

SPG Mitteilungen

Communications de la SSP

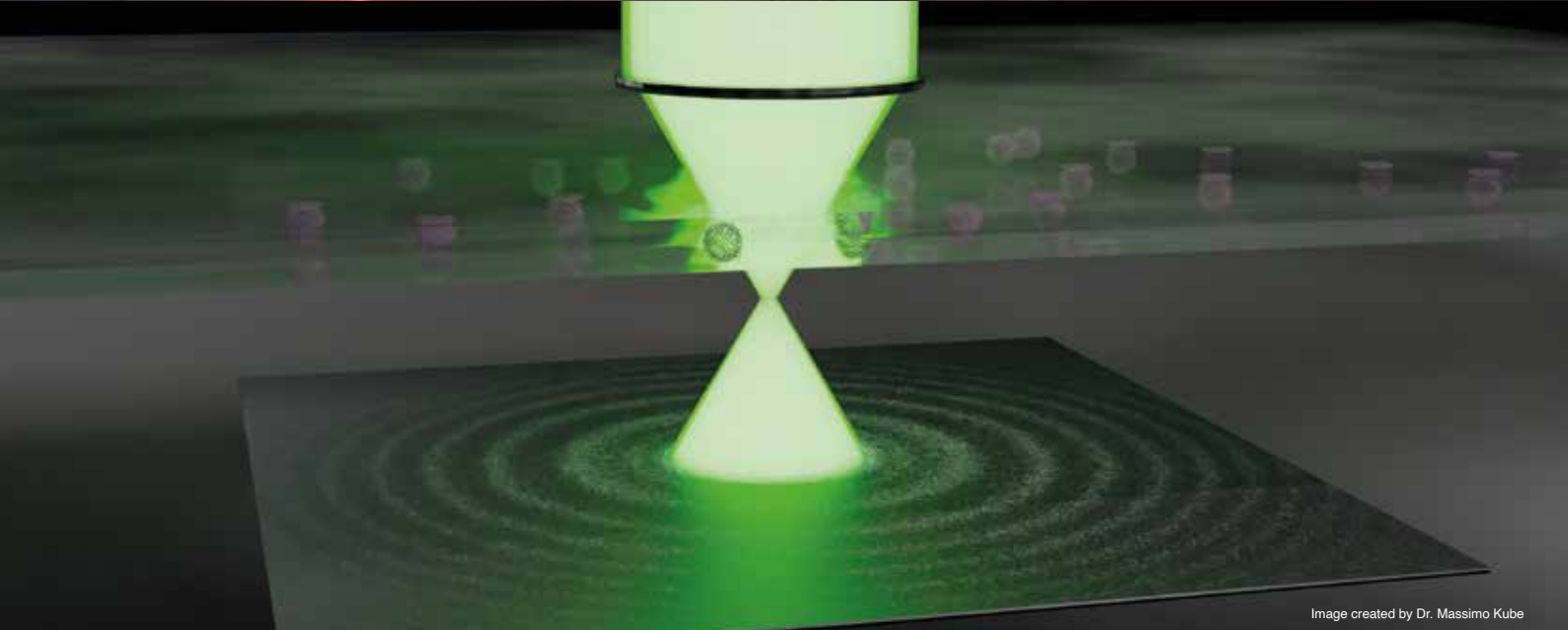
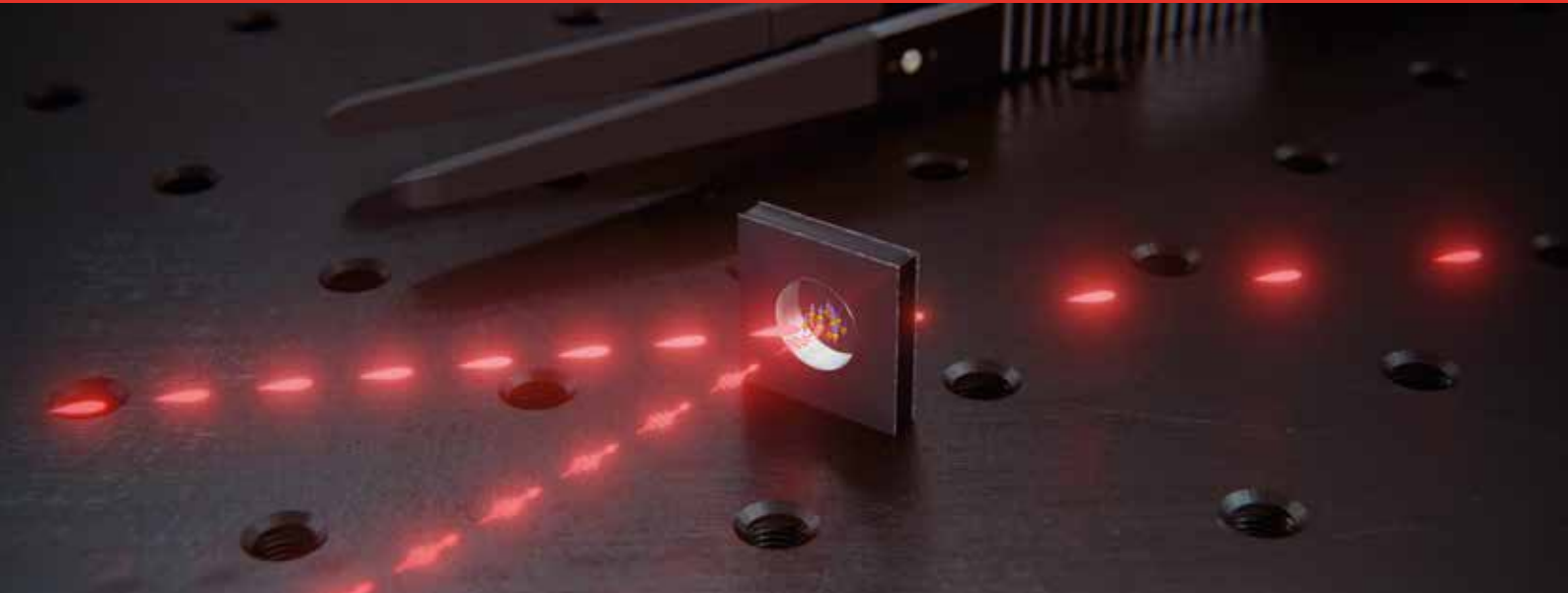


Image created by Dr. Massimo Kube

Top: Optical memory implemented in a MEMS vapor cell. Single-photon-level light pulses can be stored and re-emitted at a later point in time. Read more on p. 29.

Bottom: Artistic representation of an electron beam convergently focused below an ice layer containing apoferritin protein particles. A 2D electron diffraction pattern is recorded while the beam is stepped over the sample. The full article is on p. 34.

Annual Meeting of the Swiss Physical Society
9 - 13 September 2024, ETH Zürich

De Broglie Symposium: p. 10, Preliminary Program: p. 13

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member of the



Editorial

The Dialogue between Politics and Science

Bernhard Braunecker

The academic freedom is one of the greatest assets of a modern state, comparable to freedom of opinion and freedom of the press. If politics dictates to academia what it has to do, it also relieves it of the responsibility to develop visions, overcome boundaries of thought and set new standards. In the long term, a society would lose the creativity it needs to shape the future and not just act epigonally. Politicians, on the other hand, have the responsibility to ensure the welfare of society and they need science. Science must therefore indicate which research results are suitable for technical implementation in products in order to keep jobs or create new jobs. Science must also offer solutions to current problems as to secure the supply of energy, but it must not give advice such as closing schools in times of a pandemic which is clearly the task of politics.

The question is how should the dialogue between politics and science be conducted that both sides understand the concerns of the other? This can be the task of societies as SPS, where the transfer of knowledge from basic to applied and to industrial development can be confirmed with facts based on existing expertise. The SPS has various options at its disposal. The *Progress in Physics* series has been included in the *SPG Mitteilungen* since 2007 to explain current research results to a wider readership at first hand. All articles are written in such a way that an interested reader can follow. Particular emphasis is placed on articles from applied and industrial physics in order to arouse the interest of investors and politicians. But it is a fact that the authors of the 100 Progress articles published to date come overwhelmingly from basic and applied research at universities, while contributions from industrial physics are understandably rare.

The informative and impactful Role of Physics

This one-sidedness prompted the SPS to introduce the *SPS Focus* series in 2021. In this series, a key topic such as a reconsideration of nuclear technology (*SPS Focus* No. 1) or the influence of physics on the welfare of society (*SPS Focus* No. 2) is examined from all research perspectives, from basic research to industrial applications. The main task, however, is to show the course of the innovation chain and to formulate ideas for implementation. In the case of social focus topics such as discussed in No. 2, didactic analyses and recommendations are added, while in the case of more technological topics, solutions must be shown by physics that will be industrially feasible, stable, cost-effective, environmentally friendly and further expandable in the next years. This achieves two objectives: first, it shows the politics that modern jobs in industry can be created thanks to scientific know-how. Secondly, it makes clear that fundamental research must always be at the beginning of a technical evolution in order to understand the basic mechanisms (today at atomic level) and to know the application limits. We should not be afraid to point out that, for example, all the fascinating advances in life science are also based to a

large extent on contributions from physics in measurement technology, in theory and modeling, and in simulations of reaction dynamics. In this context the recent reorganization of the SPS Section *Biophysics and Soft Matter* is intended to strengthen the exchange of information between physicists working in research and industry.

In short: Physics has the competence to provide objective, neutral and fact-based information, but we should also be more active to present potential solutions outside our community.

In this issue we report on the sad loss of Peter Higgs (p. 27) and Niklaus Wirth (p. 26), whose computer languages Pascal, Modula-2 and Oberon were used in many institutes and industrial laboratories. But we also present positive news as the report on the 100th birthday of the former General Director of CERN Prof. Herwig Schopper (p. 25), and the interview with physicist Dr. Christa Markovits about her life, a fascinating document of our time (p. 53). The enthusiasm of younger colleagues when solving physical questions can be seen in a report about the International Physicists Tournament (IPT) on p. 62 and in an article, describing how to stimulate young people's interest in physics by enabling their contact to major industrial companies (p. 64). Finally, we would like to mention the additional events at the upcoming SPS Annual Meeting in September, namely the De Broglie Symposium as a warm-up to IYQ 2025, the inauguration of the newly founded Energy & Sustainability section, and the event to mark the 70th anniversary of CERN (p. 60).

Early Fundamental Research

The important role of fundamental research is nicely illustrated when we want to travel to the planet Mars. When Kepler deduced the elliptical shape of the orbital curve of the planet Mars, Galileo asked himself at the same time why planets were moving at all? Everybody knows that a moving body must come to rest after a while, which must be especially true for planets given the age of the world. Were not - as was taught in clerical circles - *invisible angels that drove the planets with the flapping of their wings?*¹ Galileo, however, found that a moving body continues to move if not explicitly slowed down. But why, Newton asked almost an age later, are the planetary orbits curved into ellipses? Because there must be a force directed towards the sun, the gravity. Without the fundamental research work of Galileo under the critical eyes of the inquisition and Newton, we would still need the help of busy angels to reach the planet Mars.

¹ R Feynman, *Vom Wesen physikalischer Gesetze*, Piper Verlag 1990, http://www.vixri.ru/d2/Richard%20P%20Feynman%20_Vom%20Wesen%20physikalischer%20Gesetze%20.pdf

SPG Jahrestagung in Zürich, 09. - 13. September 2024 - Réunion annuelle de la SSP à Zürich, 9 - 13 septembre 2024

Vorwort

Die diesjährige Jahrestagung der SPG, mit Beteiligung des *Schweizerischen Institut für Teilchenphysik* (CHIPP), der *Schweizerischen Gesellschaft für Neutronenforschung* (SGN), der *Schweizerischen Gesellschaft für Photonenforschung* (SSPh) und *Life Sciences Switzerland* (LS²), findet an der ETH Zürich auf dem Campus Zentrum (Gebäude ETA/ETF/ETZ/GLC) an der Gloristr. 35 statt.

Neben der bewährten Mischung aus Plenarvorträgen, Fachsitzungen und Händlerausstellung steht diesmal ein öffentliches Symposium zu Ehren von *Louis de Broglie: 100 Jahre Welle-Teilchen Dualismus* (S. 10) auf dem Programm. Ein öffentlicher Vortrag von Nobelpreisträgerin Anne l'Huillier ist eines der Highlights der Tagung. Ein weiteres Highlight ist die Eröffnungssitzung der neuen Sektion *Energie und Nachhaltigkeit* (S. 11). Ausserdem findet zum dritten Mal das *Frauen in der Physik Karriere-Symposium* statt, nun als intergraler Teil der Tagung.

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 Webseite abrufbar sein.

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

Avant-propos

Cette année, la réunion annuelle de la SSP aura lieu à Zürich, sur le Campus Central dans les bâtiments ETA/ETF/ETZ/GLC, situé à la Gloristr. 35, avec la participation de l'*Institut Suisse pour la Physique des Particules* (CHIPP), de la *Société Suisse de la Science Neutronique* (SSSN), de la *Société Suisse de la Science Photonique* (SSPh) et *Life Sciences Switzerland* (LS²).

En plus de la combinaison de conférences plénières, de sessions par domaines et de stands d'exposants, une formule qui a fait ses preuves, il y aura cette année un symposium public sur *Louis de Broglie : un centenaire du dualisme ondes-particules* (p. 10). A noter la conférence publique de la lauréate Nobel Anne l'Huillier et la séance inaugurale de la nouvelle section *Energie et durabilité* (p. 11). En outre, la réunion accueillera pour la troisième fois le *symposium sur la carrière des femmes en physique*, cette fois comme partie intégrante du programme.

Les participants sont aussi invités à s'inscrire au traditionnel dîner de la conférence (nombre de places limité).

Vous trouverez dans les prochaines pages les informations s'adressant aux membres de la SSP de même qu'un aperçu du programme préliminaire. Le programme complet ainsi que les principales informations sur la conférence seront disponibles prochainement sur la page web de la SSP.

Nous nous réjouissons de votre participation.

Generalversammlung 2024 - Assemblée Générale 2024

Montag 09. September 2024, 13:00h, ETZ E6 - Lundi 9 septembre 2024, 13:00h, ETZ E6

Traktanden

1. Protokoll der ausserordentlichen Generalversammlung vom 26. Februar 2024
2. Bericht des Präsidenten
3. Rechnung 2023, Revisorenbericht
4. Wahlen
5. Projekte
6. Diverses

Ordre du jour

- Procès-verbal de l'assemblée générale extraordinaire du 26 février 2024
- Rapport du président
- Bilan 2023, rapport des vérificateurs des comptes
- Elections
- Projets
- Divers

Preisverleihungen - Cérémonies de remise des prix

**SPG Preise, SGN Preis, Charpak-Ritz Preis
Prix de la SSP, SSSN, prix Charpak-Ritz**

**Preise für die besten Poster
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**Dienstag 10. September 2024, 11:00h, ETA F5 -
Mardi 10 septembre 2024, 11:00h, ETA F5**

**Donnerstag 12. September 2024, 10:30h, ETA F5 -
Jeudi 12 septembre 2024, 10:30h, ETA F5**

Protokoll der ausserordentlichen Generalversammlung vom 26. Februar 2024

Protocole de l'assemblée générale extraordinaire du 26 février 2024

Agenda

1. Approval of the minutes of the General Assembly from 4 September 2023
2. Vote on closing the section "Earth, Atmosphere and Environmental Physics" and opening the section "Energy and Sustainability", and election of its chairs
3. Vote on establishing a new commission for "Diversity, Equity and Inclusion" (DEI), and election of its chair
4. Information item: Candidates for other section chairs and vice president, to be elected at the General Assembly in September 2024
5. Vote on the relocation of Medical Physics from the "Biophysics, Soft Matter and Medical Physics" section to the "Applied Physics" section, combined with renaming the section to "Biophysics and Soft Matter"
6. Status of the organisation of the Annual Meeting at ETHZ on 9 - 13 Sept. 2024
7. Varia

The President opens the Extraordinary General Assembly 2024 at 8:30.

1. Approval of the minutes of the General Assembly from 4 September 2023

The protocol of the last General Assembly, published in the *SPG Mitteilungen* Nr. 72 on p. 5, is approved.

2. Vote on closing the section "Earth, Atmosphere and Environmental Physics" and opening the section "Energy and Sustainability", and election of its chairs

The SPS board decided at its meeting on 4 September 2023, to propose to the General Assembly to close the current SPS section "Earth, Atmosphere & Environmental Physics", which remained inactive for several years and without chairs, and open the new section "Energy and Sustainability". The reason to focus on energy and sustainability is their relevance and topicality. Recent global crises led to severe uncertainties among the population and politics concerning the reliable supply of energy. Here, physical knowledge is asked to support political decisions.

The president clarifies that the new section still covers the topics from the section on earth, atmospheric and environmental physics which are deeply connected with the decarbonisation and energy crisis. There is a strong will in the SPS to put the accent on providing support through reliable information towards carbon-free solutions on processes of generation, transmission, distribution, and storage of energy to ensure a stable and reliable energy supply for all. The new section will foster several prominent activities on energy science and sustainability of SPS (e.g., *SPS Focus* issues, plenary talks, dedicated sessions at the annual meetings and establishing a community sensitive to these topics and increase relations with neighbour societies who are also attentive to these issues (e.g. the French society recently produced a very interesting report on the challenge of decarbonization).

The suggested chairs, Thomas Christen (Hitachi Energy Switzerland) and Tomoko Muranaka (EPFL), presented themselves briefly. The chairs will be complemented by ad-

visors for special topics to do justice to the breadth of this field.

A discussion follows in the assembly. The points are made that the overall goal of the section should be to provide information and scientific facts to decision-makers to assist them and so have a factual impact on society. From the discussion, it emerges that the SPS role should provide such facts, remaining (as an organisation) politically neutral.

The proposed leaders of the section will have a meeting to work out a mission statement accounting for the board comments to be presented at the next General Assembly on 9 Sept. 2024 in person. A few comments are made on the name of the section which could more explicitly consider Earth and atmosphere science. This point has already been discussed in the SPS board and the chairs will elaborate on it further within their mission statement.

The closing of the old section and the creation of the new one are approved by the Extraordinary General Assembly with a large majority. Thomas Christen and Tomoko Muranaka are elected as chairs of the new section with a large majority.

3. Vote on establishing a new commission for "Diversity, Equity and Inclusion" (DEI), and election of its chair

The president presents the proposal for a new commission for "Diversity, Equity and Inclusion" (DEI). The idea for the new commission is to promote gender and overall equity, nourish diversity, and foster inclusion in all fields of physics and all working environments. It is expected to interact with related endeavors in national and international physics and broader science and technology societies. In addition, the section would sustain in the long term the *Women in Physics Career Symposium* and the associated relevant mentoring activity and representation in international activities such as the International Conference on Women in Physics of IUPAP.

In contrast to a section, the commission would have a horizontal structure across sections, and would ideally include representatives from all SPS sections.

The proposed chair, Philipp Schmidt-Wellenburg (Paul Scherrer Institut), introduces himself. The creation of the new commission is approved and Philipp Schmidt-Wellenburg is elected as its chair with a large majority.

4. Information item: Candidates for other section chairs and vice president, to be elected at the General Assembly in September 2024

This year, a large part of the SPS Board will have to be replaced and many candidates have already been identified. These candidates will be up for formal election at the next General Assembly.

5. Vote on the relocation of Medical Physics from the "Biophysics, Soft Matter and Medical Physics" section to the "Applied Physics" section, combined with renaming the section to "Biophysics and Soft Matter"

The section on Biophysics, Soft Matter and Medical Physics is very broad in scope and at the same time, Medical

Physics stands out from these topics as a particularly applied branch of physics. It is therefore proposed to relocate the topic of Medical Physics to the Applied Physics section. The refocusing and streamlining of these sections should increase their attractiveness – in particular, for so far under-represented groups of physicists, e.g., from medical diagnostic, pharmaceutical and healthcare industries, as well as scientists working in the life sciences, both in academia and industry. To achieve this, the focus on Soft Matter must be emphasized in the Biophysics and Soft Matter section. It is highlighted that aspects of Medical Physics are already well present in the Applied Physics section.

The proposed relocation of medical physics from the Biophysics, Soft Matter and Medical Physics section to the Applied Physics section, and the renaming of the section "Biophysics and Soft Matter" is approved by the Extraordinary General Assembly with a large majority.

6. Status of the preparations for the Annual Meeting at ETHZ, 9 - 13 Sept. 2024

The president gives an overview of the current status of the preparations for the SPS Annual Meeting 2024, to be held on September 9-13 at ETH Zurich.

7. Varia

A name change for the section "Education and Promotion of Physics" is proposed by Andreas Müller (Chair of this section) – because the French, German and English versions are presently not consistent with each other and do not fully represent what is being done in the section.

Proposal 1: "Education and Promotion of the Next Generation in Physics", "Education et promotion de la relève de la physique", "Bildung und Förderung des Nachwuchses in Physik"

Proposal 2: "Education and Promotion of Physics", "Education et promotion de la physique", "Bildung und Förderung der Physik".

Proposal 3: Leave the name as it is.

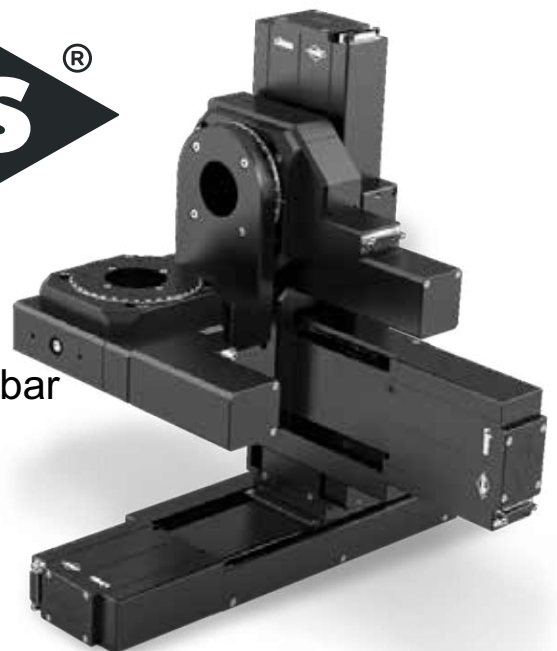
It is decided to postpone the vote on this item and think more about the exact wording in each language. A search for a new name will be conducted during the next board meeting on 6 May and a new proposal will be submitted for a vote at the General Assembly in September.





The President closes the meeting in time at 10:15.



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Mitglieder auf Lebenszeit	101
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Ehrenmitglieder	19
Beitragsfreie (Korrespondenz)	6
Total	1094

Jahresrechnung 2023 - Bilan annuel 2023

Bilanz per 31.12.2023		
	Aktiven	Passiven
Umlaufvermögen		
Postscheckkonto	125245,87	
Bank - UBS 230-627945.M1U	28890,77	
Debitoren - Mitglieder	2260,00	
Debitoren - SCNAT / SATW u.a.m.	57965,97	
Transitorische Aktiven	2000,00	
Anlagevermögen		
Beteiligung EP Letters	15840,00	
Mobilien	1,00	
Fremdkapital		
Mobiliar		1,00
Mitglieder Lebenszeit		75908,25
Transitorische Passiven		10689,78
Eigenkapital		
Vefügbares Vermögen		148765,27
Total Aktiven / Passiven	232203,61	235364,30
Gewinn / Verlust	3160,69	
Kontrollsumme	235364,30	235364,30
Verfügbares Vermögen per 31.12.2023 nach Verlustzuweisung:		145604,58

Erfolgsrechnung per 31.12.2023			
	Aufwand		Ertrag
Gesellschaftsaufwand		Ertrag	
EPS - Membership	10443,93	Mitgliederbeiträge	86632,10
SCNAT - Membership	7294,00	Sponsorbeiträge	12000,00
SATW - Mitgliederbeitrag	1750,00	Inserate / Flyerbeilagen SPG Mitteilungen	5870,00
		Aussteller	13470,00
		Zinsertrag	172,20
SCNAT Verpflichtungskredite		Ertrag aus EP Letters Beteiligung	16913,41
SPG Jahrestagung	20565,09		
Schweizer Physik Olympiade	4000,00	SCNAT Verpflichtungskredite	
Übrige Tagungen SPG / SCNAT	3398,32	SPG Jahrestagung (SCNAT)	15000,00
SPG Young Physicist's Forum	3500,00	Schweizer Physik Olympiade	3000,00
Lehrerfortbildungsevent 2014 ff	1400,00	Übrige Tagungen SPG / SCNAT	1700,00
International Physics Tournament	3605,47	SPG Young Physicist's Forum	3500,00
SPG Bulletin / Tagungsband (SCNAT)	5800,00	Lehrerfortbildungsevent 2014 ff	7500,00
Periodika (SPG Mitteilungen, Druckkosten)	28099,95	International Physics Tournament	4000,00
Internationale Zusammenarbeit	2132,74	SPG Bulletin / Tagungsband (SCNAT)	4000,00
Schweizer Jugend forscht (SJF) Physikarbeiten	2000,00	Periodika (SPG Mitteilungen, Druckkosten)	8000,00
Reisekosten Nachwuchs	233,70	Internationale Zusammenarbeit	4000,00
Swiss Young Phys. Tournament	5000,00	Schweizer Jugend forscht (SJF) Physikarbeiten	1000,00
Women in Physics Career Symposium	4000,00	Reisekosten Nachwuchs	2000,00
Science Education and Industry	5000,00	SCNAT Swiss Young Phys. Tournament	5000,00
		Women in Physics Career Symposium	4000,00
		Science Education and Industry	5000,00
Betriebsaufwand			
Löhne,	43198,21		
Sozialleistungen, berufliche Vorsorge, Versicherung	27876,97		
Porti / Telefonspesen / WWW- und PC-Spesen	586,24		
Versand (Porti Massensendungen)	4567,30		
Unkosten	7862,37		
Büromaterial	1080,15		
Bankspesen	390,00		
Debitorenverluste Mitglieder	2400,00		
Debitorenverlust SCNAT / SATW u.a.m.	9733,96		
Total Aufwand / Ertrag	205918,40		202757,71
Gewinn / Verlust			3160,69
Kontrollsumme	205918,40		205918,40



Revisorenbericht zur Jahresrechnung 2023

Die Jahresrechnung 2023 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, 20.03.2024

Public Symposium: Louis de Broglie: 100 years of wave / particle dualism

The years 1920 - 1930 are regarded as an important decade in modern physics. One of the highlights was Louis de Broglie's formulation of the duality of matter 100 years ago.

Louis de Broglie (1892 - 1987) is considered one of the most important physicists of the 20th century. In 1924, de Broglie completed his studies with the famous dissertation *Recherches sur la théorie des Quanta*, in which he suggest-

ed that wave-particle dualism could be applied to all solid matter. This bold idea was honored by the Institut de France in 1926 and 1927. In 1929, the discovery of the wave nature of electrons was followed by the Henri Poincaré Medal of the Académie des Sciences and the Nobel Prize in Physics.

The symposium takes place on Monday 9 September and can be visited free of charge, no registration needed.

Time	LOUIS DE BROGLIE: 100 YEARS OF WAVE / PARTICLE DUALISM ABSTRACTS
14:30 – 15:15	<p style="text-align: center;">Matter and Light: Louis de Broglie and our current understanding of physics</p> <p style="text-align: center;"><i>Friedrich-Karl Thielemann, Universität Basel and GSI Helmholtz Center for Heavy Ion Research; Darmstadt</i></p> <p>Today's understanding of physics is not possible without the concept of quantum mechanics, but how did it all come about? Light had been understood in terms of waves since Huygen's wave interpretation in 1690 (and Fresnel's extension in 1818), but Planck (in 1900) and Einstein (in 1905) postulated particle behaviors (photons), where the frequency or wavelength of photons was related to their energy or momentum, confirmed by Compton's experiments in the early 1920s. The Bohr model of the atom (1913) still considered electrons as particles, but with quantized angular momentum. In 1924 de Broglie introduced the theory of electron waves, before understood as particles, and proposed (more generally) that particles are wave packets which move with group velocity, having an effective mass. Following de Broglie's proposal, leading to the wave-particle duality of electrons, modern quantum mechanics was born when in 1925 Werner Heisenberg, Max Born and Pascal Jordan developed matrix mechanics and Erwin Schrödinger invented wave mechanics as solutions of the Schrödinger equation in 1926. From the wider acceptance at the Fifth Solvay Conference in 1927 to further refinements and unified formalizations by David Hilbert, Paul Dirac, and John von Neumann until 1930 only a few years had passed. Bohr won the Nobel prize in 1922, de Broglie in 1929, Heisenberg in 1932, Schrödinger in 1933, followed by many other quantum physicists since then. My colleagues in this symposium will discuss modern research and advances in this field, I focus on the role of de Broglie, a few main aspects and the history behind it.</p>
15:15 – 16:00	<p style="text-align: center;">Waves of Quantum Matter</p> <p style="text-align: center;"><i>Tilman Esslinger, ETH Zürich</i></p> <p>The wave nature of matter materializes in interference experiments with Bose-Einstein condensates. Correspondingly, the particle nature can be made observable by detecting individual atoms. Yet, it is the interactions between the atoms and between atoms and light that give rise to intriguing phenomena and a multitude of phases, including superfluid, supersolid, Mott-insulating and topological phases. I will provide a perspective on quantum gas experiments and show how we can synthetically create quantum many-body systems with tailored interactions and topology. I will highlight recent experiments in which we investigate the interplay between non-trivial topologies and strong interactions.</p>
16:00 – 16:30	<p style="text-align: center;">Coffee Break</p>
16:30 – 17:15	<p style="text-align: center;">Wave-particle duality in atom interferometers: precision measurements at the quantum limit</p> <p style="text-align: center;"><i>Philipp Treutlein, Universität Basel</i></p> <p>Atom interferometers are among the most precise measurement devices for inertial forces, electromagnetic fields and fundamental interactions. Their working principle is a beautiful embodiment of deBroglie's wave-particle duality of matter: while the wave nature of atoms gives rise to interference of the different paths through the interferometer, their particle nature gives rise to fundamental quantum noise in the detection of the resulting interference pattern. For uncorrelated atoms, this results in the so-called standard quantum limit of interferometric measurement, which is reached by today's best instruments. Surprisingly, another quantum phenomenon - entanglement - can be harnessed to overcome this limit. I will give an overview of the operating principle, applications and fundamental quantum limits of atom interferometers and show how we can use many-particle entangled states to improve their sensitivity, which promises significant advances for science and technology.</p>
17:15 – 18:00	<p style="text-align: center;">Single electron imaging vs. coherent electron beam diffraction: Optimization of image contrast in cryo-electron microscopy</p> <p style="text-align: center;"><i>Henning Stahlberg, Laboratory of Biological Electron Microscopy, EPFL and University of Lausanne</i></p> <p>Cryo-transmission electron microscopy (cryo-EM) or tomography (cryo-ET) of frozen hydrated specimens is an efficient technique for analyzing the structure of proteins or tissue sections. However, both methods face challenges due to their very low signal-to-noise ratio. Efforts to enhance their efficacy focus on minimizing the initial damage caused by the electron beam on the sample and maximizing the recovery of phase contrast signal from electrons interacting with the sample. We are exploring whether employing stroboscopic imaging with individual electrons passing through the sample at precise nanosecond intervals could potentially reduce damage for a cryo-EM sample compared to a similarly intense barrage of electrons arriving randomly, a concept previously proposed for samples at room temperature. We are further advancing convergent beam electron diffraction with a probe aberration-corrected Titan Krios and an ultra-fast pixelated detector (4D-STEM), evaluating the data with ptychography and other data analysis methods, in order to maximize phase contrast signal recovery from a frozen hydrated cryo-EM specimen. Progress in these two approaches will be presented.</p>
18:00	<p style="text-align: center;">END</p>

Public Lecture

This year we have the honor and pleasure to welcome Nobel Laureate Anne l'Huillier, who will give a public lecture addressing the path to attosecond pulses. Anne l'Huillier has been a pioneer of the field of attosecond science. Already in the 1980s, she performed several key experiments on extreme, non-perturbative nonlinear optics that demonstrated the ability of atoms to absorb many low-energy photons simultaneously or to emit high-order harmonics of low-frequency fields when exposed to high-intensity laser fields. The latter became the process that ultimately led to the generation of attosecond pulses in the early 2000s and the extension of time-resolved spectroscopy to attosecond times-

cales. To the present day, Anne l'Huillier remained at the forefront of the research field she helped to create. Besides her seminal contributions to the understanding of high-order harmonic generation and the development of associated techniques, she has been particularly active in studying the dynamics of fundamental ionization processes in atoms.

This lecture takes place on Monday 9 September and can be visited free of charge, no registration needed. It has been organised in collaboration with the Swiss Society for Photon Science (SSPh).

Time	PUBLIC LECTURE
18:30 - 19:45	<p>The route to attosecond pulses</p> <p><i>Anne l'Huillier, Lund University Sweden, Nobel Laureate 2023</i></p> <p>When an intense laser interacts with a gas of atoms, high-order harmonics are generated. In the time domain, this radiation forms a train of extremely short light pulses, of the order of 100 attoseconds. Attosecond pulses allow the study of the dynamics of electrons in atoms and molecules, using pump-probe techniques. This presentation will highlight some of the key steps of the field of attosecond science.</p>
19:45	END

Energy and Sustainability

Inaugural session

This inaugural session of the newly founded SPS section on *Energy and Sustainability* will take place on Friday 13 September and aims to start a dialogue, knowledge and know-how exchange, and possibly collaboration among physicists in academic and industrial research institutes on how to solve the huge challenges of a successful energy transition. Both facets will be touched in this first symposium (which is planned to be followed in future by similar continuation symposia, due to the large extent of the topic): *research in physics on sustainable energy and power technologies*, and *responsibly sustainable research in physics*. For this purpose, high-level speakers are invited which represent Swiss top world-class research institutions.

The first three presentations will shed light on ongoing cutting-edge science and possible future research strategies in the field. Professor **Gabriela Hug** from the Power Systems Laboratory at the ETH will start with a contribution on "The Future of the Electrical Energy System: from Rotating Masses to Power Electronics", providing an overview on possible changes of the electric power system and highlighting the associated consequences and challenges, with some focus on control strategies. Dr. **Lorenz Herrmann**, head of the advanced materials and surface department and directory board member from the EMPA, will emphasize "The importance of physics in material science & technology for sustainable energy applications", with several examples illustrating the historical fact that material science is always playing a leading role in technology revolutions like the energy transition. Furthermore, **Thomas Justus Schmidt**,

head of the energy & environment research division, directory board member of the PSI, and Professor at the Institute of Molecular Physical Sciences of the ETH, will guide us through a short journey of energy efficiency, energy storage necessities, and discuss possible pathways to reach the NetZero goal in the Swiss energy transition.

The following two speakers will, on the other hand, discuss the sustainability challenges to conduct research in large-footprint physics, like high energy and particle physics. **Sonja Kleiner**, as the Head of the CERN HSE Environment Group, will introduce CERN's strategy on environmentally responsible research. Dr. **Patrick Koppenburg**, from the Netherland National Institute for Subatomic Physics (Nikhef) and CERN will talk about a sustainable future in high-energy physics on behalf of the HECAP+ (High Energy, Cosmology, Astroparticle, Hadron and Nuclear Physics) sustainability community. Both bottom-up and top-down initiatives for energy-efficient laboratory practices will be presented to show how integrating sustainability considerations into research can accelerate the transition to a more sustainable energy future.

After the presentations a panel discussion will take place, where the presenters will answer questions from the audience, and which will be moderated by Prof. **Hugo Zbinden** from the University of Geneva.

Join us and be part of the research community at the forefront of energy transition!

Time	<p style="text-align: center;">ENERGY AND SUSTAINABILITY: Research Needs for a Sustainable Energy Transition ABSTRACTS</p>
09:00 – 09:30	<p style="text-align: center;">The Future of the Electrical Energy System: from Rotating Masses to Power Electronic</p> <p style="text-align: center;"><i>Gabriela Hug, Head of Power Systems Laboratory, ETHZ</i></p> <p>The electrical energy system is in a transition from traditional resources such as nuclear power, hydropower or coal-fired power plants to new resources such as PV and wind. Hence, synchronous machines which give the system a natural inertia are replaced by inverter connected resources. This raises various new challenges that go beyond the variability of the available energy. For example, the system inertia is reduced which leads to faster system dynamics. This presentation will show how the future electrical energy system in Switzerland could look like and the challenges that need to be solved to realize such a system and what role new control approaches can play.</p>
09:30 – 10:00	<p style="text-align: center;">The Swiss Energy Transition to NetZero</p> <p style="text-align: center;"><i>Thomas Justus Schmidt ^{1,2}</i></p> <p style="text-align: center;">¹ <i>Head of Energy & Environment Research Division, Paul Scherrer Institute, CH-5232 Villigen PSI</i> ² <i>Institute of Molecular Physical Sciences, ETH Zürich, CH-8093 Zürich</i></p> <p>The Swiss Federal Council as well as many other governments set the ambitious goal to reach net-zero greenhouse gas (GHG) emissions by mid of the century. As the required systemic and societal transitions will take decades, urgent action is imperative, as highlighted by the recent IPCC Report. Despite the well-defined target, many questions remain concerning transition pathways, social acceptance, technology developments, regulatory frameworks, and business cases. The diversity of these challenges clearly shows that only an integrated and trans-disciplinary approach can generate the required impact and guide stakeholders toward the NetZero target. This presentation will guide you through a short journey of energy efficiency in the energy transition, energy storage necessities, and possible pathways to reach the NetZero goal.</p>
10:00 – 10:30	<p style="text-align: center;">From Materials to Devices: The importance of physics in material science & technology for sustainable energy applications</p> <p style="text-align: center;"><i>Lorenz Herrmann, Head of Advanced Materials and Surfaces Department, EMPA</i></p> <p>A safe and sustainable energy supply as well as sustainable material cycles are two of the most urgent needs of our times. In all of these questions material science plays a pivotal role. At Empa we understand material science as an interdisciplinary approach bringing together chemistry, physics, biology and the engineering sciences in order to create innovations of industrial and societal relevance. One example for this is our initiative "Materials2Devices": By combining material synthesis and characterization on the nanoscale with research on upscaling and manufacturing processes, we are accelerating the adoption of basic science in real devices. Thereby the physical understanding of our new materials on the nanoscale plays a key role. During this talk, this will be illustrated by giving insights into different examples ranging from batteries & photovoltaics all the way to quantum heat engines.</p>
10:30 – 11:00	<p>Coffee Break</p>
11:00 – 11:30	<p style="text-align: center;">CERN's strategy for an environmentally responsible research</p> <p style="text-align: center;"><i>Sonja Kleiner, Head of the CERN HSE Environment Group</i></p> <p>As the World's largest particle physics research laboratory, CERN strives to deliver world-class scientific results and knowledge, while embedding environmental responsibility and sustainability in its activities. This contribution will present CERN's approach for environmentally responsible research. It will outline the present footprint of the Organization and the current projects, with a particular focus on energy related matters, aimed at minimising the laboratory's impact on the environment across its accelerators, experiments as well as its site and campus facilities. How CERN contributes to the development of technologies that may help to mitigating the impact of society on the environment will also be discussed.</p>
11:30 – 12:00	<p style="text-align: center;">A sustainable future in High-Energy physics</p> <p style="text-align: center;"><i>Patrick Koppenburg, Nikhef, Amsterdam & CERN, LHCb and future collider experiments</i></p> <p>The climate crisis and the degradation of the world's ecosystems require humanity to take immediate action. The international scientific community has a responsibility to limit the negative environmental impacts of basic research. The HECAP+ communities (High Energy Physics, Cosmology, Astroparticle Physics, and Hadron and Nuclear Physics) make use of common and similar experimental infrastructure, such as accelerators and observatories, and rely similarly on the processing of big data. Our communities therefore face similar challenges to improving the sustainability of our research. This talk will reflect on our work practices and research infrastructure and identify the opportunities and challenges, with a particular emphasis on the long-term future of particle physics.</p>
12:00 – 12:30	<p style="text-align: center;">Q&A and Panel Discussion</p> <p style="text-align: center;"><i>Moderator: Hugo Zbinden, Applied Physics, University of Geneva</i></p>
12:30	<p>END</p>

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 Dienstag von 19:45 - 21:30 (mit Apéro) sowie am Mittwoch von 13:00 - 14:30 (mit Lunch Buffet) statt.
- (p) = Plenarsprecher, (i) = eingeladene Sprecher

Das Programm am Montag 09. September 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 a lieu le mardi de 19:45 à 21:30 (avec apéro) ainsi que le mercredi de 13:00 à 14:30 (avec buffet de midi).
- (p) = orateur de la session plénière, (i) = orateur invité

Le programme du lundi 9 septembre est exempt des frais de la conférence. Il est seulement nécessaire de s'inscrire pour les autres journées.

