrir un environnement où les savoirs sont partagés, favorisant la transmission de connaissances et la sensibilisation aux enjeux de la récupération, de la réparation et de la responsabilisation. En mettant l'accent sur l'éco-responsabilité et l'économie circulaire, nous encourageons une approche durable et réfléchie face à la consommation de biens matériels.

Nouveauté au Repair'Lab: atelier "alimentations et chargeurs"

Réduire le volume des données numériques inutiles et prolonger la durée de vie des appareils


Faut-il apprendre à bricoler pour sauver le climat?

Au secours, mon imprimante n'entraîne plus le papier!

Le Repair'Lab à la Journée du Numérique Responsable

Spécial Rentrée Scolaire

Ainsi, notre mission va au-delà de la simple réparation : elle promeut un modèle de société plus respectueux de l'environnement, en intégrant des pratiques de réduction des déchets et en valorisant les ressources à travers la réutilisation et la réparation.

**Nos objectifs principaux**

- *Transmission de compétences et de valeurs :*
  Créer un espace à la fois pratique et convivial, dédié à l'acquisition de savoir-faire technique. Ce lieu offre la possibilité de poser un diagnostic précis sur un appareil défectueux, de le réparer, ou même d'apprendre les techniques nécessaires pour effectuer soi-même les réparations.
- *Sensibilisation et éducation :*
  Une approche pédagogique qui vise à sensibiliser les utilisateurs à la compréhension du fonctionnement des appareils, tout en approfondissant leurs connaissances en électronique. L'objectif est d'encourager l'autonomie technique et de renforcer la capacité à résoudre des problèmes de manière concrète.
- *Partage des connaissances et contribution à la formation académique :*
  Un lieu de partage de savoirs qui soutient activement la formation des étudiants en physique, des doctorants et de tout public intéressé par des compétences techniques. En offrant un cadre pratique d'apprentissage, il permet de compléter les enseignements théoriques avec des expériences de terrain.
- *Ateliers et animations :*
  Organisation d'ateliers interactifs permettant aux participants d'explorer de manière pratique les concepts scientifiques et techniques. Ces ateliers visent à développer les compétences des participants en favorisant l'expérimentation, la créativité et la résolution de problèmes. Ils s'adressent à un large public et sont adaptés en fonction du niveau de connaissance afin de rendre la réparation accessible et engageante pour toutes et tous.

Ainsi, ce lieu est devenu non seulement un centre de réparation, mais aussi un véritable catalyseur d'apprentissage et de diffusion des savoirs techniques et scientifiques.

**Nos valeurs et notre éthique**

Nous croyons fermement en la réparation plutôt qu'en la consommation excessive et au gaspillage. Notre engagement repose sur l'idée que chaque objet a une seconde vie et que sa réparation est souvent plus bénéfique que son remplacement.

Nous valorisons également la transmission des savoir-faire, en partageant nos compétences et nos connaissances pour permettre à chacun de développer son autonomie dans la gestion et l'entretien de ses équipements. Cette démarche s'inscrit dans une volonté de favoriser l'apprentissage continu et d'encourager une culture de la durabilité et de la responsabilité envers notre environnement.

**Nos partenaires et soutiens**

Nous ne serions pas là aujourd'hui sans l'appui précieux de nos collègues, et nous tenons à les remercier chaleureusement. Parmi nos soutiens majeurs, nous souhaitons exprimer notre gratitude envers : le Département de Physique de la Matière Quantique, la Section de Physique, le Physiscope, l'Université de Genève, l'équipe durabilité du Rectorat, le Bureau de la Transition Numérique, ainsi que rECOnsider/EcoInsight. Leur engagement et leur soutien continu sont essentiels à la réussite de notre projet, et nous leur sommes profondément reconnaissants.

**Pour en savoir plus:**

N'hésitez pas à venir nous rendre visite au Repair'Lab à Genève pendant nos heures d'ouverture.
Vous pouvez aussi lire nos articles sur notre site-web :
http://repairlab.unige.ch
N'hésitez pas à nous suivre sur nos réseaux :
Instagram: http://instagram.com/repairlab.unige
LinkedIn : https://www.linkedin.com/company/repair-lab-unige/?viewAsMember=true
Newsletter : https://listes.unige.ch/sympa/subscribe/repair-lab-newsletter

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# Energy, Sustainability and Environment (2)

*With the renaming of the section at the last general assembly (see p. 6), we adapt also the name of this article series. Its goal is still the same, to showcase examples of how physicists can contribute to the pressing topics of energy and sustainability.*

## Towards more Environment-friendly Particle Detectors

*The following article portrays the three physicists Dario Stocco, Marnik Metting van Rijn, and Christian Franck (Institute for Power Systems & High Voltage Technology, ETH Zürich), and their research towards more environment-friendly electric power transmission equipment and high-energy particle detectors.*

**Dario, can you tell us a bit about you, why did you study physics, and when did you start to think about the topics of energy and sustainability?**

***Dario:*** It was in high school in Glarus, where my great physics teacher, Mrs. Gärtner, showed me the beauty of physics, recognized my potential, and ultimately helped me decide to pursue a career in physics. Having a basic understanding of physics made me realize early on that our behavior is not sustainable. So I'm glad I now get to do more than think about it – I get to contribute.

**After completing your studies, you joined Sensirion Connected Solutions, where you developed models to quantify methane leaks for monitoring purposes. How did this experience inspire you to pursue a doctoral thesis on environmentally friendly gas mixtures?**

***Dario:*** Monitoring across the methane supply chain, including extraction sites, pipelines, and storage facilities, is a relatively new development. Until recently, it was largely unknown how much methane was being emitted, despite its global warming potential (GWP) being roughly 30 times greater than that of carbon dioxide [1]. The realistic models we developed demonstrated the severity of the actual emissions. Some sites had ongoing emissions of up to several tons of methane per month, corresponding to several hundreds of tons of $CO_2$ equivalent per month! But with proper monitoring and regulation, those emissions can be significantly reduced. From that experience, it was clear to me that I had to continue to work against these super emitters and harmful greenhouse gases.

