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48/4
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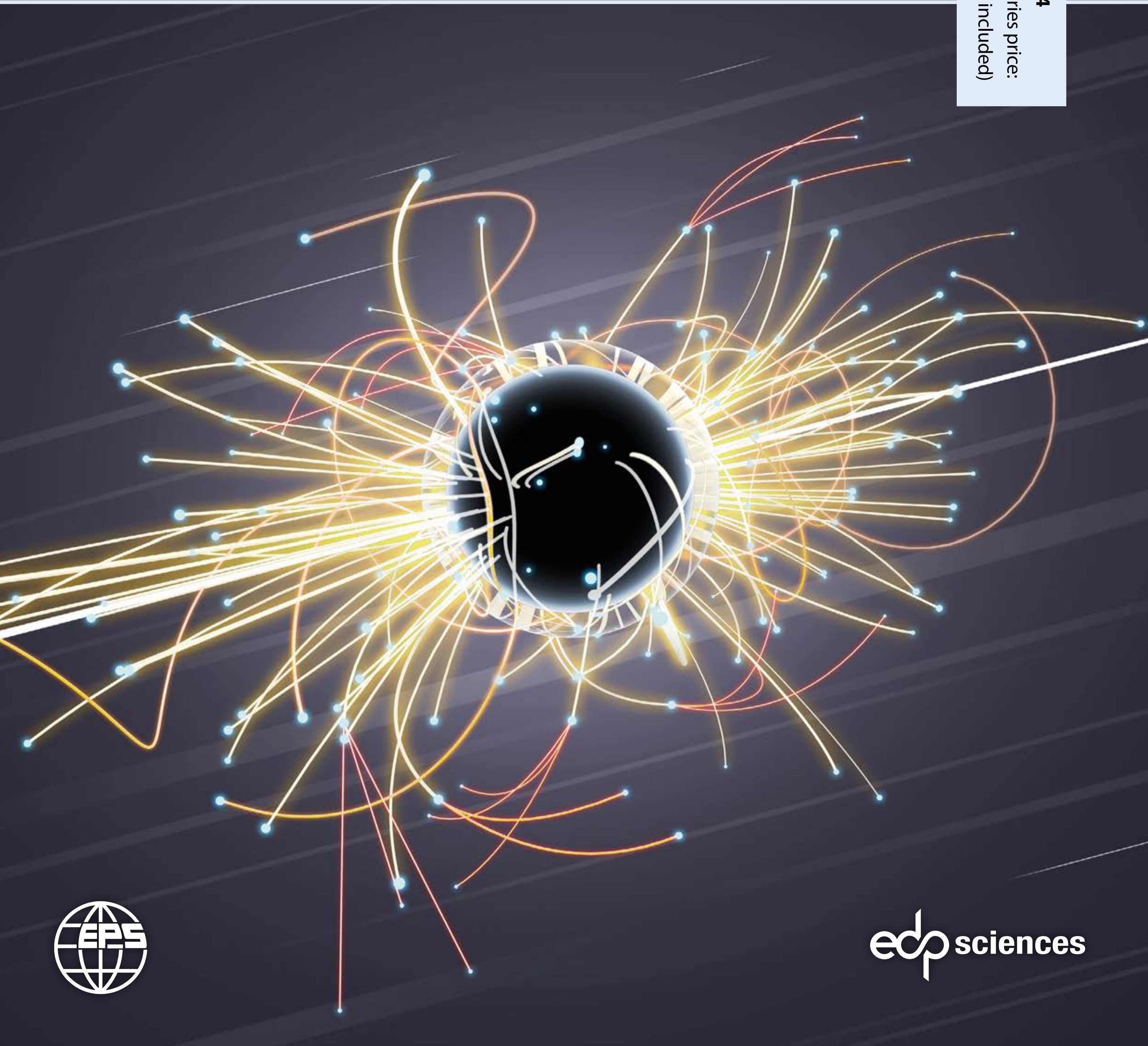

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Cover picture: Artist impression of a particle collision and blackhole in the Large Hadron Collider, ©iStockPhoto.
See p. 12 "Can we afford to wait? Designing the collider of the future"

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Designing the collider of the future

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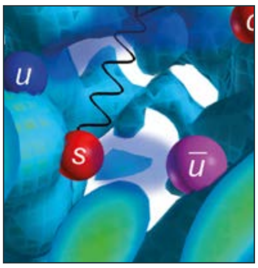
PISA testing – a global educational race?



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The NuPECC Long Range Plan 2017


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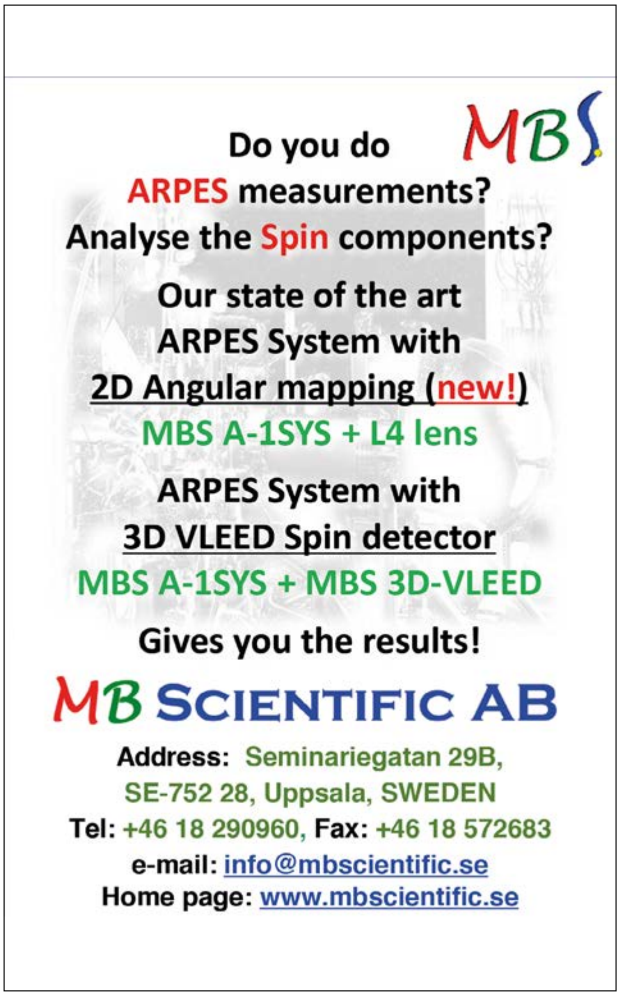
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[EDITORIAL]

Election day

Pre-election questionnaires can be an excellent instrument to promote the dialog between science and politics

On September 24, Germany will elect a new Federal Parliament, and in the German political system, the result will be decisive for the choice of the next Federal Chancellor and the composition of her or his government. In the run-up to the elections, five major scientific societies – including, of course, the German Physical Society – have submitted to the most important parties competing for seats in the new parliament a comprehensive questionnaire of "election benchmarks"; the other participating societies represent mathematics, chemistry, the biological and earth sciences. The questions cover a broad range of policy subjects such as the impact of science on political decision making, mobility of researchers, the importance of mathematics and science education, gender equality, sustainable development, and – last but not least – support for science in Germany, and for Germany as science location. The six parties contacted represent most of Germany's present-day political spectrum, and an encouraging outcome is that all of them responded to the questionnaire – including some which have not earned a reputation for placing science and education prominently on their agenda. To ensure that the initiative is not misunderstood as a recommendation for a particular political party, all answers have been published "as is", without comments from the participating societies.

It is the first time that scientific societies team up for such an exercise in Germany; I do not know whether there have been precedents in other countries, but in any event, this initiative is noteworthy in several respects, and sets an example to follow. Of course it is first and foremost a guide for voters who attach importance to science and education, and who wish to make science policy a criterion for a well-reflected decision where to cast their vote. For this reason, it is desirable that it receives broad attention from the general public, not only from the participating societies and their members.

Equally important, the questionnaire sends a strong signal to the political parties, and to the government that will emerge from the elections. Science denial is gaining ground even in the most civilised societies, and political decisions of massive impact on the future of mankind are more often than not driven by the short-winded imperatives and opportunities of the current legislative period than by long-term visions based on facts and solid scientific evidence. Against this background, such initiatives are excellent opportunities to remind political parties that good science is universal and non-partisan; to remind political decision makers of the importance of science-based, science-informed answers to the great societal challenges which we are facing together; and to remind them that a solid and sustainable science base requires sustained investment in science education, starting at high school level. The grand themes where physics can help to provide the answers – energy, climate change, the future of transportation, and many others – are well known; other scientific disciplines are poised to answer different, equally important questions.

When we ask questions to politicians, we must be prepared to answer theirs.

Last but not least, such initiatives are opportunities for scientific societies to take centre stage, demonstrating to governments, political parties, the media and the general public the role and the importance of learned societies as voices of the scientific community. It's a question of give and take – when we ask questions to politicians, we must be prepared to answer theirs. To get the dialog started, I encourage our Member Societies to team up with partner organisations in their home countries whenever important elections are coming up, to submit similar questionnaires to the candidates, and to publicise questions and answers as widely as possible. The EPS stands ready to assist its Member Societies with such actions, and should consider launching a similar one on the occasion of the next elections for the European Parliament due in 2019. The "Grand Challenges" document, which the EPS is preparing, is designed to answer many of the questions that we may be – and want to be – asked in return. ■

Rüdiger Voss,
EPS President

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First European Physics Olympiad

The first European Physics Olympiad was held on 20-24 May 2017 at the University of Tartu, Estonia, with the participation of 91 high school students and 40 team leaders from 20 countries.

Physics competitions have a long history dating back to the first Eötvös physics competition in 1916 in Hungary. The first International Physics Olympiad (IPhO) was held in 1967 in Poland. While the first IPhO was attended only by five countries, the number of teams grew persistently, and has reached 84 by 2016. In addition to IPhO, there are also several regional physics competitions, the largest ones being Asian Physics Olympiad (founded in 2000) and Ibero-American Physics Olympiad (founded in 1991), both of which are very similar to the IPhO.

Around 2000, the long-time President of IPhO, Waldemar Gorzkowski, tried to initiate European Physics Olympiad (EuPhO); however, there were no countries willing to organize it. One of the reasons was certainly that the organizational efforts and costs were expected to be not small. However, the main reason was that there was no clear need for EuPhO: European countries were satisfied with what was being offered by IPhO.

Keeping all this in mind, one may wonder, what is different now, 17 years later. A short answer is that the character of the problems has changed. During the first IPhO-s, the problems were similar to the problems of Eötvös competitions – short in formulation, aimed to test the creativity of the contestants. However, with the ever increasing number of teams and languages, grading of such problems became increasingly difficult. As a result, the problems started to become longer and include numerous subtasks. Typically, this results in a reduction of creativeness: sub-questions lead students towards the final aim of the problem along a pre-defined path. The examination papers resemble often undergraduate physics tests; with such tests, the winners are not the most creative contestants, but instead,

▲ Gold medals before closing ceremony (photo by Rael Kalda)

those who are the fastest at flawless mathematical calculations. The need for a competition where physical creativeness is put at the forefront, and the problems model real-world research (by which no-one is giving guiding questions) became increasingly acute. EuPhO is aimed to fill exactly this gap.

There are two more important differences between IPhO and EuPhO. First, the problems of IPhO are prepared by the organizing country; the problems of EuPhO are composed by the international Academic Committee. The founding Academic Committee includes seven members; the members will be rotated based on their merits and term of office. This system is expected to guarantee a stable style and difficulty of the problems. Second, at IPhO, the initial grading of the examination papers can be questioned by and will be discussed with the accompanying team leaders. At EuPhO, it is the task of the contestants themselves to appeal their grades. We expect that this approach helps students in developing their research-related discussion skills.