Special: Physics funding in Switzerland

Monday, 09.09.2024, Room ETA F 5

Time	ID	OFFICIAL CONFERENCE OPENING
10:20		Welcome note Joël Mesot
		PHYSICS FUNDING IN SWITZERLAND Chair: NN
10:30		The program of this session is not yet defined. Details will be published as soon as possible on our website.
		Discussion
12:00		END; Lunch
13:00		General Assemblies of SPS * and SSPH **
14:00		Buffer Time

* SPS: Room ETZ E 6; ** SSPH: Room ETZ E 8

Public Symposium:

Louis de Broglie: 100 years of wave / particle dualism & Public Lecture

Monday, 09.09.2024, Room ETA F 5

Time	ID	LOUIS DE BROGLIE: 100 YEARS OF WAVE / PARTICLE DUALISM Chair: Teresa Montaruli, Université de Genève
14:30	6	Matter and Light: Louis de Broglie and our current understanding of physics Friedrich-Karl Thielemann (p) Chair: Johan Chang, Universität Zürich
15:15	7	Waves of Quantum Matter Tilman Esslinger (p)
16:00		Coffee Break

Time	ID	Chair: Michel Calame, Empa & Universität Basel
16:30	8	Wave-particle duality in atom interferometers: precision measurements at the quantum limit Philipp Treutlein (p)
		Chair: Christof Fattering
17:15	9	Single electron imaging vs. coherent electron beam diffraction: Optimization of image contrast in cryo-electron microscopy Henning Stahlberg (p)
18:00		END, Break
		PUBLIC LECTURE Chair: Lukas Gallmann, ETH Zürich
18:30	10	The route to attosecond pulses Anne l'Huillier (p)
19:45		END

Plenary Session

Tuesday, 10.09.2024, Room ETA F 5

Time	ID	PLENARY SESSION I Chair: Philippe Jetzer, Universität Zürich
09:00	11	Physics of the early universe and the intensity frontier of particle physics Mikhail Shaposhnikov (p)
09:45		Award Ceremony
10:30		Coffee Break
		Chair: NN
11:00	12	Hyperbolic lattices: from table-top simulators to non-Abelian band theory Patrick Lenggenhager (i) Chair: Marc Janoschek, PSI Villigen
11:30	13	Effect of Softness and Charges on the Volume Phase Transition of Colloidal Microgels and Macro-gels studied via SANS Boyang Zhou (i)
		WOMEN IN PHYSICS CAREER SYMPOSIUM Chair: Tobias Golling Université de Genève
12:00	14	Introduction
12:15	15	Keynote: Petra Rudolf (p)
13:00		Lunch
14:00		Topical Sessions

Time	ID	SPECIAL: 70TH ANNIVERSARY OF CERN <i>Chair: NN</i>
18:30	16	CERN: Past, Present, and Future <i>Günther Dissertori (p)</i>
19:10	17	Panel Discussion <i>Fabiola Gianotti (CERN Director General)</i> <i>Further names yet to be defined.</i>
19:45		Postersession with Apéro <i>including a special set of posters related to the 70th Anniversary of CERN</i>
21:30		END

Wednesday, 11.09.2024, Room ETA F 5

Time	ID	PLENARY SESSION II <i>Chair: Christof Fattinger</i>
09:00	18	Structural Biology and Interaction Analysis in Drug Discovery <i>Matthias E. Lauer (p)</i>
		<i>Chair: NN</i>
09:45	19	Hybrid III-V/Silicon photonics <i>Kirsten Moselund (p)</i>
10:30		Coffee Break <i>Chair: Valeria Bragaglia, IBM Rueschlikon</i>
11:00	20	Neuromorphic Intelligence: spiking neural network and on-line learning circuits for brain-inspired technologies <i>Giacomo Indiveri (p)</i>
		<i>Chair: NN</i>
11:45	21	New challenges in quantum magnetism <i>Frédéric Mila (i)</i>
		<i>Chair: Andreas Müller, Université de Genève</i>
12:15	22	Physics and Education - A Journey into Plasma Physics <i>Dirk Hegemann (p)</i>
13:00		Postersession with Lunchbuffet
14:30		Topical Sessions
19:30		

Thursday, 12.09.2024, Room ETA F 5

Time	ID	PLENARY SESSION III <i>Chair: Leonid Rivkin, PSI Villigen</i>
09:00	23	Attosecond Pulses from X-ray Free-electron Lasers: Status and Outlook <i>Sven Reiche (p)</i>
		<i>Chair: Philippe Jetzer, Universität Zürich</i>
09:45	24	Questions in Theoretical Cosmology <i>Leonardo Senatore (p)</i>
10:30		Poster Award Session
10:45		Coffee Break <i>Chair: Jean-Philippe Brantut, EPFL</i>
11:15	25	Quantum Science with Superconducting Circuits <i>Andreas Wallraff (p)</i>
		<i>Chair: Sahand Jamal Rahi, EPFL</i>
12:00	26	How do single bacterial cells think? <i>Erik van Nimwegen (p)</i>
12:45		Lunch

14:00		Topical Sessions
19:00		Transfer to Dinner
19:30		Conference Dinner

Friday, 13.09.2024, Room ETA F 5

Time	ID	ENERGY AND SUSTAINABILITY: RESEARCH NEEDS FOR A SUSTAINABLE ENERGY TRANSITION <i>Chair: Thomas Christen, Hitachi Energy</i>
09:00	31	The Future of the Electrical Energy System: from Rotating Masses to Power Electronic <i>Gabriela Hug (p)</i>
09:30	32	The Swiss Energy Transition to NetZero <i>Thomas J. Schmidt (p)</i>
10:00	33	From Materials to Devices: The importance of physics in material science & technology for sustainable energy application <i>Lorenz Herrmann (p)</i>
10:30		Coffee Break <i>Chair: Tomoko Muranaka, EPFL</i>
11:00	34	CERN's strategy for an environmentally responsible research <i>Sonja Kleiner (p)</i>
11:30	35	A sustainable future in High-Energy physics <i>Patrick Koppenburg (p)</i>
		Moderation: <i>Hugo Zbinden, Université de Genève</i>
12:00	36	Panel Discussion
12:30		End; Lunch
13:30		Topical Sessions
16:00		CONFERENCE END

Women in Physics Career Symposium

THIS EVENT IS SUPPORTED BY
UNIVERSITÄT ZÜRICH, PSI VILLAGEN, SPS, SCNAT,
AND UNIVERSITÉ DE GENÈVE.

Tuesday, 10.09.2024, Room ETZ E 6

Time	ID	WOMEN IN PHYSICS CAREER SYMPOSIUM <i>Chair: Tobias Golling Université de Genève</i>
14:00	41	Career Talk 1: Laura Bégon-Lours
14:30	42	Career Talk 2: Ilaria Zardo
15:00	43	<i>Mentors and Mentees introduce themselves</i>
16:00		Coffee Break
16:30	44	<i>Mentor - Mentee Meetups</i>
17:30	45	Career Talk 3: Janine Haase
18:00	46	Career Talk 4: Anna Fontcuberta i Morral
18:30		END; CERN 70
19:45		Postersession with Apéro

Startups: The role of physics and physicists in developing a product ?

Wednesday, 11.09.2024, Room ETZ E 6

Time	ID	STARTUPS: THE ROLE OF PHYSICS AND PHYSICISTS IN DEVELOPING A PRODUCT ? Chair: Gian Salis IBM Rüschlikon, Valeria Bragaglia, IBM Rüschlikon
14:30	51	Navigating the Conservative Chip Industry: Strategies for Introducing Disruptive Technologies Manu Nair (i)
14:50	52	Axelera AI: Technology Deep Dive Riduan Khaddam Aljameh (i)
15:10	53	BTO-enhanced silicon photonics – PICs for communication and switching based on the Pockels effect Thomas Kornher (i)
15:30	54	Luxtelligence: Illuminating faster datacenters with ferroelectrics Mohammad Bereyhi (i)
15:50	55	From concept to market: the role of a scientist at Polariton Technologies Youri Popoff (i)
16:10	56	Intellectual Property (IP) as an important asset for your Start-up Catalin Cris (i)
16:30		Coffee Break
17:00	57	Building great products from fundamental research Mathieu Munsch (i)
17:20	58	Membrane-less Redox Flow Batteries using Liquid/Liquid Interfaces Federico Paratore (i)
17:40	59	From Lab to Startup: The Journey of condenZero Denys Sutter (i)
18:00	60	Making dirt shine - contamination analysis for semiconductor manufacturing Philip Eib (i)
18:20		END

History and Philosophy of Physics

Wednesday, 11.09.2024, Room ETZ E 7

Time	ID	HISTORY AND PHILOSOPHY OF PHYSICS Chair: Claus Beisbart, Universität Bern
14:30		The program of this session is not yet defined. Details will be published as soon as possible on our website.
16:30		END; Coffee Break

Physics education and communication: Good practice examples within the Swiss Physics Community

Friday, 13.09.2024, Room ETZ E 8

Time	ID	PHYSICS EDUCATION AND COMMUNICATION: GOOD PRACTICE EXAMPLES WITHIN THE SWISS PHYSICS COMMUNITY Chair: Andreas Müller, Université de Genève
13:30	91A 91B	A Course on General Relativity and Cosmology for High School Students Alice Gasparini A hands-on test module in schools on astrophysics and computer science Matthieu Heller, Sebastien Murphy
14:00	92	Physics in Advent Gernot Scheerer
14:20	93A 93B	Physics and Sustainability at School and at University Peter Kreuzer, Tomoko Muranaka
14:40	94	International Physicists' Tournament and International Young Physicists' Tournament Samuel Byland, Mathieu Suter
15:00	95	Youth@STEM4SF Barbora Gulejova
15:20	96	Discussion
15:45		END

KOND

Tuesday, 10.09.2024, Room ETZ E 7

Time	ID	KOND I: COUPLED DEGREES OF FREEDOM Chair: NN
14:00	101	Coupled magnetism and ferroelectricity in magnetic high entropy oxide Roxana Capu
14:15	102	Terahertz electric-field-driven dynamical multiferroicity in SrTiO ₃ Martina Basini
14:30	103	Phonon-Polariton Nonlinearities in Ferroelectric LiNbO ₃ Rossella Acampora
14:45	104	Strong enhancement of superconductivity in fractal lattices Askar Iliasov
15:00	105	Decoupled static and dynamical charge correlations in La _{2-x} Sr _x CuO ₄ Leonardo Martinelli
15:15	106	Investigation of the phase transition driven by ultrashort laser pulses in the charge-density-wave material K _{0.3} MoO ₃ Rafael T. Winkler
15:30	107	Resonant Ultrasound Spectroscopy Study of the Vortex Lattice Phase Diagram of Niobium Xuan Dang Dang
15:45	108	Tuning the Electronic Properties of Two-Dimensional Lepidocrocite Titanium Dioxide-Based Heterojunctions Kati Asikainen
16:00		Coffee Break
18:30		CERN 70
19:45		Postersession with Apéro

Thursday, 12.09.2024, Room ETZ E 7

Time	ID	KOND II: ADVANCES IN METHODOLOGY Chair: NN
14:00	111	Characterization of high-purity nickel single crystals by mechanical spectroscopy <i>Anna Nastruzzi</i>
14:15	112	Imaging heat transport in suspended diamond nanostructures with integrated spin defects thermometers <i>Valentin Goblot</i>
14:30	113	Electronic Viscous Flow in Hexagonal Boron Nitride Encapsulated Graphene FETs <i>Wenhao Huang</i>
14:45	114	Laser induced structural dynamics in colloidal gold nanoparticles <i>Changji Pan</i>
15:00	115	Ultrafast EBIC: A new technique for semiconductor device characterization with ps time resolution <i>Joel Rehmann</i>
15:15	116	Growth by pulsed laser deposition of SrVO ₃ thin films for optical applications <i>Tancredi Thai Angeloni</i>
15:30	117	Increasing the dynamical range of a scanning tunneling microscope <i>Ajla Karic</i>
15:45	118	Analytical redefinition of the adsorbate-induced surface response of a metal <i>Aleksandra Siklitskaya</i>
16:00		
16:30		Coffee Break
19:00		Transfer to Dinner
19:30		Conference Dinner

Friday, 13.09.2024, Room ETZ E 7

Time	ID	KOND III: MANY-BODY SYSTEMS Chair: NN
13:30	121	Collective Advantages in Finite-Time Thermodynamics <i>Alberto Rolandi (i)</i>
14:00	122	Magnetostriction measurements of quantum spin ice candidates at ultra-low temperatures <i>Ilaria Villa</i>
14:15	123	Quantum Phase Transitions with a Lee-Yang Method and Many-Body Algorithms <i>Pascal Vecsei</i>
14:30	124	Hybrid Tree Tensor Networks for quantum simulation <i>Julian Schuhmacher</i>
14:45	125	Benchmarking digital quantum simulations and optimization above hundreds of qubits using quantum critical dynamics <i>Alexander Miessen</i>
15:00	126	Fractional Topological Insulators in Twisted Transition Metal Dichalcogenides <i>Glenn Wagner</i>
15:15	127	Ferromagnetic quantum critical point protected by nonsymmorphic symmetry in a dense Kondo metal CeSi _{1.97} <i>Soohyeon Shin</i>
15:30		END

ID	KOND POSTER
141	The three-dimensional multiferroic domain structure of hexagonal manganites <i>Aaron Merlin Müller</i>
142	Identification of Defect-Sensitive Raman Modes in 9-Atom-Wide Armchair Graphene Nanoribbons <i>Ángel Labordet</i>
143	Symmetry broken phases of field biased Bernal bilayer graphene <i>Enrique Aguilar-Mendez</i>

Magnetic fields for materials research

THIS SESSION IS SUPPORTED BY THE EU PROJECT ISABEL.
([HTTPS://EMFL.EU/ISABEL/H2020-PROJECT/](https://emfl.eu/isabel/h2020-project/))

Thursday, 12.09.2024, Room ETZ E 8

Time	ID	MAGNETIC FIELDS FOR MATERIALS RESEARCH Chair: Stefano Gariglio, Université de Genève
17:00	181	Title not yet known NN
17:30	182	Engineering Phase Competition Between Stripe Order and Superconductivity in La _{1.88} Sr _{0.12} CuO ₄ <i>Julia Küspert (i)</i>
18:00	183	Influence of Oxygen Source on the High Magnetic Field Behavior of Nb ₃ Sn Wires Manufactured via Internal Oxidation <i>Gianmarco Bovone (i)</i>
18:30	184	Title not yet known NN
19:00		END; Transfer to Dinner
19:30		Conference Dinner

Applied Physics

Wednesday, 11.09.2024, Room ETF C 1

Time	ID	APPLIED PHYSICS I: PHYSICS APPLIED TO MEDICINE Chair: Leonid Rivkin, PSI Villigen
17:00	201	Advanced X-ray imaging: from the nanoscale at synchrotrons to clinical applications in hospitals <i>Marco Stampanoni (i)</i>
17:30	202	Isotopes for diagnostics and therapy of cancer <i>Roger Schibli (i)</i>
18:00	203	Proton therapy developments at PSI <i>Anthony Lomax (i)</i>
18:30	204	FLASH therapy <i>David Meer</i>
18:45	205	DEFT - A Very High Energy Electron linac for FLASH radiotherapy <i>Terence Garvey</i>
19:00	206	In-vivo range verification of proton therapy treatment with the PETITION PET scanner <i>Keegan McNamara</i>
19:15	207	PETITION PET scanner for biological adaptation of the proton treatment plan <i>Shubhangi Makkar</i>
19:30	208	POSiCS a handable gamma-camera for radio-guided surgery <i>Cyril Alispach</i>

19:45	209	Advantages and drawbacks of a back-scattering Mueller polarimetric setup comparing with surface imaging one <i>Vladislav Stefanov</i>
20:00		END

Thursday, 12.09.2024, Room ETZ E 7

Time	ID	APPLIED PHYSICS II: APPLIED PHYSICS & PLASMA PHYSICS (COMBINED SESSION) Chair: Laurie Porte, EPFL
17:00	211	Analysis of natural disruptions on JET with JOREK <i>Lili Edes</i>
17:15	212	MHD simulations of runaway electron avalanche in ITER mitigated disruptions <i>Chizhou Wang</i>
17:30	213	Kinetic simulations of the magnetized plasma-wall boundary layer in fusion devices <i>Nicole Vadot</i>
17:45	214	Turbulence-inclusive Modelling of Electron-Cyclotron Wave-Plasma Dynamics in Tokamaks <i>Ewout Devlaminck</i>
18:00	215	Sub-micrometric hollow channels in bulk fused silica <i>Pasquale Barbato</i>
18:15	216	Detection of land mines and unexploded ordnance <i>Yves Marc Acremann</i>
18:30		END
19:00		Transfer to Dinner
19:30		Conference Dinner

ID	APPLIED PHYSICS POSTER
231	Calibration of reflection and back-scattering Mueller Polarimetric setups <i>Bhanu Pratap Singh</i>

Accelerator Science and Technology

Friday, 13.09.2024, Room ETZ E 6

Time	ID	ACCELERATOR SCIENCE AND TECHNOLOGY Chair: Mike Seidel, PSI Villigen
13:30	281	High Field Magnet Roadmap at PSI/CHART <i>Douglas Martins Araujo</i>
13:45	282	NI magnet projects at PSI <i>Jaap Kosse</i>
14:00	283	Optimization and Shimming of a High Temperature Superconducting Bulk Undulator <i>Carlos Gafa</i>
14:15	284	Energy-efficient FCC-ee operation via HTS nested magnets <i>Jaap Kosse</i>
14:30	285	Lattice correction and polarization estimation for the Future Circular Collider e ⁺ e ⁻ <i>Yi Wu</i>
14:45	286	Controlling the electron beam energy at SwissFEL <i>Evan Ericson</i>
15:00	287	High Gradient Photoguns for a Potential Upgrade to the SwissFEL <i>Thomas Geoffrey Lucas</i>

15:15	288	Development and Optimization of a Field-Emission based Electron Gun for Low Energy Electron Cooling at ELENA <i>Elisabeth-Sena Welker</i>
15:30	289	Beam dynamics studies of performance reach of future ion species in the CERN accelerator complex <i>Elias Walter Waagaard</i>
15:45	290	Muon Collider Feasibility Studies: Collective effects and muon cooling <i>Joséphine Marie Bénédicte Potdevin</i>
16:00		END

Nuclear, Particle and Astrophysics (TASK)

THIS SESSION HAS BEEN ORGANISED IN COLLABORATION WITH
CHIPP.

Tuesday, 10.09.2024, Room ETA F 5

Time	ID	TASK I: DETECTOR AND PERFORMANCE I Chair: NN
14:00	301	Tests and results of the power components of the ATLAS Inner Tracker detector readout system. <i>Lucas Mollier</i>
14:15	302	Performance tests of the ATLAS Inner Tracker Pixel detector opto-electrical conversion system <i>Marianna Glazewska</i>
14:30	303	Data transmission tests of the ATLAS Inner Tracker Detector opto-electrical conversion system. <i>Una Helena Alberti</i>
14:45	304	Timing measurement ASIC using LGAD for possible HL-LHC upgrade <i>Abderrahmane Ghimouz</i>
15:00	305	Radiation hardness and annealing, strategies for space application of silicon photomultiplier technologies on a quasi-polar LEO orbit <i>Shideh Davarpanah</i>
15:15	306	CMS ECAL on-detector readout electronics radiation tests <i>Nico Härringer</i>
15:30	307	TEPX Detector for the CMS Inner Tracker Upgrade: Module Production Status and Plans <i>Amrutha Samalan</i>
15:45	308	MONOLITH - picosecond capability in a high granularity monolithic silicon pixel detector <i>Matteo Milanese</i>
16:00		Coffee Break
		TASK II: DETECTOR AND PERFORMANCE II Chair: NN
16:30	311	Production and Qualification of the Vertex Detector for the Mu3e Detector <i>Thomas Christian Senger</i>
16:45	312	Construction and Commissioning Status Report on Mu3e Experiment <i>Yifeng Wang</i>
17:00	313	Cryogenic Characterization of Neutron-Irradiated SiPMs <i>Esteban Curras Rivera</i>
17:15	314	The Outer Detector of the LUX ZEPLIN dark matter direct detection experiment <i>Harvey Birch</i>
17:30	315	Outer Detector Energy Calibration of the LUX-ZEPLIN Experiment <i>Miguel Hernandez</i>

17:45	316	Results from low temperature wafer-wafer bonded pad-diodes for particle detection <i>Johannes Martin Wüthrich</i>
18:00		
18:30		CERN 70
19:45		Postersession with Apéro

Wednesday, 11.09.2024, Room ETA F 5

Time	ID	TASK III: LOW ENERGY I <i>Chair: NN</i>
14:30	321	The n2EDM experiment - A search for new physics at the precision frontier <i>Wenting Chen</i>
14:45	322	An Active Magnetic Shield for the n2EDM Experiment - Simulation and Optimization <i>Sergey Ermakov</i>
15:00	323	An efficient spin transport system for ultracold neutrons in the n2EDM experiment <i>Gian Luca Caratsch</i>
15:15	324	A high-sensitivity Cesium magnetometer array for the n2EDM experiment <i>Victoria Kletzl</i>
15:30	325	The muEDM experiment at PSI <i>David Höhl</i>
15:45	326	Preliminary Results for the Injection Studies at Low Magnetic Fields for the muEDM Experiment <i>Diego A. Sanz-Becerra</i>
16:00	327	Muonic Atom Spectroscopy of ^{238}U <i>Anastasia Doinaki</i>
16:15		
16:30		Coffee Break
		TASK IV: LOW ENERGY II <i>Chair: NN</i>
17:00	331	Measurement of the X17 anomaly with the MEG II detector <i>Giovanni Dal Maso</i>
17:15	332	Results of the neutron to mirror-neutron oscillations at PSI <i>Nathalie Ziehl</i>
17:30	333	High-Resolution Spectroscopy of Muonic Lithium - First Steps and Prospects of the QUARTET Experiment <i>Katharina von Schoeler</i>
17:45	334	Radiative corrections and Monte Carlo tools for low-energy e^+e^- experiments <i>Sophie Kollatzsch</i>
18:00	335	Probing neutrinoless double beta decay with LEG-END <i>Aravind Remesan Sreekala</i>
18:15		

Wednesday, 11.09.2024, Room ETZ E 7

Time	ID	TASK V: PHYSICS AT LHCb <i>Chair: NN</i>
17:00	341	Heavy flavour spectroscopy at LHCb <i>Daniel Charles Craik</i>
17:15	342	Measurement of the branching ratio of $B^+ \rightarrow K^+ \pi^+ \pi^- \mu^+ \mu^-$ at LHCb <i>Anni Kauniskangas</i>
17:30	343	Search for the $B_s^0 \rightarrow \mu^+ \mu^- \gamma$ decay with photon conversions <i>Raphael van Laak</i>

17:45	344	Measurement of $\text{BR}(B_s \rightarrow K_s K_s)$ with Run 2 LHCb data <i>Kerim Guseinov</i>
18:00	345	Search for $K^0 \rightarrow \pi^+ \pi^- \mu^+ \mu^-$ decays with the Run II LHCb data <i>Luis Miguel Garcia Martin</i>
18:15	346	Search for violation of leptonic universality in Semileptonic Hyperon Decays in LHCb <i>Alexandre Brea Rodriguez</i>
18:30	347	Search for the $B_{(c)}^+ \rightarrow \tau^+ \nu_\tau$ decay at LHCb <i>Rita de Sousa Ataíde da Silva</i>
18:45	348	Search for axion-like particles at LHCb <i>Pasquale Andreola</i>
19:00		

Thursday, 12.09.2024, Room ETA F 5

Time	ID	TASK VI: MACHINE LEARNING <i>Chair: NN</i>
14:00	351	Machine Learning Methods for Top Reconstruction using the ATLAS Experiment <i>Daniele Dal Santo</i>
14:15	352	Anomaly detection techniques for ATLAS calorimeter data quality monitoring <i>Vilius Čepaitis</i>
14:30	353	Pileup for physics: building a novel hadronic physics dataset <i>Carlos Moreno Martinez</i>
14:45	354	Mitigating experimental challenges in using pileup for physics <i>Mario Alves Cardoso</i>
15:00	355	Extracting the jet energy resolution from pileup collisions <i>Antti Pirttikoski</i>
15:15	356	Machine Learning in $b \rightarrow s$ II <i>Jason Aebischer</i>
15:30	357	Leveraging transformers and RL to identify key b-hadron backgrounds <i>William Sutcliffe</i>
15:45	358	Towards an AI-based trigger system for the next-generation of imaging atmospheric Cherenkov telescope cameras <i>Tjark Miener</i>
16:00	359	Deep Learning-Based Data Processing in Large-Sized Telescopes of the Cherenkov Telescope Array: FPGA Implementation <i>Carlos Abellan Beteta</i>
16:15		
16:30		Coffee Break
		TASK VII: NEW PHYSICS SEARCHES AT CERN <i>Chair: NN</i>
17:00	361	Search for Axion-Like Particles in Photonic Final States with the FASER Detector at the LHC <i>Noshin Tarannum</i>
17:15	362	LHC Neutrinos at FASERnu and Neutrino Energy Reconstruction Methods <i>Jeremy Atkinson</i>
17:30	363	Exploring the hadronic landscapes, a novel search in multijet Events at the ATLAS Experiment <i>Stefano Franchellucci</i>
17:45	364	Search for Top Squark Pair Production with zero Lepton Final States using ATLAS Run 3 Data <i>Meinrad Moritz Schefer</i>
18:00	365	Growing Evidence for a Higgs Triplet at the LHC <i>Sumit Banik</i>
18:15	366	New Higgses at the Electroweak Scale <i>Guglielmo Coloretti</i>

18:30	367	Recent results from the NA62 experiment at CERN SPS <i>Xiafei Chang</i>
18:45	368	BDF/SHiP at the SPS ECN3 high-intensity beam facility <i>Martina Ferrillo</i>
19:00		Transfer to Dinner
19:30		Conference Dinner

Friday, 13.09.2024, Room ETA F 5

Time	ID	TASK VIII: ASTROPARTICLE PHYSICS AND DARK MATTER <i>Chair: NN</i>
13:30	371	Search for gamma-ray spectral lines from dark-matter annihilation with the DAMPE satellite <i>Jennifer Maria Frieden</i>
13:45	372	MiniFIT, The Small-Scale Version of the HERD Tracking System, From Design to Performance <i>Chiara Perrina</i>
14:00	373	Terzina Telescope: Pioneering the Detection of Cherenkov Light from Extensive Air Showers in Space <i>Martina D'Arco</i>
14:15	374	A comprehensive study of muons detected by the Large-Sized Telescope during its commission phase. <i>Vadym Voitsekhovskiy</i>
14:30	375	The next generation cameras for the Large-Sized Telescopes of the Cherenkov Telescope Array Observatory <i>Leonid Burmistrov</i>
14.45	376	Testing gravity through the distortion of time <i>Sveva Castello</i>
15:00		END

ID	TASK POSTER
381	Towards Precision X-Ray Spectroscopy of Muonic low-Z Atoms Using Metallic Magnetic Calorimeters <i>Aziza Zendour</i>
382	Detector system to study early-to-late stability of the muEDM experiment <i>Chavdar Dutsov</i>
383	Initial Results From the Michigan Xenon Experiment (MiX) <i>Erin Barillier</i>
384	Electric and magnetic field studies towards muon storage in the search for a muon electric dipole moment <i>Timothy Hume</i>
385	Precision 3D monitoring of the LHCb SciFi tracker alignment using BCAMs <i>Dimitrios Kaminaris</i>
386	SST-1M Telescopes, Preliminary Results and Deep Learning Event Reconstruction with CTLearn <i>Bastien Lacave</i>
387	Atomic Electron Detector for the LEMING experiment <i>Paul Wegmann</i>
388	An external array of remote magnetometers for the n2EDM experiment <i>Philipp Wagner</i>
389	Generate parton-level events from reconstructed events with Conditional Normalizing Flows <i>Adrian-Antonio Petre</i>
390	Production and characterization of the Cesium magnetometer cells for the n2EDM experiment <i>Lea Segner</i>

Atomic Physics and Quantum Optics

Thursday, 12.09.2024, Room ETF E 1

Time	ID	ATOMIC PHYSICS AND QUANTUM OPTICS I <i>Chair: Jean-Philippe Brantut, EPFL</i>
14:00	401	Language models for the simulation of quantum many-body <i>Juan Carasquilla (i)</i>
14:30	402	Einstein-Podolsky-Rosen experiment with two Bose-Einstein condensates <i>Paolo Colciaghi (i)</i>
15:00	403	Quantum synchronization through the interference blockade <i>Tobias Kehrler</i>
15:15	404	Quantum backflow within circular geometry <i>Arseni Goussev</i>
15:30	405	Universal entropy transport far from equilibrium across the BCS-BEC crossover <i>Meng-Zi Huang</i>
15:45	406	Nonreciprocal synchronization of active quantum spins <i>Tobias Nadolny</i>
16:00	407	Towards a two-qubit gate with grid states encoded in the motion of a trapped ion <i>Florence Berterotière</i>
16:15	408	On-chip time-bin-entangled quantum state generation and tomography for optical quantum communication <i>Giovanni Finco</i>
16:30		Coffee Break
		ATOMIC PHYSICS AND QUANTUM OPTICS II <i>Chair: NN</i>
17:00	411	Quantum technologies for trapped molecular ions <i>Stefan Willitsch (i)</i>
17:30	412	Metrology of highly excited states of the hydrogen atom <i>Simon Scheidegger (i)</i>
18:00	413	Progress towards multi-particle entanglement generation and manipulation in an optical tweezer array of ¹⁷¹ Yb nuclear-spin qubits <i>Alexander Baumgärtner</i>
18:15	414	A cavity-microscope for micrometer-scale control of atom-photon interactions <i>Michael Alexander Eichenberger</i>
18:30	415	Exploiting frequency metrology fiber networks for earthquake sensing <i>Dominik Husmann</i>
18:45	416	Bragg-spectroscopy of a dissipation-induced instability in an atom-cavity system <i>Gabriele Natale</i>
19:00		Transfer to Dinner
19:30		Conference Dinner

ID	ATOMIC PHYSICS AND QUANTUM OPTICS POSTER
431	Towards laser cooling of negative molecular ions <i>Matthias Germann</i>
432	Counter-propagating spontaneous parametric down-conversion source <i>Jost Kellner</i>

Gravitational Waves

Wednesday, 11.09.2024, Room ETZ E 8

Time	ID	GRAVITATIONAL WAVES I <i>Chair: Steven Schramm, Université de Genève</i>
14:30	451	Observational Prospects of Self-Interacting Scalar Ultralight Boson Clouds with Next-Generation Gravitational-Wave Detectors <i>Spencer Collaviti</i>
14:45	452	Fast identification of GW signals at the future Einstein Telescope <i>Sarah Baimukhametova</i>
15:00	453	Bright siren cosmology with the Einstein Telescope <i>Niccolò Muttoni</i>
15:15	454	Mass transfer stability shaping the merging BBH mass distribution <i>Max Briel</i>
15:30	455	Coupling elastic media to gravitational waves: an effective field theory approach <i>Thomas Moreau</i>
15:45	456	The impact of large-scale galaxy clustering on pulsar timing array experiments <i>Nastassia Grimm</i>
16:00	457	Global Fit of LISA Data with Galactic Binaries and Massive Black Hole Binaries <i>Stefan Strub</i>
16:15	458	Astrophysical imprints on the LISA data stream from Massive Black Hole Binaries <i>Mudit Garg</i>
16:30		Coffee Break
		GRAVITATIONAL WAVES II <i>Chair: Philippe Jetzer, Universität Zürich</i>
17:00	461	LISA Parameter Estimation with Time Domain Waveforms <i>Cecilio Garcia Quiros</i>
17:15	462	Detection and Mitigation of Glitches in LISA Data: A Machine Learning Approach <i>Niklas Houba</i>
17:30	463	Wave optics lensing of gravitational waves in the LISA band <i>Martin Pijnenburg</i>
17:45	464	Waveforms in the Post-Minkowskian Expansion <i>Lara Bohnenblust</i>
18:00	465	Data-Driven Analysis of Gravitational-Wave Source Progenitors Using Flow Matching <i>Nodens Koren</i>
18:15	466	Towards Gravitational Wave Multi-Source Parameter Inference <i>Janis Fluri</i>
18:30		<i>GW-learn Sinergia meeting</i>
19:30		END

ID	GRAVITATIONAL WAVES POSTER
481	Supermassive Stars in proto-globular clusters: Investigating Runaway Collisions and Mass Loss <i>Tassos Fragos</i>
482	Low Latency Merger Time Prediction of Massive Black Hole Binaries of LISA Data with Neural Posterior Estimation <i>Stefan Strub</i>

Electron and photon spectroscopies of quantum materials

Wednesday, 11.09.2024, Room ETF E 1

Time	ID	ELECTRON AND PHOTON SPECTROSCOPIES OF QUANTUM MATERIALS I <i>Chair: Luc Patthey, PSI Villigen</i>
14:30	501	Fast and furious: the fate of quasiparticles at high temperature <i>Anna Tamai (i)</i>
15:00	502	Interfacial electron-phonon coupling at a WS₂/hBN interface <i>Gianmarco Gatti</i>
15:15	503	Electronic band structure of strained germanium: bridging theory with direct experimental evidence <i>Enrico Della Valle</i>
15:30	504	New Developments in Deflector Analyzer Technology for ARPES <i>Saumya Mukherjee</i>
15:45	505	Doping and temperature dependence evolution of the electronic properties of electron-doped Sr₂IrO₄ seen by ARPES <i>Yann Alexanian</i>
16:00	506	Unveiling the Electronic Properties of α-SnTe: From Ferroelectric Distortion to Unexpected Topological Surface State <i>Frédéric Chassot</i>
16:15	507	Characterization of Excitons for bulk Black Phosphorus <i>Juan F. P. Mosquera</i>
16:30		Coffee Break
		ELECTRON AND PHOTON SPECTROSCOPIES OF QUANTUM MATERIALS II <i>Chair: Claude Monney, Université de Fribourg</i>
17:00	511	Exciton dynamics in two-dimensional quantum materials in space and time <i>Stefan Mathias (i)</i>
17:30	512	The Balance Between Independent and Correlated Electron Dynamics in Transition Metals <i>Erik de Vos</i>
17:45	513	Anomalous magnetic excitations in the half-filled TI-based cuprate <i>Izabela Bialo (i)</i>
18:15	514	Exploring Low-Energy Excitations and Magnetic Dichroism in Resonant Inelastic X-ray Scattering of the Ferromagnetic van der Waals Material VI₃ <i>Yuan Wei</i>
18:30	515	Spin-orbital correlations in the van der Waals magnet CrPS₄ revealed by resonant inelastic X-ray scattering <i>Zhijia Zhang</i>
18:45	516	Altermagnetism at manganite/cuprate interface <i>Yurii Pashkevich</i>
19:00	517	Charge order fluctuations in a stripe-ordered cuprate superconductor <i>Xunyang Hong</i>
19:15		END

ID	ELECTRON AND PHOTON SPECTROSCOPIES OF QUANTUM MATERIALS POSTER
531	Quantum Material Dynamics Under Pressure <i>Zia Macdermid</i>
532	Probing mono- and few-layer 1T-TaSe₂ with ARPES <i>Salony Mandloi</i>

533	Electronic structure of encapsulated mono-, bi- and trilayer Td-MoTe ₂ <i>Julia Issing</i>
534	Integrated Synchrotron X-ray and Raman Techniques for the Determination of the Fill Factor and Thickness of III-V Semiconductor Nanowire Layers grown on a Substrate <i>Dimitrios Sapalidis</i>

Spintronics and Magnetism at the Nanoscale

Tuesday, 10.09.2024, Room ETZ E 8

Time	ID	SPINTRONICS AND MAGNETISM AT THE NANOSCALE I <i>Chair: Jeffrey A. Brock, ETH Zürich & PSI Villigen</i>
14:00	601	Orbital spin-offs <i>Pietro Gambardella (i)</i>
14:30	602	Phase Transitions and Magnetic Order in a Ruby Lattice Artificial Spin Ice <i>Luca Berchialla</i>
14:45	603	Reversal time of a magnetic Cobalt nanoparticle with defects <i>Hugo Bocquet</i>
15:00	604	Micro- and nanomagnet stray field investigation for manipulation of spin qubits <i>Michele Aldeghi</i>
15:15	605	Observation of Ultrashort Spin Voltage and -Accumulation <i>Francisco Carrion Ruiz</i>
15:30	606	The magnetoelectric deflection effect <i>Samuel Harrison Moody</i>
15:45		
16:00		Coffee Break
		SPINTRONICS AND MAGNETISM AT THE NANOSCALE II <i>Chair: Lauren Riddiford, ETH Zürich & PSI Villigen</i>
16:30	611	Investigation of oxide heterostructures and 2D van der Waals materials through x-ray dichroism <i>Cinthia Piamonteze (i)</i>
17:00	612	Scanning SQUID-on-tip microscopy of 2D and chiral magnetism <i>Martino Poggio (i)</i>
17:30	613	Observation of gating-induced conformational changes of CeTi@C ₈₀ on graphene by x-ray absorption spectroscopy <i>Wei Chuang Lee</i>
17:45	614	Ultrafast soft X-ray magnetic holography at Swiss-FEL <i>Boris Sorokin</i>
18:00	615	Integration of a near-field coupling device with scanning probes for Nitrogen-Vacancy magnetic imaging <i>Jodok Happacher</i>
18:15		
18:30		CERN 70
19:45		Postersession with Apéro

Thursday, 12.09.2024, Room ETZ E 8

Time	ID	SPINTRONICS AND MAGNETISM AT THE NANOSCALE III <i>Chair: Jeffrey A. Brock, ETH Zürich & PSI Villigen</i>
14:00	621	2D Magnetic Materials <i>Alberto Morpurgo (i)</i>

14:30	622	Connection between spin-orbital excitations and low-dimensional magnetism in the van der Waals antiferromagnet CrSBr <i>Carlos Galdino</i>
14:45	623	Anomalous magnetic domain pattern in kagome semimetal Co ₃ Sn ₂ S ₂ <i>Hengli Duan</i>
15:00	624	Nature of 2D XY antiferromagnetism in van der Waals monolayer <i>Dmitry Lebedev</i>
15:15	625	Single-Molecule Magnetism and Room Temperature Ferromagnetic Crystals of Tb ₃ N@C ₈₀ <i>Lebin Yu</i>
15:30	626	High-resolution spectroscopy of a single nitrogen-vacancy defect at zero magnetic field <i>Shashank Kumar</i>
15:45		END
16:30		Coffee Break
19:00		Transfer to Dinner
19:30		Conference Dinner

ID	SPINTRONICS AND MAGNETISM AT THE NANOSCALE POSTER
641	Variation in Domain Wall Properties in Ferrimagnetic Thin Films <i>Laura van Schie</i>
642	Thermally superactive artificial kagome spin ice structures <i>Stéphane Nils Nilsson</i>
643	Intra-atomic exchange and adsorption sites of Ln atoms on NaCl thin films <i>Serni Toda Cosi</i>
644	Magnetically actuated angular dependent metasurfaces <i>Nestor Miguel Valdez Garduno</i>
645	Ordering and Thermalization of an Artificial Spin Ice based on the aperiodic Einstein Tiling <i>Tianyue Wang</i>

Neutron Science

THIS SESSION HAS BEEN ORGANISED IN COLLABORATION WITH THE SWISS NEUTRON SCIENCE SOCIETY.