**Marnik, the same questions to you: Why did you study physics in the first place and why and how did you choose the topic of you doctoral thesis ?**

***Marnik:*** I had the privilege to attend an extended physics course at K&S (MNG) Rämibühl, which helped me decide between physics and chemistry. In hindsight, it does not surprise me at all that I encountered difficulties in choosing between the two sciences: My doctoral thesis involves electron-molecule scattering cross sections and spectroscopy, both topics related to physical chemistry. Being able to combine these two fields is what persuaded me to choose my doctoral thesis.

**You're both working on environmentally friendly gas mixtures for resistive plate chamber detectors (RPCs). Can you explain what the project involves and its sustainability impact?**

***Dario & Marnik:*** The presence of a high-energy particle, like muons, can be deduced if it interacts with matter, for example, a gas mixture. In RPCs, the particle of interest penetrates a gas volume and ionizes the gas molecules, leaving freely moving electrons behind. An applied electric field accelerates these electrons, which collide with other gas molecules. During the collision, the electrons further ionize these molecules. The number of electrons hence grows exponentially, and the generated electron avalanche induces a detectable signal. In essence, RPCs serve as fast, large-area amplifiers of ionization events. Unfortunately, the gas mixture currently in operation at CERN exhibits a high global warming potential of around 1500 and is responsible for a considerable 0.4% of Switzerland's total greenhouse gas emissions. We seek to find alternative gases that can drastically reduce environmental impact while ensuring adequate detector performance.

**Why it matters?**

***Dario:*** Widely used fluorinated gases like the refrigerant R-134a or $SF_6$ and their derivatives are extremely potent greenhouse gases. Even small leaks from detectors or high-voltage equipment can accumulate to significant climate impact. Identifying and implementing low-GWP alternatives is critical for reducing long-term emissions in both science and industry.

*The Pulsed Townsend Setup (© HVL – Marnik Metting van Rijn): A pulsed UV laser releases seed electrons into a gas-filled chamber between two electrodes, thus a uniform electric field drives the electrons across the gas. As the electrons travel, they collide with gas molecules; some are scattered, some ionize the gas, others attach to molecules. The resulting displacement current is measured over time to determine drift velocity, diffusion coefficients, ionization and attachment rates.*

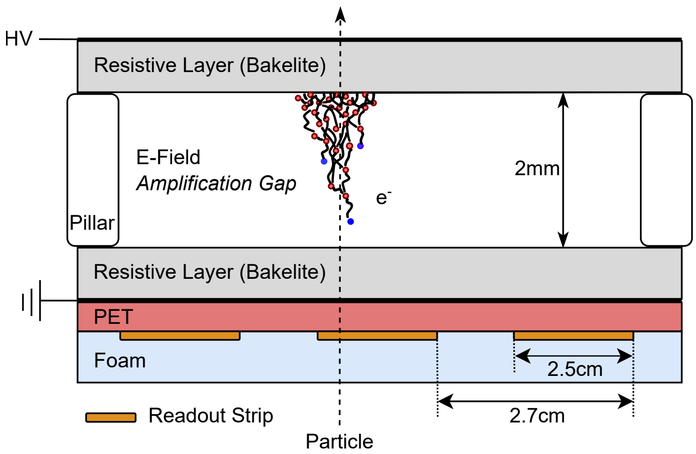
***Marnik:*** We're working on identifying alternative gases that maintain detector performance but with significantly lower environmental impact. Monte Carlo simulations of the underlying stochastic processes provide guidance and predict optimal gas mixture concentrations. These simulations, however, require the electron-molecule scattering cross sections of each individual molecule in the mixture.

### How do you obtain these cross sections?

***Dario & Marnik:*** That's where our Pulsed Townsend experiment comes in. We measure transport parameters of electron swarms in gases - drift velocity, diffusion, ionization, attachment rates - and use those to extract the needed cross sections [2]. We are currently focusing on ultra-low GWP refrigerants, as they are already commercially available in quantities required by large-scale facilities such as CERN.

### And these gases are also relevant for other applications, right?

***Dario & Marnik:*** Exactly. The cross sections are also required for the development of high-voltage insulation equipment. Providing the electrical power industry with the cross sections of an environmentally friendly gas enables them to deploy it in the numerous substations part of the electrical grid, which will have a severe impact on sustainability.




*A schematic plot of a RPC setup with schematic of avalanche (published as Figure 1 in https://doi.org/10.3929/ethz-b-000727665)*

### Christian, how was your journey of professional life and what does energy and sustainability mean to you?

***Christian:*** That I wanted to study physics was clear to me already during Gymnasium. I attended the standard curriculum in the first year, but chose one additional course in my second year as its name "Die Energiefrage" (the question of energy) caught my attention. And it was the engaging and fascinating way Prof. Heinloth held the lecture that convinced me that I wanted to contribute to solve the energy and global warming problems. I took quite some detours and several attempts before I managed to get there, but in hindsight all these intermediate steps were helpful in one way or the other. The initial plan when changing to the University of Kiel was to study and research on renewable energy production, but it didn't work out and I specialized in plasma physics instead. With this I thought I could contribute by working in fusion and decided to pursue a PhD in Greifswald, where Wendelstein 7-X was build. However, I felt I wasn't patient enough to endure the long phase of construction and joined industry after graduating. Having applied to fuel-cell and lighting research positions as well, I decided to work with switching arcs and electrical insulation in electric power transmission equipment. Thus, I indirectly helped that more renewable energy can be integrated into the network and transmitted from the place of production to where it is consumed. When I was offered the position at ETH, I chose research topics in the area of more environmentally friendly and more sustainable power transmission equipment. We have projects to replace $SF_6$, with a GWP of 23500 one of the most potent greenhouse gases, from the transmission and distribution equipment and high-energy particle physics gas detectors, high-voltage direct current (HVDC) switchgear, overhead power lines and underground cables, as well as electric motor insulation. Even though these topics are by far not sufficient to solve all our problems, they have a non-negligible impact and I feel it's very fulfilling to work in this area.