◂ (P.04) EuPhO winner Aleksei Shishkin from Russia (photo by Rael Kalda)

During the five-hour-long experimental competition round on 21st May, students were given a 1W light emitting diode, and were asked to study its V-I-curve, to determine its quantum efficiency, and to analyse the possibility of using it as a solar cell. During the theoretical round on 22nd May, the contestants needed to solve three problems with increasing difficulty. While the average score for the first theory problem was 6.4 (out of 10 points) and that of the second one 4.9, the last problem was solved (almost) flawlessly only by two students, with the average score being 1.7. That problem was devoted to the physics of a magnetically levitating superconducting puck with pinned flux: contestants were supposed to determine the force between a magnetic dipole and an infinite planar superconducting mesh with frozen-in flux from a magnetic dipole. The full set of problems, solutions, and the list of winners can be found at http://eupho.ut.ee/.

The programme of the Olympiad contained also academic and entrepreneurial career days, which, among others, included talks by Matt Taylor on Rosetta mission of European Space Agency, by Ana Godinho on CERN and opportunities for students at CERN, and by Allan Martinson on developing delivery robots. The closing ceremony included speeches by President of the Republic of Estonia, Kersti Kaljulaid, by Ana Godinho (Head of Education, Communications and Outreach, CERN), and by Tarmo Soomere (President of the Estonian Academy of Sciences).

The second EuPhO will be organized next year by Moscow Institute of Physics and Technology, Russia; tentatively, third and fourth Olympiads will take place in Latvia and Romania.

EuPhO was sponsored by CERN, European Physical Society, University of Tartu, Tallinn University of Technology, Estonian Research Council, the Council of Gambling Tax, Swedbank, Estonian Physics Society, and the city of Tartu. ■

■ **Jaan Kalda**
President of EuPhO,
Tallinn University of Technology

CALL FOR NOMINATIONS, PRESIDENT-ELECT

A number of vacancies will arise on the European Physical Society [EPS] Executive Committee in 2018, including the position of President-elect. According to the EPS bylaws, a Selection Committee has been created to establish a list of candidates for the replacement of outgoing members, and for the President-elect.

The Selection Committee is currently accepting suggestions from EPS Member Societies, Associate Members and Individual Members for the position as EPS President-elect. Please note that the individual elected as EPS President-elect will become EPS President in April 2019 for a 2 year term.

The Selection Committee will assess all proposals submitted and establish a short list of candidates with appropriate background and experience, and which will also addresses diversity issues in membership. Enquiries should be submitted by email to the Secretary General d.lee@eps.org.

The deadline for formal nominations will be 30 November 2017. ■

Research Ethics and Research Integrity– Why it matters to the Physics Community too.

Research Ethics and Research Integrity (sometimes used interchangeably as terms) are becoming increasingly important and visible topics for everyone working in science and engineering, as well as for the organisations that employ them. Of course, those working in sensitive areas of research, such as medical research, that can have an immediate impact on people and their well -being, or those who use animals in their research, expect their work to be scrutinised closely. However, it is clear that the policies and practices adopted by any researcher can have a direct effect on the public perception and image of science and scientists, the acceptability of their research activities, the impact it could have on people, the environment or society, as well as the overall credibility of their research output. Several high-profile cases of scientific fraud, publishing fake data or fake interpretation of results, have raised the debate amongst the scientific community itself. Moreover, the science and engineering community cannot hide behind the approach that may have been used in the past; that we just develop new knowledge and technologies and that it is then for others to decide whether and how this information will be exploited. We need to be much more aware of the ethical dimensions that surround our science and our research.

Where does research integrity need to be considered during the research processes? The answer is everywhere and at all stages. It needs to be built in to and embedded in the whole way that research is designed, conducted and reported. Some examples of the types of ethical issues to consider are:

- At the early stages during design of a research programme or project and bidding for funding. Can the costs be justified in terms of the potential outcomes and benefits being claimed? Are the finances, staff time and equipment all required for the work? This is particularly important where public money is being sought but also when bidding to other funders such as charities or business. Any "overclaiming" of what might be achievable can damage the credibility of not just the research leader and team but the research field itself. Fraudulent demands for funding likewise.
- When the work is being planned and conducted there are a number of areas to consider in the way that data and results of experiments are collected, interpreted and managed to ensure that all claims being made are correct and auditable and nothing is being left out or hidden because it does not support the arguments being put forward.
- When publishing results, or claiming Patents and Intellectual Property, there are many issues of authority and "ownership" to be considered. Who is included as authors, who writes the paper, particularly where issues of the publication's required language arises. Who is ultimately responsible for the quality and veracity of the publication and its contents, who identifies and deals with any concerns over plagiarism or ensures that prior work is correctly identified and referenced. Concerns over the role of supervisors and mentors for early stage researchers and their publications can also arise. Ultimately, it is all those whose names appear on a publication that are responsible for its contents and as the number of authors increases it can be a challenge to ensure that everyone named understands this and endorses the publication. Even the peer review system can raise ethical issues, for example where results that challenge the status quo, or accepted understanding, can be initially rejected. Group think amongst research communities is an ethical issue too.
- When research work is being used or exploited by others, issues of ownership arise as well as a whole range of potential conflicts of interest in follow on research activities. The relationship between Academic Institutions and spin-out companies can be particularly challenging in this regard but so can the relationship with any sponsors of research where you can go around the research cycle again of considering whether more research will really provide a better answer to their problem.

As well as these areas of research process to consider, ethical issues can arise amongst the research community and the ways in which it is governed and managed. How scientists and engineers deal with each other professionally and agree to adopt appropriate codes of conduct is an important consideration. Processes for dispute resolution, dealing with misunderstandings or differences of view are necessary, whether within an employing organisation or more widely for publishers or professional bodies. In the worst case, being clear as to how any claims of misconduct are investigated and dealt with, can help ensure fair treatment and that issues do not escalate in an uncontrolled manner.

The final aspect of research ethics to consider is where current and future research directions could have significant, or perhaps unexpected, consequences for people and society. There is a continuing need to have discussions and programmes of engagement about emerging technologies to ensure that whatever comes out of research remains acceptable to society in terms of the impact it could have. This is a challenging area to address as the scientific community itself may not be best placed to predict how others may make use of the advances that arise and the wider audience may not have the technical tools, language and conceptual thinking necessary to absorb the implications. However, this engagement is vital to ensure that scientific advances are used to greatest benefit and that science and research retain the support of those who provide a large proportion of the funding and will be affected by its consequences.

There is much useful information and a number of practical frameworks published on the Web that can be accessed to see how issues of research ethics and research integrity can be addressed by the Physics community to both refresh our ideas and help train the next generation in good practices. For example, see the recently updated ALLEA Code of Conduct for Research Integrity. ■

Frances Saunders

In memoriam

The EPS was saddened by the announcement of the death of Prof. em. Dr. Ernst Heer, Honorary Member of the European Physical Society.

Born in 1928 in Ilbach in the Canton Schwyz (CH), he attended the Argovian cantonal gymnasium in Aarau, where about fifty years earlier Einstein obtained his scientific matura as well. He studied Physics at the *Eidgenossische Technische Hochschule Zürich* (ETHZ, CH) where he started his career and obtained his doctorate in 1955 under the direction of Paul Scherrer and Wolfgang Pauli. From 1958 on he continued his studies at the University of Rochester (NY, USA). Back to Switzerland, he became full professor in nuclear physics at the Faculté des sciences of the *Université de Genève* in 1961, where he founded the *Laboratoire de physique nucléaire et corpusculaire*. He took formal responsibility of the nuclear reactor made available to the University by the Swiss National Fund (FNS) for diverse investigations and for teaching. He organised the nuclear decommissioning in 1989. His particle research concentrated mainly on nuclear interactions between protons, neutrons and antiprotons with experiments done at CERN and at the Paul Scherrer Institute (PSI).

Parallel to his academic activities he managed the *Département de physique nucléaire et corpusculaire* and became Vice-Rector of the University in 1967/73 and Rector in 1973/77. He was Member of the *Conseil national de la recherche du FNS* in 1971/80. Thanks to his rigor and his remarkable talents of organiser, he became President of the Swiss Physical Society and of the *Comité consultatif* of the Swiss Nuclear Research Institute (presently Paul Scherrer Institute, PSI) in Villigen and represented Switzerland in the CERN Council. After his retirement, in 1993, he always kept constant contact with his former department. He was also a very close friend of the first EPS Secretary General Gero Thomas.

In 1992, he established a successful 'European Mobility Scheme for Physics Students' (EMSPS), based on his experience with a similar student mobility initiative in Switzerland. He gave a true impulse to this project, financially supported by the ERASMUS programme and with the administrative support of the European Physical Society (EPS). The physics departments of the hundred participating institutions gained insight into their physics curricula when organizing the student exchanges, archived on a central computer. This scheme was not only supported by the then E.C. and EFTA partners but also by other Mobility European Projects from the TEMPUS programme involving partners from central and eastern European countries. EMSPS was the seed of further European Physics Thematic Networks such as EUPEN (European Physics Education Network), STEPS (Stakeholders Tune European Physics Studies), STEPS TWO and HOPE (Horizons in Physics Education), which ended just recently. All these networks, would have been unthinkable without the original work by Ernst Heer.

A widower by the age of 59, he is survived by his older sister Lina Helfenberger, his son Fabio, his daughter Livia and his four grandchildren. ■

Martin Pohl,
Université de Genève (CH)
Hendrik Ferdinande,
Universiteit Gent (BE)
Peter Sauer,
Leibniz Universität Hannover (DE)

DIETER MESCHEDE BECOMES PRESIDENT OF THE GERMAN PHYSICAL SOCIETY FROM 2018 TO 2020

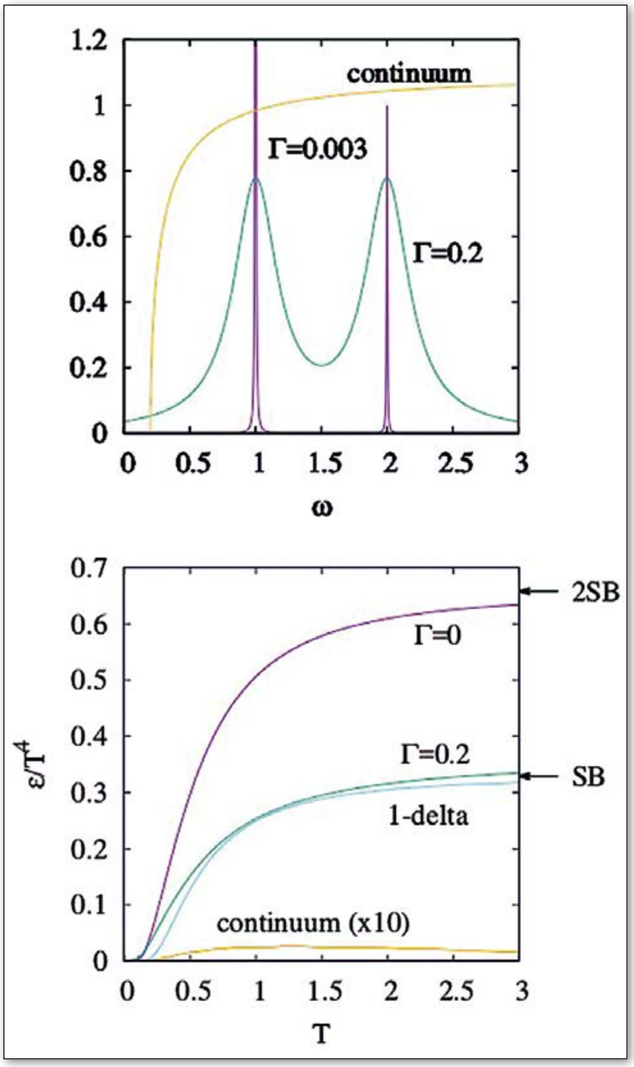
Unanimously, the board of directors of the DPG elected Bonn's physics professor Dieter Meschede as the next president of the world's largest physics society with around 62,000 members. In April 2018 Meschede will take over the post of Rolf-Dieter Heuer, who then will assume the vice presidency. It is a good practice in the German Physical Society (DPG) to choose a successor or a successor over a year before the end of the term of office of the acting president in order to familiarize them with the complex and responsible work and to ensure continuity in the DPG . Unanimously, the board of the DPG elected Bonn's physics professor Dieter Meschede as the future president of the world's largest physics society with around 62,000 members. ■

Highlights from European journals

NUCLEAR PHYSICS

Nuclear and Quark Matter **at High Temperature**

In high-temperature field theory applied to nuclear physics, in particular to relativistic heavy-ion collisions, it is a longstanding question how hadrons precisely transform into a quark-gluon matter and back. The change in the effective number of degrees of freedom is rather gradual than sudden, despite the identification of a single deconfinement temperature. In order to gain an insight into this issue while considering the structure of the QGP we review the spectral function approach and its main consequences for the medium properties, including the shear viscosity. The figure plots a sample spectral density on the top and the effective number of degrees of freedom (energy density relative to the free Boltzmann gas) at the bottom. Two thin spectral lines result in a doubled Stefan-Boltzmann limit (SB), while any finite width reduces the result down to a single SB. When spectral lines become wide, their individual contributions to energy density and pressure drops. Continuum parts have negligible contribution. This causes the melting of hadrons like butter melts in the Sun, with no latent heat in this process. ■



▲ Up: sample spectral densities, Bottom: the resulting scaled energy densities.