Tuesday, 10.09.2024, Room ETF E 1

Time	ID	NEUTRON SCIENCE I <i>Chair: Romain Franck Sibille, PSI Villigen</i>
14:00	701	Quantitative imaging and understanding of water dynamics and flow in soil and roots <i>Andrea Carminati (i)</i>
14:30	702	Surfactant linker groups modulate micelle structure <i>Ashley Peter Williams</i>
14:45	703	Exploring Microfluidic-Small Angle Neutron Scattering for Soft Matter Physics <i>Viviane Lütz Bueno</i>
15:00	704	Effect of water uptake on durability of carbonated concrete studied by neutron imaging and electrochemical technique <i>Zhidong Zhang</i>
15:15	705	Texture analysis capabilities at the neutron strain diffractometer POLDI at PSI <i>Florencia Malamud</i>
15:30	706	AMPLIFY - A Novel Neutron Instrument for Surface Scattering <i>Artur Gregor Glavic</i>

15:45		
16:00		Coffee Break
		NEUTRON SCIENCE II <i>Chair: NN, PSI Villigen</i>
16:30	711	Determination of skyrmion-hosting transition metal-oxide Hamiltonian with predictive guidance from ab-initio quantum chemistry <i>Daniel Mazzone (i)</i>
17:00	712	Dipolar-octupolar correlations in Ce ₂ Hf ₂ O ₇ quantum spin ice candidate <i>Victor Porée</i>
17:15	713	The spiral magnetic order in YBaCuFeO ₅ single crystals <i>Arnau Romaguera-Camps</i>
17:30	714	Extreme Quantum Fluctuations of the Heisenberg Antiferromagnet on the Honeycomb Lattice <i>Jose Abraham Hernandez Sanchez</i>
17:45	715	Development of a fast high-efficiency neutron detector using Lithium-6 doped glass and Silicon photomultipliers (SiPM) <i>Gjon Markaj</i>
18:00	716	A High Visibility Grating Deflectometer for the Measurement of the Neutron Electric Charge <i>Marc Persoz</i>
18:15		END
18:30		CERN 70
19:45		Postersession with Apéro

ID	NEUTRON SCIENCE POSTER	
731	Characterisation of high-energy neutron fields at the Swiss spallation neutron source (SINQ) using a Bonner sphere spectrometer <i>Daniel Zeitz</i>	

Photon Science

THIS SESSION HAS BEEN ORGANISED IN COLLABORATION WITH THE SWISS SOCIETY FOR PHOTON SCIENCE.

Friday, 13.09.2024, Room ETF E 1

Time	ID	PHOTON SCIENCE <i>Chair: Lukas Gallmann, ETH Zürich</i>
13:30	801	Hard X-ray scattering in the millikelvin domain at the SwissFEL Cristallina-Quantum endstation <i>Jakub Vonka</i>
13:45	802	Imaging Ultrafast Electronic Domain Fluctuations in a Nonequilibrium X-Ray Speckle Visibility Experiment <i>Nelson Nientsu Hua</i>
14:00	803	Two-Color Diffractive Imaging of Helium Nanodroplets <i>Linos Hecht</i>
14:15	804	Coherent diffraction imaging with micrometer-sized liquid helium droplets <i>Katharina Kolatzki</i>
14:30	805	Combined electron and ion spectroscopy of atomic and molecular clusters <i>Frederic Ussling</i>
14:45	806	High average power SESAM modelocked laser oscillator exceeding 500 W <i>Moritz Seidel</i>
15:00	807	Single-cavity dual-comb lasers and applications <i>Benjamin Willenberg</i>

15:15	808	Shot-Noise Limited Dual-Comb Supercontinuum Source <i>Alexander M. Heidt</i>
15:30	809	High-sensitivity cross-comb spectroscopy enabled by a single-cavity dual-comb optical parametric oscillator <i>Carolin Bauer</i>
15:45	810	SWIR optically pumped semiconductor lasers <i>Marco Gaulke</i>
16:00		END

ID	PHOTON SCIENCE POSTER	
821	Enhancement of single-shot THz detection using a small bias detection scheme <i>Seyyed Jabbar Mousavi</i>	
822	Small footprint integrated optical parametric oscillator with a Fabry-Perot resonator <i>Alessandra Sabatti</i>	
823	Integrated lithium niobate on insulator high purity spontaneous parametric downconversion source <i>Tristan Kuttner</i>	

Biophysics and Soft Matter

THIS SESSION HAS BEEN ORGANISED IN COLLABORATION WITH THE SWISS SOFT DAYS AND LIFE SCIENCES SWITZERLAND (LS²).

Tuesday, 10.09.2024, Room ETF C 1

Time	ID	BIOPHYSICS AND SOFT MATTER I: NEW CONCEPTS AND METHODS <i>Chair: Christof Fattinger</i>
14:00	901	Introduction: The new focus of contributions to Biophysics and Soft Matter @ SPS <i>Christof Fattinger</i>
14:05	902	A physicist's approach to neuroscience <i>Janos Vörös (i)</i>
14:30	903	Nanopore microscopy for single-cell protein profiling <i>Morteza Aramesh</i>
14:45	904	Orienting fluorophores for highly efficient plasmonic nanoantennas <i>Karol Kořatj</i>
15:00	905	Acoustic metamaterials for biomedical applications: measuring temperature with ultrasounds <i>Lucrezia Maini (i)</i>
15:30	906	The SLS upgrade and its impact on structural biology and drug discovery <i>Phil Willmott (i)</i>
16:00		Coffee Break
		BIOPHYSICS AND SOFT MATTER II: MATERIALS PREPARATIONS AND INVESTIGATIONS <i>Chair: Christof Aegerter, Universität Zürich</i>
16:30	911	Water in soft confinement of lipidic mesophase <i>Yang Yao (i)</i>
17:00	912	The cryoWriter – a controlled, automated cryo-EM preparation tool <i>Luca Rima</i>
17:15	913	Elucidating the ubiquitin-proline interaction by NMR <i>Cécilia Siri</i>
17:30	914	Large-Scale Ordered Block Copolymer Gyroid Films by Solvent Evaporation Annealing <i>René Iseli</i>

17:45	915	Understanding oleophobicity through plasma polymer substitutes for PFAS <i>Astrid Southam</i>
18:00	916	Structural Colors from Amyloid-Based Liquid Crystals <i>Tonghui Jin</i>
18:15	917	Infrared spectroscopy at the nanoscale –AFM-IR of soft materials <i>Nico Kummer</i>
18:30		CERN 70
19:45		Postersession with Apéro

Wednesday, 11.09.2024, Room ETF C 1

Time	ID	BIOPHYSICS AND SOFT MATTER III: FROM MOLECULES AND CELLS TO MEDICINES <i>Chair: Lucio Isa, ETH Zürich</i>
14:30	921	Engineering tissues with architected scaffolds <i>Marcy Zenobi-Wong (i)</i>
15:00	922	Natural protein reversible amyloid fibril for skin wound recovery <i>Jiangtao Zhou</i>
15:15	923	Ligand identification with DNA-encoded chemical libraries <i>Christoph Dumelin</i>
15:30	924	Multiplexed kinetic characterization of small molecule hits from DNA-encoded library screening (DEL) using focal Mologyraphy <i>Andreas Frutiger</i>
15:45	925	Improving oral vaccine efficacy through the study of antibody–bacterial glycan interactions and gut dynamics <i>Milad Radiom</i>
16:00	926	Advanced Instrumentation Enables Structure-based Drug Discovery on Challenging Membrane Protein Targets <i>Michael Hennig (i)</i>
16:30		Coffee Break

Thursday, 12.09.2024, Room ETF C 1

Time	ID	BIOPHYSICS AND SOFT MATTER IV: PHYSICS OF BIOLOGICAL SYSTEMS I <i>Chair: Sahand Jamal Rahi, EPFL</i>
14:00	931	Title not yet known <i>Jörg Stelling (i)</i>
14:30	932	Cell-cycle coupled evolution of dynamic protein functionalities <i>Vojislav Gligorovski</i>
14:45	933	Patterning, waves and synchronization in arrays of active filaments <i>Guillermina Ramirez-San-Juan (i)</i>
15:15	934	A nuclear jamming transition in embryonic tissues <i>Sangwoo Kim (i)</i>
15:45	935	Agent-based model for active nematics of cellular tissues <i>Mathieu Dedenon</i>
16:00	936	Mitochondrial Pearling Distributes mtDNA Nucleoids <i>Juan Cruz Landoni</i>
16:15	937	Characterizing protein interactions and dynamics in transcription factor condensates in early embryonic Zebrafish <i>Eleonora Perego</i>
16:30		Coffee Break

Time	ID	BIOPHYSICS AND SOFT MATTER V: PHYSICS OF BIOLOGICAL SYSTEMS II <i>Chair: Sahand Jamal Rahi, EPFL</i>
17:00	941	Event-driven acquisition for content-enriched microscopy <i>Willi Leopold Stepp</i>
17:15	942	Probing the role of hydrodynamic interactions in metachronal wave formation in dense ciliary arrays <i>Katerina M. Kourkoulou</i>
17:30	943	Symmetry breaking and number control at the onset of centriole duplication <i>Friso Douma</i>
17:45	944	In situ stoichiometry and organization of human respiratory chain super-complexes <i>Matthew Domenic Lycas</i>
18:00	945	Resection of DNA in response to permanent DSBs in <i>S.cerevisiae</i> <i>Marco Labagnara</i>
18:15	946	Amino Acids Effect on Protein-Protein Interactions <i>Pamina Martina Winkler</i>
18:30	947	Spatial organisation of the cell's metabolic engine <i>Kathrin Laxhuber</i>
18:45	948	Elucidating Distinct Effects of Branching Processes on Mitochondrial Networks <i>Sheda Ben Nejma</i>
19:00		Transfer to Dinner
19:30		Conference Dinner

Thursday, 12.09.2024, Room ETZ E 6

Time	ID	BIOPHYSICS AND SOFT MATTER VI: PHYSICS OF BIOLOGICAL SYSTEMS III <i>Chair: Christof Aegerter, Universität Zürich</i>
17:00	951	Maximum likelihood estimation of moments in molecular density optical nanoscopy <i>Santiago Nicolas Rodriguez Alvarez</i>
17:15	952	Connecting cilia organization to collective cilia dynamics in Paramecium <i>Daphne Laan</i>
17:30	953	Deciphering mechanisms of symmetry breaking in <i>C. elegans</i> embryos <i>Ella Müller</i>
17:45	954	A Novel Platform for the Investigation of Mitochondrial Membrane Potential Dynamics <i>Giorgio Tortarolo</i>
18:00	955	Chronobiology of DNA Damage Checkpoint Override <i>Lorenzo Scutteri</i>
18:15	956	Stabilizing effect of small molecules on colloidal and protein dispersions <i>Ting Mao</i>
18:30	957	Impact of spatial structure on bacterial resistance evolution <i>Cecilia Fruet</i>
18:45	958	Structure and function of intermitochondrial junctions in primary human T cells <i>Christian Zimmerli</i>
19:00		Transfer to Dinner
19:30		Conference Dinner

ID	BIOPHYSICS AND SOFT MATTER POSTER
971	Photosynthetic vs Photovoltaic Efficiency of <i>Limnospira indica</i> , Perspective Cyanobacteria Strain for Space Mission Live Support Systems. <i>Nikolay Ryzhkov</i>

972	Focal Molography - a new biophysical method <i>Philipp Cedro</i>
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Further Meetings

TIME	ROOM	MEETING
Monday, 09.09., 08:30	ETZ E 6	SPS Board Meeting (Non-Public)
Monday, 09.09., 13:00	ETZ E 6	SPS General Assembly
Monday, 09.09., 13:00	ETZ E 8	SSPh General Assembly
Wednesday, 11.09., 18:30	ETZ E 8	GW-learn Sinergia meeting
<i>Date to be confirmed</i>	ETZ E x	SPS DEI Commission Meeting

Aussteller - Exposants

Bruker Switzerland AG
CH-8117 Fällanden
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CH-8005 Zürich
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www.dyneos.ch

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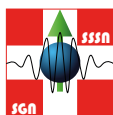
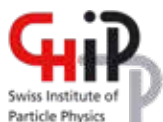
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Quantum Design AG
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<https://qd-europe.com/ch/>

SPECS Surface Nano Analysis GmbH
DE-13355 Berlin
www.specs.com

teltec systems AG
CH-5620 Bremgarten
www.teltec.ch



The winners of the SPS Awards 2024 have been selected

The SPS Award committee, chaired by Prof. Hugo Zbinden, selected the winners for 2024. The high level of all submitted works proves the scientific qualification of the younger generation of physicists in Switzerland. In combination with the unusual high number of nominations it was therefore not at all easy to make a decision.

The five winners are as follows:

SPS Award in General Physics, sponsored by *ABB Schweiz AG*:

Paolo Colciaghi (Uni Basel), for his *demonstration of entanglement between two Bose-Einstein condensates*.

SPS Award in Condensed Matter Physics, sponsored by *IBM Research GmbH*:

Patrick Lenggenhager (MPI Dresden) for his work on *emerging avenues in band theory: multigap topology and hyperbolic lattices*.

SPS Award with relation to Metrology, sponsored by *Metas*:

Simon Scheidegger (ETHZ) for work on *precise measurements of hydrogen energy levels*.

SPS Award in Computational Physics, sponsored by *COMSOL Multiphysics GmbH*:

Lucrezia Maini (ETHZ) for her her work on *acoustic metamaterials for biomedical applications*.

SPS Award with relation to Energy Technology, sponsored by *Hitachi Energy Switzerland AG*:

Alberto Rolandi (Uni Genève) for his his work on *developing new techniques to minimize energy consumption in information processing*.

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

Herwig Schopper - a century in physics

Bernhard Braunecker

The SPS would like to warmly congratulate its honorary member Prof. Herwig Schopper on his 100th birthday and wish him many more years for the benefit of physics, which he shaped and enriched throughout his life in many disciplines (from optics to particle physics) and at important institutions around the world. In his honor, CERN organized a high-profile symposium on 1 March 2024, which reviewed Prof. Schopper's personal and scientific life in several exciting lectures.

The CERN invitation says: *Director-General of CERN from 1981 until 1988, Professor Schopper has made landmark contributions to nuclear and particle physics, and to related technologies. In his early career, he played a key role in shaping today's physics research landscape in Germany, establishing laboratories and institutions before going on to leadership roles at DESY and CERN. After retirement, not content to rest on his laurels, Herwig embarked on a new career: as a science diplomat. In this capacity, he played a leading role in the establishment of the SESAME laboratory in Jordan, a synchrotron light facility for the Middle East and neighbouring regions. Over his remarkable career, Professor Schopper has rubbed shoulders with the giants of the field, counting many as friends. Few have had the opportunity to witness the evolution of particle physics from such a privileged vantage point.*



The full program, as well as the video recordings and the presentation material can be downloaded from <https://indico.cern.ch/event/1366175/timetable/>

We also want to mention that Prof. Schopper's autobiography ***Herwig Schopper, Scientist and Diplomat in a changing World*** has been published by Springer Verlag and can also be downloaded as an open access version ¹.

Here are some remarkable quotes from his memoirs (Chap. 12 *In His Own Words: Epilogue and Reflexions*)

... In my lifetime, and to my great fascination, the exploration of the cosmos and of the microcosm have become closely linked together. One cannot understand the infinitely large without understanding the infinitesimally small

¹ <https://link.springer.com/book/10.1007/978-3-031-51042-7>



and vice versa. Today, the natural sciences have evolved into numerous highly specialised disciplines, but physics and mathematics remain at their core, providing a unifying foundation. This is what makes them so interesting. It may seem that pursuing such questions of fundamental science is the province of an intellectual elite, but it has always been an essential part of human culture.

... Modern technologies have thus benefitted from fundamental research but the inverse is also true: many of these technologies have also led to the development of essential tools for fundamental research. Take, for example, electron microscopes, particle accelerators in their many different forms, and telescopes...

... We scientists must never give up on our efforts to explain and to engage with the public, and to share with them the importance of science as part of our culture.

The SPS is proud that we could convince Prof. Schopper in 2013 to contribute to our prestigious series *Milestones in Physics*, where events of epoch-making importance in physics are described at first hand. In this case, it was Prof. Schopper's important work on parity violation in the weak interaction: "The Fall of Parity" ².

² *SPG Mitteilungen* Nr. 41, p. 26 - 27 (2013)



All pictures on this page: © CERN

Niklaus Wirth: Nachruf und Würdigung

Jeder Physikerin, jedem Physiker, der sich im Lauf seiner Karriere mit Programmieren beschäftigte, ist der Name Niklaus Wirth ein Begriff, dem Vater von Programmiersprachen wie Pascal, Modula-2 und Oberon. Prof. Wirth starb am 1. Januar 2024 im Alter von fast 90 Jahren. Nachstehend bringen wir einen Nachruf von seinem engen Mitarbeiter Prof. Jürg Gutknecht.

Niklaus Wirth war neben Edsger W. Dijkstra und C. A. R. Hoare einer von drei Pionieren, die im vergangenen Jahrhundert die aufkeimende Wissenschaft der „Informatik“ entscheidend geprägt haben. Alle drei wurden mit dem nach dem Urpionier Alan Turing benannten Turing Award, der höchsten wissenschaftlichen Auszeichnung in der Informatik, geehrt. Im Gegensatz zum bereits früher verstorbenen Dijkstra und dem Theoretiker Hoare hat in der Wirth'schen Forschung die Engineering Komponente stets eine zentrale Rolle gespielt. Theorie und Formalismus waren in seinen Projekten durchwegs minimalistisch angelegt und mussten sich durch ihre Nützlichkeit in einer konstruktiven Anwendung rechtfertigen. Solange sie der Sache dienen, waren Wirth aber auch sehr abstrakte Prinzipien lieb und teuer, wie etwa die von ihm selbst entwickelte Programmiermethodik der schrittweisen Verfeinerung, die konsequente Typisierung von Daten oder das mathematische Prädikatenkalkül zum statischen Beweis der Korrektheit von Algorithmen.



Die von ihm in den Jahren 1968 - 1972 entwickelte Sprache "Pascal" erfreute sich weltweit zunehmender Beliebtheit, nicht zuletzt wegen Verfügbarkeit auf "persönlichen" Rechnern wie etwa Apple II. Später entwarf er die Pascal-Nachfolger Modula (1973 - 1976), Modula-2 (1977 - 1980) und Oberon (1985 - 1990) und implementierte sie auf dem Arbeitsplatzrechner Lilith. Die Lilith war nach dem Vorbild des Alto Computers aus dem Forschungslabor Xerox PARC im Silicon Valley mit einem hochauflösenden Bildschirm und einer Maus als Eingabegerät ausgerüstet. Meine seinerzeitige Skepsis gegenüber der Eignung „höherer“ Programmiersprachen für systemnahe Aufgaben war inzwischen längst verfliegen und der Einsicht gewichen, dass sich geeignete Abstraktionen für solche Aufgaben nicht nur ausgezeichnet eignen, sondern geradezu der Schlüssel zu ihrer Bewältigung sind. Das ultimativ überzeugende Argument lieferte schliesslich die erfolgreiche Realisierung der radikalen Wirth'schen Vision, nämlich die einheitliche Formulierung der gesamten Software des neuen Arbeitsplatzrechners, einschliesslich Benutzerschnittstelle, Anwendungen, Betriebssystem und Modula-2 Compiler in der Sprache Modula-2 selbst. Möglich wurde dies durch die raffinierte, bereits aus der Pascal Zeit bekannte Methodik der Verwendung eines so genannten Zwischencodes, M-Code genannt.

Der nächste und letzte Schritt meiner Zusammenarbeit mit Wirth bestand in der Flexibilisierung des starren Modula-2 Datentypsensystems in Form einer dynamischen, nach oben offenen Typenhierarchie, wodurch laufende Systemerweiterungen ohne Preisgabe der rigorosen Typenprüfung

möglich wurden. Diese Evolution führte zur Programmiersprache Oberon und war ein abermals bewusst minimaler Schritt in Richtung „objektorientierte Programmierung“, welche Wirth in ihrer Ganzheit als „zu pompös“ vorkam. Er war generell vom Gedanken beseelt, dass die technische Weiterentwicklung der Hardware nicht ausreichte, um die wachsende Komplexität der Software leistungsmässig zu kompensieren. Der Slogan „software is getting slower faster than hardware is getting faster“ läuft bis heute unter der Flagge „Wirth'sches Gesetz“. Mit Oberon wurde die Sprache wiederum als Mittel zum Zweck verwendet, nämlich zur Entwicklung einer kompakteren und noch leistungsfähigeren, persönlichen Arbeitsstation namens „Ceres“ auf der Basis einer nächsten Generation von Hardwarekomponenten.

Im internationalen Umfeld erfreuten sich beide Programmiersprachen Modula-2 und Oberon dank ihrer minimalistischen Struktur und dank der vollständig transparenten, quelloffenen Verfügbarkeit vor allem im kreativ-kommerziellen Umfeld der Startups und für sicherheitskritische Projekte grosser Beliebtheit, auch wenn eine flächendeckende Verbreitung wie bei Pascal ausgeblieben ist.

Die Wirth'schen Tugenden der Einfachheit, Klarheit, Transparenz, Minimalität und Ressourceneffizienz sind Querschnittskompetenzen, die unter dem Namen „School of Wirth“ im wahrsten Sinne des Wortes Schule gemacht haben. Sie haben ganze Generationen von Informatik Studierenden geprägt und Professionals hervorgebracht, welche heute im In- und Ausland und speziell im ikonischen Silicon Valley einflussreiche Positionen bekleiden und ihrerseits den Wirth'schen Spirit weitertragen und weiterverbreiten. Allerdings ist die Disziplin der Programmierung inzwischen einer Kultur des „Software Engineering“ gewichen, welche dank „smarten“ Frameworks und Packages sowie allerlei KI Bots die benötigten Kompetenzen und damit die Eintrittsschwelle in die Entwicklung von Software substanziell gesenkt hat, mit der positiven Konsequenz, dass die Türen für eine explosionsartig erweiterte Population von Software-Entwicklern in einer sich ebenso explosionsartig erweiternden Welt von Anwendungsbereichen geöffnet werden konnten, und der negativen Konsequenz, dass die hohe Qualität der Programmierung nach Wirth'schen Massstäben weitestgehend geopfert werden musste. Der Beweis für letzteres sind allgegenwärtige, stupide Fehlermeldungen wie „Ein Fehler ist aufgetreten. Probieren Sie es noch einmal“ als Zeichen der Kapitulation der Entwickler, sich unendlich im Kreise drehende Aktivitäten bei Verbindungsversuchen oder ganze Releases, deren einzige Innovation in der Korrektur früherer Programmfehler besteht. Da kommt in Erinnerung an die gute alte Wirth'sche Zeit unumgänglich eine gewisse Wehmut auf.

Jürg Gutknecht, ETH Zürich

Peter Higgs passed away at age 94, his legacy will continue driving physics for decades to come

Peter Higgs (29 May 1929 – 8 April 2024) made significant theoretical contributions in elucidating the fundamental mechanism by which elementary particles acquire mass. His work laid the foundation for decades of research and led to the discovery of a new boson, named after him: the Higgs boson, in 2012.

The mechanism, which relies on a new field and spontaneous symmetry-breaking, was proposed in 1964 by Peter Higgs at the University of Edinburgh. Independently, similar conclusions were reached by Robert Brout and François Englert at the Université Libre de Bruxelles, and by Gerald Guralnik, C. R. Hagen, and Tom Kibble at Imperial College London, around the same time ¹.

Higgs reportedly developed the fundamentals of his theory after returning to his Edinburgh New Town apartment from a failed weekend camping trip to the Highlands. He stated that there was no "eureka moment" in the development of the theory. He wrote a short paper exploiting a loophole in Goldstone's theorem (massless Goldstone particles need not occur when local symmetry is spontaneously broken in a relativistic quantum field theory) which he published in 1964. Higgs wrote a second paper describing a theoretical model (now called the Brout-Englert-Higgs mechanism), but the paper was rejected (the editors of *Physics Letters* judged it "of no obvious relevance to physics"). Higgs wrote an extra paragraph, explicitly mentioning that this mechanism entails a new massive spin-zero boson (later named the Higgs boson) and resubmitted it to *Physical Review Letters*, where it got accepted for publication. The same mechanism in a non-relativistic setting had already been proposed earlier in 1962 by Philip Anderson.

At the time of his retirement in 1996, Higgs doubted that a similar breakthrough could be achieved in today's academic culture. He cited the pressure on academics to collaborate and constantly produce papers, saying, "It's difficult to imagine how I would ever have enough peace and quiet in the present sort of climate to do what I did in 1964."

It would take nearly half a century for their theory to be experimentally confirmed. On July 4, 2012, during a special seminar at CERN, the ATLAS and CMS experiments announced that they had observed strong indications for the presence of a new particle, which could be the Higgs boson, in the mass region around 126 GeV. Higgs, who was a special guest at this seminal seminar along with Englert, commented, "It's really an incredible thing that it's happened in my lifetime."

In recognition of their contributions, Peter Higgs and François Englert were jointly awarded the Nobel Prize in Physics in 2013. Their theoretical work and the discovery of the Higgs boson stand out as an example of the deep consequences of mathematical symmetries in the physical world.

Ever since the discovery of this new boson by the ATLAS and CMS experiments in 2012, data taking at the Large

Hadron Collider continues and statistical samples containing Higgs candidate events are collected. Measuring all properties (mass, spin, width, couplings to other bosons and fermions) to establish empirically whether this new particle fulfills all what is required to be the Standard Model Higgs boson, or whether there is room for more. This new boson could still be the lightest of a Higgs multiplet in models where five Higgs bosons are predicted, as e.g. Super Symmetry would demand, also a possible substructure of this new boson, where the Standard Model Higgs boson is predicted structure less, would establish new routes for particle physics to go. Furthermore, the Higgs boson might interact with yet-to-be-discovered particles. Among these, dark matter particles emerge as prime candidates for investigation. Understanding the potential coupling between the Higgs boson and such elusive particles could offer profound insights into the nature of dark matter and its role in the universe.

Peter Higgs leaves behind a monumental legacy, defined not only by his scientific achievements but also by his inspiring personality. The impact of Higgs physics and the exploration of the intricacies of the Brout-Englert-Higgs mechanism will endure throughout the coming decades with high priority. Indeed, the European Particle Physics Strategy Update from 2020 identifies an electron-positron Higgs factory as the highest-priority next collider to be envisioned, where precision measurements and new insights become possible that are unachievable today.

Hans Peter Beck

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

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In a recent note¹ it was shown that the Goldstone theorem,² that Lorentz-covariant field theories in which spontaneous breakdown of symmetry under an internal Lie group occurs contain zero-mass particles, fails if and only if the conserved currents associated with the internal group are coupled to gauge fields. The purpose of the present note is to report that, as a consequence of this coupling, the spin-one quanta of some of the gauge fields acquire mass; the longitudinal degrees of freedom of these particles (which would be absent if their mass were zero) go over into the Goldstone bosons when the coupling tends to zero. This phenomenon is just the relativistic analog of the plasmon phenomenon to which Anderson³ has drawn attention: that the scalar zero-mass excitations of a superconducting neutral Fermi gas become longitudinal plasmon modes of finite mass when the gas is charged.

The simplest theory which exhibits this behavior is a gauge-invariant version of the model used by Goldstone² himself: Two real⁴ scalar fields φ_1, φ_2 and a real vector field A_μ interact through the Lagrangian density

$$L = -\frac{1}{2}(\nabla_\mu \varphi_1)^2 - \frac{1}{2}(\nabla_\mu \varphi_2)^2 - V(\varphi_1^2 + \varphi_2^2) - \frac{1}{2}F_{\mu\nu}F^{\mu\nu}, \quad (1)$$

where

$$\begin{aligned} \nabla_\mu \varphi_1 &= \partial_\mu \varphi_1 - eA_\mu \varphi_2, \\ \nabla_\mu \varphi_2 &= \partial_\mu \varphi_2 + eA_\mu \varphi_1, \\ F_{\mu\nu} &= \partial_\mu A_\nu - \partial_\nu A_\mu. \end{aligned}$$

e is a dimensionless coupling constant, and the metric is taken as $-+++$. L is invariant under simultaneous gauge transformations of the first kind on $\varphi_1 \pm i\varphi_2$ and of the second kind on A_μ . Let us suppose that $V'(\varphi_1^2) = 0$, $V''(\varphi_1^2) > 0$; then spontaneous breakdown of U(1) symmetry occurs. Consider the equations [derived from (1) by treating $\Delta\varphi_1, \Delta\varphi_2$, and A_μ as small quantities] governing the propagation of small oscillations

about the "vacuum" solution $\varphi_1(x) = 0, \varphi_2(x) = \varphi_0$:

$$\partial^\mu \{ \partial_\mu (\Delta\varphi_1) - e\varphi_0 A_\mu \} = 0, \quad (2a)$$

$$\{ \partial^2 - 4e\varphi_0^2 V''(\varphi_0^2) \} (\Delta\varphi_2) = 0, \quad (2b)$$

$$\partial_\nu F^{\mu\nu} = e\varphi_0 \{ \partial^\mu (\Delta\varphi_1) - e\varphi_0 A_\mu \}. \quad (2c)$$

Equation (2b) describes waves whose quanta have (bare) mass $2e\varphi_0 \{ V''(\varphi_0^2) \}^{1/2}$; Eqs. (2a) and (2c) may be transformed, by the introduction of new variables

$$\begin{aligned} B_\mu &= A_\mu - (e\varphi_0)^{-1} \partial_\mu (\Delta\varphi_1), \\ G_{\mu\nu} &= \partial_\mu B_\nu - \partial_\nu B_\mu = F_{\mu\nu}, \end{aligned} \quad (3)$$

into the form

$$\partial_\mu B^\mu = 0, \quad \partial_\nu G^{\mu\nu} + e^2 \varphi_0^2 B^\mu = 0. \quad (4)$$

Equation (4) describes vector waves whose quanta have (bare) mass $e\varphi_0$. In the absence of the gauge field coupling ($e = 0$) the situation is quite different: Equations (2a) and (2c) describe zero-mass scalar and vector bosons, respectively. In passing, we note that the right-hand side of (2c) is just the linear approximation to the conserved current: It is linear in the vector potential, gauge invariance being maintained by the presence of the gradient term.⁵

When one considers theoretical models in which spontaneous breakdown of symmetry under a semisimple group occurs, one encounters a variety of possible situations corresponding to the various distinct irreducible representations to which the scalar fields may belong: the gauge field always belongs to the adjoint representation.⁶ The model of the most immediate interest is that in which the scalar fields form an octet under SU(3): Here one finds the possibility of two nonvanishing vacuum expectation values, which may be chosen to be the $Y = 0, I_3 = 0$ members of the octet.⁷ There are two massive scalar bosons with just these quantum numbers; the remaining six components of the scalar octet combine with the corresponding components of the gauge-field octet to describe

¹ <https://www.sps.ch/artikel/meilensteine-der-physik/heretical-ideas-that-provided-the-cornerstone-for-the-standard-model-of-particle-physics-1>

Neuer SPG Preis für Arbeiten auf dem Gebiet der Sensorik, Detektion und Überwachung

Nouveau prix de la SSP pour des travaux dans le domaine de la physique des capteurs, de la détection et de la surveillance

Die Firma **Sensirion AG** (www.sensirion.com) stiftet ab 2025 einen SPG Preis, der jährlich für eine hervorragende wissenschaftliche Arbeit auf dem Gebiet der Sensorik, Detektion und Überwachung verliehen wird.

Sensirion mit Sitz in Stäfa am Zürichsee wurde 1998 als Spin-off der ETH Zürich von zwei Physikern gegründet und ist heute ein führender Hersteller von digitalen Mikrosensoren und -systemen. Das Produktsortiment umfasst Durchflusssensoren für Gase und Flüssigkeiten, Differenzdrucksensoren und Umweltsensoren für die Messung von Parametern wie zum Beispiel Feuchtigkeit und Temperatur, flüchtige organischen Verbindungen (VOC), Kohlendioxid (CO₂) und Feinstaub (PM2.5). Vertriebsbüros in den USA, in Europa, China, Taiwan, Japan und Südkorea beliefern Kunden mit standardisierten und massgeschneiderten Sensorsystemlösungen für eine Vielzahl von Anwendungen. Sensoren von Sensirion sind in vielen Produkten der Automobilindustrie, Medizintechnik, Industrie und Unterhaltungselektronik zu finden. Das innovative Unternehmen wurde für seine attraktive Unternehmenskultur mehrfach ausgezeichnet und ist heute einer der wichtigsten Arbeitgeber im Grossraum Zürich für Physikerinnen und Physiker, insbesondere auch für Direkteinsteigende nach dem Studium oder Doktorat.

Sensirion strebt dabei Markt- und Technologieführerschaft in all seinen Produktsegmenten an. Im Zentrum stehen kundenfokussierte innovative Sensorlösungen unter Gewährleistung von Energieeffizienz, Klimaschutz und Gesundheit. Der von Sensirion gestiftete und von der SPG verliehene Preis würdigt herausragende Arbeiten mit physikalischem Hintergrund mit Bezug zur Sensorik, die das Potenzial neuartiger Sensor-Lösungen beinhalten. Junge Forscherinnen und Forscher an Schweizer Hochschulen sollen dadurch motiviert werden, ihre Kreativität und ihr Talent verstärkt in diesem schnell wachsenden Feld der Sensorik einzusetzen und dadurch erste Erfahrungen mit industriellen Anwendungen zu machen.

L'entreprise **Sensirion AG** (www.sensirion.com) offrira dès 2025 un prix de la SSP qui sera décerné chaque année à un travail scientifique exceptionnel dans le domaine des capteurs, de la détection et de la surveillance.

Sensirion, dont le siège se trouve à Stäfa au bord du lac de Zurich, a été fondée en 1998 par deux physiciens en tant que spin-off de l'EPF de Zurich et est aujourd'hui un fabricant leader de micro-capteurs et de systèmes numériques. Sa gamme de produits comprend des capteurs de débit pour les gaz et les liquides, des capteurs de pression différentielle et des capteurs environnementaux pour la mesure de paramètres tels que, par exemple, l'humidité et la température, les composés organiques volatils (COV), le dioxyde de carbone (CO₂) et les particules fines (PM2.5). Sensirion dispose d'un réseau international de bureaux de vente aux États-Unis, en Europe, en Chine, à Taïwan, au Japon et en Corée du Sud offrant aux clients internationaux des solutions de systèmes de capteurs standardisés et sur mesure pour une multitude d'applications. Les capteurs de Sensirion se retrouvent dans de nombreux domaines d'applications comme l'industrie automobile, la technologie médicale, l'industrie et l'électronique grand public. Cette entreprise innovante a été récompensée à plusieurs reprises pour sa forte culture d'entreprise et représente aujourd'hui l'un des principaux employeurs de l'agglomération zurichoise pour les physiciennes et physiciens, en particulier pour ceux qui entrent directement dans l'entreprise après leurs études ou leur doctorat.