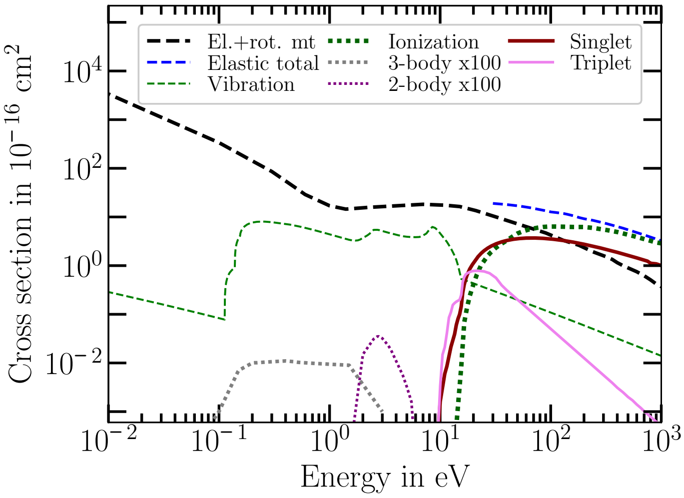
### Dario and Marnik told us about their project. Can you tell us more about the other research projects in your group and in particular how physicists can contribute to them?

***Christian:*** The field of power engineering in general, and that of high-voltage engineering in particular, is very interdisciplinary. Some of the innovations in the field were enabled by developments in other fields. When material science advanced with metal oxide varistors, the technology of surge arresters changed completely. Similarly, the improved basic understanding of switching arc physics has led to an almost complete dominance of self-blast breaker technology. In the research in my group we try to determine and quantitatively describe the basic underlying principles of processes involved in various gaseous and solid insulation technologies to enable fast and predictable development improvements. The replacement of greenhouse gases described by Dario and Marnik before is one example. Methods from atomic and molecular physics as well as physical chemistry are applied for a relevant application. The measurement and derivation of electron-molecule interactions are of help for gaseous particle detectors, but also for the development of $SF_6$ free gas insulated switchgear and improved dry etching and chemical vapor deposition processes. These are used in the semiconductor industry, chip manufacturing, or photovoltaic module production, to name only a few.

To understand also the processes in the solid insulation material of underground or subsea high-votlage direct current (HVDC) cables helps to improve the cable design and to increase the life-time in operation. We have just started a project to investigate the breakdown processes in dynamic export cables, those cables that deliver the power of hundreds of MW from floating windmills and converter platforms off-shore to the land. The unique combination of thermal, electrical, and mechanical stress require a very detailed understanding of the basic process that free charge carriers have in polymers, which eventually also lead to damage in the cross-linked bonds. In collaboration with electrical and mechanical engineers, as well as material scientists and chemists, physicists are ideally trained to reveal and describe fundamental processes, down to the scales where quantum mechanics matter.

**You're educating and mentoring many students, what advice can you give them if they want to contribute to the transition of our society towards a greener way of living?**

***Christian:*** Studying an engineering discipline or natural sciences of course is an ideal basis for this. During your studies, you're exposed to a vast number of different topics and areas. It is not always easy to find those areas that attract you most and also have a short- to medium-term contribution to a more sustainable society. But being aware of this can help you to find your right area of specialization during studies and guide your job search afterwards. In engineering studies the link to industry is very close and natural, but after I had studied physics, the step into industry wasn't that obvious to me at the time. But I can only encourage every young physicist not to only think about working in governmental research centers (like I did initially), but also to explore the exciting world of industrial research and development. Applying your physics training for a meaningful application towards a more environmentally sustainable society is equally rewarding, if not more, than searching for the next elementary particle or the origin of our existence.




*Set of electron scattering cross sections for R134a (published as figure 3 in https://doi.org/10.3929/ethz-b-000678002)*

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# EPS Young Experimental Physicist Prize 2025: Interview with Thea Klæboe Årrestad

*In 2025, **Thea Klæboe Årrestad** and **Laura Zani** were jointly awarded the EPS Young Experimental Physicist Prize. Thea Klæboe Årrestad received the award for her groundbreaking work integrating machine learning techniques into real-time data processing and event selection. The prize was awarded by the High Energy and Particle Physics Division of the European Physical Society.*

*Thea Klæboe Årrestad developed a new approach to processing and selecting data produced at the LHC and detected at CMS at CERN in Geneva. This work was instrumental in creating the first anomaly-detection-based trigger in the CMS detector, marking a paradigm shift in particle physics experiments towards real-time, AI-driven decision-making. This approach uses machine learning strategies to train a neural network to characterize how typical a given event is. This metric is then used to identify rare events that could be caused by an unspecified new physics signal.*

*After earning her bachelor's degree in physics from the University of Bergen in Norway, Thea Klæboe Årrestad moved to ETH Zurich for an exchange program, where she completed her master and Ph.D. studies and is now a fellow researcher. Switzerland offered Thea the perfect conditions to launch her physics career and grow as a researcher.*

*The Swiss Physical Society (represented by Margherita Boselli and Philipp Schmidt-Wellenburg) met with Thea, who kindly agreed to an interview to help us get to know her better.*

**Thea, what made you decide to study physics, and when did you make that decision? Did you encounter any career crossroads?**

According to my parents, I decided to become a physicist before I could even pronounce the word "physics." I have always been fascinated by the sky and the stars. I remember sneaking out of my house at night as a child to look at the stars from a hill near our home in Norway. I wanted to become an astrophysicist since I was in primary school. As soon as I could, I started working at a planetarium and a science center. Then, I enrolled in physics at the university, and I wrote my bachelor's thesis on astrophysics and cosmology.

Then, I read "The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe", written by Frank Close, which described the research conducted at CERN. I was blown away. This book was a turning point for me. I realized that particle accelerators and detectors could be used to study the beginning and evolution of the universe, which shifted my goal. I searched for the best place to continue my studies and receive the best education in particle physics, and I chose ETH Zurich for an exchange program. I also found out about the CERN summer student program, enrolled, and was accepted. Interestingly, the summer I was at CERN was the summer of the announcement of the discovery of the Higgs boson. On July 4, 2012, I was there, standing in line in front of the CERN main auditorium, ready to witness a historic moment: the announcement of a particle predicted almost 50 years earlier. This experience convinced me that this is what I want to do forever.