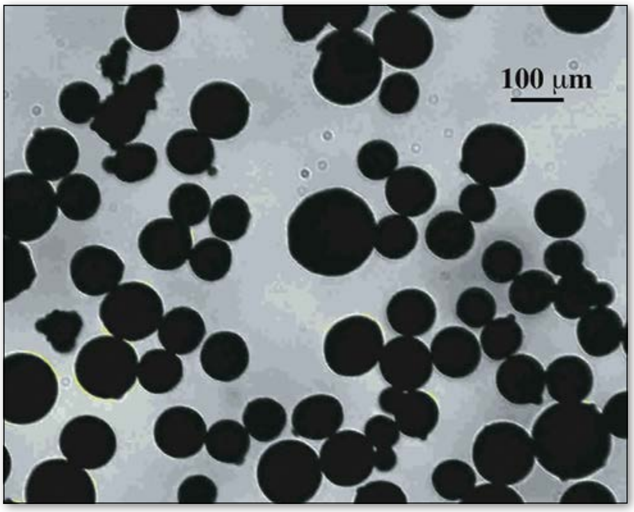
■ **T.S.Biró**, **A.Jakovác** and **Z.Schram**
'Nuclear and quark matter at high temperature',
Eur. Phys. J. A **53**, 52 (2017)

MATERIAL SCIENCE

Granular material conductivity increases in mysterious ways under pressure

Scientists reveal how electrical resistance in metallic granular media decreases as the pressure on the micro-contact interface between the grains increases

What happens when you put pressure on a bunch of metallic microbeads? According to physicists, the conductivity of this granular material increases in unusual ways. So what drives these changes? The large variations in the contact surface between two grains or the rearranging electrical paths within the granular structure? In a recent study published recently, the authors made systematic measurements of the electrical resistance—which is inversely related to conductivity—of metallic, oxidised granular materials in a single 1D layer and in 3D under compression. They showed that the granular



▲ Image of grains of copper powder through a microscope.

medium conducts electricity in a way that is dictated by the non-homogenous contacts between the grains. These findings have implications for industrial applications based on metallic granular material. ■

■ **M. Creyssels**, **C. Laroche**, **E. Falcon** and **B. Castaing**, 'Pressure dependence of the electrical transport in granular materials', *Eur. Phys. J. E* **40**, 56 (2017)

RELATIVITY

Proving Einstein right using **the most sensitive Earth rotation sensors ever made**

A new study use the most precise inertial sensor available to date to measure whether Earth partially drags inertial frames along with its rotation

▲ Physicists have now found a way to measure Earth's rotation in an extremely accurate way (©Fotolia).

Einstein's theory of gravity, also referred to as General Relativity, predicts that a rotating body such as the Earth partially drags inertial frames along with its rotation. In a study recently published, a group of scientists based in Italy suggests a novel approach to measuring what is referred to as frame dragging. The authors propose using the most sensitive type of inertial sensors, which incorporate ring lasers as gyroscopes, to measure the absolute rotation rate of the Earth. The experiment aims to measure the absolute rotation with respect to the local inertial frame, which is what is referred to as frame dragging. In principle, the ring laser should show one rotation around the Earth's axis every 24 hours. However, should observation by reference to fixed stars in the sky show a slightly different rate of rotation, the difference can be attributed to frame dragging. The authors' proposed experiment, called GINGER, requires two ring lasers to provide a reference measurement. Their proposed solution can accurately test the frame dragging effect at 1%, a vast improvement compared to previous experiments, which has 19% and 5% error in their measurement. ■

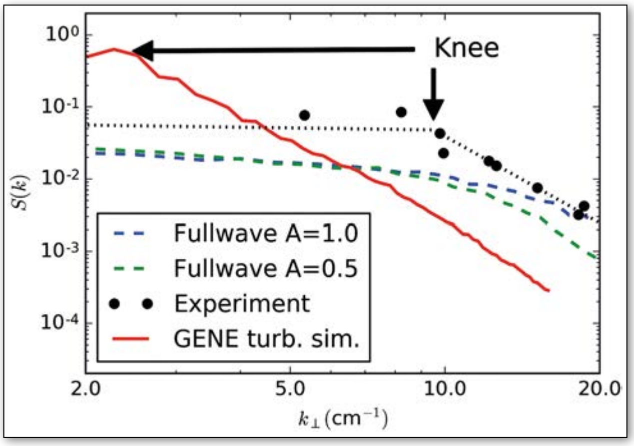
■ **A. D. V. Di Virgilio**, **J. Belfi**, **W.-T. Ni**, **N. Beverini**, **G. Carelli**, **E. Maccioni** and **A. Porzio**, 'GINGER: a feasibility study', *Eur. Phys. J. Plus* **132**, 157 (2017)

PLASMA PHYSICS

X mode Doppler Reflectometry k-spectral measurements in ASDEX Upgrade: experiments and simulations

Doppler reflectometry is a microwave backscattering diagnostic for measuring flows and density fluctuation spectra in fusion plasmas. One longstanding problem is the discrepancy between the Doppler spectrum and the density fluctuation spectrum from turbulence simulations: The red "GENE" curve has its knee at a different wavenumber compared to the experimental Doppler measurements. The knee position is intrinsic to the turbulent drive mechanism and should be the same in both.
We coupled the sophisticated plasma turbulence code GENE to the fullwave code IPF-FD3D to model the scattering and the power response of the reflectometer in the presence of realistic turbulence. Dashed lines in the figure are the result

▼ Power spectra over perpendicular wavenumber. "GENE" shows density fluctuations, the others are scattered microwave power (a.u.).



of fullwave simulations. The blue curve (A=1) reproduces the knee position, but not the power law of the experiment. Reduction of the density fluctuation strength yields a better fit (A=0.5). The apparent shift of the knee is therefore a characteristic of the diagnostic.
This breakthrough reconciles turbulence simulations and experiment and shows that extra-ordinary mode scattering is taking place in the non-linear regime. ■

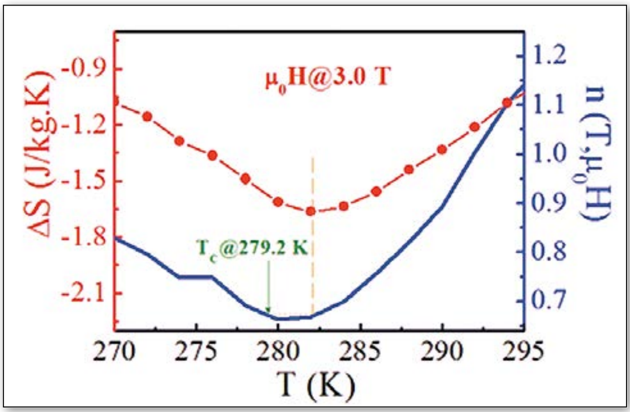
■ **C. Lechte**, **G. D. Conway**, **T. Görler**, **C. Tröster-Schmid** and **the ASDEX Upgrade Team**,
'X mode Doppler reflectometry k-spectral measurements in ASDEX Upgrade: experiments and simulations', *Plasma Phys. Control. Fusion* **59**, 075006 (2017)

MATERIAL SCIENCE

Accurate determination of Curie temperature in helimagnet FeGe

Cubic helimagnet FeGe, the prototype of skyrmion materials near room temperature, has emerged and may impact future information technology. The magnetic entropy change (MEC) of helimagnet FeGe and the close relationship between the MEC and critical exponents of a second-order phase transition were studied. A relatively small MEC under external high magnetic field indicates the coexistence and competition between exchange anisotropy and magneto-crystalline anisotropy, and a stable balance is formed in the precursor region when the applied magnetic field cannot completely transform FeGe into a single magnetic structure phase. Based on the obtained magnetic entropy change and critical exponents, an accurate Curie temperature of helimagnet FeGe under zero magnetic field is confirmed to be 279.1 K, lower than 282 K deduced directly from the derivative magnetic susceptibility and higher than 278.2 K previously reported.

▾ Magnetic entropy change (ΔS) dependence on magnetic order exponent (n) at external magnetic field 3.0 T.



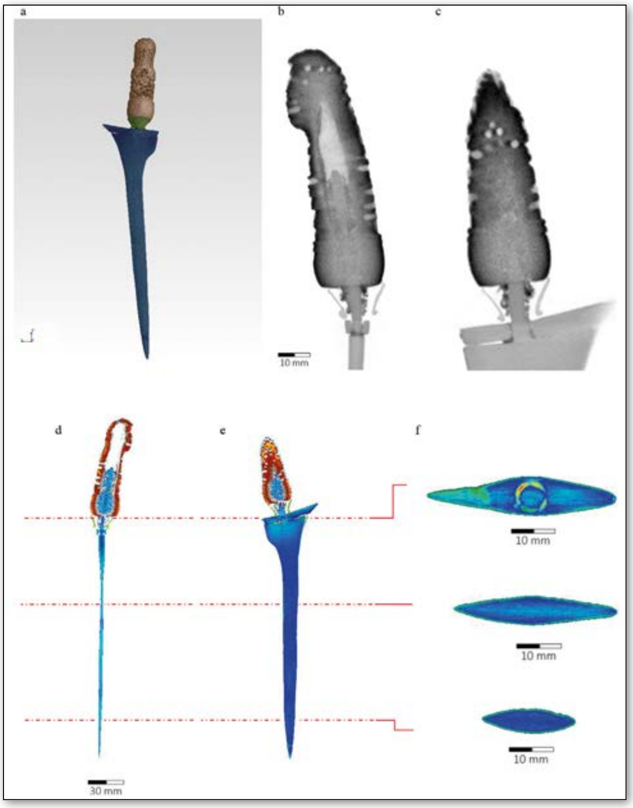
So, the accurate determination of Curie temperature is conducive to reconsider the inhomogeneous chiral-spin state and reconstruct the magnetic phase diagram in the precursor region of helimagnet FeGe. ■

■ **L. Xu**, **H. Han**, **J. Fan**, **D. Shi**, **D. Hu**, **H. Du**, **L. Zhang**, **Y. Zhang** and **H. Yang**,
'Magnetic entropy change and accurate determination of Curie temperature in single-crystalline helimagnet FeGe', *EPL* **117**, 47004 (2017)

APPLIED PHYSICS

Imaging helps **to spot fake ancient daggers**

Combining neutron and X-ray imaging gives clues to how ancient weapons were manufactured



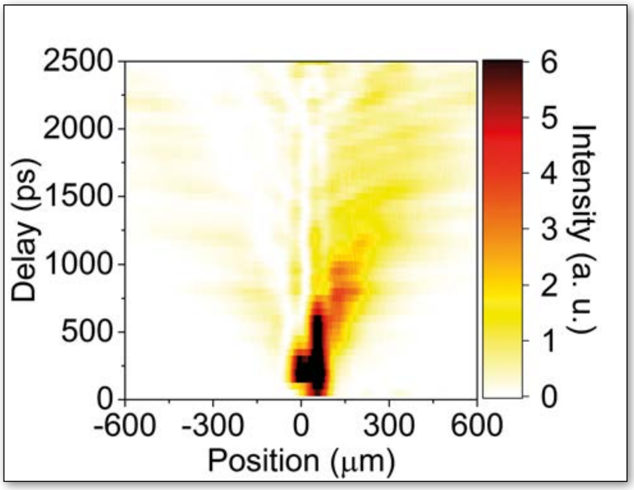
▴ Three dimensional reconstruction of the sample analysed using white beam neutron tomography.