Sensirion s'efforce d'être à la pointe de l'innovation dans tous ses domaines d'activité et revendique ainsi le leadership technologique. L'accent est mis sur des solutions innovantes axées sur le client et garantissant l'efficacité énergétique, la protection du climat et la santé. Le prix nouvellement fondé par Sensirion et décerné par la SSP récompense des travaux remarquables de physique en relation avec la technologie des capteurs et dont les résultats ont le potentiel de contribuer à de nouvelles solutions de capteurs. Nous souhaitons ainsi motiver les jeunes chercheuses et chercheurs des hautes écoles suisses à mettre en œuvre leur créativité et leur talent dans ce domaine en rapide croissance de la technologie des capteurs et à faire ainsi leurs premières expériences dans des applications industrielles.

SENSIRION

Progress in Physics (101)

Scalable optical memories in MEMS vapor cells for quantum networking

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The roadmaps towards a quantum internet [1, 2] envision revolutionary breakthroughs, like its classical analog had in our everyday lives. Quantum networks promise to enable private communication between remote parties through the distribution of provably secure cryptographic keys, relying on the laws of quantum physics [3]. Furthermore, they could help overcome scalability concerns in quantum computers, as well as allowing the exchange of computation results in the form of qubits, or sharing entanglement between distant recipients [4]. Quantum metrology could also benefit from quantum networks through enhanced precision by combining the measurements of remote quantum sensors in a network [5, 6].

Quantum networks are composed of nodes that can store and process quantum information. These network nodes are linked via quantum channels. Through these flying qubits, typically single photons, can be sent either to directly transfer quantum information, share entanglement, or synchronize probabilistic operations [7]. First realizations of elementary networks for entanglement distribution have been demonstrated in a variety of platforms [8]. In [9] entanglement between two remote single atoms each trapped in a cavity was generated and subsequently manipulated by local qubit rotations. Event-ready Bell tests have been performed to verify the entanglement of two trapped atoms at separated nodes [10]. Hybrid approaches were pursued as well, as in [11] where two different rare-earth ion based quantum memories operating at different wavelengths were entangled through spontaneous parametric downconversion

(SPDC) photons. Moreover, a truly heterogeneous interconnect between a cold atomic ensemble and a rare-earth doped crystal was successfully demonstrated making use of quantum frequency conversion [12]. Recently, the first three-node networks for entanglement distribution were realized. This is the state-of-the-art. In cold atomic ensembles, entanglement of nodes was achieved through three-photon interference [13]. Further, the heralded generation of a GHZ state across three independent nitrogen vacancy centers in diamond nodes was reported on in [14], constituting a small network with quantum memories at the nodes capable of storing and processing quantum information. Subsequently, quantum teleportation between non-neighboring nodes was also shown in that system [15].

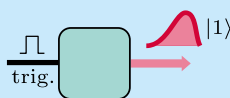
Optical interconnects that reversibly map quantum states between matter and light are fundamental for the realization of quantum networks. Single-photon sources and quantum memories thus constitute their building blocks. Realistic, large-scale implementations of quantum networks pose demanding challenges for these elementary components. They should be easy to operate in environments outside of a laboratory, while at the same time being scalable and, preferably, easy to mass-produce.

Due to their simple atomic level structure and strong optical transitions, alkali metals are a convenient platform for implementing quantum memories. Significantly, their high vapor pressure allows for operation at room temperature. This results in relatively simple setups without the experimental overhead required by cryogenic or ultra-high vacuum systems. Additionally, bandwidths of hundreds of MHz to single GHz can be reached in hot vapor memories, allowing them to be matched with high quality single-photon sources such as semiconductor quantum dots [18 - 20] or SPDC sources [21, 22].

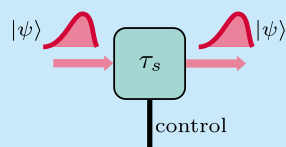
Hot alkali vapors are generally contained in vapor cells, which can range from conventional glass-blown cells, com-

Quantum Network Building Blocks

(a) Single-Photon Sources



(b) Quantum Memories



(a) An ideal single-photon source is an apparatus that emits exactly one photon. The distinction can be made between deterministic sources, where the photon is produced at the push of a button, and probabilistic ones, which emit spontaneously, at random points in time. The latter type can be just as useful given that photons are systematically produced in pairs. In that case one can be detected to herald the generation of the other [16].

(b) A quantum memory can be described as a device that takes an input quantum state from a single photon and faithfully preserves it in time. (If desirable, it might also perform an operation on the input state.) At a later point in time, this device should be able to re-emit the single photon in said quantum state [17].

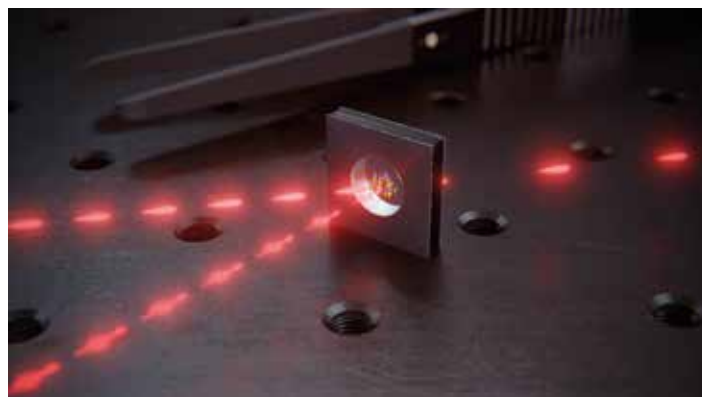


FIG. 1. Artist's depiction of an optical memory implemented in a MEMS vapor cell. The 2 mm thin cell can store weak light pulses consisting on average of a single photon and re-emit them at a later point in time.

monly used for spectroscopy, to wafer-scale microfabricated cells [23]. Up to now, microfabricated cells were used predominantly in the field of quantum sensors, for compact atomic clocks, magnetometers and gyroscopes [24]. So far, no quantum memory was implemented in MEMS (micro-electromechanical system) cells. Nevertheless, the MEMS fabrication capabilities are promising for the development of scalable quantum networks – they could enable spatial multiplexing of memories with hundreds of independent vapor cells on a single wafer, and satisfy the miniaturization requirements of satellite-borne applications [25].

Storing Single Photons in Hot Vapor

A prominent choice for storage schemes in atomic ensembles are three-level lambda-systems as depicted in Fig. 2. Lambda systems are composed of two metastable ground-states and one excited state. The long coherence times of the atomic ground states aid in preserving the stored information. Initially, the atoms are prepared in the ground state $|g\rangle$. The incoming single photon is chosen to be resonant to the $|g\rangle \rightarrow |e\rangle$ transition. A strong control pulse, resonant to the second leg of the lambda ($|s\rangle \rightarrow |e\rangle$), is shun on the ensemble as the single-photon arrives, which maps it to a spin wave between the two ground states. In other words, the incoming photonic excitation is mapped onto a shared coherent excitation of the atoms. This process can be represented as

$$|1\rangle_{ph} \otimes |g_1, g_2, \dots, g_N\rangle \leftrightarrow |0\rangle_{ph} \otimes \frac{1}{\sqrt{N}} \sum_{j=1}^N |g_1, g_2, \dots, s_j, \dots, g_N\rangle.$$

The resultant atomic excitation is known as Dicke state, or as W state in the field of quantum information theory, which is particularly robust against particle losses [26]. In the experiments described below, the excitation is stored in an entangled state containing on the order of a billion atoms.

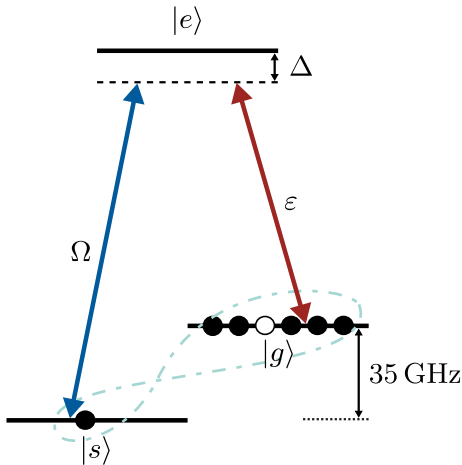


FIG. 2. Lambda-scheme used for light storage in the atomic ensemble. The atoms are initialized in the ground state $|g\rangle$. The ground-state splitting determines how easy it is to filter out the control pulse after the memory and sets an upper limit to the input's bandwidth. The signal input ϵ and the control pulse Ω are on two-photon resonance. The detuning Δ is optimized empirically. The incoming photon is mapped onto a spin wave between the two ground states.

Depending on the exact operating regime (determined by the power and detuning of the control pulse) the underlying physical process varies. In our implementations the relevant phenomenon is called electromagnetically induced trans-

parency [27], which can be understood as an interference of different absorption paths that prevents the excitation of the atom into the short-lived state $|e\rangle$, instead storing the photon in the ground state. The read-out process works through time-reversal. Once a photon is stored, it can be read-out at a later point in time by applying a second control pulse. Since the phenomenon is based on a collective effect, due to constructive interference of the single atoms, the re-emission of the photons is directional along the same direction as the input (contrary to fluorescence which is isotropic). This important detail makes the process particularly convenient for collecting the output.

Implementing a quantum memory ground-state scheme in a warm atomic ensemble comes with some major challenges. At room temperature, all the ground states of alkali metals are equally populated. The strong control pulse used for reading in and out of the memory can couple to these states and produce additional, typically thermal, light, e.g. through spontaneous Raman scattering. These noise photons can be generated with the same frequency and polarization as the signal photon and can't necessarily be filtered out after the memory. It is therefore imperative to initialize the atoms in the desired state to inhibit these processes. However, even for a perfect initial state preparation, the control pulse can couple to state $|g\rangle$ and lead to four-wave mixing [21, 28, 29]. Furthermore, real atoms have a far more complex level structure than the idealized three-level scheme needed for storage. These additional states can contribute to the read-out noise as well as adding spurious absorption channels, which absorb the incoming photon incoherently without storing it [30, 31]. A clever choice of scheme is necessary, e.g. by exploiting selection rules or engineering the level structure through the Zeeman effect, to suppress such possible detrimental processes.

Recently, our group demonstrated the successful suppression of noise processes in a rubidium ground-state memory, leading to the first storage and retrieval of high-bandwidth single photons in such a system [32]. That study showed the feasibility of interfacing hot vapor memories with single photons by measuring non-classical number statistics of the memory output. An important challenge is to realize such a memory in a microfabricated MEMS cell.

MEMS Vapor Cell Memory

In [33], we reported the first experiment demonstrating storage and retrieval of light in a microfabricated rubidium vapor cell. The cell shown in Fig. 3(b) was originally fabricated by the University of Neuchâtel for miniaturized atomic clocks [34]. By applying a tesla-order static magnetic field, a clean three-level lambda scheme was isolated – this reduces the spurious effects of other energy levels. In the so called hyperfine Paschen-Back regime the energy splittings induced by the Zeeman shift are larger than the hyperfine splittings. The magnetic interaction dominates and the hyperfine interaction can be treated as a perturbation, leading to the decoupling of the nuclear spin I and the total angular momentum of the electron J . This allows optical control and addressing single transitions even in a Doppler broadened medium. For further details about the Paschen-Back regime we refer the reader to [35].

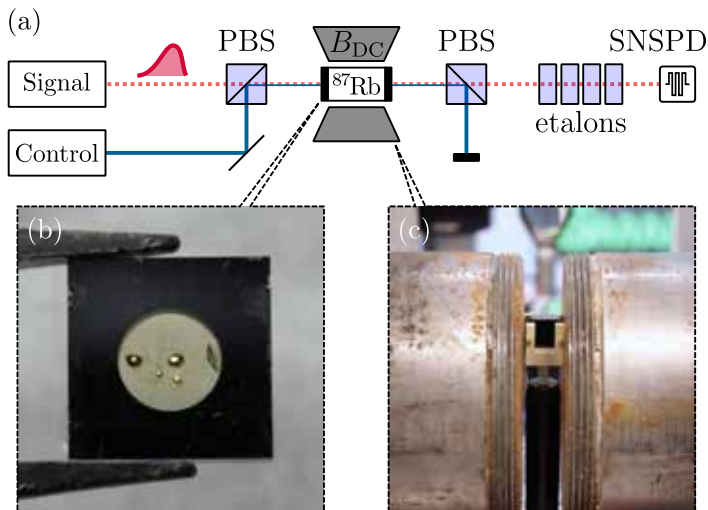


FIG. 3. (a) Sketch of the experimental setup. A strongly attenuated laser generates the single-photon-level signal pulses which are overlapped with the control pulses on a polarizing beam splitter (PBS). The heart of the memory – a rubidium MEMS cell – is placed in a static, tesla-order magnetic field B_{DC} . The memory read-out is "cleaned" by suppressing the control pulse through polarization and spectral filtration. The memory output is finally detected with a superconducting nanowire single-photon detector (SNSPD).

(b) Front view of the microfabricated vapor cell. The contained ^{87}Rb can be recognized as droplets on the cell window. By homogeneously heating the cell windows the Rb condenses on the side walls, "cleaning" the windows.

(c) An electromagnet is used to generate the strong magnetic field. The cell is placed between the ferromagnetic cores, where the field is most homogeneous. For future developments compact permanent magnets are envisioned to reduce the package size drastically (similar to what is used in [36]).

The efficiency of a quantum memory scales with the optical depth of the vapor. However, for a vapor cell with a thickness of merely 2 mm, the optical depth is negligible at room temperature. In fact, for alkali metal atoms the vapor pressure has a strong dependence on temperature. By heating the MEMS cell the atom number density thus increases, resulting in a higher optical depth. Hence, good memory efficiencies can be reached even in thin cells. In this particular case the cell was heated to about 90°C by illuminating it with infrared lasers.

A schematic representation of the experimental setup is shown in Fig. 3(a). The signal is generated by pulsing and attenuating a laser to the level that each pulse contains only one photon on average. These pulses are shaped to have a FWHM of about 1 ns and to resemble the envelope of photons from a downconversion source. The necessary strong control pulses are generated by an optically amplified laser. Signal and control pulses are timed to arrive simultaneously at the vapor cell.

Once the input light pulse is stored, we wait for a storage time of 80 ns before applying the read-out pulse. After retrieval, one major experimental challenge is to discriminate the $10^8 - 10^9$ photons constituting the control pulse from the single reemitted photon. For this purpose the memory output needs to be filtered in polarization and frequency. Calcite prisms with excellent polarization extinction ratios of at least 8 orders of magnitude are used to separate the orthogonally polarized control. Furthermore, a cascade of etalons is used for spectral filtration. The frequency difference between signal and control is given by the hyperfine splitting of

the atomic species (and the applied magnetic field). In total, the control light is suppressed by more than 15 orders of magnitude, while the signal transmission through the whole setup stays at around 20 %. The detection of the memory output is performed with superconducting nanowire single-photon detectors.

A typical arrival-time histogram for the storage of laser pulses attenuated to the single-photon level in the MEMS cell is shown in Fig. 4(b). Before each storage attempt, the atoms' initial state is prepared by optical pumping.

Zero time delay here corresponds to the arrival time of photons that are not stored in the memory, simply leaking through to the detector. After approximately 80 ns, the read-out control pulse is applied. The photons retrieved from the memory constitute the second peak. In order to estimate the read-out noise generated by the memory, a second measurement is performed with the signal input physically blocked. From the counts accumulated within the retrieval time-window (shaded area in the figure) of both measurements, the key figures of merit of the memory can be computed. A signal-to-noise ratio $\text{SNR} = 7.9(8)$ and a memory efficiency $\eta_{\text{B0 ns}} = 3.12(17) \%$ were achieved. The memory efficiency is the fraction of noise-corrected counts detected in the retrieval time window with respect to the total amount of storage attempts that were made during the integration time. Although, this latter quantity might seem low, it specifies an end-to-end efficiency that includes all experimental losses and inefficiencies along the optical path. Correcting for said losses yields an internal efficiency (extrapolated to arbitrarily short storage times) $\eta_{\text{int}} = 24(3) \%$. This value, which describes the efficiency of the physical process itself and is often the quantity cited in literature, is reasonably close to the theoretical maximum [37] for an optical memory with the given optical depth.

By repeating the experiment for various storage times, a change in efficiency can be observed. From the efficiency drop towards longer storage times (see Fig. 4(c)) the memory lifetime can be extracted. Commonly, the memory lifetime is defined as the storage time at which the efficiency drops to $1/e$ of its maximum value. For this first memory implementation in a MEMS cell, a lifetime of $224(8)$ ns was measured.

Outlook

Different applications require different sets of vapor cell parameters. The proof-of-principle experiment presented here was implemented with a microfabricated cell that was designed for atomic clocks. This leaves ample room for improvement in the next iteration. By optimizing the cell design and its filling specifically for quantum memories, several of the current limitations will be overcome and the performance – in terms of signal-to-noise ratio, efficiency, and lifetime – improved.

The initial state preparation of the atoms is crucial for minimizing the read-out noise. If additional states, especially the storage state $|s\rangle$, remain populated, the strong control pulse can couple to them and generate read-out noise. If the Rb number density is too high, the state preparation becomes less efficient due to an effect called radiation trap-

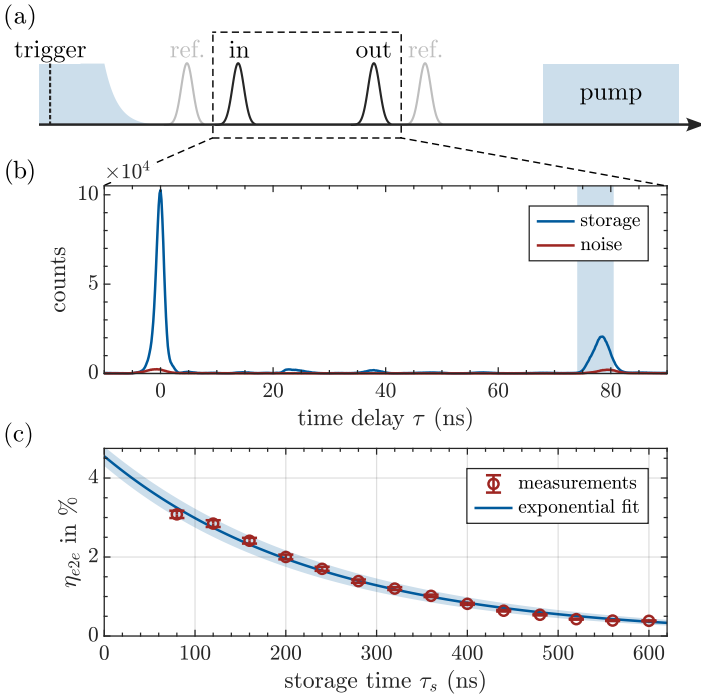


FIG. 4. (a) Pulse pattern applied to the memory. After receiving a trigger, the pump laser initializing the atoms is switched off. Two control pulses, separated by the storage time, are applied for the read-in and read-out of the memory. The signal input is timed to arrive at the atoms together with the first control pulse.

(b) Typical arrival-time histogram of a storage experiment with an integration time of about 1 min (blue trace). The peak at zero time delay comes from photons that leak through the memory during read-in without being stored. After approximately 80 ns, the read-out control pulse is applied. The photons retrieved from the memory constitute the second peak. All detection events within the shaded area – the retrieval time-window – contribute to the memory efficiency and signal-to-noise ratio. A second measurement, where the signal input is physically blocked, is performed to estimate the noise contribution (red trace).

(c) By varying the storage time, the memory lifetime can be extracted from the decrease in efficiency. The change in efficiency is well fit by an exponential decay, suggesting the lifetime is limited by loss processes.

ping [38]. When optically pumping a vapor, an excited atom emits a photon when relaxing back into the desired ground state. Under moderate conditions, these photons exit the medium, but in a sufficiently dense vapor these photons can be reabsorbed by other atoms, leading to a process which competes with depletion pumping and makes it less efficient. By adding a buffer gas, e.g. N_2 , molecular ro-vibrational degrees of freedom provide the atoms with a non-radiative relaxation channel through collisions. This process, known as quenching, improves the initial atomic polarization at high density, reducing the read-out noise [39], and potentially reaching a regime as in [32], where actual single-photon storage was demonstrated.

An alternative to increasing the cell's optical depth without simultaneously increasing the alkali number density is to provide a longer optical path through the atomic vapor. The small size of MEMS vapor cells is key to their good scalability. By engineering cells where the light is internally routed through the vapor by reflections within the cell, path lengths of the order of 10 mm could be achieved [24].

In a hot vapor the atoms are in motion. A current limitation of the memory lifetime are the atoms leaving the interaction

volume during the storage time. The later the control pulse is applied for readout, the less atoms contributing to the collective coherent excitation are addressed. Matching the vapor cell's inner diameter to the transverse beam profile ensures that the atoms are confined within the interaction volume. The atoms collide with the cell walls, but remain addressable as they bounce back into the control beam's path. To ensure that the atoms' collisions with the cell walls do not scramble the stored information, spin-preserving coatings [40], such as paraffin wax, must be applied to the walls. An improvement of three to four orders of magnitude in lifetime, depending on the number of collisions for which the spin is preserved, is expected with this technique. Beyond that, second-long storage times have been demonstrated in hot vapors by applying elaborate schemes to combat decoherence [41].

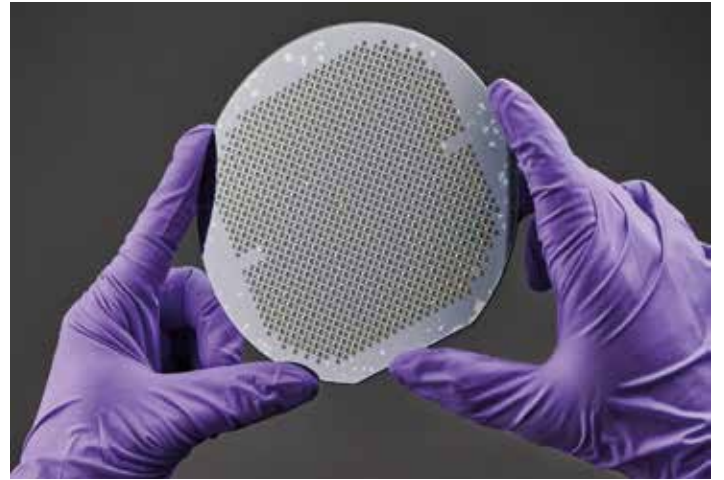


FIG. 5. Hundreds of vapor cells can be fabricated on a single wafer, potentially constituting hundreds of independent quantum memories. Photo courtesy of CSEM Neuchâtel.

Recently, the *Scalable High Bandwidth Quantum Network (sQnet)* project started, funded through the Quantum Transitional Call by the State Secretariat for Education, Research and Innovation (SERI). It involves a collaboration between the Treutlein and Warburton groups at the University of Basel and the CSEM in Neuchâtel, combining atomic vapor quantum memories, state-of-the-art single-photon sources based on semiconductor quantum dots, and the expertise in fabricating wafer-scale vapor cells as well as waveguides on-chip. The goal of this collaboration is to create a scalable platform for high-bandwidth quantum networks based on high performance elements. A hybrid optical interconnect in which single photons emitted by semiconductor quantum dots are stored in compatible quantum memories implemented in tailored MEMS cells will be realized by combining these elements. A further step will be to use on-chip nonlinear optics to efficiently convert the near-infrared single photons to telecom wavelengths to drastically reduce the losses in transmission through optical fibers. With such a toolbox, first quantum networking tasks such as sharing entanglement between quantum memories over telecom links could be implemented. Demonstrating the feasibility of a scalable quantum networking platform operating with high efficiency and at high bandwidth would pave the road for more complex networking tasks and scaling up to multiple nodes.

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Progress in Physics (102)

Structural analysis of proteins by cryo-electron ptychography

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Introduction

Cryo-electron microscopy (cryo-EM) is a method that uses a transmission electron microscope (TEM) to record images of frozen hydrated protein solutions that are prepared as a thin film of approximately 100 nm thickness. In conventional cryo-EM, the TEM is used to illuminate the sample with a broad and parallel beam of electrons. The electrons traverse the thin specimen, and lenses in the TEM are used to form a phase-contrast image behind the specimen, which is recorded with a large area camera (Figures 1 and 2) [1]. Important parameters for high-resolution cryo-EM are not only the choice of the instrument hardware including its camera, but also the quality of the environmental conditions of the instrument setup and the instrument alignment. In cryo-EM of frozen preparations of a homogeneous preparation of biological particles, the so-called single particle analysis (SPA), a large number of images are recorded with the help of automation softwares. Typical recording times for a full dataset range from hours to days and reach up to 20'000 or more dose-fractionated movie recordings for one sample. Recorded images typically show projection maps of protein particles at very low signal to noise ratio. However, if the signal from hundreds of thousands of such protein particle images is computationally combined, a high-resolution 3D reconstruction of the average protein map can be obtained. Such SPA processing requires that the majority of the particles are the same. If more than one type of protein particles were present, then classification algorithms can be used to

reconstruct these. Typically, up to 10 different particle types, or particle conformations can be recognized. Once a 3D map of a protein has been reconstructed at a resolution better than 3.5 Å, an atomic model for the protein can be built into the 3D map (Figure 1). Cryo-EM is an extremely productive tool to study the atomic resolution structure of proteins, as long as the proteins are large enough to be visible in the noisy images, and as long as they are available in sufficiently homogeneous preparations. If strong heterogeneity is present in the ensemble of particles, then cryo-EM fails. Cryo-EM was recognized with the Nobel prize in Chemistry in 2017, awarded to Richard Henderson, Joachim Frank, and Jacques Dubochet [2]. Jacques Dubochet is an Emeritus Professor of the University of Lausanne, and he had studied physics at the institute that today is the EPFL, which triggered the creation of the Dubochet Center for Imaging with its three sites in Lausanne, Geneva and Bern [3].

Ptychography – A diffraction approach to imaging

Cryo-EM suffers from the low signal-to-noise ratio of the recorded images, and from the resolution limits of the TEM imaging process. An alternative to recording real-space images with the TEM is to exploit the strong interaction of the electron beam with the sample and record electron diffraction patterns. When applied to 3D crystal specimens, this 3D electron diffraction is a powerful method that can determine atomic details about protein structures from 3D crystals that are much smaller than needed for X-ray crystallography [4].

The TEM can also be used with the electron beam focused to a tiny point on the specimen surface, and this sub-Angstrom sized probe is then scanned over the sample, while recording non-scattered and scattered electrons as a function of the probe position, which is called Scanning Transmission Electron Microscopy (STEM). For cryo-EM specimens, integrated Differential Phase Contrast STEM has recently been shown to be able to determine high-resolution details of vitrified biological samples at low electron doses [5].

A hybrid approach that combines real-space and reciprocal space data collection is ptychographic imaging [6]. In ptychography, a beam is focused on a small specimen area, and this beam is then stepped over the surface of the sample in a tight raster, while a camera behind the sample is recording the diffraction patterns from those specimen locations (Figure 2). Computer data

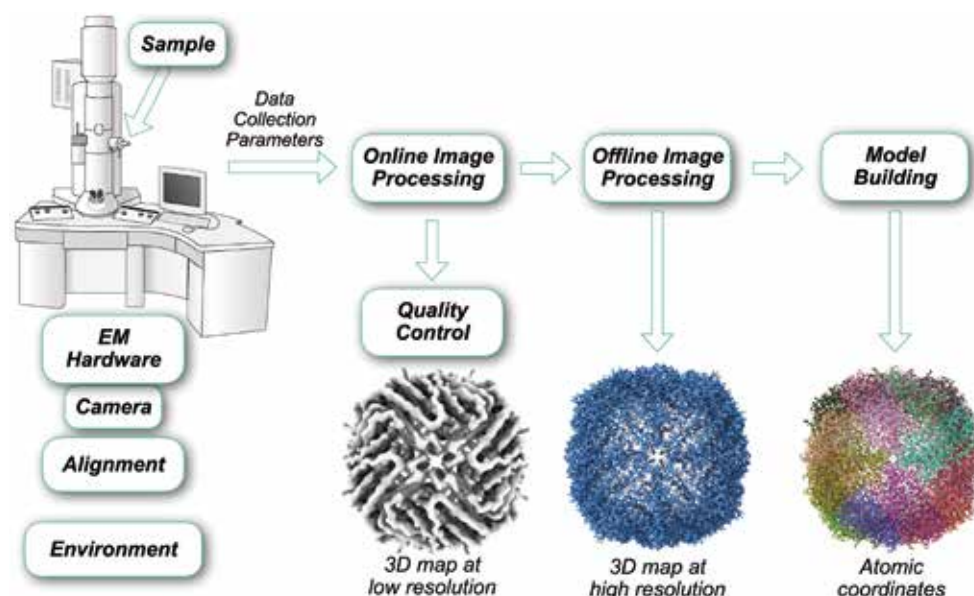


Fig. 1: The single particle cryo-EM workflow. A frozen sample is imaged with a cryo-EM instrument. Important parameters are the instrument hardware, the instrument alignment, and the environmental disturbances of the instrument location. During automated image collection, online data processing is performed as quality control, here resulting in a 3D map of Apoferritin at 7 Å resolution. After data collection, extensive fine tuning of image processing can produce 3D maps at up to 1.09 Å resolution (here shown: EMD-19436). Building of an atomic model into the 3D map can be done manually or with help of computers (here shown: PDB-8RQB).

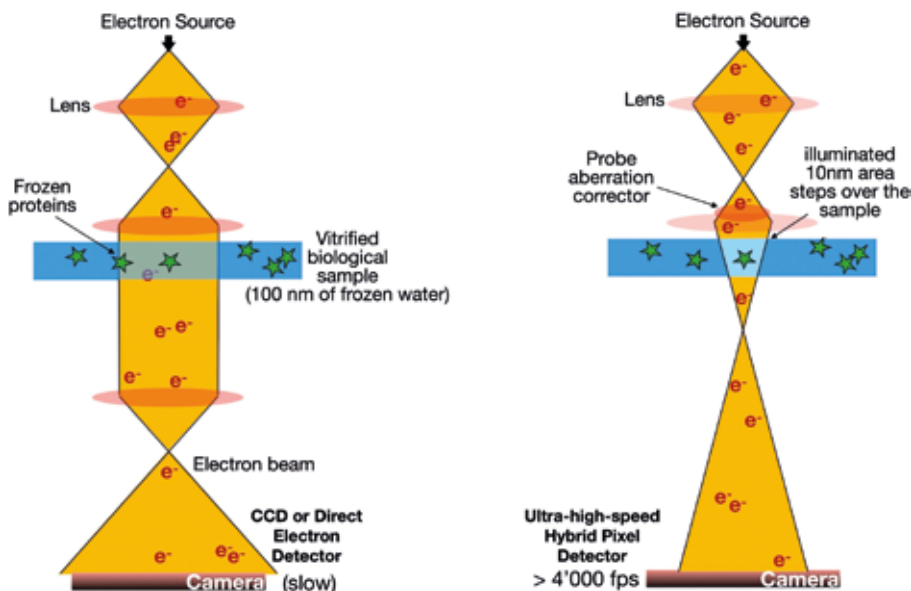


Fig. 2: The electron path in an electron microscope. Left: Conventional (real-space) imaging as it is used in cryo-EM. The beam creates a parallel illumination of micrometer diameter on the sample. A phase-contrast image is created on a camera with (slightly defocused) lenses underneath the sample. A typical exposure time is one second, but the camera may record a few dozen sub-frames during that second if used in movie-mode. Right: In convergent beam electron diffractive imaging, such as in ptychography, the electron beam forms a narrow probe of 10 nm diameter or less. After the sample, in principle no further lenses are required, and the pattern of electron diffraction from the sample is recorded with a hybrid pixel detector. Here, the beam steps over the sample surface at very high speed (e.g., hundreds of positions per second), and at each position the electron diffraction pattern is recorded.

analysis can then reconstruct the 2D or even 3D structure of the sample. In Switzerland, ptychography with an X-ray beam from a synchrotron is performed at the Paul Scherrer Institute [7,8].

Ptychography can also be done with an electron beam. In electron ptychography, the electron beam in the TEM is focused to a narrow beam that can be parallel or convergent. This electron “probe” of merely a few nanometers in diameter is stepped in a 2D raster over the sample, which diffracts the electrons. The diffraction patterns from each probe position are recorded with a 2D camera that is capable of accepting the very high beam intensity often found in the center of the diffraction pattern. This combination of a 2D stepping raster with a 2D detector for data collection in scanning transmission electron microscopy gives this method the name “4D STEM”. Hybrid pixel detectors are ideal cameras for this purpose due to their high dynamic range and speed [9]. Recorded diffraction patterns correspond to a dataset in reciprocal space. The diffraction patterns have a high signal-to-noise ratio and offer in principle access to structural knowledge about the sample at a resolution much higher than any aperture-limited real-space imaging method. But the diffraction patterns only contain amplitude information about the specimen. The phase information about the specimen is missing and has to be obtained with additional methods.

The diffraction patterns recorded in the ptychography process still need to be combined with phase information in order to be able to determine the structure of the frozen proteins. This can be done computationally by one of various algorithms. The ptychography algorithm exploits the knowledge of the partially overlapping positions of the electron beam on the sample. An iterative algorithm cycles the recorded dataset between reciprocal (Fourier) space and real (Image) space via Fourier transforms, while applying constraints onto the dataset in the two spaces. In reciprocal space, a trivial constraint is to insist on the known amplitudes from the recorded diffraction patterns. In real space, a simple constraint is to average the image signal from image segments, at which two or more electron probes were overlapping. Additional constraints can be found and applied in both spaces. This hybrid input output algorithm [10,11] converges under suitable conditions to a solution that satisfies

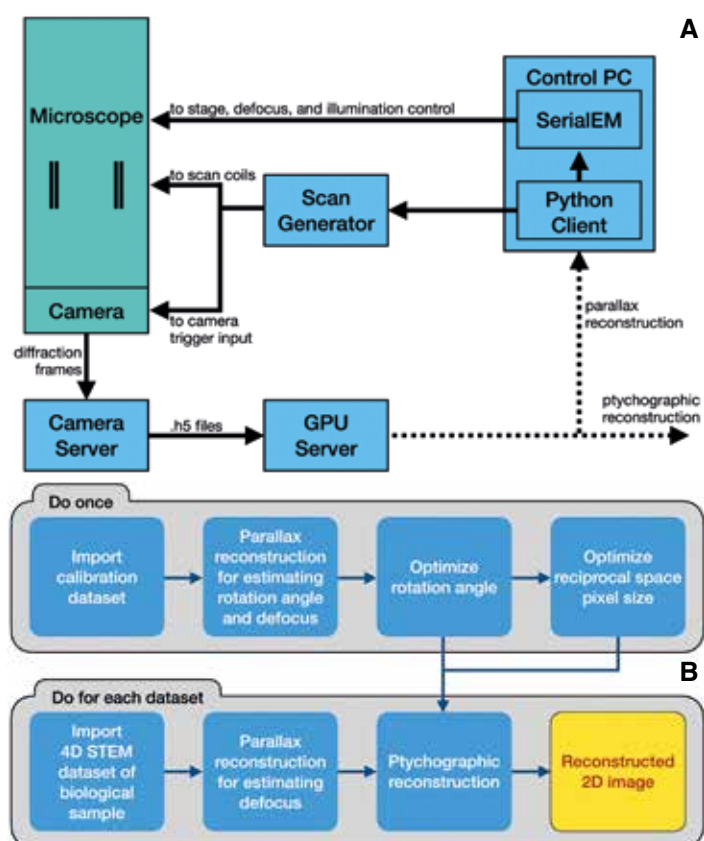


Fig. 3: The cryo-electron ptychography workflow. (A) Experimental setup. The pixelated camera is mounted below the electron microscope which collects the diffraction images. The microscope and an external scan generator are controlled by an PC. Once an acquisition is started, a signal is sent to the external scan generator, which controls the scan coils, which in turn move the electron beam across the sample in a specific 2D raster. For each beam position a trigger signal is sent to the camera. After acquisition, the images are moved to a GPU server for further processing and image feedback to the control PC. (B) Processing pipeline. For a given dataset one calibration image is acquired. This image is used to estimate beam parameters and determine the pixel size of the final images. The individually acquired datasets are processed to determine the defocus value for each, and then a final image is reconstructed, which is used for further processing in a conventional single particle cryo-EM image processing pipeline as shown in Figure 1.

all constraints and then not only delivers the high-resolution projection image of the sample, but also reconstructs the

shape and profile of the electron beam that was stepping over the sample.

In materials sciences, electron ptychography has been used with high electron doses, exposing the samples with millions of electrons per square Angstrom ($e/\text{\AA}^2$) of specimen surface, so that the ptychography algorithm can produce highly contrasted and almost resolution-unlimited images of the sample. The Muller group, for example, studied a crystalline PrScO_3 sample by electron ptychography, reporting 0.16 \AA resolution maps that are merely limited in resolution by atomic lattice vibrations [12].

For life sciences cryo-EM samples, only very low electron doses can be used, before the frozen water of the sample melts and the proteins are destroyed from the electron beam. When recording electron ptychography data of vitrified proteins, a dose budget of merely 100 $e/\text{\AA}^2$ can be used. Current ptychography reconstruction algorithms were not designed for such low electron counts in the diffraction patterns, so that the data reconstruction algorithm is difficult to bring to a convergent solution. In practice, the low electron count is the factor that limits the achievable resolution in 4D STEM of biological specimens.

Cryo-electron ptychography of frozen hydrated specimens has been demonstrated by the groups of Wang and Kirkland, when studying vitrified virus-like particles with 4D STEM under low-dose conditions [13]. Their work showed for the first time the outstanding potential for contrast of the method, but left space for further resolution improvements. As discussed below, we have recently shown cryo-electron ptychography of frozen hydrated apoferritin samples, reaching 5.8 \AA resolution [14].

There is plenty of room at the bottom to further improve the sensitivity of cryo-electron ptychography of beam sensitive life sciences specimens. Data collection schemes, dose fractionation, computational corrections for slowly accumulating electron beam damage and specimen drift, and additional algorithmic constraints during image processing, all still should be developed for or adapted to cryo-electron ptychography, in order to become able to harvest the full potential of this method also for life sciences samples.