**What happened after that? How did you begin working with machine learning techniques for particle detection?**

After completing the CERN summer student program and my master's degree at ETH Zurich, I stayed on to pursue my Ph.D. Since finishing my master's degree, I have become interested in machine learning techniques for data reconstruction. Fortunately, I started using similar tools shortly after 2012, when artificial intelligence began to surpass traditional image reconstruction algorithms. I was in the right place at the right time, as my work aligned with the significant technological advancements in these techniques. Initially, we used self-made CERN machine learning libraries for our analysis, but more and more libraries were progressively developed, even by industry. I was driven by the excitement of these new tools and wanted to explore their potential in my field. My working environment and my Ph.D. supervisor, Ben Kilminster, provided the ideal conditions for exploring this new research area. Despite this not being the original plan, I was supported and trusted, and I had the freedom to focus on deep learning techniques for data analysis.

At that point, I was using machine learning techniques in a more traditional way to process large amounts of data and enhance the signal from the background for my analysis. For my Ph.D., I performed three analyses, and while I didn't discover any new particles, we developed a generic technique that improved the performance of the analysis. I then started questioning the bottleneck of the rare event selection process, which sparked my interest in triggering. In CMS, only a small percentage of the produced data is available for analysis, so I wondered how we could optimize the selection and filtering process to ensure we selected the right data. This is how I became interested in using machine learning in triggering systems. It was a challenging task because the system employed FPGAs (field-programmable gate arrays), which are usually programmed by engineers, and it needed to respond rapidly within time intervals of 50 ns. I started working on developing machine learning tools that could meet these requirements and be programmed on the FPGAs of the CMS level-1 trigger. As a postdoc, I dedicated much of my time to this project, driven by the goal of improving data selection.

**Can you identify a moment when you started thinking of yourself as a researcher?**

I was fortunate to find an environment where I could work as a researcher from the beginning of my career. No one ever told me to do things in a specific way. There has always been room for discussion and personal initiative. I could always be creative and excited, and I could get support to pursue my goals whenever I needed it. Of course, at the beginning of my Ph.D. program, I was very dependent on my group's seniors, but relatively quickly, I felt I could come up with, and develop, my own ideas. At the same time, I never lost my motivation to learn more. I am confident in saying that I always feel like a student, too. I hope to continue being a researcher and a student.

**What advice would you give to young physics students considering pursuing a Ph.D.? Is there anything you wish you had known when you were their age?**

I think I got where I am through stubbornness. I was motivated from the beginning, but there were certainly many things that could have stopped me. I failed some exams and was not the best student, but I managed not to lose my self-confidence or motivation. This was crucial to continuing my career. I think that one doesn't need to be the best at everything. If people are curious and motivated, they shouldn't let failures stop them. This is particularly important for women, who often underestimate themselves and give up too early. People should not feel afraid of not being good enough.

**What are your research aspirations for the next few years?**

My ultimate goal is to become a professor at ETH Zurich. I am grateful to this institution, and I love working there because of the excellent research environment and high-quality students. I believe that teaching should be an important part of my career. Teaching provides an opportunity to learn and delve deeper into various aspects of physics while interacting with young, curious, and creative minds. Students often ask me very good questions that push me to deepen my understanding.

**Could you tell us a little about yourself outside of the Physics Department?**

Outside of work, I have two fantastic daughters, who are six and eight years old, and a fantastic partner. I am very grateful to be a mother and to have a supportive partner. I also make time for sports; I do a lot of trail running. My family and the beauty of nature—which, of course, includes studying its underlying laws—are the things I am most grateful for.

**In closing this interesting interview, could you summarize your research in a few words?**

Currently, my research is focused on ensuring that we are exploring physics beyond the standard model. We know there's something beyond it because many things need explanation. However, we need to find a way to ensure we don't miss this physics in our data. To reach this goal, we are exploiting the potential of machine learning tools for data selection, triggering systems, and analysis.

# The winners of the EPS High Energy and Particle Physics Prize 2025

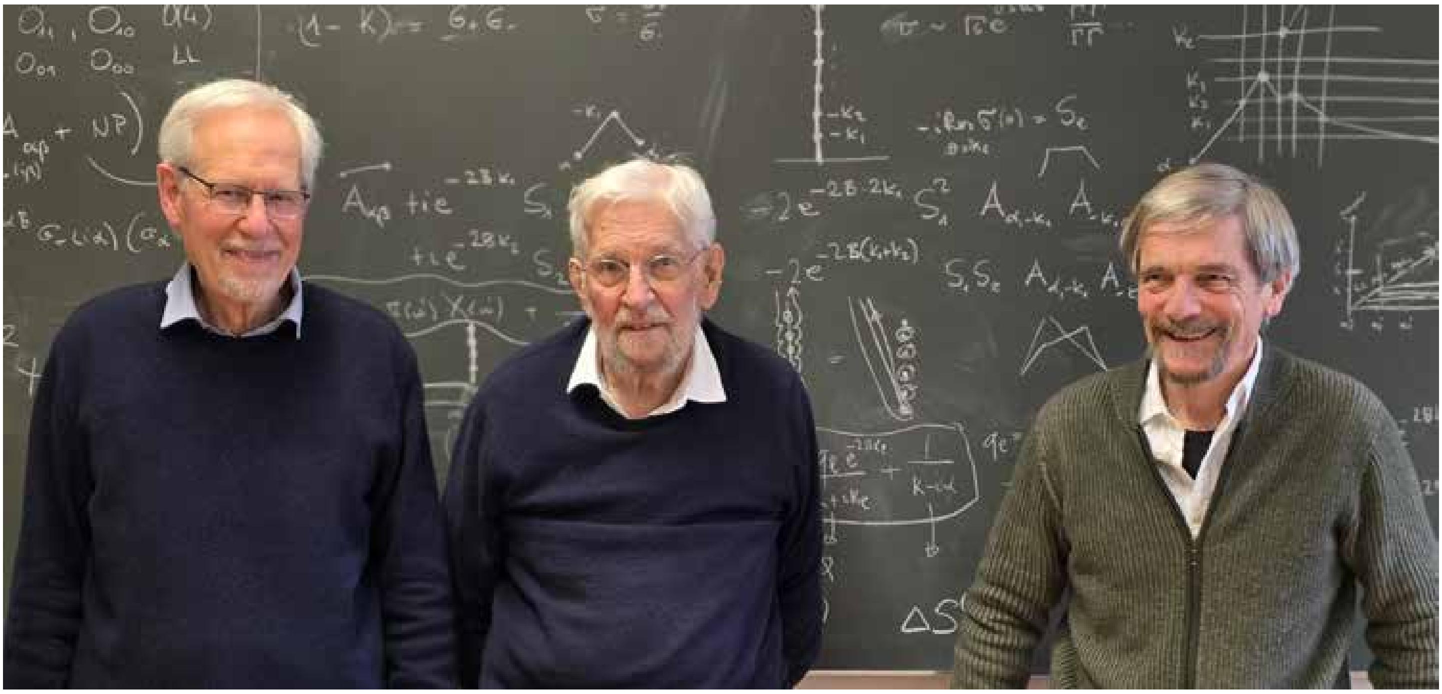
*Gilberto Colangelo, Uwe-Jens Wiese, Uni Bern*