Since the 19th century, collectors have become increasingly interested in weapons from ancient Asia and the Middle East. In an attempt to fight forged copies, physicists are now adding their imaging power to better authenticate these weapons; the fakes can't resist the investigative power of X-rays combined with neutron imaging. In a study published recently, the authors have demonstrated the usefulness of such a combined imaging approach to help museum curators in their quest to ensure authenticity. They can now reliably tell first-class modern copies of early daggers and swords from authentic ones. In this study, the authors focus on a kris—the distinctive weapon of Malaysia and Indonesia—and a kanjar— a double-edged dagger with a slightly curved blade and a pistol-grip made of metal, ivory, jade or some other hard-stone found *e.g.* in Persia and India. The authors found the internal structure of the traditional kris examined in this study was inconsistent with descriptions of traditional forging methods to be found in the extant literature, thus suggesting the artefact was a fake. By contrast, the kanjar analysed in the study is most likely to be authentic, as the material distribution in the volume of the blade conforms to traditional metallurgical processes. ■

■ **F. Salvemini**, **F. Grazzi**, **N. Kardjilov**, **F. Wieder**, **I. Manke**, **D. Edge**, **A. Williams** and **M. Zoppi**,
'Combined application of imaging techniques for the characterization and authentication of ancient weapons',
Eur. Phys. J. Plus **132**, 228 (2017)

MATERIAL SCIENCE

Unidirectional control of optically induced spin waves



▲ Optically induced spin waves propagating to the right.

For future information technologies, the field of magnonics is rapidly emerging. Spin waves – collective modes of spin precessions – are promising information carriers in magnonics, as Joule heating is negligible and propagation damping is low. Spatial control of the spin wave is indispensable for future application such as spin-wave switching, spin-wave-assisted recording, and sensing of small magnetic fields. In this article, unidirectional control of optically induced spin waves in a rare-earth iron garnet crystal is demonstrated. We observed the interference of two spin-wave packets with different initial phases generated by circularly polarized light pulses. This interference results in unidirectional propagation if the spin-wave sources are spaced apart at 1/4 of the wavelength of the spin waves and the initial phase difference is set to $\pi/2$. The propagating direction of the spin wave is switched by the polarization helicity of the light pulses. Moreover, in a numerical simulation, applying more than two spin-wave sources with a suitable polarization and spot shape, arbitrary manipulation of the spin wave by the phased array method was replicated. This achievement opens up a field of magnetic materials science and explores an alternative sensing technique using magnetic fields. ■

■ **I. Yoshimine**, **Y. Y. Tanaka**, **T. Shimura** and **T. Satoh**,
'Unidirectional control of optically induced spin waves',
EPL **117**, 67001 (2017)

NUCLEAR PHYSICS

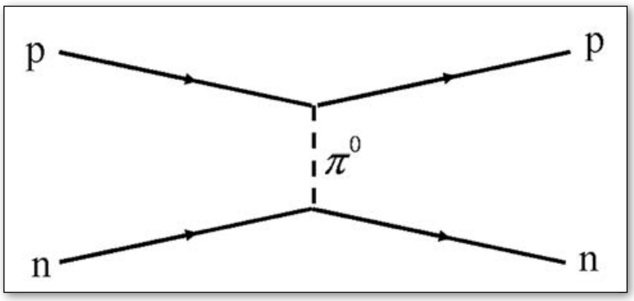
Wavy energy potential patterns from scattering nuclei **reveal hidden information**

New approach to analysing anomalies in collisions between atomic nuclei promises a new perspective on how they interact.

Anomalies always catch the eye. They stand out from an otherwise well-understood order. Anomalies also occur at sub-atomic scale, as nuclei collide and scatter off into each other—an approach used to explore the properties of atomic nuclei. The most basic kind of scattering is called 'elastic scattering', in which interacting particles emerge in the same state after they collide. Although we have the most precise experimental data about this type of scattering, the author contends in a paper published recently that a new approach to analysing such data harbours potential new interpretations of fundamental information about atomic nuclei. ■

■ **R.S. Mackintosh**,
'Elastic scattering phenomenology',
Eur. Phys. J. A **53**, 66 (2017)

▼ A Feynman diagram of proton-neutron scattering mediated by a neutral pion.



CAN WE AFFORD TO WAIT? DESIGNING THE COLLIDER OF THE FUTURE

Michael Benedikt and Frank Zimmermann – DOI: https://doi.org/10.1051/epn/2017401
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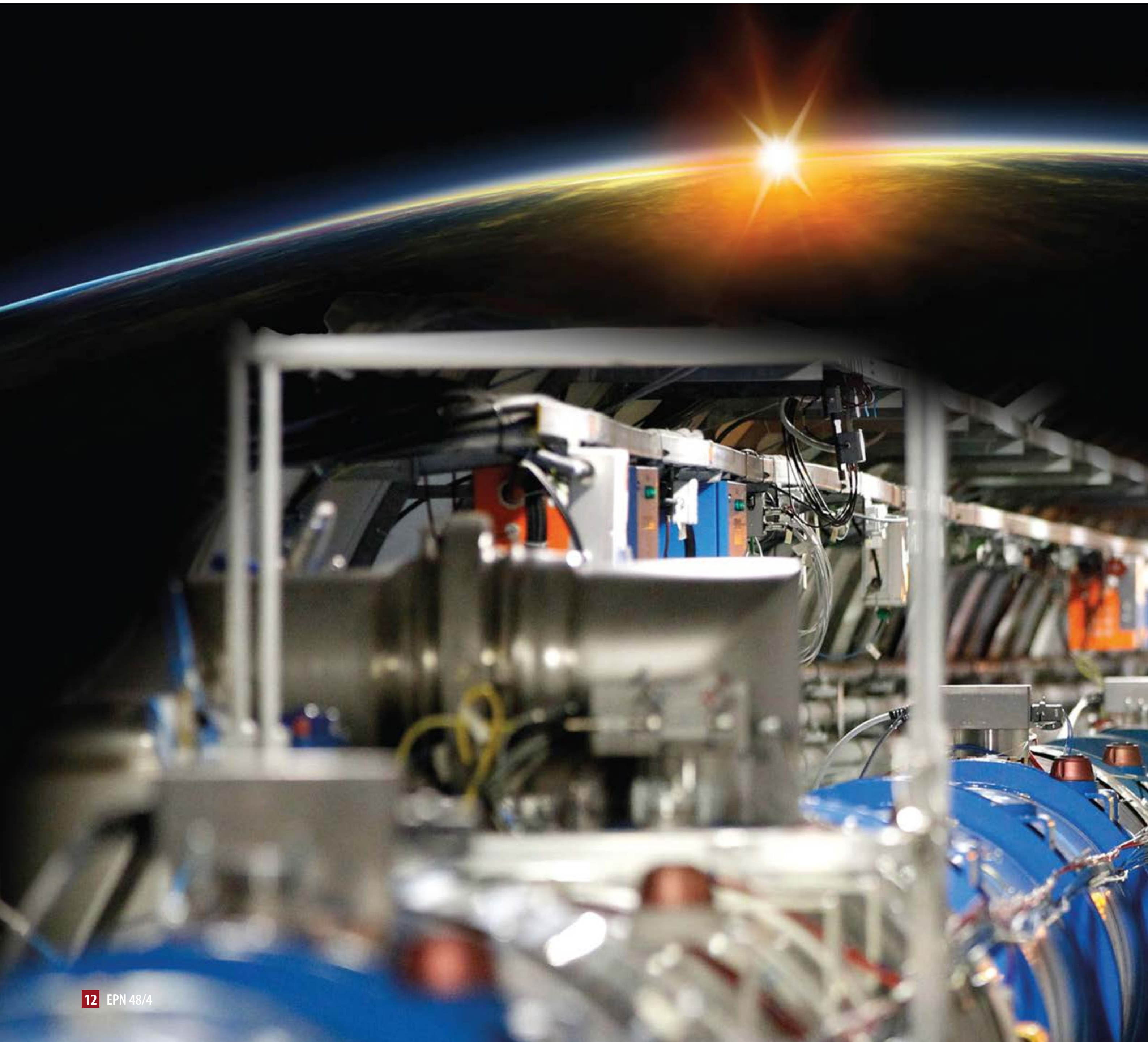
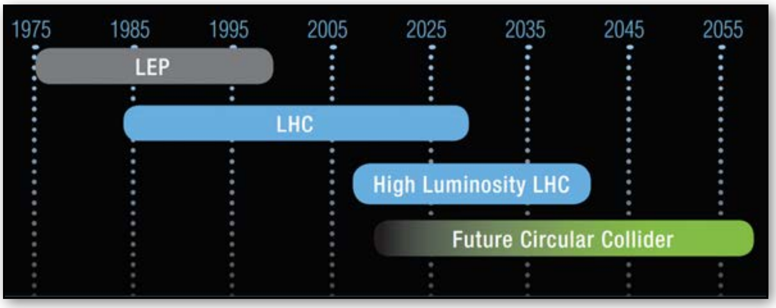
Designing a future circular collider is a next step in humanity's quest to explain the world. This effort is not only about striving for a profound understanding of nature, but also about creating an exciting perspective for future generations.



On 4 July 2012, during a special seminar in the main auditorium of the European Organization for Nuclear Research (CERN), the discovery of the Higgs boson was announced under the eyes of the world. This long elusive enigma had been the most sought-after particle in modern science, since the formulation of the Brout–Englert–Higgs mechanism back in 1964. Its discovery was a historical milestone not only for the Large Hadron Collider (LHC), but for the worldwide physics community, and resulted in the award of the 2013 Nobel Prize for Physics to Peter Higgs and François Englert.

The Higgs discovery, marking the end of a fifty years' adventure, completes the so-called Standard Model of particle physics, which describes the fundamental building blocks of matter and their interactions (except for gravity). It is one of many instances in the history of science where more than a working life passed between the initial formulation of a theory and its final experimental confirmation. Often enormous patience is required for ultimate success. The discovery of gravitational waves, first predicted by Einstein's theory of general relativity in 1916, but only detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO) collaboration in 2016, offers another glaring example. These two recent discoveries - of the Higgs boson and of gravitational waves - are linked to the two great theoretical frameworks of modern physics: quantum mechanics and general relativity, respectively. Unfortunately, with so far no signs of supersymmetry at the LHC, these two fundamental theories remain fully disconnected. A future high-energy collider might be the tool required to unravel this great mystery.