Cryo-electron ptychography to study frozen proteins

We have developed a cryo-electron ptychography setup, based on a 300 kV Titan Krios transmission electron micro-

scope that is equipped with a corrector for spherical lens aberrations (Cs-corrector) above the sample. This Cs-corrector enables the formation of a highly convergent electron beam that is nevertheless fully coherent. The focused electron beam can be stepped over the sample in a custom scan pattern with the help of a TVIPS Universal Scan Generator connected to the instrument, so that for example spiral scan patterns of the beam become possible. Diffraction data are recorded with a Dectris ELA detector at 4'500 frames per second. A much faster data collection will become possible with the Dectris ARINA detector, which in binned operation allows recording diffraction patterns at speeds up to 120'000 frames per second.

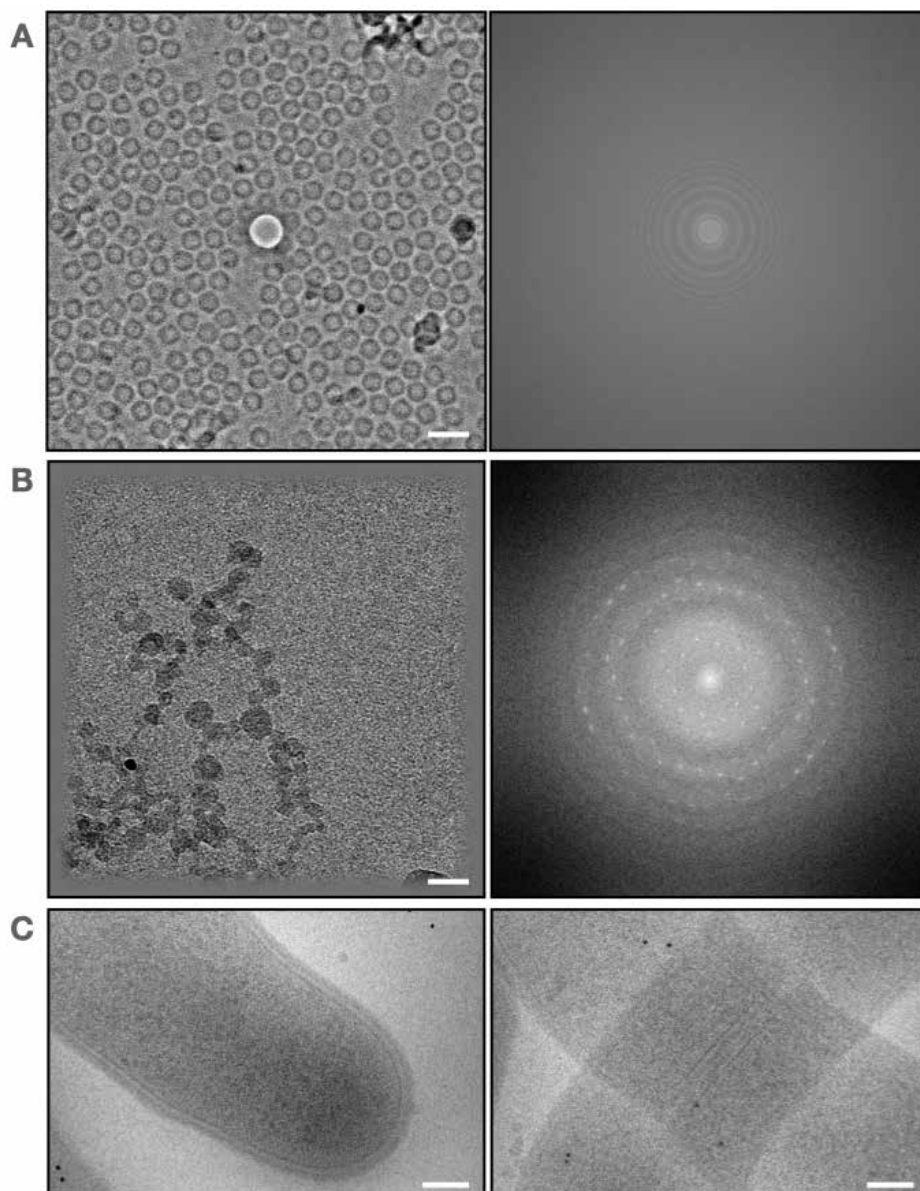


Fig. 4: 4D-STEM of biological cryo-EM specimens.

A, Left: Cryo-electron ptychography reconstruction frozen hydrated Apoferritin sample, allowing the 3D reconstruction at 5.8 \AA resolution [14]. Scale bar: 20 nm. Right: Fourier transform of the image.

B, Left: Cryo-4D-STEM parallax reconstruction of a frozen hydrated bacteriorhodopsin 2D crystal sample. The real-space image does not reveal features to the naked eye. Scale bar: 10 nm. Right: The Fourier transform on the same image on the left shows diffraction spots beyond 1 nm resolution.

C, Cryo-electron ptychography image of frozen bacteria. The sample on the left is approximately 600 nanometer thick, the one on the right showing two bacteria overlaid on top of each other has twice that thickness. Both samples could not have been successfully imaged by conventional cryo-EM. Cryo-electron ptychography is especially promising when combined with tomographic acquisition schemes for imaging thicker samples in cell biology. Scale bars: 200 nm.

Recorded cryo-electron ptychography patterns are processed with a multi-GPU Linux computer, using the py4D-STEM software package [15], resulting in highly contrasted two-dimensional real-space images of the specimens (Figure 3).

In this work, we used cryo-electron ptychography to record data of frozen hydrated Apoferritin sample, using a convergence semi angle (CSA) of the electron illumination of 4 mrad, and obtaining a 3D map of the protein at 5.8 Å resolution (Figure 4). Further resolution improvement is expected from the ongoing implementation of collecting data under dose-fractionation, with a higher CSA, and recording much larger datasets with the help of automation.

Conclusion

Electron ptychography in materials sciences holds the world record in resolution. It is a variant of scanning transmission electron microscopy, by stepping the electron beam over the specimen in a 2D pattern, while for each position recording a 2D diffraction pattern, hence the name 4D STEM. We applied cryo-electron ptychography to vitrified protein particles, which allowed a medium-resolution 3D reconstruction of the proteins from a very low number of protein particles.

Further resolution improvements will require transferring several technologies to cryo-electron ptychography that have been developed for conventional cryo-EM, such as recording data under electron dose-fractionation and computationally accounting for accumulating beam effects in the data analysis. Further optimization of the data recording schemes, such as optimizing electron beam convergence angles, stepping patterns, beam defocus and diameter of the illuminated surface area, electron doses, and specimen geometries, promise to strongly boost the achievable resolution, so that the very high contrast of this method can be exploited to its fullest extent.

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Progress in Physics (103)

Einstein Telescope: the exploration of the Universe with Gravitational Waves

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Gravitational waves (GWs) were predicted by Einstein in 1916, as a consequence of his theory of General Relativity. In General Relativity space-time becomes dynamical, and GWs can be visualized as tiny ripples on the space-time structure, that propagate as waves, at the speed of light. About one century after Einstein's prediction, the LIGO-Virgo Collaboration (LVC) observed for the first time the GWs emitted by the coalescence of a binary black hole (BBH) system. This first detection took place on Sept. 14th, 2015 [1], and represented a milestone in science. In this first detection, two black holes with masses about 36 and 29 solar masses, that since millions of years were orbiting around each other, losing energy by GW emission, finally coalesced and formed a single black hole of about 62 solar masses. To give an idea of how extraordinary this event was, one can mention that, in the last 10 millisecond of the merger, a mass m of about 3 solar masses was transformed into energy, according to $E = mc^2$, and carried away by the GWs. During these 10 ms, the luminosity (energy radiated per unit time) of this single stellar event was 10 times larger than the estimated electromagnetic luminosity of all stars and galaxies of the Universe. Despite that, when the GW reached our observatories on Earth, after having traveled for about 410 Mpc (by comparison, the typical distance among galaxies is of the order of the Mpc), it induced perturbations on the structure of space-time of just about a part in 10^{21} . Still, after decades of developments, the LIGO detectors were able to observe it, by monitoring, with interferometric techniques,

the change in the distance between the mirrors of an interferometer, induced by the passage of the GW. To get an idea, the change in the distance between the two mirrors in each arm of the interferometer, placed 4 km apart, was about 1000 smaller than the size of an atomic nucleus! The discovery, announced in Feb. 2026, had a huge resonance in the media worldwide, and was awarded with the Nobel Prize already the year after the announcement, in 2017.

Another extraordinary milestone was the detection, on Aug. 17, 2017, of the first binary neutron star (BNS) coalescence [2]. The event was observed in coincidence with a gamma-ray burst detected by Fermi-GBM [3] and by INTEGRAL [4]. The electromagnetic counterpart was subsequently identified and followed by dozens of telescopes in all bands of the electromagnetic spectrum [5]. This event was an extraordinary example of multi-messenger astronomy, i.e., astronomy where a source is observed and studied with different messengers, such as electromagnetic signals and GWs, and had important implications in many fields, from relativistic astrophysics to nuclear physics, nucleosynthesis in the Universe, and cosmology.

Nowadays, after improvements in the detectors, BBH coalescences are routinely detected, with events observed at a rate of about one every few days during the latest observing run. The current catalog of GW detections now contains about 90 BBH coalescences, two BNS coalescences

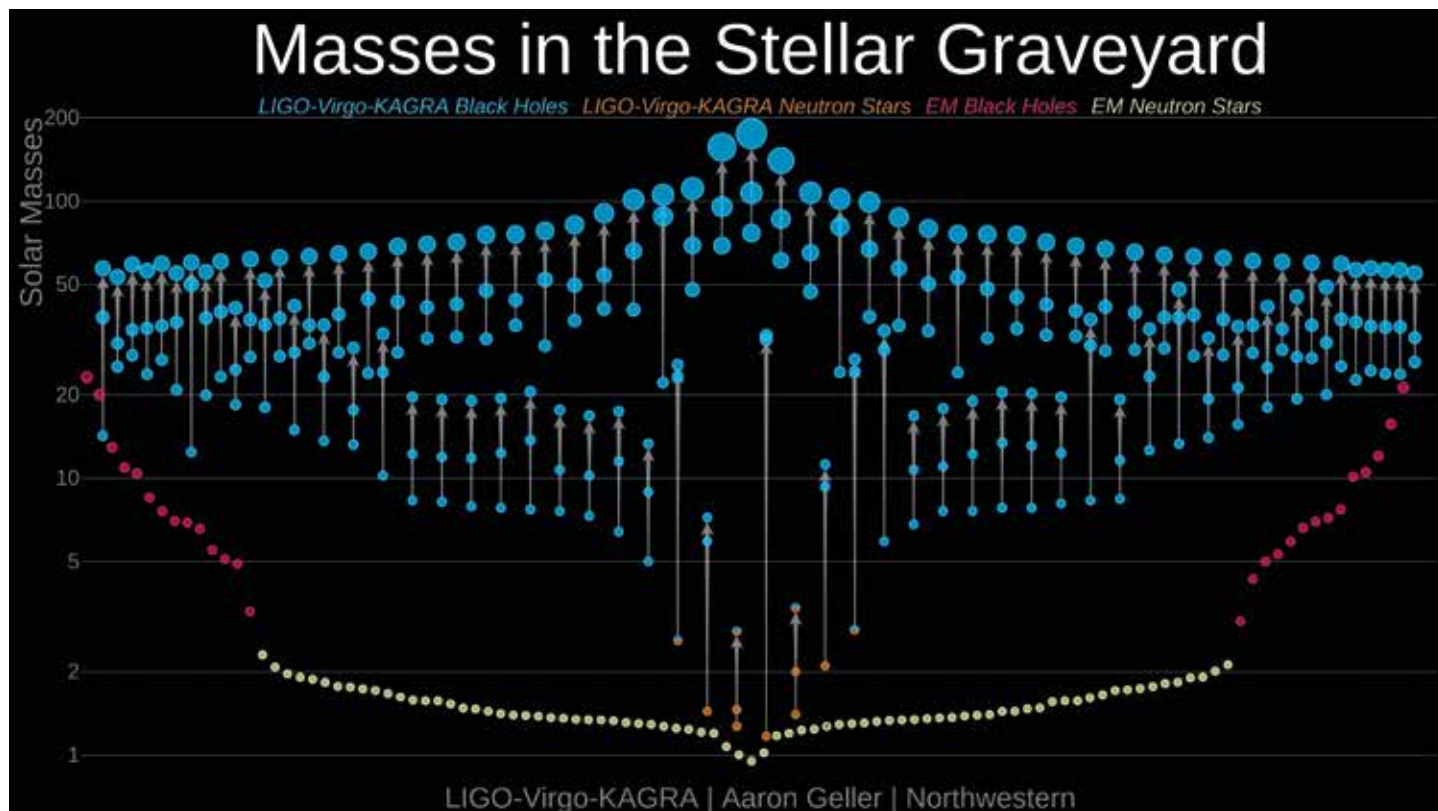


Figure 1: Masses of the BHs (blue) and NSs (orange) detected during the O1, O2 and O3 runs. Also shown the BHs that were known from electromagnetic observations of X-ray binaries (red), and the NSs observed electromagnetically (yellow); from <https://www.ligo.caltech.edu/MIT/image/ligo20211107a>, credit: LIGO-Virgo/Aaron Geller/Northwestern University.

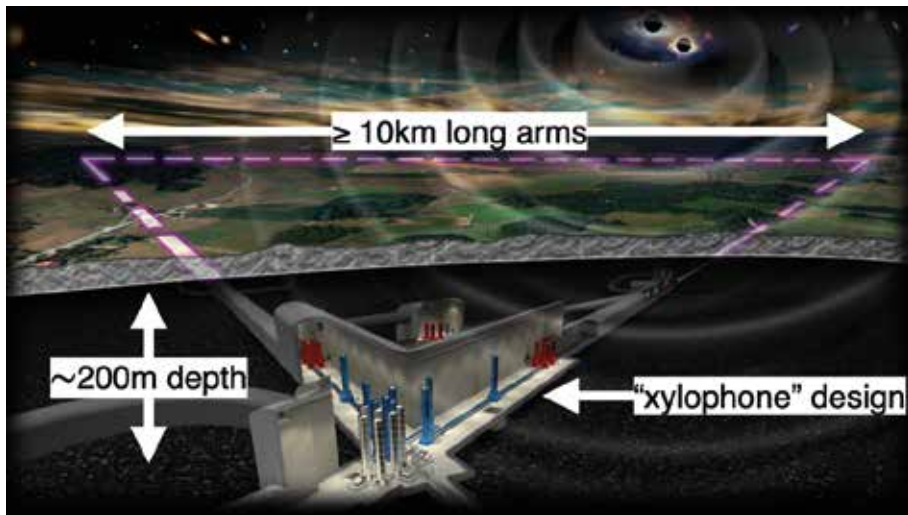


Figure 2: An artist rendering of the Einstein Telescope. Credit: ET Collaboration.

and two neutron star–black hole coalescences [6,7]. Fig. 1 shows the catalog of current observed events.

These discoveries are allowing us to observe the Universe through a new and, from many points of view, unique window, and have already started to provide important results in fundamental physics, astrophysics, and cosmology. However, second-generation (2G) GW detectors, as the current LIGO and Virgo detectors are called (to distinguish them from initial LIGO/Virgo) have intrinsic limitations, and the scientific community has long been aware of the need for a new generation of ground-based detectors. In a sense, current detectors have shown the existence of an unknown territory, and the next generation of experiments has been designed so to deeply explore it. The main projects that have emerged, for ground-based GW detectors, are Einstein Telescope (ET) [8,9] in Europe and Cosmic Explorer (CE) [10,11] in the US, and could become operative by the late 2030s. At the same time, after decades of preparation, the LISA space interferometer [12] is scheduled to launch in 2034. Third-generation (3G) ground-based detectors such as ET and CE operate in a frequency band very different from LISA; so ET/CE and LISA will be complementary, similarly to electromagnetic telescopes operating in different bands of the electromagnetic spectrum.

Fig. 2 gives an artist rendering of the Einstein Telescope.

Its design involves several innovative elements that allows it to make a jump in sensitivity, compared to current detectors. While several aspects of the design, including the detector geometry, are still under definition, the current baseline configuration involves a facility about 200 m underground; this is because one of the main source of noise that ground-based detectors must fight is seismic noise, which is significantly reduced going underground. The arm-length of the interferometers will be increased to 10 km (compared to 3 km for Virgo and 4 for LIGO). In one option for the geometry of the detector, three nested interferometer will form a triangle, in a single underground facilities, but other designs are currently under study, including the possibility of two L-shaped interferometers in two widely separated sites, still in Europe, and possibly reaching an arm-length of 15 km. Each interferometer will actually be in a so-called “xylophone” configuration made of two instruments, one optimized for GWs of high frequencies and one, working at cryogenic temperatures, optimized for low frequencies. Two official candidate sites have been proposed, one in Italy, in Sardinia and one in the Netherlands, in the Meuse-Rhine region, and are strongly supported by the respective governments. The final site(s) and geometry selection depends on many aspects, including on-going geological studies, studies of the scientific potentials of different configurations, analysis of the risks involved, as well as financial and political aspects, and will possibly finalized by 2026. The current schedule is that ET might enter into operation by the late 2030s.

The ET Collaboration now counts over 1600 members, organized in Research Units all over the world. Switzerland is significantly involved in ET, through the University of Geneva and its Research Unit, as well as its Gravitational Wave Science Centre (GWSC, <https://gwsc.unige.ch/>), that brings together research groups from the Department of Theoretical Physics, the Department of Nuclear and Particle Physics, and the Department of Astronomy of UniGe; several members of the UniGe Research Unit have significant re-

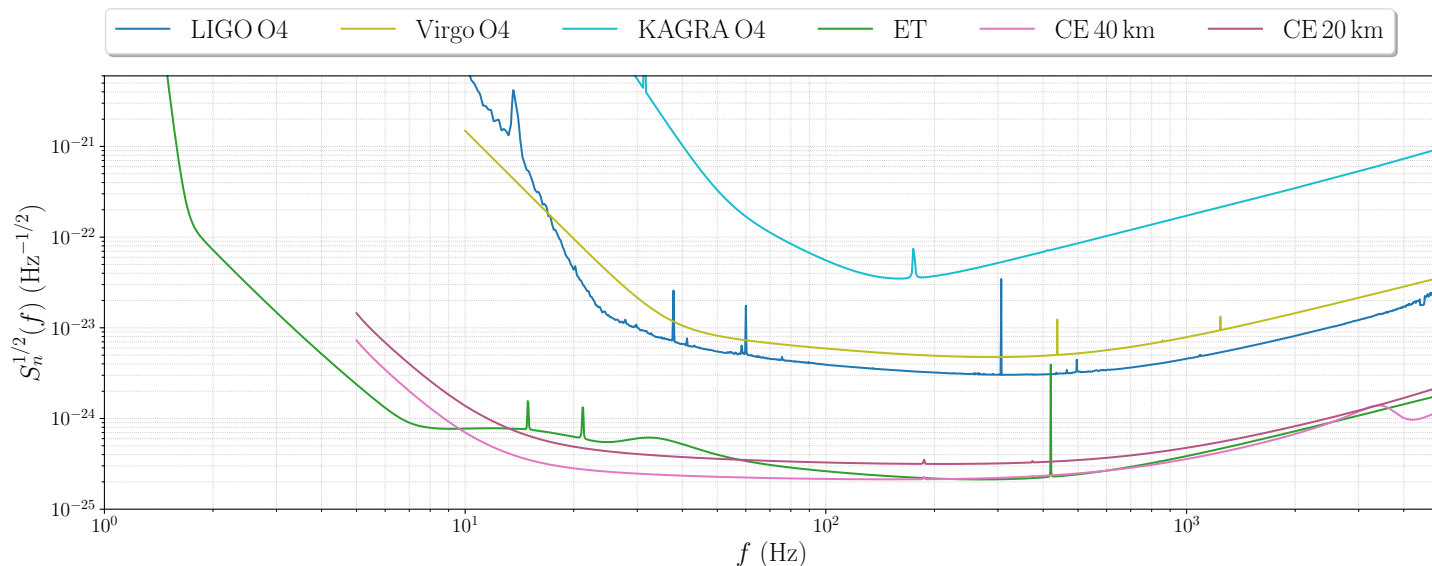


Figure 3: Sensitivities of ET, CE-40 km and CE-20 km, compared to the sensitivities expected for LIGO, Virgo, and KAGRA at the end of the O4 run. From [14].

sponsibility roles in the Collaboration, including the role of co-Chair of the Observational Science Board (<https://www.et-gw.eu/index.php/the-et-collaboration/observational-science-board>), that includes over 450 scientists, organized in 10 thematic divisions, and coordinates all the work on the Science Case for ET.

at the center of galaxies, and whose merger is one of the main target of LISA.

GWs also allow us to penetrate into regions that are opaque to electromagnetic radiation. For instance, they will give us access to the interior of neutron stars, carrying the imprint of the equation of state of nuclear matter at densities inaccessible with any other experiment, and providing us unique information on the fundamental theory of strong interaction, quantum chromodynamics, in this regime. Also, if a sufficiently strong stochastic background of GWs is produced close to the Big Bang, it will arrive to us unaltered, carrying pristine information on the first instants of the Universe (by comparison, the Cosmic Microwave Background carries a picture of the Universe about 100'000 yr after the Big Bang, since the earlier epoch is not transparent to electromagnetic radiation).

The combination of large distances explored (up to the depth of the Universe, with redshifts $z \sim 10-100$), extended range of masses (from subsolar to 10^4 solar masses), sheer number of detections (of order $10^4 - 10^5$ BNSs and BBHs, per year), detections with very high signal-to-noise ratio, and the fact that GWs can carry messages from regions inaccessible to electromagnetic radiation, will provide a wealth of high-quality data that have the potential of triggering revolutions in astrophysics, cosmology and fundamental physics.

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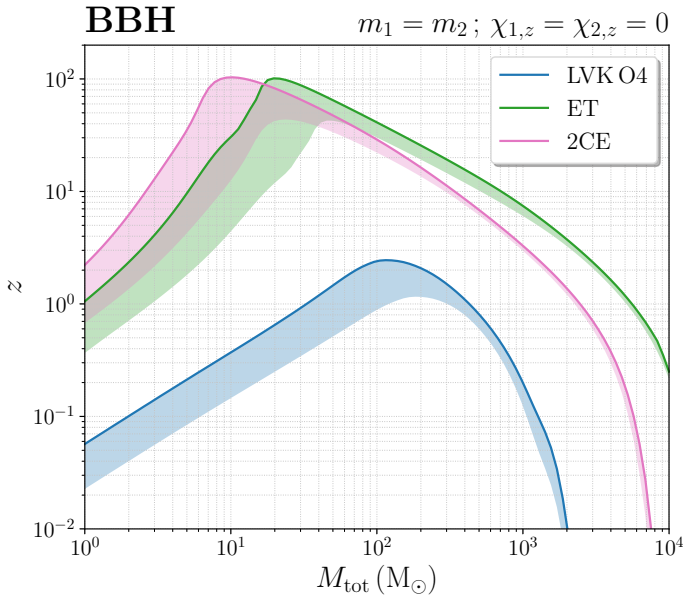


Figure 4: Detection horizons for the LVK detector network during O4, for ET, and for a network of two CE detectors (with 20 and 40 km arms). The shaded bands represent the maximum z out to which 50 % of the population with given masses and spins could be detected. From [14].

The Science Case of ET is very rich and covers many areas of fundamental physics, astrophysics, and cosmology (see [9, 13] for detailed discussion). To have a first glimpse of the scientific potential of 3G detectors, we show in Fig. 3 the detector sensitivities and in Fig. 4 the corresponding detection horizons (i.e., the maximum redshift to which a source with a given total mass can be detected) for ET and CE, and compare it with the result expected for the 2G detector by the end of the O4 observing run, which is currently ongoing. We see from Fig. 4 that, for optimal values of the masses and source orientation, ET and CE can reach redshifts higher than 10, and in fact in some cases up to 100, thereby exploring all the observable Universe up to the so-called dark ages, before star formation begun. Current models of stellar evolution, together with the LIGO-Virgo observations at low redshift, predict about 10^5 BBH coalescences/yr and $10^4 - 10^5$ BNS/yr, and ET and CE will then detect basically them all. This means that these detectors will detect a compact-binary merger every about 5 minutes! Some of these events will have a very large signal-to-noise ratio (SNR): we forecast that there will be more than 10^3 events/yr with SNR larger than 100, and in fact many of them with SNR up to several hundreds; their waveform will then be reconstructed with great accuracy, allowing us to perform accurate test of General Relativity, fundamental physics, and cosmology. ET will also significantly extend the range of masses for which black hole binaries are detectable, from sub-solar masses (a smoking-gun signature of primordial black holes, produced in the early Universe by the collapse of primordial density fluctuations) up to masses of $(10^3 - 10^4)$ solar masses, that would be the bridge to the supermassive BHs known to exist

Dealing with Messiness in Introductory Physics Teaching: A Field of Application of Large Language Models

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1. Introduction

Artificial Intelligence (AI) has arguably been around since 1956 [1], and chatbots have been around since 1965; some of us, the author included, may have even programmed versions of ELIZA [2] on their original IBM PCs (the one with the click-clack keyboard) or their Apple IIs. Other systems followed, some of them equally deterministic (essentially a collection of if-statements), some of them more probabilistic, relying on statistical methods to make predictions and decisions. The latter incorporate uncertainty and randomness, and they are oftentimes better suited to dealing with complex, real-world scenarios where data is incomplete, noisy and messy; Large Language Models (LLMs) like GPT fall into this category [3].

As physicists, we are generally far from computer-phobic, and we incorporate a wide spectrum of computing into all aspects of our work, except for two concepts we may have been somewhat snobbishly avoiding: SQL-databases (“too bookkeepish”) and AI (“too messy”). AI in general, and even Machine Learning (ML) in particular, may have been dismissed as only useful if one has no clue what is really going on. With the notable exceptions of having to deal with the vast amounts of data produced by for example particle physics or astronomy, by its very nature, ML is mostly phenomenological and thus dangerously close to messy fields like biology (because life is so messy). Physics, being highly theoretical and mathematical, has its own methods of understanding the universe that might not always align with AI’s data-driven approach. And in any case, when it gets too messy, it is time to resort to the spherical cow [4].

So, why would we suddenly want to deal with messy AI when it comes to education? I would like to propose the following argumentation chain: the active pursuit of learning is maybe one of the most human activities; humans are messy (and neither spherical nor bovine); thus, when it comes to deploying educational technology in pursuit of helping humans learn, it needs to be the messy kind of technology – like LLMs. In the following, this idea of essential messiness, and of the potential role of AI related to it, is discussed for four aspects of undergraduate physics teaching: language, problem solving, programming, and cheating.

2. Chatbots and Messy Language

Physics uses very precise language, and communicating physics relies on adhering to definitions and terminology; different from everyday language, words like momentum, energy, and power are not synonymous. We also use arcane expressions like “fall off quadratically” or “to first order;” it is a learning goal of introductory physics to teach this language, but students will not be there yet [5,6]; while still exploring, students need to be able to speak like the novices that they are [7]. In a survey at ETH Zurich, many students stated that they use LLMs to get an entry into a new field if they do not even know how to ask the right questions [8]; they appreciated that they do not need to be embarrassed to ask ChatGPT “dumb questions.” LLMs can deal with the messiness.

Students are aware that all LLMs hallucinate and are generally willing to put up with that; however, they also complain that a two-class society is developing between students who can afford the subscription-based versions and the much less powerful openly available models. They thus called for

ETH to provide a more reliable model for its courses, which would be available for everybody [8]. Consequently, ETH started an experiment called Ethel, which would offer custom-chatbots for courses based on actual course materials: scripts, exercises, slides, lecture recordings, etc. The bots use a method called Retrieval Augmented Generation (RAG) [9], where reliable documents are made available as reference while LLMs deal with the

1. Die Ausbreitungsgeschwindigkeit nimmt mit der λ ist, desto schneller kehren die Massenelemente in

2. Die Ausbreitungsgeschwindigkeit nimmt mit der λ ist, desto langsamer kehren die Massenelemente in

1.2.9 Energiedichte

Wir wollen uns nun der **Energiedichte** dW/dV von men. Diese setzt sich aus der **kinetischen Energiedichte** dE_k/dV zusammen, welche die poten der einzelnen Massenelemente des Mediums untereinander Mit den Ergebnissen aus dem vorherigen Abschnitt kö dichte einer transversalen Seilwelle $\xi(x, t)$ herleiten. Aus dem Physik I Kurs ist bekannt, das die kinetische der Welle gegeben ist durch

$$dT = \frac{1}{2} v^2 dm,$$

wobei $v = \frac{\partial \xi(x,t)}{\partial t}$ die Geschwindigkeit des Massenelemente Mit der Beziehung für die Massendichte $\rho = \frac{dm}{dV}$ folgt f

$$\frac{dT}{dV} = \frac{1}{2} \rho \left(\frac{\partial \xi}{\partial t} \right)^2$$

Wir werden nun die elastische Energiedichte dE_{el}/dV spannung $S = F/A$ wirkt, ist die in einem um die Längs verschobene potentielle Energie gegeben durch $dW =$

Explain that example about waves on a rope, I don't get what that "dm" is about.

The term "dm" in the context of the wave on a rope example represents a small mass element of the rope. When waves propagate in a medium like a rope, the energy of the wave is distributed among small pieces or elements of that medium.

In the given example, they're considering a small segment of the rope with mass "dm". This segment is small enough that it can be treated as a point mass for the purpose of calculations, but large enough that it contains a very large number of atoms so macroscopic quantities like mass can still be defined.

The kinetic energy of this mass element "dm" is given by the equation

$$dT = \frac{1}{2} v^2 dm,$$

where $v = \frac{\partial \xi(x,t)}{\partial t}$ is the speed of the mass element, and $\xi(x, t)$ is the displacement of the rope at position x and time t .

The kinetic energy density (kinetic energy per unit volume) is then obtained by dividing this kinetic energy by the volume of the mass element, which is dV . With $\rho = \frac{dm}{dV}$ as the mass density of the rope, the kinetic energy density becomes

$$\frac{dT}{dV} = \frac{1}{2} \rho \left(\frac{\partial \xi}{\partial t} \right)^2.$$

I hope this clarifies the role of "dm" in the energy calculations for a wave on a rope. Let me know if you have any further questions!

The "v" in your answer seems different from the "v" we got out of the partial differential equation for $\xi(x,t)$ - is that the velocity of the wave?

Yes, the "v" in the context of the equation for $\xi(x, t)$ is indeed the velocity of the wave, more specifically, the phase velocity. This is the speed at which a particular phase of the wave (for instance, the crest) propagates in space. It can be represented by the equation $v = \frac{\omega}{k}$, where ω is the angular frequency of the wave and k is the wave number.

In the kinetic energy equation, v represents the speed of the small mass element "dm" of the rope, which is a function of time and position on the rope and is related to the displacement of the rope.

These two "v"s, while represented by the same letter, refer to different concepts. The context should make it clear which one is referred to.

Retrieval Augmented Generation in action: the right window shows a dialogue with Ethel, which is based on the information in the lecture script on the left.

conversational aspects (and bridge language-differences, as they can deal with a wide spectrum of spoken languages).

The figure shows a dialogue with Ethel. The lecture script has over 300 pages and is written in German; in addition, LaTeX is understood and spoken by the bot. RAG allows learners to ask specific questions about the lecture materials in multiple languages, and it does not require exact terminology or search phrases (i.e. allows for “messiness”); as everything is in course context, students can simply refer to “that example about waves on a rope” and resolve confusion about terms or symbols in the script (e.g., “the ‘v’ we got out of the partial differential equation for $\eta(x,t)$,” where “eta” is not even the correct Greek character). The LLM acts as a conversational and reasoning agent to deal with the messiness, while the knowledge comes from the materials, leading to less hallucinations.

The setup uses on-campus servers in connection with GPT-4 running on Swiss datacenters under the same licensing terms used for other cloud services dealing with confidential data [10]. This setup allows for faster dialogues than GPTs [11], and it has no hard limit on how much reference data is used. We received very encouraging feedback to this simple approach from both students and faculty, and we plan on further developing it, e.g., course materials getting automatically “digested” (embedded) as soon as faculty adds them. Future versions might use a fine-tuned, open-weight, and potentially on-premises models like Llama, Mistral, or Gemma instead of a commercial backend. ETH Zurich and EPF Lausanne are currently collecting “donations” of course materials from faculty for tuning; it is an experiment, and it remains to be seen if this works.

3. Problem-Solving and Messy Derivations

While most of us physicist likely enjoyed physics lectures and appreciated the inspiration, fun, role-modeling, and valuable perspectives gained (which we aim to pass on to our students), we would probably also admit that we learned more physics facts and methods from solving problems – on paper and in the lab. The process of deriving and arriving at a solution, including all the detours and errors, is what in the end helped us master the concepts; the journey is the goal. Educational technology can help provide more opportunities for learning by assessment, also known as formative assessment; unfortunately, many of these technologies only focus on the final answer (“42 Newton”) instead of the way how to get there, which for a learner is the most important part. The reason: “42 Newton” is nice and clean, and one can check this final result deterministically, but the non-linear journey towards it might be a mess.

While the mathematical capabilities of LLMs still leave a lot to be desired (for example, do not count on them being able to count), the text corpus used for the training of the most popular ones is extensive enough in the foundational sciences to derive the solutions of about 80 % of introductory physics problems, including freshly authored ones that are guaranteed not to be part of the training [12,13]. Rather than seeing the challenge of students cheating on homework, we should see the opportunity of providing immedi-

ate, individualized feedback or even assisting in grading student-provided derivations.

In a feasibility study, we tested AI-grading of a synthetic dataset of homework solutions, looking at the complete answer derivation, and found an F^2 of 0.84 between AI-grades and instructor grades on a grading rubric considering correctness of argument, straightforwardness, symbolic correctness, and numerical correctness of the solution path [13]. While not good enough for high-stakes summative exams, the result encouraged us to provide automated feedback on handwritten formative assessment (“exercise sheets”) in an introductory physics course. As students are handing in their work as scanned PDFs anyway for teaching-assistant feedback, we used MathPix [14] to transcribe them into machine-readable format and GPT-4 for AI-feedback on the solution, based on the problem and the instructor-provided sample solution. The feedback was not always correct (which students are aware of [8]), and we had to work on the “character” of this virtual teaching assistant by refining the prompts, but in the end, we received nothing but encouraging evaluations from the students.

Currently we are working with a high-stakes thermodynamics exam, where we aim to put the complete workflow to the test: scanning of exam sheets, transcription with MathPix and GPT-4V, and rubric grading. This data set of 252 exams with four multi-part problems with a detailed step-by-step grading rubric is hopefully going to give us a better understanding of uncertainty and confidence levels.

A major caveat: as with so many of the popular cloud services, there are legal challenges for their production usage. While GPT-4 and GPT-4V are covered by existing agreements of ETH Zurich, we would still need to attend to the contractual details with MathPix, should we decide to use this service outside the research protocol and without informed consent by the learners.

4. Messiness and Programming

Over the recent decades, Computational Physics have found an entry into introductory physics courses [15]. While visualizing and “playing with” physics using simulations and computerized data collection is widely acknowledged as beneficial [16], a common concern of educators is that struggling with the syntax of for example VPython could easily distract from the physics; the author regularly used VPython in his courses and can attest to the potential of a parenthesis being in the wrong place to take up a disproportionate amount of instructional time. LLMs can deal with messy instructions, assist in debugging, and produce syntactically correct code. At the same time, the LLM might make some of the very same physics errors that students do (like, “forgetting” to norm a unit vector [12]); thus, LLMs can overcome hurdles imposed by syntax (which are arguably not part of the learning objectives of an introductory physics course) in favor of concentrating on and debugging the physics.

5. The Messiness of Cheating

With LLMs performing at the level of a B-student in introductory physics, a large concern is cheating; will students still

do the exercises themselves, or will they have GPT generate their answers, as it is frequently bemoaned in the humanities with its take-home essays?

According to the student survey at ETH Zurich, students make extensive use of AI-tools for a variety of tasks, many of them language-oriented, such as grammar checks, translations, summaries, and feedback on writing. It is also frequently used for first drafts of computer programs, debugging, and explaining code. For other tasks in the STEM disciplines, GPT was deemed too unreliable, and in any case, students remarked that they were worried about not learning the materials [8]. In this context, it is important to note that course grades and study progress are mostly determined by high-stakes exams, which take place under controlled conditions on-campus, often with just paper-and-pencil and a non-programmable calculator. It is thus not worth it to cheat on homework exercises during the semester.

The situation is different in university systems where grades are determined by a variety of small assignments over the course of the semester. Here, cheating is and likely always was rampant, using commercial non-AI sites like Chegg [17] or simply copying from peers. There is evidence that as of the end of 2023, student behavior in physics has hardly changed with the availability of AI-tools, and traditional means are still strongly preferred [18].

On the other hand, tools like Chegg have a delay till solutions become available, which to a certain extent makes them “exam safe” if the problems had not previously been published. While having remote exams in physics might have been irresponsible before, this practice, which established itself during COVID-19, is certainly irresponsible now [18]; short of total surveillance via cameras and microphones, no number of other lockdown tools will help protect the honest students (which are in the majority).

The findings on cheating are distressing, since there is substantial evidence that repeated exposure to and interaction with the materials, including frequent in-semester assessment, rather than cramming during exam preparation, yields better learning outcomes [19-21]. LLM feedback from highly scalable and quick handwritten in-class quizzes might be key to resolving this dilemma; besides, personalized feedback from these systems might be attractive enough to make cheating appear undesirable and unprofitable.

6. Conclusion

As physicists, we may have been spared from having to fundamentally rethink our curricula because LLMs are so bad in math. This flaw is intrinsic, since these systems are calculators for words, not numbers. However, LLMs can be trained to use helper applications; GPT-4 already makes extensive use of Python and R to figure out the math that it cannot do itself (when “analyzing” shows up in a dialogue, tools like sympy are being invoked and arrive at the correct solution, which then gets embedded into the response). Sooner or later, we will be in the same shoes as Computer Science and the humanities, and we have to rethink where

we are going with introductory physics courses. In that respect, LLMs are like pocket calculators: students used to spend huge amounts of instructional time learning how to do things like square roots on paper – nobody does that anymore except for numbers like 49 or 121 and their immediate vicinity, since we already carry what used to be supercomputers in our pockets or on our wrists. Our introductory physics curricula, essentially unchanged since the modern physics revolution, just got a little messier.