***Jürg Gasser***, ***Heinrich Leutwyler***, and ***Martin Lüscher*** share this year's "High Energy and Particle Physics Prize" of the European Physical Society for their groundbreaking contributions to the theoretical understanding of the strong interaction in the non-perturbative regime.

At a fundamental level, the strong interaction, which is responsible for the binding of atomic nuclei as well as of the protons and neutrons inside them, is described by Quantum Chromodynamics (QCD) — the relativistic quantum theory of quark and gluon fields. QCD — an integral part of the standard model of particle physics — is asymptotically free, i.e. quarks and gluons interact less and less with increasing energy. Consequently, the high-energy regime can be addressed with perturbative QCD calculations using Feynman diagrams involving quarks and gluons. At low energy, on the other hand, quarks and gluons are permanently confined inside protons, neutrons, pions, and other strongly interacting particles: they do not exist in isolation. Quark fields of different handedness, or chirality, possess a symmetry that is spontaneously broken. This results in the presence of Nambu-Goldstone bosons – pions, kaons, and the eta-meson — which are the lightest strongly interacting particles. Spontaneous chiral symmetry breaking is analogous to spontaneous magnetization in condensed matter physics. In that case, the Nambu-Goldstone bosons are magnetic spinwaves, also known as magnons. Confinement and chiral symmetry breaking are non-perturbative phenomena that are inaccessible to perturbative calculations using QCD Feynman diagrams.

On the other hand, unlike quarks and gluons, the Nambu-Goldstone bosons are weakly interacting at low energies and their dynamics are accessible to a perturbative effective theory. Partly based on earlier work by Steven Weinberg, in the mid-1980s Jürg Gasser and Heinrich Leutwyler pioneered a systematic low-energy expansion, known as chiral perturbation theory. Using this extremely powerful technique, numerous low-energy properties of QCD have become accessible to perturbative Feynman diagram calculations, not in terms of fundamental quark and gluon, but in terms of effective pion, kaon, and eta-meson fields. In this way, deep analytic understanding has been obtained for a wide variety of physical Nambu-Goldstone boson properties, including masses, form factors, scattering amplitudes, and many others. The results of chiral perturbation theory depend on a few parameters, including the quark masses, the pion decay constant, as well as, at higher order, the so-called Gasser-Leutwyler coefficients. Besides the strong interaction, chiral perturbation theory also captures the electromagnetic and weak interaction features of Nambu-Goldstone bosons at low energies, and has led to a comprehensive detailed understanding of their dynamics. Not surprisingly, Jürg Gasser's and Heinrich Leutwyler's pioneering work continues to have an enormous impact on particle physics. Furthermore, their systematic effective field theory technique has important applications also in nuclear and even in condensed matter physics, for example, in the context of magnetic spinwaves.

Even more important is the fact that the thorough formulation of chiral perturbation theory has contributed to a new and deeper understanding of quantum field theory (QFT) in general. Indeed today QFTs are viewed as a tool to systematically account for the fundamental principles of causality, locality and conservation of probability, as well as any relevant symmetry, in theoretical calculations. When these are compared to measurements, this typically happens in a



*The winners of the EPS Prize from left to right: Martin Lüscher, Heinrich Leutwyler and Jürg Gasser.*

specific energy range, the same in which the theory aims to be valid. In this sense, any QFT should be viewed at best as an effective field theory (i.e. valid in a certain energy region), rather than a fundamental one (i.e. valid at all scales). This also applies to the standard model, despite all its remarkable successes. One of the strongest advocates of this point of view has been Steven Weinberg, but the systematic formulation of chiral perturbation theory and its successes in many different contexts, has certainly contributed significantly to its broad acceptance. Indeed, a recent CERN Courier article [1] dedicated to illustrate the central role played by effective field theories in our current understanding of Nature at a microscopic level aptly describes the one formulated by Gasser and Leutwyler as the "mother of modern effective field theories".