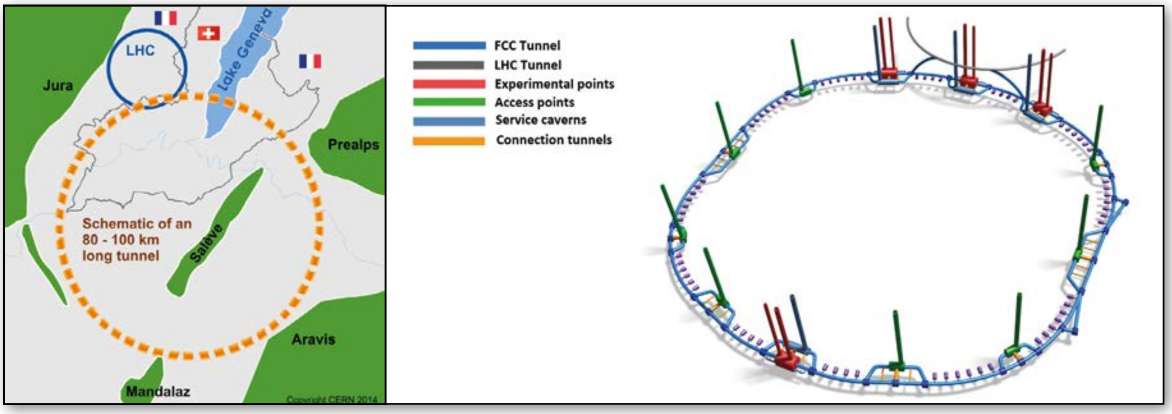


▲ **FIG. 1:** The goal of the FCC study is to explore post-LHC scenarios for a circular collider in order to ensure the seamless continuation of the world's particle physics programme after the LHC era. The significant lead time of approximately twenty years for the design and construction of a large-scale accelerator calls for a coordinated effort.

Presently, we are in an intermediate period, waiting for more data from the high-energy physics experiments at the LHC and elsewhere. At the same time the increased volume and precision of the data, being collected since 2012, confront the Standard Model with more exquisite tests.

Now that the Standard Model is almost complete we are free to focus on the big questions beyond it, such as the properties of dark matter, the mechanism behind the expansion of the universe, the origin of the matter-antimatter asymmetry, the hierarchy problem, and the naturalness of the mass of the Higgs boson. These questions, and the need to study the recently-discovered Higgs boson in greater detail, call for the full exploitation of the LHC including its high-luminosity phase (HL-LHC), whose rich physics programme extends up to around 2035.

A future energy and intensity frontier circular collider coming into operation soon after the completion of the HL-LHC research programme will offer unprecedented physics possibilities and could herald a profound change of scientific paradigm in modern physics. Given the long lead times of at least 20 years (see Figure 1) required to design, develop and build such a complex machine it is more than timely to start thinking about a post-LHC accelerator facility. Such is the purpose and scope of the Future Circular Collider (FCC) study [1] (fcc.web.cern.ch), which was launched as a direct response to the 2013 update of the European Strategy for Particle Physics.



▸ FIG. 2: (a) Sketch of a future 80–100-km-long tunnel in the Geneva area, which would allow for a 100-TeV, energy-frontier proton collider and also, as a potential intermediate step, a high-luminosity e^+e^- collider serving as a W, Z, H and $t\bar{t}$ factory. (Image credit: CERN) (b) Schematic of the underground infrastructure preliminary layout. FCC study envisages a 100 km in circumference tunnel, nearly four times the size of the present LHC (Image credit: CERN/FCCstudy)

A large-scale research infrastructure for Europe

Presently we are testing our theories in the new energy regime opened up by the LHC. If new physics is uncovered at the LHC we will surely need to study it and further push the intensity and energy frontiers. But what if there is no sign of new physics at the LHC? In that case new experiments at higher energies but also of greater precision will be required to unravel the many unsolved mysteries of the Universe.

To prepare for either case, CERN has initiated the FCC study for a future large-scale research infrastructure centred on a new-generation circular hadron collider with a circumference of about 100 kilometres, able to reach proton-proton collision energies of 100 TeV [5] – about 8 times above the LHC – and a corresponding energy in heavy-ion collisions. A future high-luminosity electron-positron collider, which could be housed in the same tunnel, is being considered as a possible first step [6]. A high-energy LHC upgrade is yet another option.

The FCC study explores the feasibility and reliability of all these possible future machines and associated options such as ion operation and lepton-hadron collisions (FCC-he); it also develops key-enabling technologies and examines the various physics opportunities. These efforts will culminate in a Conceptual Design Report and a cost review that will inform the next Update of the European Strategy for Particle Physics expected around 2020.

Investment in frontier research will reinforce and revive European competitiveness, employment, and prosperity, while preparing the next generation of accelerators. However, the FCC study extends well beyond Europe: it is organized as an international collaboration, bringing together as of today 116 institutes from 33 countries. This is in line with CERN's long standing tradition. LHC is but the latest example in a series of ambitious, and successful global accelerator projects and scientific discoveries that have rewritten the particle physics textbooks.

At CERN for more than fifty years, scientists from all around the world have peacefully been working together to develop new technologies and the necessary infrastructure for answering some of the most puzzling questions of mankind, greatly advancing technologies and scientific understanding in parallel. Can we afford not to prepare a future for the next generation?

The discovery of the Higgs boson was only the beginning

It is often stated that the Higgs boson concludes a long-standing effort of describing the building blocks that make up our Universe. However one should not neglect the peculiarity of the discovered boson per se. The Higgs is a unique particle – starting already from its rather low mass – and its properties could be a portal to new physics. It is a keystone of the Standard Model and everything we learn about it may be linked to the deepest laws of nature.

There are two complementary paths that should be further explored: precision measurements of the Higgs properties where new physics can manifest itself as tiny deviations from Standard-Model predictions, and searches for new particles and new processes beyond the Standard-Model.

A 100 TeV proton-proton collider could produce conclusive answers to various open questions surrounding the Higgs boson and, in addition, solve some of the most tantalizing puzzles related to the matter-antimatter asymmetry, to dark matter and to dark energy [2]. This machine would offer a bold leap into completely uncharted territory, probing energy scales where fundamentally new physics principles might come into play.

In addition, a future circular electron-positron collider reaching c.m. energies up to 350 GeV (serving as W, Z, Higgs and top factory), will allow for the highest precision measurements ever, of many of the key parameters of the Standard Model [3]. These high-precision measurements in the clean environment of a lepton machine could unveil rare processes and deliver hints for new physics.

Finally, the potential of heavy-ion physics [4] at the hadron collider, and the additional option of hadron-lepton collisions illustrate the enormous versatility and richness of the FCC facility. This multi-faceted research infrastructure would offer profound insights into how matter and the universe behave under extreme conditions.

The various scenarios explored within the framework of the FCC study can be compounded into a research continuum well extending through the end of the 21st century. While preparing for this future collider complex, we should heed a lesson from science history: even, or especially, if our presently favoured theories are proven wrong we may discover something unanticipated, and possibly truly revolutionary, as was the case, *e.g.*, with the Geiger-Marsden experiments.

The brave new world

The development of a future circular 100 TeV collider requires significant advancements of numerous technologies. The FCC study has launched long-term R&D programmes in partnership with many outstanding research centres and universities. As demonstrated by past endeavours, the effective interplay between fundamental science and technological R&D has a great transformative potential for our daily lives.

Successful technology R&D relies on interdisciplinary synergies, taking into account the experience from past and present accelerator projects. Ranging from superconducting technologies to new electronics and from novel coolants to reliability studies, the FCC study develops innovative approaches with a great potential impact on industry and society.

The quest for higher energies requires a new magnet technology. Magnets based on Nb_3Sn superconductor can reach magnetic fields of 16 T (almost doubling the magnetic field of the LHC Nb-Ti dipole magnets). Such magnet development is supported by the European Commission through the EuroCirCol project (https://fcc.web.cern.ch/eurocircol). Small Nb_3Sn test coils at Lawrence Berkeley National Laboratory and at CERN have already achieved dipole fields around 16 Tesla [7]. The HL-LHC itself will include a few tens of real Nb_3Sn accelerator magnets (though with a field of "only" 11 or 12 Tesla), thus helping advance the technology for a future circular hadron collider.

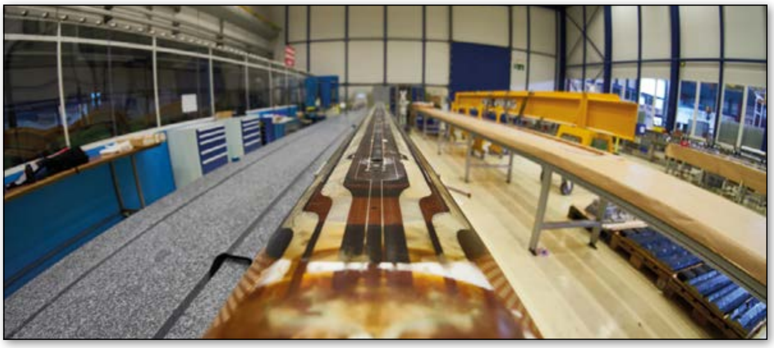
▲ FIG. 3: FCC Collaboration brings together 116 institutes from 33 countries as of June 2017 (Image credit: CERN)

The key element of the future electron-positron collider is a 100 MW RF system [8], for which advanced cavity production techniques and highly efficient RF power sources are being developed. In addition, an ultra-high vacuum and beam screen system [9] for the hadron collider along with a sustainable large-scale cryogenics infrastructure [10] are further examples of key technologies developed in the frame of the FCC study.

The FCC R&D technology programme is aiming not only at demonstrating the basic feasibility but also at reducing the associated costs and at guaranteeing a sustainable operation. The future circular collider will be much more than a scaled-up version of existing machines.

Fundamental research endeavours often bring about unexpected, life-changing results — as in the case of the basic research that led to the development of magnetic resonance imaging and PET tomography. It was also at CERN that the world-wide-web was invented, changing the lives of billions of people. Present research efforts in superconductivity – to name but one of the many different areas covered by the FCC study – can equally find many life-changing opportunities from transportation to medical applications. Although the benefit of any particular scientific endeavour is unpredictable, there is no doubt that investing in basic research has always paid off over time. Basic science research may transform our world.

◄ FIG. 4: The FCC study offers the opportunity to young researchers from all over Europe to develop now the technologies that will shape our future (Image credit: (left) Robert Hradil & Monika Majer, (right) CERN)



▲FIG. 5. Photo of the Nb_3Sn magnet coil that will be used in future high-field magnets allowing to reach 12 T for the High Luminosity upgrade of the LHC. The same material (Nb_3Sn) is also studied for the 16 T for a future circular collider (Image credit: CERN).

Concluding remarks and future directions

The fact that we need more complex machines to reach higher energies and intensities, poses a challenge not only to the scientific community but also for a society based on knowledge and innovation. We need to use our creative minds to invent and develop new technologies, or to push the existing ones, within the bounds of technical and financial feasibility.

The FCC collaboration is now moving to prepare a design report and cost estimates for all collider options to be delivered by the end of 2018. The vibrant and global R&D programme of FCC paves the way for future energy and intensity-frontier colliders that could replace the LHC by the end-2030s.

New large-scale research facilities are important to explore more deeply, and to push further, the boundaries of our knowledge. Over the past 50 years, high-energy colliders have been one of the most successful roads of exploration, leading to great discoveries such as the W and Z bosons, top quark and most recently the Higgs particle.

To remain a key player in science and innovation, in a world that is becoming ever more competitive, Europe should try to secure its current pole position in high-energy physics. Designing and building new machines implies investing in fundamental R&D on novel technologies. The effective collaboration between researchers and industrial partners from an early stage onward is one of the important cornerstones of the FCC study.

Looking at the present physics landscape, we can recognise an ocean of challenges and opportunities not only for physicists, but also for engineers, innovators, and early-stage researchers, and for the future of our societies. Despite the lack of clear evidence for the next big discovery we can't afford to ignore the many fundamental unanswered questions about the nature of our universe. The future is ours to shape! ■

▼FIG. 6: First hardware for FCC: Designing a novel beam screen system. The first prototypes of a new beam screen vacuum system to cope with the requirements of a 100 TeV collider are currently tested. (Image credit: CERN)

About the Authors

Dr. Michael Benedikt was appointed CERN study leader for the Future Circular Collider (FCC) study in 2013. He started his career with a PhD on medical accelerator design, as a member of the CERN Proton-Ion Medical Machine Study group. After obtaining his degree, in 1997, he joined CERN's accelerator operation group. He led the PS2 design study from 2005 to 2008 for a new high-performance synchrotron as potential replacement of CERN's Proton Synchrotron. From 2008 until 2013 he was project leader for the design and construction of the accelerator complex for the Austrian hadron therapy centre MedAustron in Wiener Neustadt

Dr. Frank Zimmermann is the deputy leader of the Future Circular Collider (FCC) study. A senior accelerator scientist at CERN, he also serves as the Editor of the journal "Physical Review Accelerators and Beams" (PRAB). He has earlier worked at SLAC, USA, and DESY, Germany. In 2002 he received the EPS-IGA accelerator prize. He is a fellow of the American Physical Society.