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The next future of space projects on cosmic ray physics

Mercedes Paniccia (AMS), Merlin R. Kole (POLAR-2), Martina D'Arco, Teresa Montaruli, Caterina Trimarelli (Terzina)

In this article, we describe three pioneering space-based experiments, involving the Département de Physique Nucléaire et Corpusculaire of the Faculté de Science de l'Université de Genève. They aim at improving our understanding of high-energy astrophysical phenomena, such as gamma-ray bursts (GRBs) and cosmic rays below the knee at a few PeVs (the knee of protons is the steepening of the cosmic ray spectrum from a power law $\frac{dN}{dE} \propto E^{-2.7}$ to $E^{-3.1}$ at about 3×10^{15} eV = 3 PeV for protons) and in the region beyond 100 PeV to beyond the ankle (the hardening of the spectrum at about 5×10^{19} eV) of Ultra High Energy Cosmic Rays (UHECRs).

After a short introduction on cosmic rays, the AMS experiment, in operation for 13 years, and its results are presented. Then, two next future missions are described: POLAR-2, which builds upon the legacy of its predecessor POLAR and aims at unravelling the polarization signatures of GRBs with unprecedented precision. Additionally, we foresee in 2026 the launch by ASI of the NUSES satellite mission, with on board a payload focusing on the detection of Cherenkov light emitted by EAS induced by UHECRs and neutrinos in the Earth's atmosphere.

1. Intro to Galactic cosmic rays in the GeV to multi-TeV energy range

In the energy range from 0.5 GeV to multi-TeV, cosmic rays are predominantly protons, with helium nuclei accounting for ~10 %, electrons, and nuclei heavier than helium only about a few %. Positrons and antiprotons are very rare as they are mostly secondary products of interactions of heavier cosmic rays with the interstellar medium. Their abundance relative to protons amounts to only about 1/1000 and 1/10'000 respectively. So far, there is no confirmed observation of anti-nuclei: anti-helium nuclei abundance relative to helium nuclei is less than 1/10⁹. Cosmic protons, electrons, and most nuclei, such as oxygen, silicon, and iron, are primaries originating from cosmic sources. Some nuclei, such as lithium, beryllium, boron, fluorine, scandium, titanium, and vanadium, are overwhelmingly produced in spallation reactions of heavier primary cosmic-ray nuclei with the interstellar medium during their journey through the galaxy. Most cosmic nuclei are a mixture of two or more isotopes having different origins, as He nuclei which are composed of the primary ⁴He and the secondary ³He. Secondary species and radioactive isotopes in secondary cosmic rays, which have a lifetime of the same order of magnitude as the cosmic-ray propagation time scale in the galaxy, are of particular importance in modelling galactic cosmic rays. Cosmic rays are accelerated diffusing through expanding shocks and propagate in the interstellar medium scattering on the irregularities of the galactic magnetic field. Both these mechanisms depend on the particle's momentum, or magnetic rigidity $R = \text{momentum}/\text{charge}$. Cosmic-ray propagation is described in terms of a rigidity-dependent diffusion coefficient which embeds the properties of the galactic magnetic field turbulence. Simultaneous measurements of the individual rigidity spectra of secondary species and their primary progenitors, as B/C,

B/O, F/Si, or Sc/Fe, are the key experimental tools to probe cosmic-ray propagation as their ratio directly maps the rigidity dependence of the diffusion coefficient. Comparing the spectra of unstable secondaries, as ¹⁰Be, to those of stable secondaries, as ⁹Be, allows us to determine the grammage (the distance times the density) through which cosmic rays propagate in the volume of the galaxy (or equivalently their escape time from the Galaxy), and to derive the normalization of the diffusion coefficient. Current models assume that all primary nuclei have identical featureless power-law rigidity spectra, and that the diffusion coefficient follows a featureless power law in rigidity, and it is independent of the particle's charge, leading to identical featureless power-law spectra for all secondary nuclei. The AMS-02's observations are challenging this paradigm.

2. AMS-02 and its upgrade

The Alpha Magnetic Spectrometer, AMS-02, is a state-of-the-art high-energy particle detector installed on the International Space Station (ISS) in May 2011 to perform precision measurements of cosmic-ray particles, anti-particles, nuclei, and anti-nuclei of energies ranging from 0.5 GeV to multi-TeV. The AMS-02 experiment addresses outstanding questions in fundamental physics, the matter-antimatter asymmetry, the nature of dark matter, and the existence of exotic forms of matter, and in cosmic-ray physics, the origin, the acceleration, and propagation mechanisms of galactic cosmic rays. Thanks to its large acceptance and long-duration mission, spanning over more than an entire 11-year solar cycle, AMS-02 is also delivering time-resolved particles and nuclei fluxes of great interest to solar physics, space weather, and space radiation studies.

AMS-02 combines five detectors, a Transition Radiation Detector (TRD), a Time Of Flight (TOF), a nine-layer (L1 to L9) Silicon Tracker, of which 7 inserted in a permanent magnet, a Ring Imaging Cherenkov (RICH), and an electromagnetic calorimeter (ECAL). They provide redundant measurements of the particle's charge along its trajectory inside the apparatus, and independent measurements of the particle's rigidity, velocity, and energy. The silicon tracker measures the rigidity and charge sign from the track's bending inside the magnetic field. The two TOF layers and the RICH determine the particle's velocity at percent and permille accuracy respectively. Combined with the rigidity measurement, these provide isotope identification in the kinetic energy per nucleon range from 0.5 GeV/n to 12 GeV/n. The ECAL measures the energy of electrons and positrons with percent accuracy. Identification of leptons against hadrons with a rejection power of 1/10⁵ is achieved combining the ECAL 3D shower reconstruction with the TRD response. The redundancy of the AMS-02 detector also allows the measurement of nuclei fragmentation cross sections and to determine the isotopic composition of light fragments. So far, AMS-02 has collected more than 230 billion cosmic ray events and has provided unprecedented-precision measurements of specie-resolved energy spectra of electrons and positrons, rigidity spectra of protons, antiprotons, nuclei from helium to silicon, sulfur,

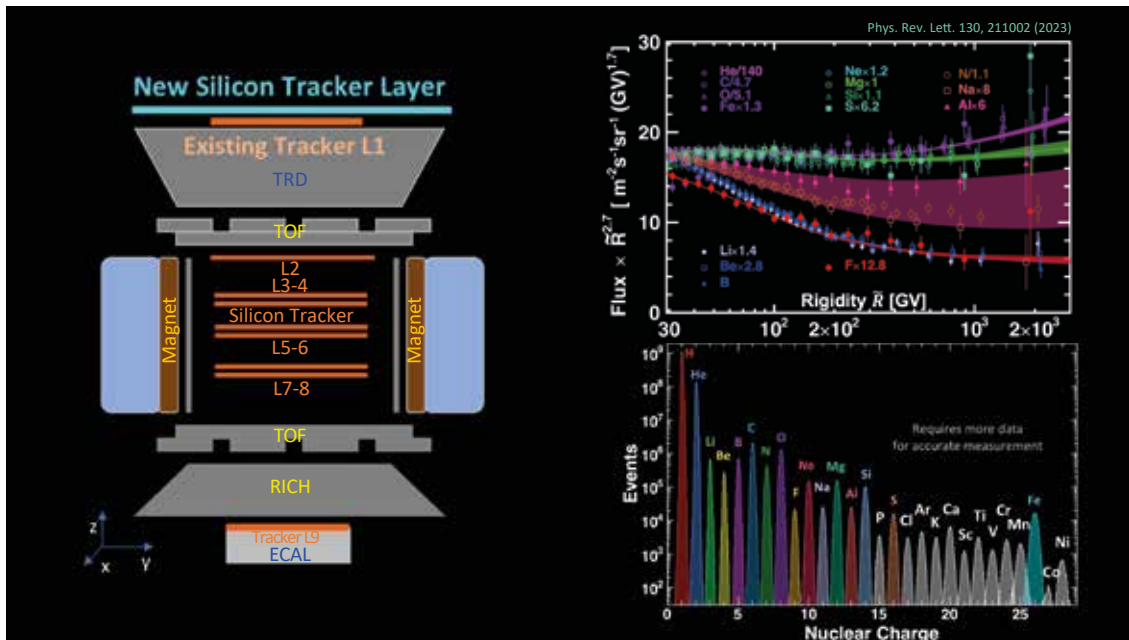


Figure 1: Left: Schematic view of the AMS-02 apparatus with its five detectors, the nine-layers of Silicon Tracker (L1 to L9) and the permanent magnet, the Transition Radiation Detector (TRD), the Time Of Flight (TOF), the Ring Imaging Cerenkov (RICH), and the electromagnetic calorimeter (ECAL). Also shown is the upgraded AMS-02 with the addition of a new Silicon Tracker layer at the top of the apparatus. Right: current AMS-02 results on cosmic nuclei rigidity spectra (top) and collected statistics for all cosmic-ray nuclei up to nickel (bottom).

and iron, and helium isotopes. The AMS experiment is run by an international collaboration of 44 research institutes and universities from 14 countries in Europe, Asia, and the Americas. The experiment is led by the US Department of Energy and sponsored by NASA. The University of Geneva is a founding member of the AMS Collaboration through the AMS group at the Department of Nuclear and Particle Physics. The Geneva group has played an important role in the construction and commissioning of the silicon tracker, and currently, its activities are focused on data analysis. In the last years, it has given primary contributions to the measurements of the spectra of nuclei heavier than oxygen and is now leading the measurement of the isotopic composition of beryllium and lithium nuclei. The nuclei measurements have led to the first observation of two classes of spectral shapes for both primary, He-C-O-Fe and Ne-Mg-Si-S, and secondary nuclei, Li-Be-B and F, and to the detailed characterization of the spectra of mixed primary and secondary nuclei, N, Na, and Al. In addition, all the nuclei spectra measured so far by AMS-02 are not compatible with the assumption of featureless power laws as all hardens above 200 GV, as previously observed for protons and helium from other experiments. The AMS-02 measurements of light secondary-to-primary ratios, B/C, Be/C, Li/C, B/O, Be/O, and Li/O have shown for the first time that the hardenings of the spectra of nuclei up to oxygen are due to a hardening of the diffusion coefficient. Moreover, AMS-02 has observed that the medium-mass secondary-to-primary ratio, F/Si, is different from light secondary-to-primary ratios questioning the assumption of an universal diffusion coefficient. The origin of this difference is not yet understood. It may arise from the properties of the galactic interstellar medium at different distances. Heavy cosmic nuclei probe smaller galactic volumes because of the dependence of their fragmentation cross-sections with the mass.

Precision measurements of secondary nuclei heavier than fluorine, namely titanium, scandium and vanadium, and

their ratios to their main progenitor, iron, will bring crucial information to solve the fluorine puzzle. AMS-02 has the needed sensitivity to perform such measurements. However, due to the natural low abundance of heavy species, to obtain individual spectral measurements of such nuclei with precision comparable to that of lighter nuclei, the collection of more events is required. AMS-02 is operating smoothly and it will continue acquiring data for the entire ISS lifetime, until at least 2030 as in the currently approved NASA financial budget. The AMS-02 detector had originally been designed

with a super-conducting magnet, lately replaced by the permanent magnet to match the lifetime of the spectrometer to the ISS's lifetime at the cost of reducing the geometrical acceptance by a factor of 3. To restore the originally planned acceptance, AMS-02 will be upgraded by installing an additional silicon tracker layer, L0, at the top of the apparatus. The upgrade will also allow us to improve the current AMS-02 measurements of electrons, positrons, and antiprotons at high energy. L0 is currently under construction in China. The launch of the ISS and its installation are scheduled for early 2026.

3. POLAR-2

Gamma-ray bursts (GRBs) are, and will during the coming years, remain one of the prime targets of multi-messenger astrophysics. On the 17th of August 2017, the first Gravitational Wave (GW) signal from a binary neutron star merger event was observed jointly by 2 gamma-ray detectors as well as a range of X-ray, optical and radio telescopes. The observed event was a GRB, an extra-galactic phenomenon previously only observed through photons.

Despite gamma rays being the messengers through which the very first GRB was discovered, one of its parameters, its polarization, remains largely unmeasured. Studies using the 3 other parameters, their arrival time, direction, and energy, have each led to novel insights into GRBs. The momentum, or arrival direction, of the photons, has been used to prove the extra-galactic nature of GRBs. The arrival time has allowed us to divide them into short and long GRBs and associate these with different progenitors. Finally, their energy has provided us with a wealth of insights, one of which being that the emission is not purely thermal but rather originates from some, yet unknown process inside of relativistic jets. Although 1000's GRBs have been detected over the last 50 years, the origin of the gamma-ray emission remains a

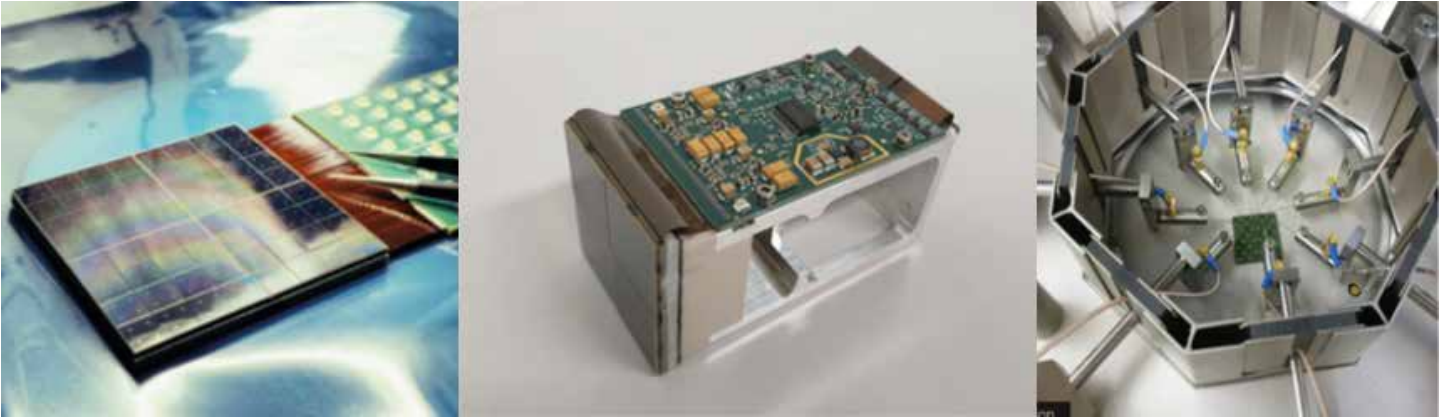


Figure 2: The SiPM array used to read out 64 scintillators from POLAR-2 on the right. The middle figure shows the SiPM connected to the POLAR-2 front-end electronics. On the right, the probe station which tests the SiPMs is shown.

mystery and traditional studies appear to be unable to solve this. The most promising measurement to break the current stalemate on gamma-ray burst modeling is determining their polarisation. Such measurements are highly challenging; however, they are theorized to answer questions regarding the origin of the gamma rays, the geometry of the emission region and the potential presence of magnetic fields. Due to the large wealth held by the polarization, a range of attempts has been made over the last 20 years to measure it. The most successful of which were performed by the POLAR collaboration.

The POLAR mission, a Chinese, Swiss and Polish mission, detected 55 GRBs after being launched as part of the Tiangong-2 space lab in 2016. It performed polarization measurements in the energy range of 50–500 keV of 14 of these as well as of the Crab pulsar. Although the measurement results of POLAR are the most constraining GRB polarization measurements to date, they are only able to constrain the polarization degree to be below $\sim 40\%$. Therefore, the results remain consistent with most of the existing theoretical predictions. This, along with the hint of an evolution of the polarization with time observed in 2 of the GRBs indicates the need for a significantly more sensitive detector. For this purpose, the POLAR-2 detector was initiated in 2017, followed by an approval for launch towards the China Space Station (CSS), through a United Nations Office for Outer Space Affairs call in 2019. The project is currently foreseen to be launched in 2027 towards the CSS. A prototype of the detector successfully underwent space qualification measurements in 2022, and its scientific performance was tested extensively during 2023 with dedicated polarized beams. The production of the flight model was started in 2024 by an international collaboration consisting of teams from Switzerland, Poland, Germany, and China.

Compared to its predecessor, the POLAR-2 detector will be a factor of 4 larger, thereby employing a total of 6400 plastic scintillator bars. These scintillators are read out in groups of 64, using segmented SiPM arrays connected to their frontend, the electronics holding the Silicon Photomultipliers (SiPMs) developed for POLAR-2 are shown in Figure 2. As the GRB photons enter the detector they can undergo Compton scattering in the detector array, followed by photo-absorption in a second scintillator. Their azimuthal scattering angle can be constrained using the relative position of the two scintillators in which the photon interacted. As

the photons will scatter preferentially perpendicular to their initial polarization, this measurement allows us to determine the polarization of the incoming photon flux.

While the increase in the detector dimensions provides an increase in the effective area of a factor of 4 compared to POLAR, further improvements to its design allow for additional improvements in its sensitivity. Particularly the switch from PMTs as used in POLAR, to SiPMs results in a significant increase in sensitivity at lower energies.

Thanks to all the design improvements, POLAR-2 is approximately an order of magnitude more sensitive compared to POLAR. The instrument will be able to perform constraining polarization measurements for GRBs with fluences as low as 10^{-6} erg/cm² (10^{-13} J/cm²) which typically occur several times per week. As a result, POLAR-2 will produce approximately 50 measurements per year with a precision equal to or better than the most precise measurements available to date.

Although dedicated to gamma-ray polarimetry, the POLAR-2 detector will also play a leading role in providing transient alerts to the multi-messenger community. This is thanks to its large effective area, which exceeds 2000 cm². This large effective area, combined with continuous observations of half the sky and almost continuous communication to ground will allow POLAR-2 to send alerts within one minute from the onset of about 1 GRB every 2 days. Current predictions indicate that POLAR-2 will perform approximately 2 joint detections per year with gravitational wave detectors. As the instrument furthermore has access to a GPU onboard the CSS, studies are currently ongoing on how to optimize GRB spectral and location information within such alerts. As a result, POLAR-2 will, for many GRBs, provide the first detailed alert to the ground to instruments such as CTA, optical and radio telescopes.

4. The Terzina telescope on board the NUSES satellite

The NUSES (Neutrinos and Seismic Electromagnetic Signals) satellite mission is an upcoming project aimed at exploring new scientific and technological pathways for future astroparticle physics space-based detectors. The mission is scheduled to be launched in 2026 and will operate at a Low Earth Orbit (LEO) with an altitude at the Beginning of Life (BoL) of 535 km, along with a high inclination of 97.8° (LTAN = 18:00) in a sun-synchronous orbit along the day-

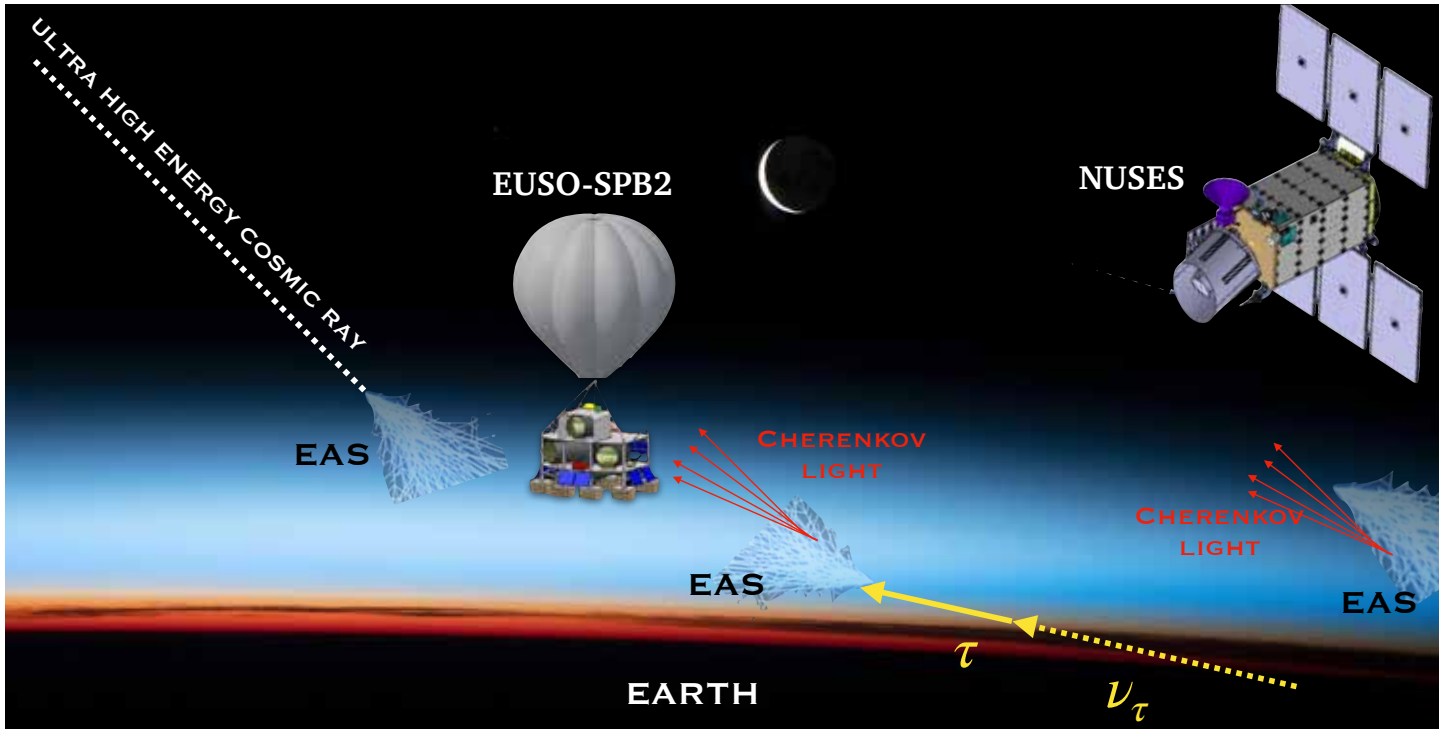


Figure 3: The principle of detection of Cherenkov light emitted by downing extensive air showers induced by ultra-high energy cosmic rays and upgoing ones induced by earth-skimming neutrinos from balloon-borne experiments, such as EUSO-SPB2 [1], and space missions as NUSES.

night boundary. The NUSES mission is expected to last for three years.

The satellite will host two innovative scientific payloads: Ziré and Terzina. Ziré is a scintillation and silicon photo-sensing matrix that aims to study Gamma-Ray Bursts (GRBs) and detect cosmic rays (CRs) in the energy range of a few to hundreds of MeVs. It will also search for possible correlations of earthquakes with electrons in the van Allen belts. The second payload, Terzina, is a new optical telescope concept designed to detect Cherenkov light in space and neutrinos. It serves as a pathfinder to future space missions like POEMMA dedicated to UHECR detection and UHE earth-skimming neutrinos. POEMMA and Terzina use SiPMs for the detection of the Cherenkov light induced by extensive air showers (EAS) in the Earth's atmosphere. This needs to be dark to detect the flash of light which lasts typically 10 ns up to several tens of nanoseconds.

In the following, we will focus on Terzina. However, it is worth mentioning the technology developments targeted by NUS-

ES as this microsatellite will be a pathfinder and a precursor of a fleet of flying elements. The Thales company in Italy (TAS-I) will prove the concept of the New Italian Micro BUS (NIMBUS), which is a new ballistic platform concept for LEO microsatellites. This foresees a modular approach relying on standard trays. Additionally, at UNIGE, we are cooperating with the Fondazione Bruno Kessler on the development of robust photosensors for space applications. These are based on the NUV-MT, which uses metal trenches to reduce crosstalk between sensor microcells to a few per cent level of accuracy.

Terzina's science scope is to detect the Cherenkov light emitted by extensive air showers (EAS) induced by ultra-high-energy cosmic rays (UHECRs) and Earth-skimming neutrinos. At extremely high energies, tau neutrinos and muon neutrinos passing through the Earth can produce tau and muon leptons, which can emerge by decaying or interacting in the atmosphere. These interactions result in Earth skimming events, which create EAS moving in the atmosphere from bottom to top, unlike the downgoing EAS

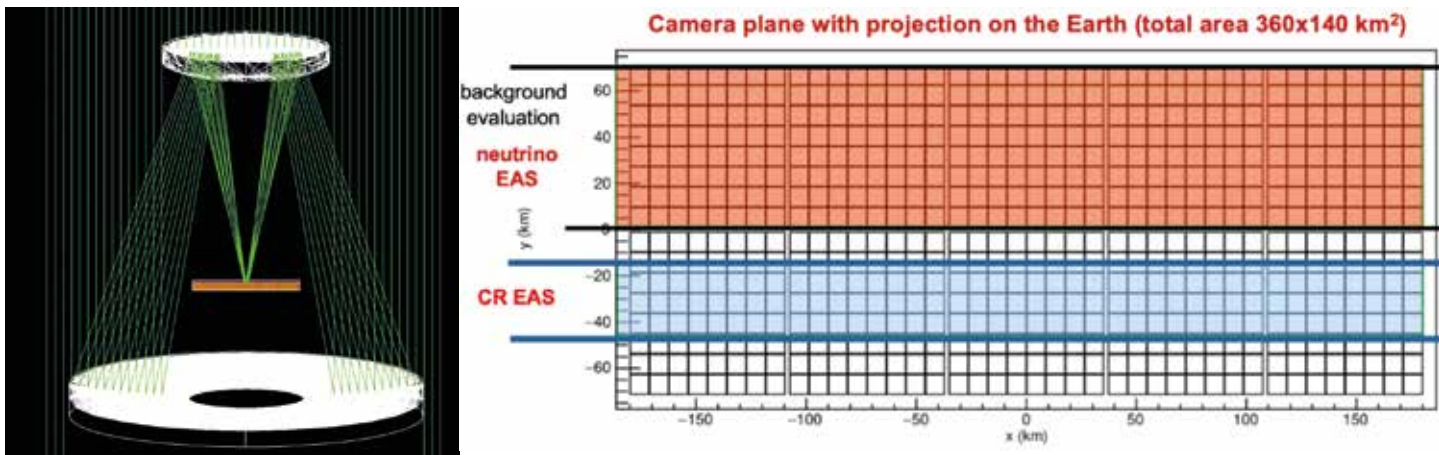


Figure 4: Left side: the optical system of Terzina. Right side: the focal plane with two row of 5 SiPM arrays of 8 × 8 pixels. The upper arrays will be sensitive to the Earth and UHE neutrinos and the lower to the UHECRs produced in the Earth's atmosphere.

produced by UHECRs in the layer of the atmosphere above the limb. The Cherenkov emission from these EAS can be detected by space-based instruments with high exposures. As Terzina is sensitive to particle interactions at distances of few 1000 km, the effective detection area is huge compared to the mirror area of the order of 0.1 m^2 of the telescope.

The telescope will be inclined at an angle of 67.5° with respect to the nadir, with the optical axis pointing towards the dark side of the Earth's limb. The expected duty cycle of the telescope is around 40% due to the passage of the Moon across the orbit and residual sunlight in the detector, with the addition of a random background from lights of cities and thunderstorms and reflections of light on other satellites.

The Terzina detector is made up of a near-UV-optical telescope with Schmidt-Cassegrain optics and a Focal Plane Assembly (FPA) shown in Fig. 4 on the right. The optical system uses a dual-mirror configuration (see Fig. 4 on the left) consisting of a primary mirror, which is placed about 40 mm away from the FPA and has a radius of about 394 mm, and a secondary mirror with a radius of about 144 mm. The two mirrors are positioned about 280 mm apart and the equivalent focal length is 735 mm.

The FPA is designed to detect photons from both below and above the Earth's limb. It has a rectangular shape with a 2:5 aspect ratio and is composed of 10 SiPM (Silicon Photomultiplier) arrays. Each array contains 8×8 pixels of $3 \times 3 \text{ mm}^2$ each, arranged in 2 rows of 5 arrays each, for a total of 640 pixels overall.

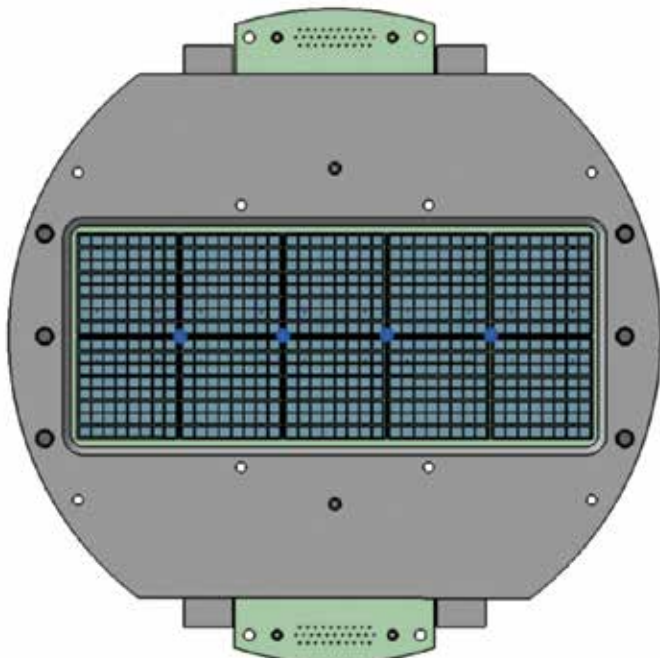


Figure 5: The TERZINA SiPM photosensing plane (FPA) composed of 10 8×8 tiles of $3 \times 3 \text{ mm}^2$ produced by Fbk.

Thanks to the Schmidt-Cassegrain optics, the upper row of 5 SiPM arrays is dedicated to observing events coming from below the Earth's limb. It will provide a clear characterization of the background and might observe a few neutrino-induced EAS. Even one would be of such high energy that would be sent as a trigger to all electromagnetic and other

neutrino telescope detectors. The lower row of 5 SiPM arrays will observe UHECRs above the limb.

A simulation pipeline has been constructed at the UNIGE to evaluate the performance of the telescope. Using the Extensive Air Shower Cherenkov Simulation (EASCherSim) computational framework, the Cherenkov emission observed from a space-based telescope during an above-the-limb EAS has been estimated. The Cherenkov emission can be observed from a small layer of the atmosphere with an angular size of less than 1° , at an altitude above the limb ranging from 20 km up to 50 km, given the observation geometry from the Terzina altitude and atmospheric characteristics. The Cherenkov spectrum shifts more to the red wavelength than for Cherenkov light observed from the ground and is affected by a dip due to ozone absorption. We have implemented in the Geant4 toolkit the design of the Terzina telescope geometry mechanically and optically implemented by the Italian company Officina Stellare (see the CAD model of the telescope in Fig. 6). The result is a dedicated Monte Carlo simulation of photon propagation to the telescope which will allow to exactly predict the performance of the telescope.

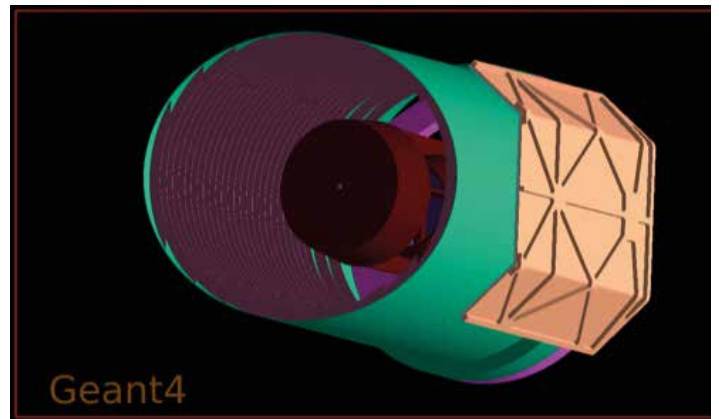


Figure 6: The Terzina CAD model

The background of Terzina is expected to consist of electrons (trapped) and protons (trapped and solar). It will also include the Night Glow Background and city lights, as well as atmospheric factors such as auroras, lightning, and clouds.

We anticipate that cosmic ray electrons and protons will be the primary sources of background as the ionizing radiation from protons and heavier nuclei can cause damage to the silicon of SiPMs. Additionally, neutrons can induce dislocations within the crystal structure. These sources of damage increase the Dark Count Rate (DCR). The extent of the damage depends on the cosmic ray radiation spectra obtained with the SPENVIS NASA code for the Terzina's orbit. We utilize the full simulation of the telescope to estimate the radiation dose accumulated during the 3-year mission by the SiPMs. We compare the simulation to the results of tests of electron and proton radiation exposure tests. The sensors were exposed to a proton beam of about to MeV at the IFJ PAN Institute and electrons from strontium $^{90}\text{Sr}/^{90}\text{Y}$ decay which has a two-decay mode extending to 2 MeV.

As SiPM performance degrades under the action of (mostly ionizing) radiation, their robustness for space application will depend on their radiation hardness, the strategy to recuperate their performance through annealing and the radiation

quantity to which they will be exposed. An annealing strategy was defined as compatible with the maximum dissipation allowed for the photo-sensing plane of the camera of 5 W, where the recovery at each cycle is about 40 % at moderate achievable temperatures of about 60°C after 60 hours of heating. The main effect of the damage in the sensors will be due to solar protons and 1/3 trapped protons in the van Halen belts. If the damage accumulates over time the power consumption due to the dark count rate it generates will become out of specification.

In conclusion, the Terzina telescope is an innovative optical telescope designed to detect high-energy neutrinos and cosmic rays. The mission holds the promise of advancing our understanding of astrophysical phenomena and paving the way for future breakthroughs in space-based astroparticle physics research.

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Physics Anecdotes and Personal Recollections (29)

Testing large optical Systems

Bernhard Braunecker

We explained in Nr. 71 and 72 of this journal special concepts of optical metrology. We apply in this issue the wavefront method WF to verify the optical quality of large optical systems and especially of space telescopes before their launch into space.

Testing the Herschel Telescope

As an example of a large scale WF measurement methodology, we mention the tests performed in 2008 of the big Cassegrain telescope of the Herschel satellite which provided astronomical data in the IR range of 10 - 60 μm in the years from 2009 to 2013. The telescope consisted of a concave parabolic primary mirror of 3.5 m diameter¹ and a convex hyperbolic secondary mirror of about 30 cm diameter, both mirrors made of sintered SiC-100 material and using M93-Cryogenic Invar for all the supporting structures as the spider legs between prime and secondary mirror² (Fig. 1). The correct mirror mounting was tested in a vacuum chamber at University of Liège (BE), where also temperature cycles could be run.

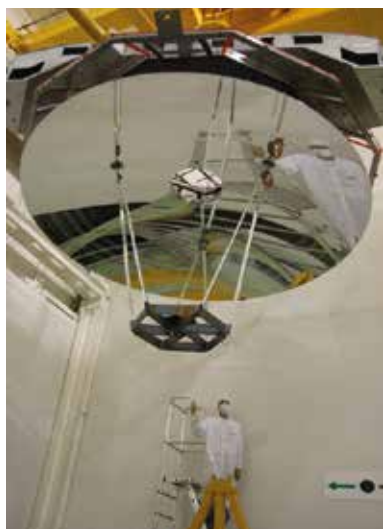


Fig. 1: Herschel Cassegrain Telescope

where also temperature cycles could be run.



52 Liquid mirrors are aligned on optical bench inside the chamber

Fig. 2: The oil pot assembly used as reference mirror

The applied measurement principle was *Autocollimation*, where a laser source is placed at the known back focal point of the telescope and the emitted plane wavefront at the primary mirror is reflected from a plane reference mirror outside the telescope and focused back through the telescope to a 2D-sensor in the nominal focal plane. For cost reasons, however, the plane autoreflexion mirror of 3.5 m diameter was replaced by an arrangement of up to 52 small subapertures in the form of well reflecting oil pots of $D_{\text{Ref}} \sim 20$ cm diameter (Fig. 2).

Since Herschel should be placed in Lagrange point L2, its best focus position had to be checked at 70 K, the temperature at L2. Therefore the oil pot array had to be thermally protected from the cold telescope by thermal shrouds which mechanical apertures were only shortly opened during the

¹ Maximum payload diameter of ESA's Ariane 5 ECA rocket, the space carrier.

² https://www.esa.int/Science_Exploration/Space_Science/Herschel_overview

laser shot. The test results showed surprisingly that the position of the best focus moved by 11.7 mm when cooling down from room temperature to 70 K, and thus significantly exceeded the expected tolerance range of ± 1.6 mm. Since nothing could be changed on the telescope at that time, the only thing left to do was to manually defocus it by -11.7 mm at room temperature, that later in L2 the full spatial resolution should be obtained at 70 K. However, the associated risk could only be addressed if the pre-correction would be constant in time, so it was necessary to understand all the unexpected error sources. Of this error value, 8.5 mm could be explained mainly by insufficient knowledge of thermal material constants³; errors which, however, would be constant in time, while the remaining contribution of 3.2 mm was suspected but not proved to be due to so-called *cryo-quilting*. This effect is observed when the backside of a large mirror is milled out in a cell shape structure for weight reduction reasons. Numerical simulations of the primary mirror construction showed, that the thinned layer of SiC-material over a cell can slightly bend under the applied extreme cooling conditions. This causes many local pseudo-spherical WF distortions which, when added-up, could explain indeed the missing 3.2 mm of defocus.

But is this last value still valid when Herschel reaches L2 after several months of travel? The uncertainty was that these local deformations at 70 K were not confirmed by the measurements due to the too widely spaced oil pots. Therefore there was some remaining risk when defocusing the telescope at room temperature to the full amount of -11.7 mm. Fortunately Herschel later at L2 captured images of the specified full resolution over its entire working period of four years, whereby surely the large IR wavelength was an advantage⁴. Nonetheless ESA asked us if there were alternative solutions to measure the WF gradient at any point inside a large test aperture to avoid the information loss by a fixed arrangement of small subapertures?

Large scale Hartmann WFS

Our idea was to repeat the classical Hartmann test which we described in Nr. 72, where a hole is scanned across a large test aperture. In this case, however, the Hartmann hole is replaced by a 90° prism from the size of an oil pot of small diameter D_{Ref} (Fig. 3), which hypotenuse reflects a well collimated laser beam in z-direction, i.e. into the telescope along its optical axis. The optics focuses the beam on a position sensitive detector PSD, where the position vector $\mathbf{R} = (x, y)$ of the intensity centroid allows to determine the gradient of the transmitted WF. It is a mix of the telescope's optical aberrations which should be measured, and the small deviations of the incident beam direction along the z-axis⁵. The prism is moved in $\mathbf{v} = (u, v)$ direction across the telescope aperture, which unavoidably causes mechanical errors. Any

³ The thermal expansion data of Cryo-Invar at 70 K are extremely low but also slightly shape dependent. Since the material was also used for the sockets in the prime mirror carrying the spider legs, any insecurity of the thermal data can lead by insufficient construction to mechanical tensions and surface distortions, which contribute to the global wavefront deformations.