Still, many important aspects of QCD are neither accessible to high-energy QCD perturbation theory in terms of quark and gluon fields nor to low-energy chiral perturbation theory in terms of Nambu-Goldstone boson fields. In such cases, QCD itself can be addressed with the non-perturbative method of lattice gauge theory that was introduced by Kenneth Wilson in 1974. In this formulation, the ultraviolet divergences of quantum field theory are regularized by the introduction of a 4-dimensional Euclidean space-time lattice, whose spacing must be sent to zero in order to take the physical continuum limit. This puts QCD on a solid mathematical basis and allows its numerical simulation with Monte Carlo methods, similar to the ones used in statistical mechanics or in the event generators for high-energy particle physics experiments. Lattice QCD is the only known method that allows us to obtain non-perturbative results for the strong interaction between quark and gluon fields from first principles. Lattice QCD calculations, which require large numerical resources on supercomputers, must address a number of statistical and systematic uncertainties. The lattice spacing must be sufficiently small while the lattice volume must still be sufficiently large, in order to extrapolate reliably to the infinite-volume continuum limit. In addition, the quark masses, which are input parameters, must be tuned close to their physical values, and chiral symmetry must be properly represented in the regularized theory.

Since its very beginning in the mid-1970s, Martin Lüscher has had an enormous impact on the development of lattice QCD as a reliable, accurate tool for obtaining important results on the strong interaction from first principles. Already shortly after getting his PhD, he rigorously constructed the transfer matrix for lattice QCD, which guarantees that complex-valued Euclidean time can be analytically continued to the real-valued physical Minkowski time. The positivity of the transfer matrix proves probability conservation in QCD, which implies the validity of the optical theorem, for example, in proton-proton scattering. Together with his collaborator Peter Weisz, Martin Lüscher obtained analytic understanding for how to improve the convergence to the continuum limit of vanishing lattice spacing. Numerical simulations of QCD necessarily take place on a lattice with a finite volume, which implies systematic finite-volume effects. Instead of trying to just minimize these effects, Martin Lüscher developed a very sophisticated finite-volume method that allows the extraction of coupling constants, scattering phase shifts, and resonance parameters, besides facilitating a reliable extrapolation to the infinite-volume limit. In the late 1990s, he very significantly advanced our understanding of chiral symmetry beyond perturbation theory, with an impact not only on the strong but also on the electroweak interaction. More recently, Martin Lüscher introduced extremely precise techniques for determining the energy scale of lattice QCD, which is vital for accurate comparisons with experimental data. As if all these very advanced mathematical and numerical developments were not enough, he also constructed a most sophisticated pseudo-random number generator that is useful in Monte Carlo simulations also beyond lattice QCD.

In fact, lattice QCD and chiral perturbation theory nicely complement each other in many different ways. Lattice QCD, for example, provides input for the a priori undetermined low-energy parameters of chiral perturbation theory from first principles. Chiral perturbation theory, on the other hand, predicts the quark mass dependence of physical quantities and thus helps lattice QCD to approach the physical point. This is just one out of many examples of the complementarity and possible synergies among the two approaches, which are possible because both are based on an understanding of the strong interaction, and QFT in general, which is fundamentally non-perturbative. There is a deep underlying connection between the two approaches and it is beautiful to see this emphasized by a shared prize. This connection is much more significant than the fact that all three prize winners originate from Bern and spent almost all or some part of their careers at Bern University, but perhaps not completely unrelated.

The research of Jürg Gasser, Heinrich Leutwyler, and Martin Lüscher has tremendously advanced our understanding of the strong interaction. This is vital for a correct determination of fundamental standard model parameters, including quark masses and mixing angles. This is, in turn, of utmost importance for the ongoing and future experiments at CERN — or anywhere else around the world — that aim at discovering new physics beyond the standard model.

1 See: https://cerncourier.com/a/a-theory-of-theories/

# Bücherecke - Le coin aux livres - Book Corner

*Med. Dr. Alexander Schläfli*

**Mitteilungen Schweizerischer Reisender. Zweites Heft: 1864. Reisen in den Orient.**

*Verlag von J. Wurster & Comp., Winterthur, 1864*


Mittheilungen
Schweizerischer Reisender.
Reisen in den Orient
Winterthur

Auch dieses Jahr werden wieder vier Dissertationen in den Naturwissenschaften mit dem Schläfli-Preis der Scnat ausgezeichnet, diesmal in Geowissenschaft, Physik, Biologie und Chemie. Die Preise sind nach ihrem Stifter, dem Arzt und Weltreisenden **Alexander Friedrich Schläfli** benannt und wurden erstmalig 1866 verliehen. Er vermachte sein gesamtes Vermögen von etwa 9600 CHF damals der Schweizerischen Gesellschaft für Naturwissenschaften (SGN, heute Schweizerische Akademie der Naturwissenschaften SCNAT) unter der Bedingung, "*dass die Gesellschaft [...] einen jährlichen und immerwährenden Preis über eine Frage der physikalischen Wissenschaften stiften soll*". Seitdem haben bis heute 136 Preisträgerinnen und Preisträger diesen ältesten und angesehensten Wissenschaftspreis der Schweiz erhalten.

Kurz zu seiner Vita: Alexander Friedrich Schläfli wurde am 30.10.1832 in Burgdorf geboren und verstarb bereits in jungen Jahren am 5.10.1863 in Bagdad [1]. Er war ein Cousin des Mathematikers **Ludwig Schläfli** (1814 - 1895), der sich mit Geometrie und Funktionentheorie beschäftigte [2]. Auf die Einführung der Schläfli-Indizes zur Charakterisierung platonischer Körper hatten wir in den *SPG Mitteilungen* Nr. 69 hingewiesen [3]. Alexander Schläfli studierte hingegen von 1851 bis 1855 Medizin in Zürich und Paris und schloss das Studium 1855 als Dr. med. an der Universität in Jena ab. Ab diesem Jahr war er im Dienst der türkischen Krone in Konstantinopel und amtete als Militärarzt bei den tunesischen Truppen. Schläfli war ein Sprachengenie und beherrschte unter anderem anscheinend auch Arabisch, Türkisch, Armenisch, Persisch, und zudem vermutlich auch diverse kurdische Dialekte. Er unternahm ausgedehnte Forschungsreisen in den Epirus, das Schwarzmeergebiet, sowie die in diesem Reisebericht geschilderte Reise von Istanbul mit dem Schiff bis Syrien und von dort mit Kamelkarawanen in den heutigen Irak, von Mossul mit dem Floss den Tigris hinab bis Bagdad, von dort nach Indien (Bombay) und anscheinend auch noch nach Ostafrika und Mauritius. Er starb dann am Ende dieser langwierigen und schwierigen Reise 1863 an der Ruhr (Dysenterie), einer bakteriell ausgelösten Infektion.