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PISA TESTING
A GLOBAL EDUCATIONAL RACE?

Svein Sjøberg – DOI: https://doi.org/10.1051/epn/2017402

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The OECD's PISA project is not an educational project. It is a political project and has to be understood as an instrument of power. PISA is normative, it tells what young people should learn, regardless of the nations' culture, nature, traditions and values. The battle to improve PISA rankings may conflict with our work to make science relevant, contextualized, interesting and motivating for young learners.

PISA, The Programme for International Student Assessment, was initiated by the OECD (Organization for Economic Cooperation and Development) in 2000 and has since then dramatically changed educational debates as well as policies worldwide. Although scientists and educators may appreciate the thinking behind the framework for testing, they also need to understand the wider social, ideological context of PISA.

The PISA project has to be understood as a social phenomenon and a political project, in essence a well-funded instrument of power that has steadily increased its influence on the educational discourse and policies in the now 70 participating countries. The educational debate has become global, and the race to improve PISA-rankings has become high priority in many countries.

While no feedback is given to students, teachers or schools, for governments the PISA-test is a high-stakes test. Governments are blamed for low scores, and governments are quick to take the honour when results are improving. Perceived bad rankings often create a crisis or panic, and governments are urged to do "something" to improve scores. But PISA cannot, by its design, say anything about cause and effect. Ill-informed school reforms are often introduced to improve PISA scores. National curricula, cultural values and priorities are pushed aside.

Many of the reforms that are legitimized by PISA can be characterized as New Public Management and neoliberal policies. Key words in these reforms are standardization of curricula, more testing, belief in competition, privatization and free choice of schools.

A global standard for all schools?

International studies are important, and can help us see our own country's education in perspective. Such studies, also of students' achievement in science and mathematics have been around more than 60 years. The acronym TIMSS (Trends in Mathematics and Science Study) is well known, and has provided interesting data for some decades. This study is descriptive and analytical, testing traditional knowledge and skills as close as possible to school curricula. TIMSS has been run mainly by academic institutions, and has no political or educational agenda. TIMSS researchers have by and large been careful in drawing causal conclusions and making recommendations, but TIMSS has influenced policy development as well as public debates in many countries.

The scene changed dramatically when the OECD entered the scene with its PISA-project in 2000. Since the first publication of results in 2001, the PISA-results have become a kind of global "gold standard" for educational quality - a single measure of the quality of the entire school system. An OECD- report on the policy impact of PISA, proudly states that "PISA has become accepted as a reliable instrument for benchmarking student performance worldwide, and PISA results have had an influence on policy reform in the majority of participating countries/economies" (Breakspear 2012).

Similarly, Andreas Schleicher (2012), director of PISA and recently also of Directorate of Education and Skills in OECD, in a TED talk starts his presentation by stating that PISA is "really a story of how international comparisons have globalized the field of education that we usually treat as an affair of domestic policy."

▲ ©iStockPhoto

What Does PISA Claim to Measure?

How does PISA present the project, what do they claim to measure? The following was stated already in 1999, before the first PISA testing took place in 2000:

> *How well are young adults prepared to meet the challenges of the future? Are they able to analyse, reason and communicate their ideas effectively? Do they have the capacity to continue learning throughout life? (OECD, 1999, p. 7)*

If these points had been formulated as research questions in a research proposal for a 2 hour test for 15-year old students, the proposal would certainly have been rejected as too ambitions and unrealistic. Nevertheless, exact these words have been repeated in all later PISA reports.

In essence, the PISA creators are claiming that they have identified the essential skills and competencies necessary for future life, for all young learners, regardless of country, culture, history and nature.

So, although PISA explicitly states that it does not test school knowledge and that it does not test according to national curricula or test school knowledge, the PISA results are interpreted by OECD officials and policymakers around the globe as valid measures of the quality and the efficiency of national school systems.

The PISA test is anonymous, and no results are reported back to the students, their teachers or even schools. Results are only reported at the "system level", most often at the national level. When results are released in early December every third year, the main attention is given to the ranking of countries as given by the mean scores. The media reports are like reporting from sport events. If you google the term PISA and shock, scandal or crisis, you find hits from all over the globe.

The context of school science

In most countries, science is part of the school curriculum through the whole of its compulsory years. Scientists should always remember that the prime purpose of school science in these years is not to recruit the future scientist. Science at this level should contribute to the wider goals, ideals and values that the country has for its public school system, giving a foundation for future life and development for each individual. School science should open the eyes for young people to appreciate science and to understand how important science is for our culture, our world-view and for meeting the challenges of the future. **While science as academic disciplines may be universal and independent of culture, school science needs to be embedded in the culture, and build on the interests and concerns of the learner**.

For the young learner, interest, enjoyment and engagement in science-related activities may be more important than achieving high test scores at this level. Positive attitudes are likely to last longer than the actual knowledge content that is taught. For some learners, positive experiences with school science may be the start of a science-related career, for others it might mean a lasting positive attitude to science. Test-driven teaching and rankings may be counterproductive, both for the possible future scientist and for the great majority.

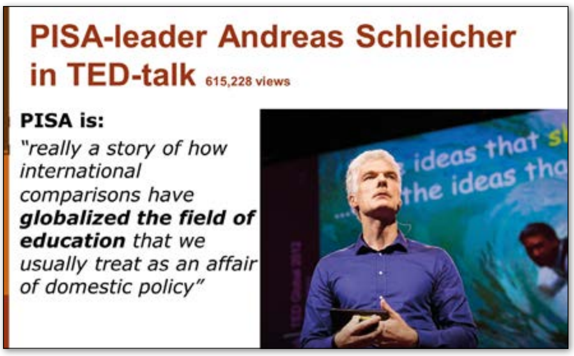
International tests need to be culture-neutral and decontextualized by design, if intended to measure an internationally valid construct. The selection process for PISA test items actually assures that no country or culture is favoured. Items that in the trial do not "function properly" are removed. So, while educators in science and other subjects argue for "context-based" teaching, tests like PISA have to avoid items that are contextualized in order to make a "fair test". Therefore, if higher rankings on international standardized tests become *a priori*ty for the national authorities, one may miss a key concern: to show the relevance of science and to stimulate the interest and curiosity in science.

The power of PISA

PISA is organized by the OECD, an organization that is "owned", governed and financed by its member states, the highly industrialized countries of the world. The prime mandate of the OECD is to promote economic growth and development in a global free market economy. Over the last decades, the importance of human resources and education has become an important concern for OECD's activities, and PISA has become the key project in this context. While the OECD has only 34 countries, the total number of countries and economies that take part in PISA is now about 70.

Since the first PISA round, PISA has extended its ambitions, range and scope. While PISA is a test for 15-year olds, a "PISA for adults" (PIAAC) has also been launched, and a "PISA for Development" is also developed, targeting what is considered to be competencies needed for young people in developing countries. A "PISA for schools" test is also developed as a commercial product. This test enables schools and school districts to compare themselves on a "PISA-like" scale with each other and with nations that are "PISA-winners". Plans for measuring aspects of pre-school and kindergarten are also on the drawing board.

In short: The OECD now provides indicators, numbers and rankings from early childhood to pension age



▸ **FIG. 1:** First words on PISA leader Andreas Schleicher's TED-talk on PISA.

that countries can (and do!) use to shape their own policy from a global context.

This work is certainly of great value. But statistics does not only describe reality, it also shapes and defines reality. **The mean PISA-score of a country is used as the definition of the quality of the nation's school system, and PISA-point per dollar is used as an indicator for the efficiency of the school system**.

While the OECD does not have formal political power, it exerts influence through its reports, policy papers and expert advice. This influence is called "soft power", "governance by numbers" and "governance by comparison", and there is an abundance of literature providing details of how OECD exerts this power globally to define reality and exert its power (see *e.g.* Meyer & Benavot 2013).

In many countries new curricula have been introduced, caused by "PISA-shocks", (*e.g.* Norway, Denmark, Sweden, Germany and Japan). In many countries new national standards as well as new systems of obligatory national testing have been introduced. Some of these are directly influenced by PISA documents, as also proudly noted in a comprehensive report by the OECD itself (Breakspear 2012).

PISA in alliance with commercial interests

The strife for better test scores also serves commercial interests. Companies deliver products like tests and teaching materials that are supposed to increase scores, and cramming schools make substantial profit from preparing students to achieve higher test scores. The largest PISA contractor is the US-based non-profit assessment and measurement institution ETS. Maybe more important is that the world's largest commercial educational company, Pearson Inc. was involved in PISA 2015 and won the bid to develop the framework for PISA 2018. The joint press release from OECD and Pearson explains:

> "*Pearson, the world's leading learning company, today announces that it has won a competitive tender by the Organisation for Economic Co-operation and Development (OECD) to develop the Frameworks for PISA 2018. […]. The frameworks define what will be measured in PISA 2018, how this will be reported and which approach will be chosen for the development of tests and questionnaires." (OECD & Pearson 2014)*

The partnership with PISA/OECD is also a strategic door-opener for Pearson "with 40,000 employees in more than 70 countries" into the global educational market. In company with the OECD, Pearson also produces "The Learning Curve", a ranking of nations according to a set of test-based indicators. PISA leader Andreas Schleicher sits on the Advisory Panel of The Learning Curve. These rankings get media coverage and further create anxiety among politicians and policymakers. The result is a further pressure toward doing "something" to climb the league tables.

MEDIZIN Menschenversuche: Wie Patienten zu Opfern werden SEITE

DIE WOCHE

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BILDUNG UND ERZIEHUNG IN DER KRISE

Schule macht dumm

Vernachlässigte Kinder, miserable Leistungen: DIEWOCHE zeigt Auswege – und wie die Schule der Zukunft aussehen muss

◂ **FIG. 2:** "Schule macht dum". The first PISA-results created a crisis in Germany, and led to large investments in science and mathematics education. (Bad results may be good news for science and mathematics educators)

PISA scores: uncertainties and errors

When looking at the actual mean scores on PISA, one may notice that the majority of the OECD countries are in middle group, with rather small differences in means. If it was a bike race, one would have said most countries came in the "peleton", and got the same time. In fact, rather small changes in total score can shift the country's rankings 10 to 20 places.

Moreover, the uncertainty in the published PISA-score is substantial. Some of this is measurement sampling error. Additional uncertainties are related to the calculations of the published PISA scores that are based on the test results. The total PISA test consists of some 10 hours testing time, and each student gets about two hours test from this pool. The national PISA score and other population parameters are calculated by using a rather elaborate technique, using Rasch analysis and Item Response Theory (IRT). The assumptions about the properties of data that underlie the use of these techniques are questioned by many psychometrics experts. The method was actually strongly modified in the last round of PISA, causing dramatic changes in scores for some countries.

These uncertainties and possible sources for others errors are not well communicated in the PISA reports.