⁴ https://www.sps.ch/varia/archive/engelberg_lectures_2007
 ⇒ File: WE4_-_Large_Space_Telescopes_v3_Doyle.pdf

⁵ The reconstruction of the WF phase term in the entrance pupil from the measured intensity centroid \mathbf{R} is described in detail in the SPG Mitteilungen Nr. 72 on p. 38. In paraxial approximation the plane WF tilt angle α is obtained from $\tan(\alpha) = \mathbf{R} / F$.

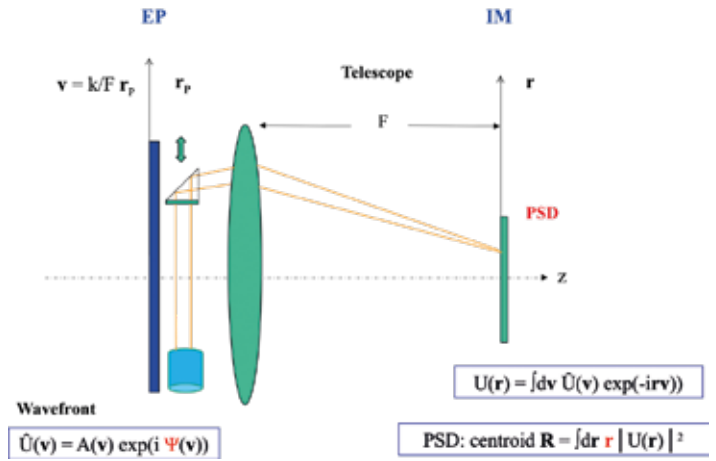


Fig. 3: The prism is moved in \mathbf{v} direction and deflects the collimated laser beam into the telescope. Any angular distortion of the beam leads to a spot displacement \mathbf{R} on the PSD.

displacement errors in $u = x$, $v = y$, z are irrelevant, but not the roll error γ around the u -axis and the yaw error α around the v -axis. Both angular distortions are not distinguishable from a WF gradient of the telescope in v -direction, resp. in u -direction.

The scan is performed first in x -direction, called *fast x-scan*. After then the whole platform is moved a small step δy in y -direction, called *slow y-scan*, to run another x -scan. The measurement goal is to monitor the angular distortions of both scans. As illustrated in Fig. 4 the setup consists of two stages, first a platform (blue) carrying the sensor unit with the deflection prism (green circle). A motor moves the sensor unit along the x -direction, while the platform itself is riding on the second stage which moves it in y -direction. Both stages include a stationary autocollimator unit, emitting several laser beams at different wavelengths, and a CCD sensor.

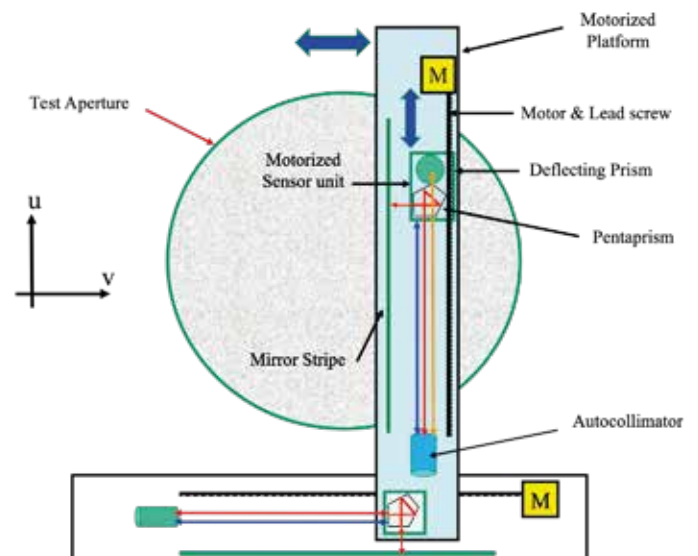


Fig. 4: Measuring the WF across a large test aperture. The motorized platform (blue), moveable in $v=y$ -direction, carries the motorized sensor unit with a deflection prism (green) and a pentaprism. The blue light from an autocollimator is reflected of the front surface of the pentaprism and backfocused on a CCD to measure the pitch and yaw errors of the mechanical motion. The red light is reflected of a mirror stripe through the pentaprism to measure the roll error. The orange light is reflected by the hypotenuse mirror of a 90° prism into the telescope and focused on the PSD (see Fig. 3).

		Fast scan in x=u direction			Slow scan in y=v direction		
		Angular Error	Offset at CCD 1		Angular Error	Offset at CCD 2	
			Prism Reflex	Mirror Reflex		Prism Reflex	Mirror Reflex
WF _x	X _{PSD}	α _{Yaw,(y)}	z _{CCD1} /f	-	γ _{Roll,(y)}	0	x _{CCD2} /f
WF _y	Y _{PSD}	γ _{Roll,(x)}	0	y _{CCD1} /f	α _{Yaw,(x)}	z _{CCD2} /f	-
irrelevant	0	β _{Pitch,(z)}	(y _{CCD1} /f)	-	β _{Pitch,(z)}	(x _{CCD2} /f)	-

Table 1: Scanning variant with **fast x-** and **slow y-**scan. The WF errors correspond to a spot on the PSD sensor in the focal plane of the telescope at coordinates $[X_{PSD}, Y_{PSD}] = F [WF_x, WF_y]$ with F focal length of telescope. The reflections of the pentaprisms and of both mirror stripes are measured on the CCDs of both autocollimators with focal length f.

Variant 1 with Mirror Stripes

Parallel to both motorized lead screws a small mirror stripe is permanently mounted to measure the roll errors. A pentaprism is part of the sensor unit which front surface is coated to be reflective for blue light, but transmissive for other wavelengths. When blue light emitted by the autocollimator is reflected from the front surface, one gets the platform's pitch and yaw errors from the spot position on the CCD-sensor, but not the roll error. When red light is emitted which is reflected from the mirror stripes, its spot position on the sensor is now proportional to the roll error⁶. Moving the platform to the next v-position by δv leads to similar roll, pitch and yaw errors but now in y-direction. They must be measured in the same way as in x-direction (Fig. 4).

Table 1 summarizes, that a WF-gradient WF_x (tilt of plane WF around the y-axis) which would lead to an x-offset at the PSD in the focal plane of the telescope, is corrupted twice, first by a yaw angular error $\alpha_{Yaw,(y)}$ of the fast x-scan motion and second by a roll angular error $\gamma_{Roll,(y)}$ of the slow y-scan. Both errors can be measured, the first one as reflex of the front surface of the pentaprism on the CCD 1 of autocollimator1, and the second one as reflex of mirror stripe 2 on the CCD 2 of autocollimator 2. The measurement of the WF-gradient WF_y (tilt of plane WF around the x-axis) is carried out in the same way and shown in the table. We tested recently the concept to measure the roundness of an approximately 1 m long cylindrical drive shaft. The shaft was positioned in x-direction and was scanned with a laser interferometer moving in x-direction and measuring the distance in y-direction.

Variant 2 with Wedge Element

The idea of both mirror stripes as reference surfaces is a huge step forward compared to the use of a large autocollimation plane mirror. Nonetheless it is interesting how to avoid them and what is the price to pay? One idea is to replace the pentaprism by a transparent wedge which double-reflects the laser light (red/green). This leads to two separated focus spots on the CCD of the autocollimator which rotate around the optical axis if the wedge is rotated. The problem is to separate the roll, pitch and yaw errors with sufficient accuracy. Especially critical is to avoid any interference between the reflections from the internal wedge sides. It is surely helpful to install inside the collimator some holographic elements which generate not single spots but patterns on the CCD to detect more easily any rotation.

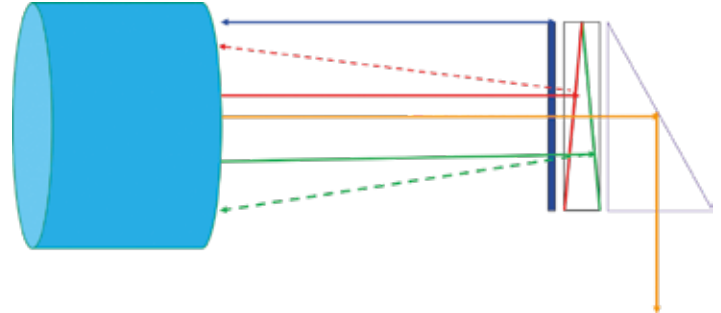


Fig. 5: The autocollimator emits laser light of different wavelengths (also in time sharing mode) to monitor pitch and yaw from reflections of the blue plate, but also from both sides of the wedge plate (green, red).

Variant 3 with multiple Scan

The following concept was developed by Leica for ESTEC, which also avoids the mirror stripes, but needs a second fast/slow full scan where the scanning setup is rotated by 90° around the z-axes, followed by a single scan with the setup rotated by 45°⁷.

According to Table 1 the elimination of the mirror stripe in the fast x-scan would only allow to measure the WF-gradient WF_x (tilt of plane WF around the y-axis), but not WF_y . Since in the slow y-scan the error $\gamma_{Roll,(y)}$ contribution to WF_x is not measurable without mirror stripe, its amount must be considered as unknown variable in the numerical evaluation.

In mathematical terms a scan in x-direction gives applying eq. (2b) from⁸

$$X_{PSD}(u, v) = \int du' dv' B(u - u', v - v') \delta\psi(u', v') / \delta u' + O_x(v),$$

where the integral is taking over the small diameter of the probe beam D_{Ref} . X_{PSD} is the x-component of the centroid R_{PSD} of the beam on the PSD sensor, corrected with the reading of autocollimator sensor for $\alpha_{Yaw,(y)}$ in the fast x-scan and multiplied by the total intensity $I = \int du dv B(u, v)$. $B(u, v)$ is the beam intensity function, ψ the aberrated WF phase of the telescope optics and $O_x(v)$ the unknown offset of the roll error in slow y-scan.

If the gradient of the WF phase ψ does not vary too much within the beam profile one may write

$$X_{PSD}(u, v) / I = \delta\psi(u, v) / \delta u + o_x(v)$$

6 The metallic mirror stripe can be an arrangement of many short pieces which true angular orientation is measured by independent pre- and post-calibration runs.

7 Investigations and Evaluations on Optical Terminal Test Facilities, ESA-Contract No. 8133/88/NL/PR

8 SPG Mitteilungen Nr. 72, p. 38 'Optical Wavefront Sensing'.

with $o_x(v) = O_x(v)/l$. Integrating this equation with respect to u (i.e. in x -direction), one arrives at

$$\int_0^u du' X_{\text{PSD}}(u', v) / l = \psi(u, v) + o_x(v) \cdot u + c_x(v),$$

where $c_x(v)$ is an unknown integration constant. To eliminate the unknown terms $o_x(v) \cdot u$ and $c_x(v)$, the scan procedure above is repeated after a rotation of the scan setup about the z -axis by 90° . Then the result of this second fast/slow full scan will be

$$\int_0^v dv' Y_{\text{PSD}}(u, v') / l = \psi(u, v) + o_y(u) \cdot v + c_y(u).$$

The difference of the two equations for $\psi(u, v)$ yields an equation of the type:

$$f(u, v) = o_x(v) \cdot u - o_y(u) \cdot v + c_x(v) - c_y(u),$$

where $f(u, v)$ stands for the difference in the left hand sides of the two equations. By e.g. expanding all functions into a power series in u and v , it is seen that this equation determines all unknown functions up to the following terms: $o_x(v)$: $a \cdot v + b$ and $o_y(u)$: $a \cdot u + c$ due to the 90° rotation, $c_x(v)$: $c \cdot v + d$, $c_y(u)$: $b \cdot u + d$, where a, b, c, d are unknown constants. As piston and tilt are not considered ambiguities, the only significant constant is a , the others can be put to zero. That is $\psi(u, v)$ can be determined up to term $a \cdot u \cdot v$ representing astigmatism. It is clear that a single scan with the measurement setup rotated at an angle of 45° will eliminate this last ambiguity.

Stitching Method

Often one only wants to obtain a rough idea of the WF under test. To reduce the time effort, it is advisable to select in a first step large sampling steps δu and δv to obtain a first estimate of the WF of the full aperture by interpolation.

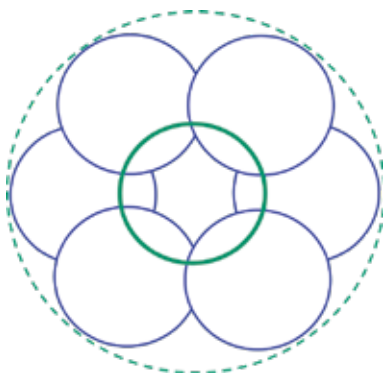


Fig. 6: Stitching concept. The fit of the WF parts inside the six overlap zones allows to eliminate the mechanical driving errors.

This was the concept in the Herschel case with the oil pot array. If the WF results are negative, one can easily repeat the scan with smaller sampling steps. The variable sampling strategy leads to another interesting application, the 'stitching' method, where δx and δy are kept smaller than D_{Ref} , that adjacent WF measurements overlap (Fig. 6).

In a first step the measured WF ψ_0 at sampling point $\mathbf{r}_0 = (x_0, y_0)$ (green circle) is developed as usual according to 24 or 36 Zernike polynomials, and also the WFs ψ_i ($i = 1 \dots 6$) of its adjacent six neighbors (blue circles). But they include the unknown mechanical tilt errors. To get rid of them the Zernike polynomials of ψ_i are numerically shifted by $\delta \mathbf{r}_i = (\delta x_i, \delta y_i)$ with respect to ψ_0 . Then separate best fits are performed

over each of the six central overlap areas using the Zernike polynomials of both ψ_0 and $\psi_i(\mathbf{r}_0 + \delta \mathbf{r}_i)$ to minimize the error functions $F_i = \int \int dx dy [(\psi_i - \psi_0) + a_i + b_i x + c_i y]^2$. The fit results lead to new piston and tilt values (a_i, b_i, c_i) to correct the first three Zernike terms of each $\psi_i(\mathbf{r}_0 + \delta \mathbf{r}_i)$. Finally, a global Zernike fit of ψ_0 and all six corrected ψ_i is performed within the dashed green circle D_{Stitch} . The advantage is that any mechanical tilt errors are eliminated by the algorithm and we obtain from the seven measured WF with small aperture D_{Ref} the full WF over the larger diameter D_{Stitch} ⁹.

Additional Comments

The advantage of the scanning method is that one can easily drive to all critical points as for example to the mentioned spider socket regions or to cell structure boundaries of the Herschel telescope, where higher order aberrations are expected due to thermal tensions. It makes sense to replace the folding mirror in Fig. 4 by a commercially available Shack-Hartmann WF sensor of about 1 inch diameter for local checks and to replace the PSD in the telescope's focal plane by a laser diode. If a thermal shield is needed to isolate the 'cold' telescope from the 'warm' WF scanning units as in the case of Herschel, a mathematical equivalent polar scan (r, ϕ) is better suited than the described cartesian x, y scan¹⁰.

Conclusions

Measuring the WF of large optical apertures is always an engineering challenge, independent what variant is chosen. Highest precision of all components and their mechanical drives are often not sufficient to reach the specified measurement accuracy for space or astronomical applications. Variant 1 needs two mirror stripes, but is a well proved method in daily industrial use, robust and accurate, however critical for larger apertures. Variant 2 is attractive due to its compactness, but sensible to clearly separate the angular distortions and to avoid interferences. The use of holographic elements in the entrance pupil of the autocollimator may be helpful. The advantage of Variant 3 is the simple scanning hardware excluding the roll error measurement. The rotation of the scan set-up by 90° and 45° needs more mechanical effort. In conclusion each variant has its pros/cons and the optimum solution depends on the constraints as size of the aperture, accuracy, thermal environment and speed.

⁹ The stitching method was developed in 1989 at Leica Geosystems in Heerbrugg called WILD LEITZ AG at this time, when our fabrication had to quickly measure a plane mirror of 12 inch diameter. Since the test tool was a WYKO-interferometer of only 6 inch free aperture diameter, we tried the stitching idea. To check the method, we measured first the WF of an existing plane mirror of 6 inch free aperture diameter. Then we manually reduced the aperture diameter of the WYKO-interferometer to 3 inch and moved it according to Fig. 6 to the six adjacent hexagonal positions. From the seven single WF measurements of 3 inch diameter we computed the virtual 6 inch WF and compared it to the direct measurement. The difference was better than $\lambda/10$ pV over 90 % of the 6 inch mirror area. The interesting results were presented at the DGaO Conference in Berlin in 1989. Today the stitching method is a standard option in most commercial interferometers.

¹⁰ The thermal shield would be a rotating disk of special heat reflecting material of the diameter of the large test aperture, including a small radial slit of the width of the measuring subaperture, the Shack-Hartmann sensor.

Physics and Society

Christa Markovits, retired physicist of PSI and contemporary witness

Alice Kohli

In February 2024, the proton accelerator facility HIPA at PSI celebrated its 50th anniversary. Among the revellers was 88-year-old Christa Markovits. She was a pioneer of the Swiss Institute for Nuclear Research and the only woman among the builders of HIPA. She is also a contemporary witness to the history of Europe in the 20th Century.

Christa Markovits was born in Budapest in 1936, just as clouds of World War II gathered ominously. Her early years were marked by the chilling realities of war. And the end of that war meant the start of the iron grip by Soviet occupation, causing further hardship and deprivation. Her journey to pioneering work in nuclear research paints a portrait of resilience against a backdrop of history's darkest moments. "I was fourteen when I decided that I wanted to attend technical high school," she remembers at 88 years old, sitting on a sofa in her study at home in a quiet residential district in Basel. Given the circumstances, it was a pragmatic decision. Had she had the choice, she might have studied history of art. However, her father was an architect who owned a firm, and he was considered a capitalist in communist Hungary. Only proletarians and peasant children were admitted to university studies.

Christa Markovits had figured out how to achieve a decent work in her future. She knew that a matriculation certificate combined with a diploma in machine engineering obtained at a technical high school would provide access to the Technical University of Budapest.

But even though she passed the admission exams year after year, she was only allowed to go to university two years later. In the meantime, Christa had to find something else to do. So, she started working in a former Siemens factory that produced X-ray machines.

The factory supervisor placed Christa Markovits in the office. According to the communist regime's five-year plan, the teenager placed orders for parts of X-ray machines. "That was beautiful work," she recalls. She had to make sure that all the material necessary was available for the production of the X-ray machines that were going to be exported worldwide, as far as China.

In the two years Christa Markovits worked at the factory, she learned all the six-digit serial numbers of all the parts of the machines by heart and knew exactly which part went where. She was intrigued by these machines and became curious to find out how they did what they did.

The Hungarian Revolution of 1956

Finally, the Technical University admitted her to study engineering. Christa Markovits was 20 years old and three weeks into her undergraduate studies when the Hungarian Uprising against the one-party socialist regime gained mo-

mentum. Twelve days later, Soviet tanks entered the country.

Christa Markovits decided to flee from Hungary—along with a quarter million of her compatriots. The young woman chose to set out on her own; her parents and sisters would only head west months later. "I crossed fields and thorny hedges to get to the Austro-Hungarian border," Christa Markovits remembers.

On the road, she joined a young couple with their baby. "When we saw the flares of the Soviet missiles, we had to lie flat on the ground. It was already freezing, and there was snow. I only had a small bag with me, containing my last salary from the factory."

A large part of the salary – and a salami sausage she carried with her – was used to pay a peasant, who led them to the border. Two days later she arrived in Vienna, where she stayed in a makeshift shelter – a primary school gymnasium, the floor lined with mattresses and bags of straw.

Christa Markovits recalls that the city hall in Vienna had been completely restructured for the Hungarian refugees. There were desks with little flags on every floor. On the second floor, there was a desk with a Swiss flag. Even though she had never been there, she knew that she wanted to go to Switzerland. Her father had once told her that Switzerland was the best country in the world because it was peaceful and neutral.

The young woman stood by the Swiss desk in the city hall of Vienna every day from morning until the evening until, one day, a lady told her that she would be given a spot to go to Switzerland. A train organized by the Red Cross took her to the promised land, where she was put in a barrack in Walenstadt. She stayed there for a couple of weeks.

"We were given forms to fill in about what we could do and what we wanted to do," Christa Markovits recalls. "I wrote there that I had finished the technical high school, worked in a factory for X-ray machines, and that wanted to study Physics."

At that time, Fritz Houtermans was an ordinarius professor of physics at the University of Berne. He had offered to take on eager physics students from Hungary. So, Christa Markovits was sent to Berne.

The University officials must have been surprised, that it was a girl that wrote down physics on her form. Much more so than nowadays, women were hugely outnumbered by men in the field of physics. The University of Berne cannot make reliable statements about the proportion of women in physics in 1956, as the data was not yet collected at that time.

The database for Historical Statistics of Switzerland (HSSO) provides the student numbers of the University of Bern by faculty. In the academic year 1956/57, of the 351 students enrolled at the faculty of Philosophy II, which included the subject of physics, a mere 23 were women. This corresponds to a share of 6.5%, and presumably even less for physics.

Christa Markovits was not only one of the very few women at the faculty, she also hardly spoke any German. Luckily, she knew some English. The authorities placed her with a Bernese family with three children. She shared a room with the family's daughter, was given books, and learned German. "The family was very nice and we became friends quickly."

After a year with the family, Christa Markovits received a small scholarship. During her studies, she moved from mansard to mansard. During lunch breaks, she would sell flowers at a stall near the railway station to earn extra income. But still, she could not afford lunch at the canteen with her colleagues.

"I was happy," Christa Markovits hastens to point out. Her studies went well. "Only once did I have a crisis." She was working on her diploma thesis in geological radiometry. The whole process of geological sample preparation was new to her. After she was instructed in the technique, she was left to work on her own in a lab on the second sublevel of the building.

Every now and then, she had to go upstairs to use the precision scale. "People turned away from me when they saw me coming," Christa Markovits recalls. They heard the crackling of the Geiger-Müller-tubes. "I was really lonely". During the writing of her diploma thesis, she suffered from anxiety attacks and sometimes had difficulties leaving her home. She sought treatment for her anxiety and was glad to be able to talk to a group of Hungarian refugees that regularly met in Bern, where she eventually also met her later husband, musicologist Michael Markovits.

In 1964, she successfully completed her thesis titled "Radioactivity Measurements of Lead of Volcanic Origin from the Mount Vesuvius", supervised by Professor F. G. Houtermans at the University of Berne.

From atomic clock to cyclotron to cancer treatment

After finishing her studies, Christa Markovits continued working for the University of Berne. As an assistant, she organized practical workshops for students. She was also regularly sent to the High Altitude Research Station on Jungfrauoch at 3454 meters above sea level, to take care of the apparatus for the automatic measurement of cosmic radiation. She had to change films, valves, do repairs – all on her own. Digitalisation was yet unknown, it was a completely analogue world.

It was strenuous. It would take the young woman four hours to get to the High Altitude Research Station, which often made it impossible to return the same day. But she liked it. "I always liked working, and I always got along well with my colleagues," Christa Markovits says. Nevertheless,

Born Krisztina Barabas in 1936 into a family with Jewish ancestors in Budapest, Hungary, Christa Markovits's early years were tainted by the ominous shadow of Nazi occupation. Forced to wear the yellow star of David and hidden for months in various shelters throughout Budapest, Christa Markovits's survival during the Holocaust was a testament to her family's resourcefulness and a stroke of fortuitous luck.

Of the approximately 800'000 Hungarian Jews, only 200'000 survived the Holocaust. Christa Markovits (she adapted her first name to be easier to spell for the Swiss) wrote an autobiographical testimony about what she and her family lived through in World War II. Together with 14 other survivors of the Holocaust it was published by Suhrkamp, in a collaboration with the Swiss Foreign Department. The anthology is named "Mit meiner Vergangenheit lebe ich" (all texts in German):

<https://www.suhrkamp.de/buch/mit-meiner-vergangenheit-lebe-ich-t-9783633542772>

Following the war's end, Christa Markovits's path led her through the tumultuous landscape of post-war Europe, ultimately finding refuge in Switzerland. In the aftermath of the Hungarian Revolution of 1956, her family was scattered across continents in search of safety. Amidst the chaos of fleeing their homeland, only one of Christa Markovits's sisters was granted entry into Switzerland, defying the authorities' decree to close their doors to further refugees.

Despite all the challenges, Christa Markovits determinedly pursued her studies. Her journey from a factory worker in Budapest to a pioneering physicist in Switzerland exemplifies an indomitable spirit. Yet, it is crucial to also acknowledge the additional layers of adversity she likely faced as a woman in a predominantly male-dominated field. Physics, like many STEM disciplines, has historically been a challenging terrain for women to navigate. From ingrained biases to systemic barriers, the path for female physicists has often been layered with obstacles. For Christa Markovits, studying physics as a refugee, separated from her family, and in a foreign language would have undoubtedly magnified these challenges.

Institutional biases and gender stereotypes may have hindered her recognition and advancement, despite her undeniable talents and contributions. The narrative of her journey serves as a poignant reminder of the resilience required of women who dare to carve out careers in fields where they are underrepresented.

Christa Markovits's story prompts reflection on the importance of addressing gender disparities and fostering inclusivity within academic and scientific communities, ensuring that all individuals, regardless of gender, have equal opportunities to thrive and be recognized for their achievements.

Today she lives as a widow alone and is busy with the publication of the manuscripts of her late husband she loved. Without grandparents, they could not afford to establish a family with children.

she began looking for a job outside her university. "I never dreamed of making a discovery of my own," she says. "But I know my strengths. My vision was working in a team on interesting projects with fellow physicists, engineers and technicians." Finally this dream came true at SIN and PSI a couple of years later.

Before that, an opportunity opened up at the Neuchatel Observatory, where she was involved in research on a new type of atomic clock, replacing caesium by thallium. After three years at the Neuchatel Observatory, Christa Markovits followed Professor Jean Pierre Blaser, the former director of the observatory, to ETH Zurich.

She assisted him in his lectures and co-edited his textbooks. Blaser was involved in promoting nuclear energy in Switzerland and planned to build a proton cyclotron complementary to the machines at CERN.

In response to his efforts, the Swiss parliament founded the Swiss Institute for Nuclear Research (SIN) in 1968. The proton accelerator was the core of the SIN. Protons were accelerated to approximately 80 percent of the speed of light before being directed onto targets. The collisions in carbon targets produced pions and muons, and the collisions with lead targets produced neutrons.

Christa Markovits was in charge of designing and building the beamline leading the protons from the 72 MeV injector cyclotron to the 590 MeV main accelerator, today called HIPA. She was the only female scientist on the team. A picture of the inauguration of the cyclotron in 1974 shows her in the middle of the circularly aligned magnets, wearing a bright red sweater. She later worked as head of the control room at the proton accelerator, often at night and on weekends.



In 1988, SIN merged with the Federal Institute for Reactor Research (EIR) right across the Aare River, and the newly founded research facility was named the Paul Scherrer Institute (PSI). The 1990s marked the emergence of cancer treatment with protons at PSI, an activity which had been developed at SIN: A new and exciting field of research for Christa Markovits.



Christa Markovits during the HIPA celebration in February 2024 in front of the inauguration picture from 1974, which is still exhibited at PSI. Photo: David George

She was involved in the eye irradiation project (OPTIS) for many years until her retirement in 1996. "I was responsible for the physical part of the project, the guidance of the proton beam and the safety", she says. It was a pioneer project – OPTIS was the first facility of its kind in Europe, and patients came from all over the world.

At the beginning, the proton beam traveled 40 meters before it reached the patient's eye with an accuracy of microns. Nowadays, the accelerator has a fixed beamline, and the patient is moved in front of it. "I was and still am enthusiastic about the OPTIS project", Christa Markovits says.

This was confirmed by her group leader in the Accelerator Division of PSI at the time: "Her experience in beam optics, the perfect preparation of shutdown work and the detailed and precise documentation of the systems entrusted to her have enabled successful accelerator operation", he wrote in a reference letter for her retirement.

He continues: "If both the control room and the medical staff can enjoy problem-free OPTIS operation today, it is not least thanks to the dedicated commitment and coordination of Ms. Markovits." And ends with: "She was a very pleasant employee who maintained a good relationship with her colleagues and superiors thanks to her balanced and friendly manner."

Never someone to boast about her own achievements, Christa Markovits was very happy about that reference letter. Even though it was only at the very end of her career, she felt acknowledged for her work at last. When she received the invitation to celebrate the 50th anniversary of HIPA, she was delighted. And she enjoyed every minute she got to spend with her old colleagues.

Kurzmitteilungen - Short Communications

Zweiter Netzwerkanlass der SATW

Gian Salis

Die Schweizer Akademie der Technischen Wissenschaften (SATW) organisierte am 26. Januar 2024 einen Netzwerkanlass mit dem Ziel, einen Austausch zu ermöglichen zwischen der SATW und deren Mitgliedsgesellschaften, zu denen auch die Schweizerische Physikalische Gesellschaft gehört. Etwas mehr als 30 Vertreter und Vertreterinnen trafen sich am SATW Hauptsitz in Zürich. Vorstandsmitglied René Hüsler führte durch den Nachmittag. Nach einer Vorstellungsrunde wurde das bereits vor einem Jahr bei einem ersten Anlass geäusserte Interesse an einer stärkeren Zusammenarbeit der verschiedenen Vereine bekräftigt und diskutiert. Synergien werden gesehen beim Verbreiten von Publikationen, beim Vermitteln von Experten, bei der Verstärkung der gegenseitigen Sichtbarkeit, sowie beim 'Scouten' von neuen Technologien.

Nach dieser Einführung gab Peter Seitz, Vizepräsident der SATW, ein Referat über Quantencomputing. Er stellte zu Beginn die rhetorische Frage, ob man Zeit investieren soll in den Bau eines Quantencomputers, und ob man damit Geld verdienen kann. Nach einem Exkurs in die Komplexitätstheorie umriss er die Klasse der Probleme, die für einen klassischen Rechner unmöglich zu lösen sind, die ein Quantencomputer jedoch in sinnvoller Zeit erledigen könnte. Die Neuartigkeit eines solchen Rechners beruht auf den quantenmechanischen Eigenschaften der Superposition und der Verschränkung. Diese Konzepte veranschaulichte er anhand der Polarisierung von Photonen. Danach umriss er die momentane weltweite Umbruchstimmung mit über 550 Startups und staatlichen Förderprogrammen, die vor allem ausserhalb der Schweiz in ihrer Grösse beeindruckend sind. Er erwähnte auch den wichtigen Punkt, dass Durchbrüche bei der Entwicklung neuer Quantenalgorithmen den entscheidenden Schub liefern könnten, um Quantencomputing erfolgreich zu machen.



In der Pause wurde dann angeregt über die Faszination des Quantencomputings und die im Vortrag aufgeworfenen Fragen diskutiert. Danach gab Edith Schnapper, verantwortlich für die Nachwuchsförderung an der SATW, einen Überblick, wie der momentane Fachkräftemangel adressiert wird. Aktivitäten zielen auf eine Stärkung der MINT-Kompetenzen bei Kindern und Jugendlichen, das Durchbrechen von Stereotypen, das Abbauen von Berührungängsten und generell auf die Verbesserung des Ansehens von MINT-Berufen insbesondere bei Mädchen. Neben dem Nachwuchs möchte man auch Lehrpersonen und 'Gatekeepers' wie Eltern und Peers erreichen, welche bei der Entscheidung der Berufswahl oft das Zünglein an der Waage spielen. Angebote der SATW sind zum Beispiel die TecDays an Mittelschulen oder die 'Swiss TecLadies', welche jungen Frauen als Rollenmodell und Mentoren zur Seite stehen.

Der Anlass wurde mit einem Apéro beendet, wo die Teilnehmenden ihr Netzwerk weiterspinnen konnten. Einen ergänzenden Bericht über den Anlass und Fotos findet man auf <https://zurl.co/TJXI>.

Finals of the Swiss Physics Olympiad in Aarau

The finals of the 2024 edition of the Swiss Physics Olympiad took place on 9 and 10 March at the Neue Kantonsschule in Aarau. More than 900 students from Switzerland and Liechtenstein participated in the first round of this competition. In a second round of qualifiers, 28 young physics talents were selected for participation in the finals. In the concluding ceremony, 15 students were awarded gold, silver and bronze medals. The two best performing finalists, **Elias Bauer** (left) from Kollegium St. Fidelis and **Kenneth Arockia** from Kantonsschule Olten, were awarded with the "Nachwuchsförderpreis / Prix de la Relève" of the Swiss Physical Society.

Pictures: Markus Meier



Bücherecke - Le coin aux livres - Book Corner

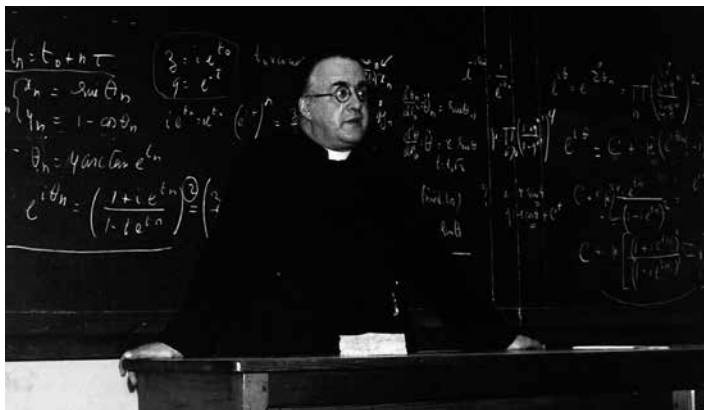
Jean-Pierre Luminet

The Big Bang Revolutionaries

The Untold Story of Three Scientists Who Reenchanted Cosmology

Discovery Institute Press, ISBN 978-1-63712-040-8

As part of its series of special symposia, the SPS organized a symposium in 2019 at the University of Bern on the occasion of the 125th anniversary of Georges Lemaître's birth, which attracted a large audience¹. In four presentations the person and the work of the Belgian priest and later director of the Pontifical Academy of Sciences (*Pontificia Academia Scientiarum*) were assessed from today's perspective. One of the speakers was Jean-Pierre Luminet, CNRS Marseille talking about *Philosophical aspects and implications of Lemaître's contributions to modern cosmology*.



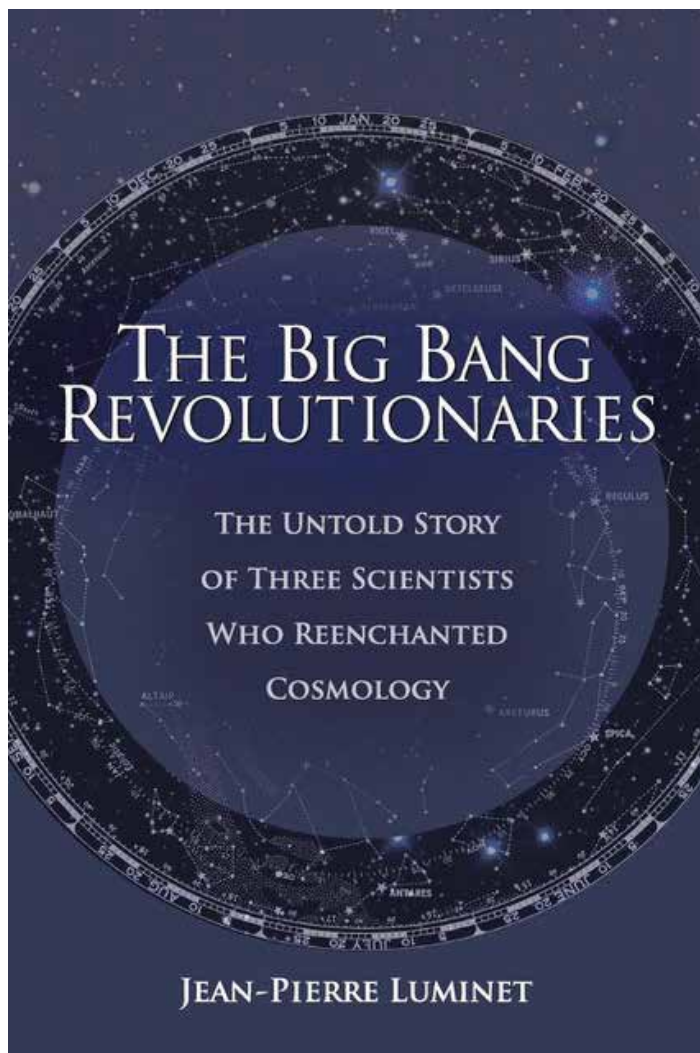
Jean-Pierre Luminet has now published a book entitled *The Big Bang Revolutionaries: The Untold Story of Three Scientists Who Reenchanted Cosmology*, released on 23 April 2024.

In the book's foreword we read from **Abraham (Avi) Loeb**, Frank B. Baird Jr. Professor of Science and Director of the Institute for Theory & Computation, Harvard University:

..... I particularly appreciate the discussion of the pioneering work and personality of Lemaître, who can justly be called the father of scientific cosmology. With its discussion also of cosmic topology, the book is a unique contribution to the history of cosmology....

The text of the back cover summarizes:

Many widely read scientific writers of our day mistakenly attribute the concepts of the expanding universe and the Big Bang to Edwin Hubble and Albert Einstein. Hubble did provide evidence of an expanding universe, but he neither discovered such evidence nor accepted the radical idea that space itself was expanding. As for Einstein, he held out against the idea of an expanding universe for more than a decade, and ceased working in the field as soon as he had to amend his view. The real heroes of the Big Bang revolution are the Russian Alexander Friedmann and Belgian priest Georges Lemaître. That they are virtually unknown to the general public is one thing. That their contribution is underestimated by astrophysicists and cosmologists is another, for the concepts they promulgated are among the most



remarkable achievements of twentieth-century science. The Big Bang Revolutionaries amends the record, telling the remarkable story of how these two men, joined by the mischievous George Gamow and in the face of conventional scientific wisdom, offered a compelling view of a singular creation of the universe in what Lemaître termed a “primeval atom.”