Sein Reisebericht, der mit der Ankunft in Bombay im Januar 1863 endet, ist abrufbar unter *https://www.e-rara.ch/zuz/content/titleinfo/9280554*

Die Lektüre dieses Berichts ist sehr zu empfehlen. Er ist elegant und in einer bereits modern anmutenden Schreibweise verfasst, worin Schläfli tagebuchartig seine Eindrücke über Land, Personen, Zustände, Bräuche in ruhiger und unaufgeregter Weise schildert. Das ist nicht selbstverständlich bei all den Widrigkeiten, denen er trotzen musste, denn nahezu jeder Tag brachte unglaubliche Schwierigkeiten mit sich wie räuberische Überfälle, extreme Klimabedingungen und schlimme hygienische Zustände. In nahezu jedem Abschnitt der langen Reiseroute wurde gekämpft: jeder gegen jeden, Kurden gegen Türken, Türken gegen Armenier, Araber gegen Perser, aber auch kurdische Stämme untereinander bekriegten sich wie die Stämme der Duerin, Beskan, Berasi und Milli (Seite 20). Nicht immer half ihm sein türkischer Diplomatenpass, oft jedoch sein Beruf als Hakim, als Mediziner.

Seine kritische Sichtung der sozialen, religiösen und politischen Umstände und deren Ursachen lassen die Auflösung jeglicher politischer Ordnung erkennen, hauptsächlich verursacht durch den Zerfall des osmanischen Reiches, aber auch durch das unverantwortliche Vorgehen der Kolonialmächte, die nicht nur das Land rohstoffmässig ausplünderten, sondern auch durch Billigimporte von Textilien die wirtschaftliche Lage in Nahost destabilisierten. Die heutigen labilen Zustände in dieser einstigen kulturellen Wiege der Menschheit sind in seinen Schilderungen bereits klar erkennbar und sie lassen Zweifel aufkommen, ob sich die Lage je beruhigen lässt.

*Bernhard Braunecker*


1 Heinz Balmer: "Schläfli, Alexander", in: Historisches Lexikon der Schweiz (HLS), Version vom 09.08.2011. *https://hls-dhs-dss.ch/de/articles/032096/2011-08-09/*

2 Seine Publikationen können unter *https://www.e-rara.ch/search/quick?query=ludwig+schl%C3%A4fli* gefunden werden.

3 "Kepler, Platon und Schläfli", *SPG Mitteilungen* Nr. 69, Februar 2023, *https://sps.ch/de/articles/physics_anecdotes*; DOI: 10.5281/zenodo.8025711

# SATW Annual Congress 2025

*Bernhard Braunecker*

The motto of the annual congress of SATW, which took place on 27 May 2025 at FHNW Muttenz, was ***Artificial Intelligence and Quantum Technologies*** with connection to life science, especially to the pharmaceutical, medical and food industry [1].

The program was opened by three presentations about quantum computing. First by a virtual talk given by the physicist *Jian-Wei Pan* of the Chinese University of Science and Technology UCST, a former graduate student of the Austrian Nobelprize laureate Anton Zeilinger, who explained their actual work in quantum computing and quantum communication, especially how to maintain quantum entanglement over large distances, e.g. between several satellites connected by laser light. Then *Alessandro Curioni* (IBM) draw attention to the importance of quantum computing for pharmaceutical drug development, where he explained IBM's strategy in the next 5 years to focus on error corrected systems. He mentioned that the merger of quantum technology with AI concepts delivers a lot of synergies in many joint applications. The message of the third talk from *Annalisa Pawlosky* (Google), an expert in AI, was more pessimistic about the role of quantum computing in pharmacy. Some of the typical pharma-related problems are expected to need thousands of qubits and billions of error corrected operations, a fact which is not new to experts but also not seen as unsolvable.

The three talks were followed by a Pitch Session, where first an expert from the investment company *Quantonation* reported about their strategy to collect venture capital for early-stage computing startups. Another company *QAI ventures* is investing world wide in about 27 startups all working in quantum technologies.

The third part covered presentations to the topic *Artificial Intelligence and Machine Learning*: First *Stefan Plazer* (CTO Nestlé) decribed the growing importance of AI in precision food technologies, covering the whole food chain from starting with the combination of AI and remote sensing for precision farming to detect desease in plantations, followed by AI assisted breed selection of plants and ending with AI algorithms to optimize the food recipe development. They use machine learning concepts to control their production facilites also to optimize subprocesses as the careful drying of food material.

Then *Jurgi Camblong* (Sophia Genetics SA) focused on the role of AI in precision medicine, where he presented SOPHiA DDM for data driven multimodal analytics. Here they combine data from radiology, genomics, clinical, biological, ... to feed into mathematical models that allows to predict e.g. the recurrence of cancer for a patient. The exciting congress program showed that Switzerland is in a good position in analysing, modelling, simulating and understanding complex structures and dynamical processes in life science.

It is obvious and this was also confirmed by most contact persons that physics has a dominant role to push and mature the innovation chain. A detailed summary can be found under [2].

In the morning as part of the SATW general assembly our former SPS board members Hans Peter Beck (Uni Bern), and Andreas Fuhrer (IBM) as well as Andreas Pautz (PSI) received their certificate of appointment as individual academy members.

In a final discussion round with representatives of the Swiss Quantum Initiative, FHNW, quantumBasel and Google, the current and future state of the art in QC worldwide was scrutinized, but also where Switzerland stands and what role it could and should play in the future? The fact is that, as in other sectors as nuclear technologies, the USA and China are tackling the problems that still undoubtedly exist with massive investments and will therefore also solve them in the foreseeable future. Switzerland can only keep up in this fight of the giants through pragmatism and focusing on specific use cases, such as in pharmaceuticals, through intensive international networking with the key players in the USA (IBM, Google), Europe and above all in China, and through active promotion by venture capital investments of start-ups. All these aspects were thankfully discussed at the congress.