PISA, THE PROGRAMME FOR INTERNATIONAL STUDENT ASSESSMENT

- Organized by the OECD (Organization for Economic Cooperation and Development)
- Testing every 3 years. Started in 2000, now 6 rounds
- Three main domains: reading, mathematics and science
- Testing national samples of 15 year olds in schools
- Data also from students' and principals' questionnaire
- Results from PISA 2015 published in December 2016
- 72 countries and economies take part
- Testing based on a framework ("curriculum") developed by appointed experts
- Test items not "school science"
- The test is digital/electronic from 2015

Experts on psychometry criticise PISA for downplaying the problematic nature of the calculations and the lack of openness regarding sources of error and methodological uncertainties. Experts also criticise PISA reports for drawing unwarranted conclusions, and urge OECD to have a "a more measured approach to reporting and interpreting PISA Results" (Rutkowski & Rutkowski 2016). Some scholars use even stronger words, arguing that PISA is a "Tale of flaws and hubris" (Meyer 2013).

PISA: Intriguing findings

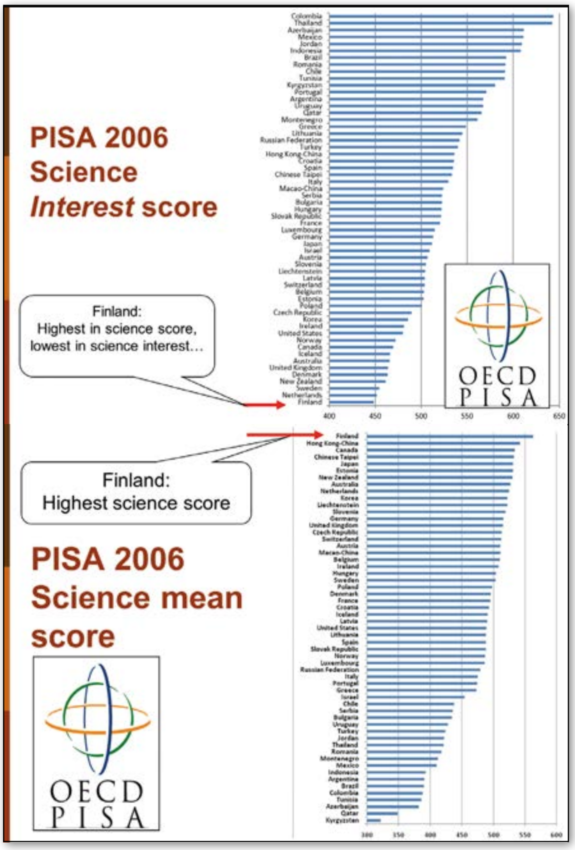
While the PISA scores and country ranking receives a lot of attention, other results pass more or less unnoticed. Here are some of the intriguing problematic results:

- Money and resources spent on education do not seem to be positively related to PISA scores.
- Class size is not related to PISA scores.
- PISA-scores correlate negatively with investment in and the use of ICT in teaching.
- PISA science scores seem unrelated to the time given to science in school.
- There is clear negative correlation with a country's PISA test score and the construct "Interest in science". For instance, Finland was in PISA 2006 on top of the PISA science score and at the very bottom of the index for interest in science. (see figs below)
- "PISA-winners" (Japan, Korea, Taiwan, Shanghai, Finland) students report very little use of inquiry-based teaching, the kind of teaching is recommended by the EU (2007) as well as by ICSU (2011). IBSE (Inquiry-Based Science Education) is also the key concept in Horizon 2020 to get funding for research and development in science education.
- Even for the variation within the same country, the PISA finding is that "in no education system do students who reported that they are frequently exposed to enquiry based instruction [….] score higher in science." (OECD 2016, p 36)
- Experiments play a crucial role in science, and have always played an important role in science teaching at all levels. But when it comes to PISA, the recent report states that: "activities related to experiments and laboratory work show the strongest negative relationship with science performance" (OECD 2016, p 71)

Whether one "believes in PISA" or not, such intriguing results need to be taken seriously and discussed. ■

About the Author

Svein Sjøberg is professor emeritus in physics education at Oslo University. Educated as a nuclear physicist, later also in education (MA) and educational psychology (PhD). Svein has been involved in expert committees on science education for national institutions and research councils in several countries as well for UNESCO, OECD, The European Commission and ICSU (International Council of Science). Has been awarded several national and international prizes and awards for his research and outreach activities..



▸ FIG. 3: Science was the main subject in PISA 2006. Finland came out on top of the PISA test score, but at the very bottom on the "Interest in science"-score.

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THE NUPECC LONG RANGE PLAN 2017: PERSPECTIVES IN NUCLEAR PHYSICS

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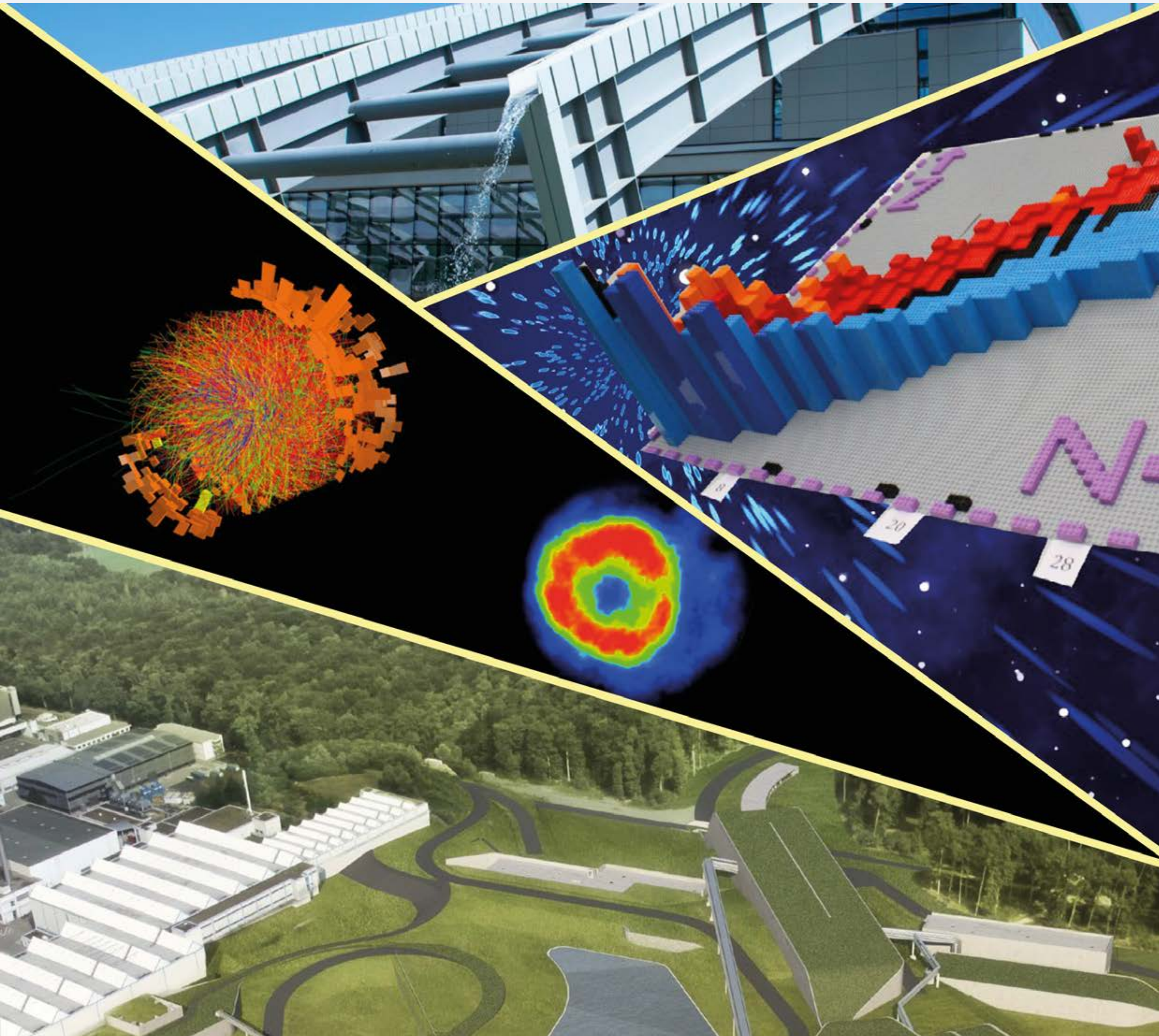
The Nuclear Physics European Collaboration Committee (NuPECC) is an independent Committee associated to European Science Foundation (ESF). Its mission is "to provide advice and make recommendations on the development, organisation, and support of European nuclear research and of particular projects". The delivery of long range plans represents thus the core of the NuPECC's activities. In the past four long-range plans (LRPs) were issued in 1991, 1997, 2004 and 2010.

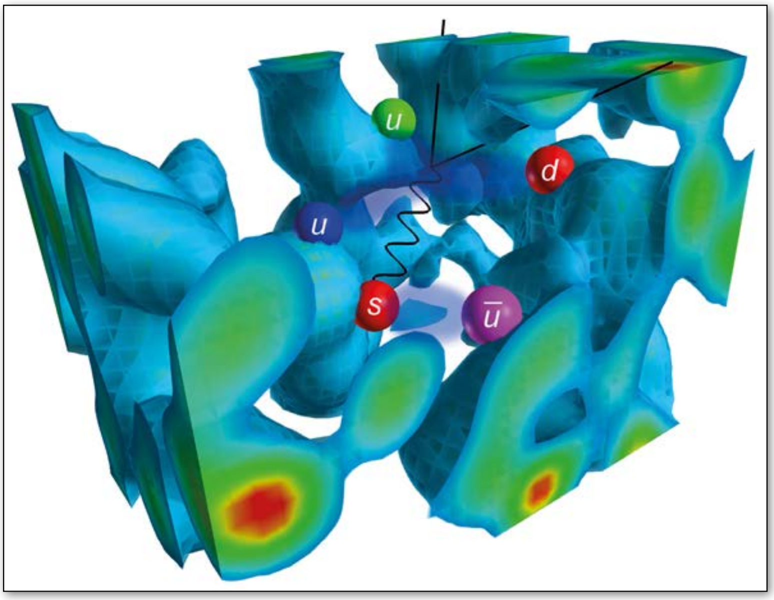


On the 19th of June 2017 the "Long Range Plan for Nuclear Research in Europe" prepared by NuPECC was released after approximately 20 months of work for its preparation. This document comes 7 years after the previous Long Range Plan (LRP) . During these 7 years substantial progress was made in the different areas of Nuclear physics (schematically shown in Fig.1). Although NuPECC's recommendations in previous LRP's were decisive for approval of facilities (from the smallest ones as *e.g.* LUNA at LNGS to the largest international facility FAIR) it turned out that their full construction is requiring in some cases additional time. Therefore when it was decided to build this new LRP it was clear that several previous plans need to be updated and consolidated according to the present conditions and to the new projects.

As in the case of the previous editions, this LRP is expected to play the role of an important reference and guide for the field for at least the next 6 years.

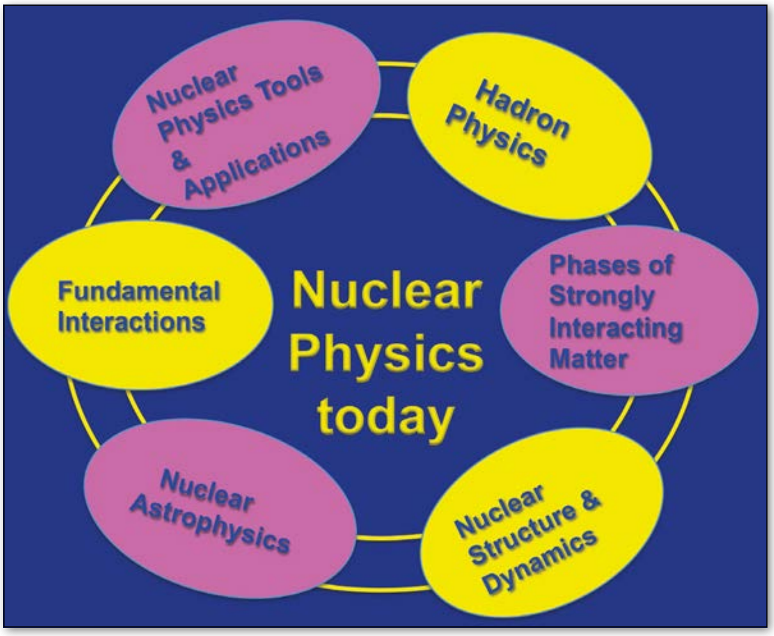
Similar to several countries in the world beyond the European boundaries, today Nuclear Physics is defined as a field including different research domains sharing the difficult but stimulating task to study nuclear matter in all its forms and of exploring their possible applications. The knowledge of the properties of nuclear matter is essential if one wants to address several key issues for the understanding of the different stages concerning the origin and the evolution of the universe.