For more book details:

<https://discoveryinstitutepress.com/book/the-big-bang-revolutionaries/>

and

<https://www.amazon.com/Big-Bang-Revolutionaries-Scientists-Reenchanted/dp/1637120400/>

Perhaps also interesting is an interview with Lemaître which was recently discovered:

<https://www.youtube.com/watch?v=O4toGaR1Cul>

or

<https://www.youtube.com/watch?v=KXxpgqv0Bc>

Bernhard Braunecker

¹ https://www.sps.ch/events/diverse_veranstaltungen/125th_anniversary_of_georges_lemaître

Simon Marius: Pionier der Teleskopastronomie bei Jupiter und Venus

Pierre Leich, Nürnberg

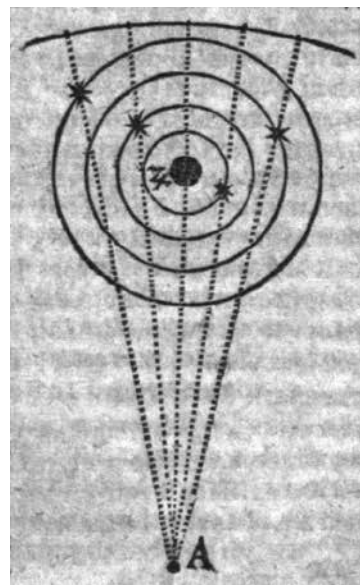
An dem markgräflichen Hofastronomen Simon Marius sind zumindest drei Umstände bemerkenswert: Wohl als erster Berufsastronom außerhalb der Niederlande hatte Marius über seinen Förderer Hans Philipp Fuchs von Bimbach Kenntnis vom Teleskop und dessen optischen Aufbau und er war auch unter den ersten Astronomen, die mit dem neuen Instrument astronomische Beobachtungen höchster Relevanz vornahmen. Es waren Befunde, deren Interpretation bei der Weltsystemfrage zu wichtigen Argumenten wurden, auch wenn sich Marius aus empirischen Gründen nicht zum Copernicanismus durchringen mochte.



Porträt von Simon Marius aus seinem Hauptwerk **Mundus Iovialis**, Nürnberg 1614. Quelle: Stadtarchiv Gunzenhausen, Foto: Joachim Schlör

Nach eigener Aussage positionierte sich Marius jedoch bereits im Jahr 1596 gegen das ptolemäische Weltsystem und vertrat ein Modell, das ihm erst im folgenden Jahr als tychonisches Weltmodell bekannt wurde. Auf Basis des damaligen Wissensstandes, der noch keinen Beweis des Heliozentrismus erlaubte, war dieses kinematisch äquivalente System durchaus fortschrittlich. Es konnte sowohl

die scheinbaren Planetenschleifen als auch die mit dem Fernrohr entdeckten Phänomene wie Jupitermonde, Venusphasen und Helligkeit der Planetenscheiben erklären, ohne gleichzeitig in Widerspruch zu gewissen Annahmen der aristotelisch-ptolemäischen Naturphilosophie sowie dem gesunden Menschenverstand zu treten. Dynamisch ist die doppelte Erdbewegung erst in der neuzeitlichen Mechanik aufzuklären.



Zum Dritten begann Marius wohl bereits Ende 1609 das Jupitersystem zu untersuchen. Der Beginn der Rückläufigkeit und die nördlichste Lage am 9. Oktober, die größte Erdnähe am 6. und die Opposition am 8. Dezember sowie die lange Sichtbarkeit um die Wintersonnenwende ließen Jupiter für jeden Astronomen als lohnendes Objekt erscheinen. Als Ersteller von Kalendern waren Marius diese Umstände bekannt, weswegen es nur folgerichtig war, dass Marius zeitgleich zu Galileo Galilei die Entdeckung der vier großen Jupitermonde gelang.

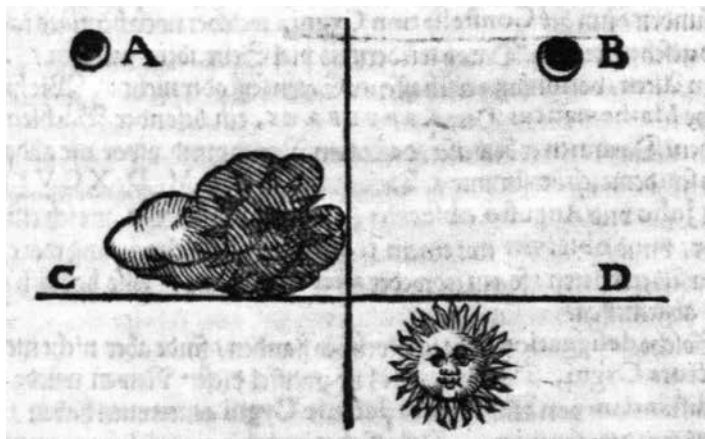
In seinem **Prognosticon Astrologicum** auf das Jahr 1612 gibt Marius die erste Darstellung des Orbitalsystems der Jupitermonde. Quelle: Staatsarchiv Nürnberg, Exemplar: Fürstentum Brandenburg-Ansbach, Staats- und Schreibkalender (129), Nr. 274

Leider hat Marius es versäumt, in diesen drei Bereichen seine wissenschaftlichen Leistungen frühzeitig zu veröffentlichen, und wir sind auf seine eigenen Berichte angewiesen, die durch das gewichtige Wort von Galilei diskreditiert wurden, sodass Marius fast drei Jahrhunderte als Plagiator gehandelt wurde. Erst Anfang des 20. Jahrhunderts wurde gezeigt, dass Marius völlig unabhängig arbeitete.

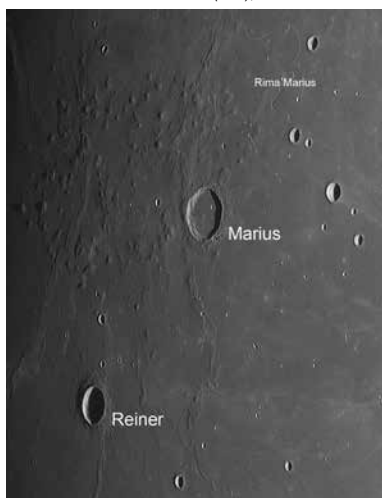
Schon seit Winter 1610 auf 1611 beobachtete Marius Venusphasen und realisierte, dass die nun mit dem Teleskop erkennbare Phasenfolge belegt, dass sich die Venus um die Sonne dreht. In seinem Hauptwerk von 1614, dem **Mundus Iovialis**, berichtet Marius von seiner jahrelangen Forschung am Jupitersystem. Dass sich die Bewegung der Jupitermonde nur von der Sonne aus betrachtet als gleichförmig darstellen lässt,



Panoramaansicht auf die befestigte Stadt Onoltzbach (Ansbach). Quelle: Kupferstich aus der *Topographia Franconiae* von Matthäus Merian, Frankfurt a.M. 1648; Stadtarchiv Ansbach



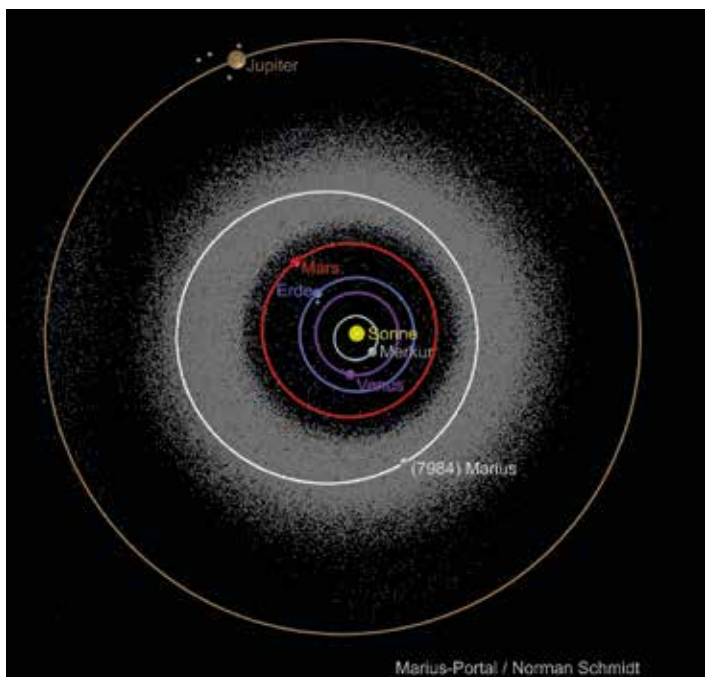
Im *Prognosticon Astrologicum* auf das Jahr 1612 erklärt Marius auf Folio A3r korrekt die Venusphasen, die offenbar von Stand der Sonne abhängen: links 5. Februar 1611 abends, rechts 25., 26. und 27. Februar 1611 morgens, CD Horizont, C Occidentalem, D Orientalem. Quelle: Staatsarchiv Nürnberg, Exemplar Fürstentum Brandenburg-Ansbach, Staats- und Schreibkalender (129), Nr. 274



Auf dem Mond wurde ein gut 40 km großer Einschlagkrater nach Marius benannt. Nördlich davon liegt die durch Lavaströme entstandene Rille „Rima Marius“. Foto: Bernd Liebscher

überzeugte ihn davon, dass sich auch der Jupiter um die Sonne dreht.

Er erkennt sogar die differentielle Bewegung der Jupitertrabanten, doch während Kepler später daran sein drittes Planetengesetz kontrollieren wird, sieht Marius keinen gesetzmäßigen Zusammenhang: „Die periodischen Umläufe sind, wie ich festgestellt habe, ungleich: Die eines näheren Trabanten sind schneller, die eines entfernteren Trabanten sind langsamer.“

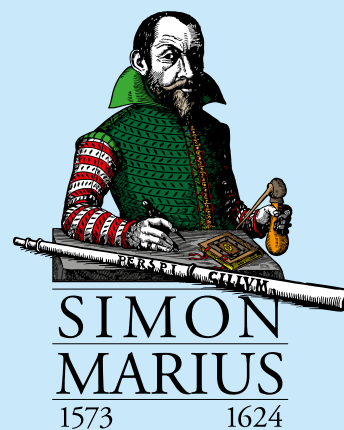


Orbit des 2014 von der Internationalen Astronomischen Union (IAU) nach Marius benannten Asteroiden „(7984) Marius“. Quelle: Mit 150.000 Asteroiden gerechnete Illustration: Norman Anja Schmidt

mer. [...] Ob aber dieses Ansteigen oder Nachlassen der Geschwindigkeit von der Kreisbewegung des Jupiter selbst und allein abhängt oder nicht, gleichwie Herr Kepler [...] über die Sonne und ihre Planeten Merkur, Venus, Mars, Jupiter und Saturn schlüssig vermutet hat, ist mir bis jetzt ungewiß und von mir nicht beobachtet.“ Obwohl er deswegen keine Meinung über die Sache äußern will, resümiert dennoch: „Um aber die Wahrheit zu sagen, ich missbillige völlig diese Methode“.

War es bei Galilei die gesprungene Linse, die ihm ein Dreivierteljahr kostete, so bringt sich Marius im Fall von Kepler selbst um die Chance, zu den ganz Großen seiner Zeit aufzuschließen.

Im vergangenen Jahr hatte der markgräfliche Hofastronom Simon Marius 450. Geburtstag und in diesem Jahr ist sein 400. Todestag. Die Simon Marius Gesellschaft (SiMaG) nimmt beide Jubiläen zum Anlass, im Jahr 2024 an den süddeutschen Astronomen zu erinnern und hat ein internationales Jubiläumsjahr unter dem Titel „Simon Marius 1573 – 1624“ ausgerufen.



Nach Auftaktveranstaltungen in Nürnberg, Ansbach und Gunzenhausen diskutierten am 21. Juni in Ansbach die Teilnehmer einer Tagung vom Arbeitskreis Astronomiegeschichte der Astronomischen Gesellschaft (AKAG) und der SiMaG über „Simon Marius und der Wandel im Weltbild“, zwei Vortragsreihen stellen Marius und seine Zeit vor und zwei Simon-Marius-Pop-up-Sternwarten laden in Nürnberg und Ansbach zu Beobachtungen ein. Ausstellungen der Bayerischen Staatsbibliothek und vom Markgrafenmuseum Ansbach präsentieren Originalwerke.

Ein Supernovaüberrest und zwei Straßen werden nach Marius benannt und im Marius-Portal wird ein neues Menü „Briefe und Bildnisse“ freigeschaltet, dessen Kern die Wiedergabe aller erhaltenen Briefe vorsieht. Das Hauptwerk *Mundus Iovialis* wurde überarbeitet als zweisprachige Ausgabe neu aufgelegt, es wird in Form keramischer Tafeln tief im ältesten Salzbergwerk der Welt eingelagert und über eine Funkanlage ins Weltall ausgestrahlt. Ein Satellit wird einen Auszug zur Erde funken.

Die Hochschule Ansbach entwickelt eine generative Marius^{KI}, die natürlichsprachige Fragen zu Simon Marius beantworten kann. Bei mehreren Anlässen wird das Kurztheater „Simon auf der Couch“ des ART & Friedrich e.V. die vielfältigen Kränkungen bearbeiten, die der fränkische Astronom zeitlebens und darüber hinaus hinnehmen musste. Marius' Frau Felicitas sorgt dafür, dass ihr Mann endlich professionelle Hilfe erhält und bringt ihn zu einer Therapeutin unserer Zeit.

www.simon-marius.net/2024_de.php

CERN Celebrates 70 Years of Scientific Discovery and Innovation, and Exploring Farther

Hans Peter Beck, University of Bern

On 29 September 1954, in the aftermath of the Second World War, twelve European countries established CERN – the European Organization for Nuclear Research to bring excellence in scientific research back to Europe and to foster peaceful collaboration in fundamental research. CERN is the first of Europe's intergovernmental research organizations that today has become the world's largest particle-physics laboratory fulfilling the dreams of its founders as summarized in the convention: "*The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.*" This collective effort has pushed back the frontiers of human knowledge and of technology.

As more powerful accelerators and experiments were built, foundational discoveries and innovations were made: among others, Georges Charpak revolutionised detection with his multiwire proportional chamber in 1968, the neutral currents were discovered in the 1970s, the W and Z bosons were discovered in 1983, the precision measurement of the Z boson and of other parameters of the electroweak theory was made in the 1990s thanks to the Large Electron Positron (LEP) collider, the Large Hadron Collider (LHC) started up in 2009, and the Higgs boson was discovered in 2012. CERN is also the birthplace of the World Wide Web and has generated technologies that are used in other fields, including medical diagnostics and therapy and environmental protection.

Today, CERN counts 23 member states, 10 Associate Member States and a vibrant community of 17,000 people from

all over the world, with more than 110 nationalities represented. Currently, the Laboratory is home to the Large Hadron Collider, the world's most powerful particle accelerator. Building on its remarkable legacy of research and technological development, CERN is already looking to the future, in particular by studying the feasibility of a Future Circular Collider.

Throughout 2024, CERN will be marking its 70th anniversary with a series of scientific, informative, and festive events and activities, aimed at all types of audiences, at CERN and in the Organization's Member States and Associate Member States and beyond. A combination of science, art and cultural events will discuss the evolution of particle physics, CERN's significant contributions, today's big questions to tackle, and what are ideas for the near and not so near future to advance particle physics and what these imply for CERN. Detailed information about 70 years of CERN and each of these events taking place in all CERN member countries can be found on <https://cern70.cern/>.

Public events at CERN are ongoing, where on 18 April "*The virtuous circle of knowledge and innovation*" did highlight technologies key to particle physics with impact on society. On 19 May the CineGlobe festival featured a documentary movie "*CERN: an extraordinary human endeavour*" showcasing global partnership, open science, training, education, and more. On 6 June "*The case of the (still) mysterious Universe*" ponders about the big open questions in particle physics, and on 4 July "*Exploring farther: machines for new knowledge*" discusses future facilities for particle physics and at CERN.

The official ceremony will take place on 1 October, hosting high-level authorities from CERN member states, associate member states, observer states, non-member states and other key stakeholders. A high-level Swiss federal representation can be expected, but is not yet unveiled.

A special event, organised together with the Swiss Institute for Particle Physics (CHIPP), will take place at the annual meeting of the Swiss Physical Society in Zürich, in the evening of 10 September 2024 (see p. 14).

A public lecture will be held by particle physicist and rector of ETHZ, Günther Dissertori, followed by a panel discussion with CERN Director General Fabiola Gianotti and other high-level representatives covering the various relationships between CERN and Switzerland, discussing CERN as a global enterprise and driving force for research and innovation in the past, present, and a promising future. Afterwards a special collection of posters marking milestones of several CHIPP institutes' past will be shown in the frame of the poster session, all accompanied by an apéro riche.



ANS / JAHRE / ANNI CERN 

An enjoyable innovation evening at CERN

Teresa Montaruli

On Thursday, 18 April 2024, more than 700 people, and many more following the event in streaming ¹, spent quite an evening on the innovation developments proving the leading role of CERN and physicists all over the world on future developments in space science, medicine, computing, AI, plasma physics and superconductivity. The new auditorium of the Science Gateway at CERN hosted, with the moderation of Paola Catapano, the presentations, and discussions of numerous scientists on the very profound between knowledge and innovation, from which technology transfer results. Three fields that represent the axes of work of CERN, acceleration, particle detectors, and computing, were discussed initially by several outstanding scientists with leading roles in innovation research.

Alessandra Lombardi discussed accelerators and colliders at CERN and how they work. She illustrated the impressive evolution of their magnets and the transfer of this technology to society. As an example, two applications were illustrated in health care, carbon ion and proton accelerators for cancer therapy, and low energy accelerators for art diagnostics, as the MACHINA project is doing to create as small as 1 m-scale transportable LINACs.



Amalia Ballarino showing the low-emission superconducting technology application to airplanes with Airbus Upnext.

Amalia Ballarino discussed the enabling technology of superconductivity for accelerators and the evolution of superconducting magnets on which CERN is a leading laboratory. Niobium-titanium superconducting coils allow the transfer of ~13000 Amperes with many wires in parallel in the coldest place in the world in a vacuum, the beam pipes at 1.9 °K of LHC of 27 km. She also discussed Magnetic Resonance Imaging magnets as well as the future challenges of this application of superconductors. A project of CERN with industry for the future of electrical transmission in the more sustainable airplanes of the future associated with fuels with liquid nitrogen at 20 °K was explained. Along with this discussion on sustainable technology, Tabea Arndt, a superconductor expert, and curator for the German BMBF (Bundesministerium für Bildung und Forschung) using high-temperature superconductivity, presented the advantages of superconducting electric power grids, applications for re-

newable energy, such as wind turbines where low-weight, energy-efficient materials can be used and DC industrial magnets for metal production which increases sustainability through 60 % decreased CO₂ emission, electric motors for transports on boats, or trucks with liquid hydrogen which are proved already to make 1 refilling for 1047 km and trains.

The following presentations concerned detection. Daniela Bortoletto described the many detectors in the experiments of LHC, such as ATLAS, with dimensions comparable to 1/2 of Notre Dame, CMS, ALICE, and LHCb. She illustrated imaging detectors used for medical diagnostics, such as TIMEPIX, and Jan Jakubeck, creator of a CERN spinoff, showed the outcomes of making it a product for education in schools, but also radiation monitors for radiation in space, useful for studying the behavior of material exposed to cosmic rays and solar particles beyond our atmosphere. The presentation by Steffen Kappler from Siemens illustrated medical diagnostics through the disruptive technology of photon counting detectors and CT applications.

This event was part of a series of events for the 70th anniversary of CERN, others being listed here ², and including a future event that will see the participation of the father of the World Wide Web, Tim Berners-Lee.

At the end of the evening, big data computing needs for experiments like LHC (or SKAO) streaming more 100 Pbyte/year were discussed with Michele Grossi, coordinator of Quantum Algorithms in the Quantum. LHC data streaming needs are comparable to those of big companies such as Google or Amazon and this pushed CERN to invest in the Quantum Initiative, where quantum computing is the new frontier of CERN.

Then a zoom connection allowed to contact with Prof.s Nicolas Gisin, University of Geneva and chair of the Swiss Quantum Commission ³ of SCNAT, the Austrian Physicist Reinhold Bertlmann, and the Nobel Laureate Alain Aspect. Bertlmann is a colleague of Anton Zeilinger, also Nobel Laureate, and also a good friend of John Bell whom he met for the first time at the welcome event at CERN in 1978, where he spent some research time, showing how relevant the theory division of CERN is. Bell, with his inequality, created the fundamentals of Quantum Computing and he had written a paper on how the different colors of socks of Bertlmann inspired him.

The three started a debate during which Nicolas Gisin explained how Alain Aspect arrived at the first experimental demonstration of Bell's inequality. Gisin pushed this further by creating a company that produces tools to prove Bell's inequality out of the laboratory. The spin-off is called *ID Quantique* ⁴, based in Geneva, a first step in realizing the quantum dream of using entanglement for real life applications, such as winning over the world challenge of more efficient and secure computing and data transport.

² <https://cern70.cern/>

³ <https://quantum.scnat.ch/>

⁴ <https://www.idquantique.com/>

¹ <https://www.youtube.com/watch?v=cYvln3SWPEM>

Report on the International Physicists Tournament 2024

Martina D'Arco, Université de Genève

While most of their classmates rested from their coursework, over 200 university students from around the world gathered in Zürich during the Easter holidays to participate in a Physics competition held at ETH Zürich between 2 and 6 April. This has been the 16th edition of the International Physicist Tournament (IPT) bringing together a large number of individuals, united by their passion for physics and the excitement that academic research can instill in those involved.

The IPT of this year had a remarkable attendance of 21 teams, including Mexico for the first time. Anastasiia Vasylychenkova, the IPT's president since 2021, acknowledged that there were some logistical challenges. "We had to ensure that the games were played fairly among all the teams since not every team had the chance to play with every other team and not all the jurors could observe all the teams."

Organizing this edition would not have been possible without the great support of the local team. "It received a lot of support from the ETH side. The work that Andreas Vaterlaus and Mathieu Suter, respectively professor and PhD at the ETH, did as part of the local team for many years, and of Alberto Rolandi, secretary of IPT and PhD at UNIGE, has been invaluable," continued Anastasiia.

"There were so many things that could have gone wrong" added Mathieu. "I think we have set in place excellent planning and preparation work and all the people assisting us on every detail and problem did an excellent job". The organizers of the IPT are grateful to all the entities that supported them during the tournament and to the city-state and canton of Zürich for providing city tours, accommodation logistics, and public transportation tickets to all participants. Participants had the opportunity to visit the Paul Scherrer Institute, which was made available for the event. They also are grateful for the funding received from organizations and enterprises such as Swiss Life, the Cogito Foundation, SwissMAP, and the Swiss Physical Society and the significant logistical support and provision of spaces provided by ETH throughout the tournament week.

The IPT week followed months of preparation by the participating teams. The list of problems that were to be solved was published in September on the official website of this year's edition and the teams started studying them from that moment onwards. To advance through the selection process, the teams had to submit reports on some of the problems they had solved, like an article for a scientific journal.

Some countries had multiple teams competing, so they held national selections to decide which team would represent their country at ETH. For example, Switzerland, the USA, and Italy each had two universities participating, so the or-



ETH Zürich. Credits: IPT local team.

ganizing team helped local organizers set up mini-competitions that mirrored the official event.

The students from both EPFL and ETH teams stated that they didn't feel any competition between themselves, even though they were competing to enter the Final Tournament. "It is more like a collaboration" explained a member of the ETH team. "We went to EPFL to discuss some of the problems and to learn about their work. We trained together and had great discussions. It's always nice to meet people nearby who are working on similar things, exchange ideas, and learn from each other." The students from both teams agreed that forming a larger Switzerland team would be beneficial for building new friendships, sharing ideas, and learning interesting things. "After the national selection, we became one big team," a member of the EPFL team, and this is evident from their interactions during the IPT

where they appeared to be classmates of the same university.

One may wonder: "What is IPT exactly?" The IPT is an innovative approach using a game to simulate a peer review process. In this game, three teams participate in "Physics Fights," with each team taking on the role of a Reporter, Opponent, and Moderator. The roles of all three participants are well-defined. The Reporter presents a solution to a physics problem, highlighting key physical concepts and findings, sharing original ideas and comparisons with self-conducted experiments. The Opponent, on the other hand, analyzes the advantages and drawbacks of the solution and the Reporter's presentation. This leads to a discussion between the Reporter and the Opponent, focusing on how to correct or improve the solution. At the end of the discussion, they are encouraged to agree on what can be changed or improved in the Reporter's solution. The role of the Moderator consists of managing and supervising the dialogue between the Reporter and the Opponent, and subsequently between their teams. This helps to ensure that both parties stay on track and focused on the issues being discussed, making it easier for the audience and jurors to comprehend the problems and the proposed solutions to their fullest extent.

Every role has its own set of advantages and challenges. Jennie Russell, from the USA team, had the opportunity to act only as a Reporter during the IPT. However, when observing her team members, she found out that the Moderator role is the most interesting "just because it is so hard to balance the discussion between the other two players". She enjoyed the role of the Opponent too. "It provides an interesting opportunity to challenge the Reporter's work and make improvements to the solution. If everyone is willing, it's almost like working together. Sometimes the discussion

can become tense and argumentative, but it's still possible to have a collaborative conversation.”

As an external observer of the competition, I noticed that the Opponent's role was not solely focused on attacking and criticizing the Reporter but also on engaging in a conversation with the Reporter by asking genuinely interested questions and suggesting improvements to the Reporter's strategy. This fosters a cooperative environment rather than confrontation, with broader implications for the participating students.

The semifinals and the finals

During the IPT week, the highest-scoring team from the selective Physics Fights advanced directly to the final. Teams ranked 2nd-7th went to the semifinals, which consisted of two Physics Fights. This year, the first included the teams of Italy and Brazil, while the second featured Germany, USA, and Poland.

In the morning session, the participants discussed various physics problems including smart water and bubbles under a wet glass. Later in the day, the announcement of the three teams that qualified for the finals was made at the ETH Honggerberg campus. France was the first team to qualify due to their high score from the Selective Physics Fights. The other two finalists were Germany and Italy. The Italian team was particularly enthusiastic about making it to the finals and commented on the result positively. “We didn't expect to arrive in the finals,” said the team. “We didn't even expect to make it to the semifinals.”



The solution of Team Germany during the finals. Credits: IPT local team.

During the finals, which were held in the AudiMax of ETH, an interesting episode took place. Despite the tense atmosphere, with three teams competing against each other to win a competition that had occupied their minds for months, all participants were captivated by the presentation given by the German team. They were intrigued by the team's solution and the experiment they demonstrated, which was so impressive that all the finalist teams stayed behind during the break to learn more about the mechanics behind it.

This moment demonstrates how physics can bring people together and promote collaboration among competitors. Even though the environment was competitive, the shared curiosity brought all participants together.

Closing ceremony

The closing ceremony was held in the same place as the finals, on Saturday 6, in the afternoon. Mathieu and Anastasiia extended their heartfelt thanks to the entire organizing team for their invaluable assistance throughout these months, especially during the week of the event.

During the ceremony, Mairi Sakellariadou, President of the European Physical Society (EPS), made her appearance at the competition for the first time, acknowledging the significant educational value of the event and providing participants with an overview of what EPS represents. “The event was very good, and people were very enthusiastic and well prepared,” she said, after the closing ceremony, while also suggesting improvements for future editions, to elevate the event to a more professional level.

Following that, the closing ceremony proceeded with the presentation of certificates to the outstanding participants, leading up to the announcement of the top three rankings. Germany secured the first position with a score of 51.33, followed by France with 48.50, and Italy with 46.17.

Conclusion and general comments on IPT

Asking around for personal feedback on this IPT week, the response from all participating students was overwhelmingly positive. For the EPFL students, “This week was a phenomenal experience. It was so great to see physicists from all over the world who worked on the same problem as you”. The USA team enjoyed experiencing the collaborative nature of science: “It gave us a good view of what science should be like in terms of collaboration, and in terms of different approaches and different minds coming together to talk about science.”

The Italian team commented that by tackling certain problems, they were able to delve deeper into specific topics that they may not have been able to explore during their university courses. This required a lot of personal studies, which allowed them to approach the world of research by reading papers and conducting experiments on their own. The experience was very educational, and the team had a fantastic week overall.

Reflecting on the impact that the IPT makes in the lives of all the people who participated in it, Mathieu mentioned: “I think that one of the values of IPT is to try to be more inclusive. The IPT is international, it comprises students from different cultures, from different backgrounds. It is great to meet people of all nationalities since they have different approaches to physics and communication. The IPT is a great experience as it is not only about physics but also about the human aspect of it.”

There is one more thing worth considering about the IPT, which is how events like this can help combat the stereotype of girls and women in science. An interesting comment was made by the only girl in the two Swiss teams, Marie Mennerat. When asked about her experience with the IPT, she mentioned that one thing that affected her was the difference in the number of girls on some teams compared to the Swiss team. For instance, the team from Brazil had four girls out of eight participants. “I was pleasantly surprised and wished that more girls were encouraged to pursue physics also in Switzerland. A girl might feel out of place when surrounded

by a big team of boys, but my team was very helpful and supportive.”

In conclusion, the 16th edition of the IPT at ETH Zürich was a great success, showcasing the passion for physics and the collaborative spirit among students from around the globe. The tournament provided an invaluable educational experience for participants, fostering deeper exploration of physics concepts and promoting collaboration in problem-solving, highlighting the profound connections that physics can create. As the event concluded, participants expressed overwhelming positivity about their experience, underscoring the transformative impact of the IPT in promoting inclusivity and challenging stereotypes in the field of science.



Shaping high school science education with tech industry in action for sustainable development

Barbora Bruant Gulejova, STEM Ambassador (University of Bern, Albert Einstein Center for Fundamental Physics LHEP / CERN – ATLAS experiment; EPFL); Founder of “Youth @ STEM for Sustainable Future”

The SPS contributes to increasing the “Swissness” of the national STEM [1] expertise, which is instrumental to keep the world-leading position of the country in innovation and economic progress [2], by supporting the pioneer project “Youth at STEM for Sustainable Future” Youth@STEM4SF. This groundbreaking innovative outreach project aims to effectively inspire high school students, especially girls to become future STEM specialists and scientifically literate society leaders; and to shape the science school curricula in Switzerland and abroad to make a significant impact in fostering better awareness about the value of science for society and for sustainable decision making.

Despite the demand for STEM-related jobs growing faster than in other sectors, there is a worrisome decline in the interest of youth, particularly among girls, in pursuing careers in these fields. This trend is counterproductive and alarming, given that the demand for STEM skills in the workforce of the European market was expected to triple from 8 % to 23 % between 2015 and 2025 while the employment in STEM-related sectors was predicted to rise by only about 6.5 % [3]. This implies a significant shortage of people with the skills needed to drive the 4th industrial revolution and solve the UN Agenda 2030 / Sustainable Development Goals - SDGs [4]. While physics-based industries significantly contribute to European socio-economic progress [5, 6], the persistent challenge of recruiting high-quality engineers is exacerbated by a substantial gender gap. In most countries, women remain underrepresented in academic STEM fields (below 20% in post-graduate physics positions, 22% in AI). In 2019, women made up just 19 % of inventors, and only 2 % of venture capital for tech went to women-led start-ups [3].

One reason for this issue is the prevalent misperception that basic research, especially physics, is complex, abstract, uninteresting, exclusive, and lacking appealing career prospects [7]. Moreover, the general awareness and appreciation of the role of science in our society is rather

low [8, 9]. Much of these stereotypes can be attributed to the disconnection of high school science curricula from real-life applications and societal challenges [10], and a substantial historical lag (depending on the subject up to a century) between school content and cutting-edge scientific knowledge [11].

One should not count only on extra-curricular activities offered by the scientific community to bridge this gap. Often with content catering to students already inclined towards STEM, their impact is limited also by the awareness, motivation, and time constraints of science teachers, facing difficulty in introducing new subjects within curricula.

Innovative approaches in physics / STEM education and outreach are required. Contextualizing these disciplines within real-life scenarios, especially applications with societal and environmental relevance (well represented by SDGs), proves to be a potent tool for fostering students’ interest and appreciation in physics [12, 13]. Medical applications from particle physics [14 - 17], for instance, are particularly inspiring for girls who may be undecided about their career paths [18 - 20].

New engaging science education content is crucial, but not enough. A top-down approach officially endorsing and integrating it into the science school curricula, including training of science teachers (inter)nationwide, is vital and provides an effective implementation of new subjects and teaching methodologies. Therefore, the issue can be effectively solved only by a systemic transformation of science education at the high, middle, and even primary school levels. Such a mission can be best tackled only as a collaborative endeavor of a multi-stakeholder community, including scientific, education, and policy-making, but also industrial actors. The significance of coordinated efforts to raise awareness about the role of science in society has been acknowledged through recent declarations, such as



the UN International Year of Basic Sciences for Sustainable Development (IYBSSD) in 2022/2023 [21, 22] and the International Decade of Sciences for Sustainable Development (IDSSD) from 2024 to 2033 [23].

Clearly, in this context, sustainable development is the key strategic entry point to create an appreciative dialogue of scientists with society, including shaping the official school science education. Even if teaching sustainability is becoming gradually compulsory in high schools, not only in Switzerland [24], due to the lack of science teaching resources on sustainability, the subject is typically addressed only during geography and economy lessons, strengthening the wrong perception of being unrelated to physics and STEM.

The new Swiss high school education plan PEL [25, 26], emphasizes the inclusion of multidisciplinary skills, sustainable development, applied sciences, career decision capacity, and innovative modular teaching formats like thematic days. For these aspects, inherently included as an additional layer to existing STEM education and outreach activities, the Youth@STEM4SF project has been recognized as a perfect pioneering case of implementing the new PEL by the national competence center for sustainable development education, foundation education21 [27, 28].

Youth@STEM4SF leverages the unexplored inspirational avenue by showing science in action for society and sustainable development. It achieves this through engaging with industry and role models from diverse STEM backgrounds of both genders. The industrial community has an important role to play in contextualizing science, by showcasing concrete applications, technologies (directly or indirectly aligned with SDGs), and the vast array of STEM-related career opportunities (70 % beyond academia!). The project is anchored in an innovative outreach concept recommended by the European Committee for Future Accelerators ECFA [28] based on a proposal by the author [29] in 2018, where a broad population would be reached thanks to the synergy with industry and knowledge transfer, involving captains of industry as ambassadors for physics and STEM education. After a 5-year conceptualization phase in collaboration with the international multistakeholder community, including experts from various intersections of Big Science with business, outreach, education, physics teachers, industries, educational authorities, and the UN, Youth@STEM4SF

emerged from the 4S+ concept [30] under the umbrella of IYBSSD. The aimed feasibility for all stakeholders has been proven by the successful inaugural Swiss pilot, with financial backing from SPS, SCNAT, education21, and Rotary [31], and a substantial push from the Swiss Industry Liaison Office with Big Science Infrastructures [32]. To build a Swiss brand to be implemented abroad in the scale-up phase, this has been realised during the first Youth@STEM4SF days at Gymnase Bugnon-Sevelin in Lausanne on 11 May 2023 [33] and an upgraded version (with a more interactive format) on 13 March 2024. During these two thematic

days, both within and outside of school premises, nearly 100 students (around 16 years old) with 3 science teachers have been inspired by 12, including 5 female, role models. First, during an interactive session, a Youth@STEM4SF founder and female physicist with EPFL and CERN background connected physics and STEM with SDGs through concrete examples of applications from particle, nuclear physics and Swiss research-industry ecosystem. A wide range of examples of possible career paths with STEM diploma, also beyond academia, was shown. Later during the workshop at school and dive-in tours in the companies, the engineers & scientists of both genders from pioneering tech industries, ABB and EPFL spin-offs Solstis and DAPHNE, shared information about their career paths. They inspired the audience by highlighting crucial decisions, exciting journeys and stories, always reflecting on the pivotal role of their STEM background and transferable skills in creating value for society.

With the support of IUPAP, and Italian partners [34], the first international edition of Youth@STEM4SF took place as an official pre-event of upcoming Big Science Business Forum 2024 [35], in Trieste on 18 March 2024 with a regional counsellor level opening. Almost 100 participants from Italy and Slovenia enjoyed the inspirational presentations and a roundtable on “Big science meets industry”, replacing company visits with 8 inspirational role models representing the successful interface between research and industry, and an interactive visit to natural science museum [34].

The impact of the program was systematically assessed through pre- and post-questionnaires and interviews, focusing on key performance indicators such as awareness, attitude, and interest in STEM studies. Initial results are highly encouraging: 30 % more students can envision a STEM career after the program, while in particular large increase was observed by girls. Thanks to the relatable female role models, girls find physics and engineering more accessible. Additionally, half of the students wish to serve as ambassadors for science in their future non-scientific careers. Students felt empowered for physics careers: “I am much more confident about security in the job market as a physicist, and I can see many different opportunities to explore. It would be wonderful to have such lessons at schools.”

Youth@STEM4SF day always closes with a brainstorming interactive session, where students reflect in groups on their favourite examples of science applications for SDGs, and the engaging ways how to learn about these at school, using digital tools, like simulations, applications, or games. A good example is the game on cancer hadron therapy, where different types of particles are shot at cancer cells. This session is a warm-up for the motivated students to work on the subject officially in the framework of the maturity work and/or to take part in the Youth@STEM4SF competition with the possibility of winning an internship in a tech company or delivering a speech at the UN Youth Forum. The valuable input from students and teachers will be also used for the co-creation of missing high school resources integrating sustainable development to science curricula, in the framework of a new ResponSE project with EPFL and the University of Bern [36], aiming to design inquiry-based learning Open Educational Resources, e.g. [37]. This is part of the Youth@STEM4SF scale-up within IDSSD, where more data will be gathered for robust statistical analysis, encompassing to larger number of Swiss schools (private, public / IBO [38], gymnasiums, vocational), age groups, and geographical coverage. This would widen the number and variety of participating industries, and thus the scope of science and societal aspects.

To enhance the impact of the inspirational tech industries as recommended by the ECFA [28], a proposal has been officially made to establish a network of physics- and STEM-based industries, serving as ambassadors for STEM education. The proposal garnered first support from three leading companies - ABB, CAEN, and DAPHNE. It was put forth following the high-level multistakeholder roundtable at the recent EPS Forum 2024 in Berlin [39], in alignment with invitation by UNESCO, the UN lead body for IDSSD, to take coordinated action aimed at raising the awareness about science and encouraging young people, especially girls, to join STEM fields. This pledge will be extended to more industries at the upcoming BSBF 2024 in Trieste [35].

All relevant stakeholders from science, schools, or industries, are invited to join the mission to reshape science school curricula to meet the challenges of the 21st century, which will continue to be pursued as a multistakeholder collaborative endeavour under the umbrella of IDSSD.

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