1 https://www.satw.ch/de/news/wie-ki-und-quantentechnik-die-pharmaforschung-in-der-schweiz-transformieren-einblicke-vom-jahreskongress-der-satw

2 https://www.technik-und-wissen.ch/ki-und-quantencomputing-werden-die-arzneimittelentwicklung-veraendern

# 100 Years of Quantum Mechanics: A Centennial Symposium in Zurich

*Katharina Müller, Universität Zürich*

In 2025, we celebrate a century since the birth of quantum mechanics – one of the most transformative theories in physics.


On this occasion, the University of Zurich organizes several events, including a Quantum Symposium held on 27 June at Campus Irchel. The symposium brought together leading experts to reflect on the development, meaning, and impact of quantum mechanics over the past hundred years.

In his historical outline, Domenico Giuliani (Leibnitz University Hannover) showed the foundations on which Schrödinger developed his revolutionary equation. Renato Renner (ETH Zurich) addressed fundamental questions in his theoretical reflections on the interpretation of quantum mechanics. Wenchao Xu (ETH Zurich/Paul Scherrer Institute) explained the current state of research on atomic qubits, where fields of individually controllable atoms can be used as quantum bits. Andreas Fuhrer (IBM Rüschlikon) took a look at the near future of commercial quantum computers, where one of the challenges is the high susceptibility to error of quantum calculations. In short interludes between the talks, Christof Aegerter demonstrated simple experiments illustrating quantum effects. Together, the event offered a multifaceted view of a theory that continues to shape our understanding of nature – and our technological future.

More than 200 participants attended the symposium on a hot summer afternoon. On the same day, the accompanying exhibition [1] opened in the University Library. It explores the groundbreaking developments in quantum mechanics and the pivotal role Zurich played in the 1920s. The exhibition showcases the pioneering ideas of scientists such as Wolfgang Pauli, Gregor Wentzel, Erwin Schrödinger, and Walter Heitler, who worked in Zurich in the early 20$^{th}$ century. It brings to life fascinating phenomena like wave-particle duality, entanglement, and quantum tunneling.

1 https://www.physik.uzh.ch/en/Quantum25/Exhibition.html

**Editors Note**

The info box on page 2 and the link to an article in the *SPG Mitteilungen* Nr. 75 also point to the successful activities of the UZH to present Zurich's important role as one of the cradles of quantum physics to the public. The pleasingly large number of visitors to the symposium confirms this type of special event, presenting a topic from both a historical and a current perspective, in accordance with "whoever has an origin also has a future" ("wer eine Herkunft hat, hat auch eine Zukunft").

# Kurzmitteilungen - Short Communications

## 9th International Jost Bürgi Symposium on Saturday, 25 April 2026

The successful concept of the traditional annual Jost Bürgi Symposium will be continued in 2026. The approach is not only to evaluate Bürgi historically with respect to his precise clocks and instruments and scientific achievements (Logarithm and his mathematical 'Kunstweg'), but also to see how his work extends into the present day. It is highly motivating for young people in particular to know that their work can be traced back to Bürgi's and Kepler's time and has been continuously improved since then. While in 2025 the theme "Bürgi and clocks" spanned the arc from clocks from former times to today's greatly miniaturized atomic clocks, the theme on 25 April 2026 will be "Bürgi's legacy in surveying and navigation". While the historical section is still being discussed, the two lectures in the modern section will deal with the surveying of the Gotthard Base Tunnel, and the presentation of the newest humanoid robot of Hexagon – Leica.

Int. Jost-Bürgi-Symposium Lichtensteig

## Joseph Fraunhofer Award / Robert M. Burley Prize to Juerg Leuthold

One of the most prestigious scientific prizes in optics and photonics is the Joseph Fraunhofer Award / Robert M. Burley Prize of OPTICA, the former Optical Society of America, which is annually awarded to scientists in recognition of significant research accomplishments in the field of optical engineering. This year's recipient is Juerg Leuthold, the head of the Department of Information Science and Electrical Engineering of ETH Zurich for pioneering plasmonics based devices, and in particular developing broadband modulators and detectors with highest bandwidths. Leuthold and his research group advanced the field of plasmonics by bringing up some of the fastest plasmonic modulators featuring a bandwidth of 1 THz, and graphene-plasmonic detectors offering bandwidths in excess of 500 GHz. His group has also pioneered some of the fastest optical memristive devices.

Juerg Leuthold is also co-author of the Progress in Physics article on page 32.

**In the *SPG Mitteilungen* Nr. 75 (p. 31 - 33) we informed about the Vera C. Rubin Observatory with its compact telescope of impressive large field of view of 3.5 deg diameter and its large sensor of 3.2 Gpixels. Now first images were taken, showing a glimpse of the huge possibilities to be explored in the next years.**

https://rubinobservatory.org/gallery/collections/first-look-gallery)

**Credit for all space pictures on this page: NSF–DOE Vera C. Rubin Observatory; credit for the drone view of the observatory: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/T. Matsopoulos**

*This image combines 678 separate images taken by NSF–DOE Vera C. Rubin Observatory in just over seven hours of observing time. Combining many images in this way clearly reveals otherwise faint or invisible details, such as the clouds of gas and dust that comprise the Trifid nebula (top) and the Lagoon nebula, which are several thousand light-years away from Earth.*

*This image captures a small section of NSF–DOE Vera C. Rubin Observatory's view of the Virgo Cluster, revealing both the grand scale and the faint details of this dynamic region of the cosmos. Bright stars from our own Milky Way shine in the foreground, while a sea of distant reddish galaxies speckle the background.*

*Made from over 1100 images captured by NSF-DOE Vera C. Rubin Observatory, this image contains an immense variety of objects, demonstrating the broad range of science Rubin will transform with its 10-year Legacy Survey of Space and Time. The image includes about 10 million galaxies, roughly 0.05 % of the approximately 20 billion galaxies Rubin Observatory will capture over the next decade.*