The overarching goal of nuclear physics is to unravel the fundamental properties of nuclei from their building blocks, protons and neutrons, and ultimately to determine the emergent complexity in the realm of the strong interaction from the underlying quark and gluon degrees of freedom of Quantum Chromodynamics (QCD). This requires detailed knowledge of the structure of hadrons, the nature of the residual forces between nucleons resulting from their constituents and the limits of the existence of bound nuclei and ultimately of hadrons themselves. A thorough understanding is vital for the complex structure of nuclei, nuclear reactions, and the properties of strong-interaction matter under extreme conditions in astrophysical settings and in the laboratory. Nuclei also constitute a unique laboratory for a variety of investigations of fundamental physics, which in many cases are complementary to particle physics.



▲ FIG 2: Pictorial view of a QCD calculation for the structure of the particle Lambda 1405 (from CSSM, University of Adelaide).

▼ FIG 1: Pictorial illustration of the different sub-fields of Nuclear Physics.



Substantial experimental and theoretical efforts are being made world-wide to address the central questions of nuclear physics, which include:

- How is mass generated in QCD and what are the static and dynamical properties of hadrons?
- How does the strong force between nucleons emerge from the underlying quark-gluon structure?
- How does the complexity of nuclear structure arise from the interaction between nucleons?
- What are the limits of nuclear stability?
- How and where in the universe are the chemical elements produced?
- What are the properties of nuclei and strong-interaction matter as encountered shortly after the Big Bang, in catastrophic cosmic events, and in compact stellar objects?

These fascinating topics in basic science require concerted efforts in the development of new and increasingly sophisticated tools such as accelerators and detectors. It is important to emphasise that knowledge and technical progress in basic, curiosity-driven nuclear physics has significant societal benefits including the training of a highly skilled workforce and broad applications in industry, medicine, and security.

The research driven by the goal of answering to these important questions is organized in six different subfields of nuclear physics defined by NuPECC as: Hadron Physics, Properties of Strongly Interacting Matter (at extreme temperatures and density), Nuclear Structure and Dynamics, Nuclear Astrophysics, Symmetries and Fundamental Interaction as well as Applications and Societal Benefits.

Understanding the physics of hadrons requires a large variety of complementary experiments and theoretical tools (see *e.g.* Fig. 2). In experiments, electromagnetic and hadronic probes can be used to study various aspects of hadron structure, spectroscopy and dynamics at different energy scales, at existing and future facilities.

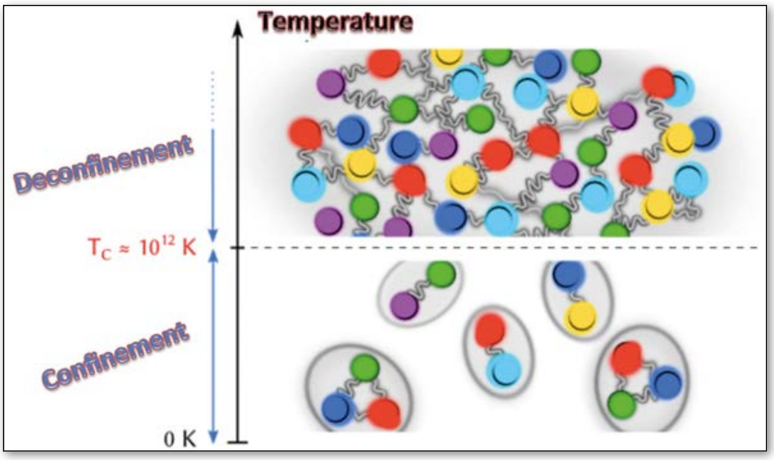
The transition between the primordial quark-gluon plasma (QGP) from big bang and the hadron formation has, as far as we know, not left any imprint that is visible in present-day astronomical observations (see *e.g.* Fig. 3). However, the energy or baryon densities necessary to form the QGP may be recreated in the laboratory (such as in ALICE at CERN) via heavy ion collisions at sufficiently high energies in the nuclear dimension.

Presently is still unclear how the nuclear chart emerges from the underlying strong interactions. This requires the development of a unified description of all nuclei based on systematic theories of strong interactions at low energies and experiments providing different observables for nuclear excitations and decays particularly for radioactive nuclei, far from stability (see *e.g.* Fig. 4).

Many, if not all, nuclear properties of stable and unstable nuclei and of nuclear reactions are relevant for the description of astrophysical processes such as stellar burning, the evolution and explosion of stars, the chemical evolution of the Galaxy and its assembly history (see *e.g.* Fig. 5).

Specific very high precision measurements in stable and unstable nuclei (including nucleons and antinuclei) allow tests of our understanding of nature and of symmetries that are complementary to experiments at the highest energies (see *e.g.* Fig. 6). In some cases they offer higher sensitivities to new effects beyond the Standard Model (SM) of particle physics. This research is and will be performed in the future at several laboratories.

Applications derived from basic Nuclear Physics Research have a large impact on many aspects of everyday life. Society benefits from the large investments done in basic Nuclear Physics research are in areas as diverse as nuclear medicine, energy, nuclear stewardship and security. Improvements in nuclear applications are obtained thanks to an increase of the basic knowledge on nuclear structure and decay, nuclear reactions and nuclear system properties but also thanks to the developments in related technologies, such as accelerator science (see. *e.g.* Fig. 7), instrumentation and high-performance computing.

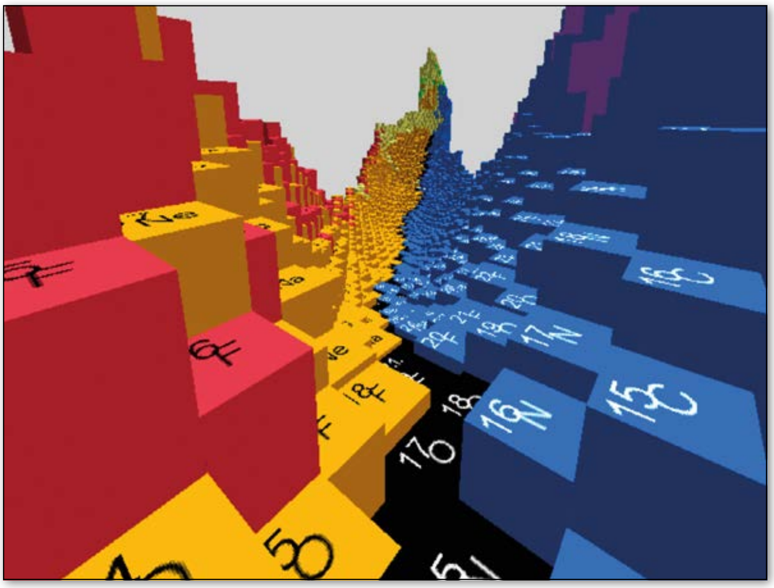


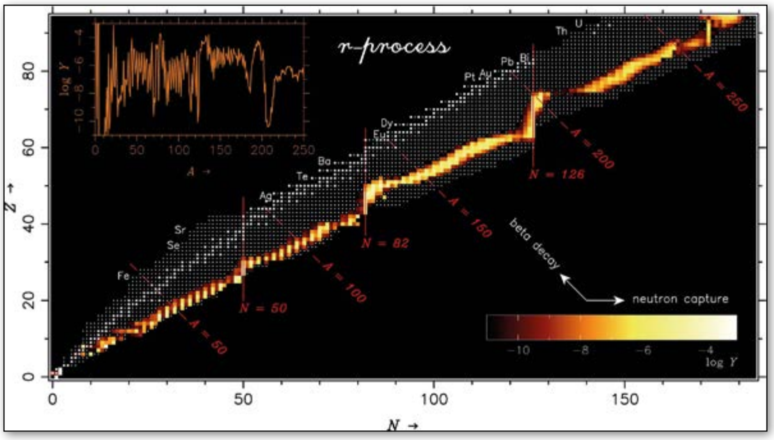
▲ **FIG 3:** Schematic illustration of the quark confinement in baryons and mesons and, at high temperature, the quark deconfinements.

The preparation of NuPECC Long Range plans is a bottom up process. It requires dedicated efforts from many physicists of the nuclear physics community. The contributors were organized in six working groups each corresponding to one of the subfields given above and led by two Conveners and three Liaison Members of NuPECC. The Working Groups were given the charge to delineate the most exciting physics in their subfields, to highlight recent achievements, and future perspectives. Draft reports from the Working Groups were presented and discussed in internal workshops and at NuPECC Meetings.

A Town Meeting to discuss the NuPECC LRP was held at the "darmstadtium" in Darmstadt, from January 11 – 13, 2017. The Town Meeting was attended by almost 300 participants, including many young scientists. The programme contained, in addition to the presentation of the Working Groups, sessions on future facilities: FAIR, the ISOL facilities (SPIRAL2, ISOLDE and SPES), ELI-NP in Bucharest, NICA and the Dubna Superheavy Element Factory, as well as a presentation of CERN from its scientific director. For the international context the overview given by the Chairs of of the two committees NSAC (USA) (Nuclear Science Advisory Committee of

▼ **FIG 4:** Illustration of the valley of stability within the nuclear chart. Stable nuclei (black) are the most tightly bound, whereas nuclei with proton or neutron excess are unstable (picture from CSNSM Orsay).





the Department of Energy) and ANPhA (Asia) (Asian Nuclear Physics Association) were much appreciated. The Town Meeting was concluded by a general discussion.

The recommendations with their wording were extensively discussed, not only at the town meeting but also later on at the NuPECC meetings. It is not possible here, due to space limits, to quote them directly in their complete form and thus the reader is invited to read our webpage http://www.nupecc.org/pub/lrp2017.pdf.

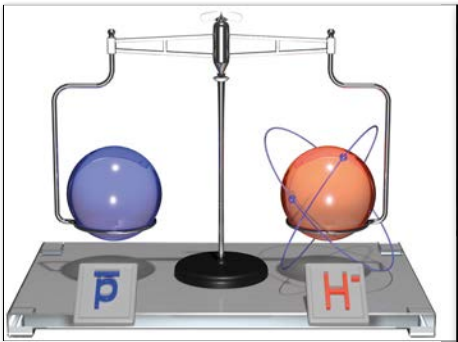
In short, the recommendation section includes the following : i) a recommendation for the construction and operation of the flagship facility FAIR with its experimental programme at the four scientific pillars APPA (fundamental interaction and applied sciences), CBM (compressed barionic matters with heavy ion reactions), NUSTAR (nuclear structure and astrophysics with radioactive beams) and PANDA (hadron physics with antiprotons); ii) support for construction, augmentation and exploitation of world leading ISOL facilities for low energy radioactive beam in Europe (SPIRAL2 (France), HIE-ISOLDE (CERN), and SPES (Italy)); iii) the exploitation of the existing and emerging facilities, the latter being ELI-NP in Bucharest (providing lasers and gamma beams) and NICA in Dubna (for hadron physics and quark gluon plasma); iv) support for ALICE and the heavy-ion programme on the quark-gluon plasma at the LHC (CERN) experiments with the planned experimental upgrades; v) support to the completion of AGATA (a European array for gamma spectroscopy) in full geometry; vi) support for Nuclear Theory. In addition, the particular role of R&D for future projects, of education and training, and of small scale facilities are underlined in the recommendation section and also in the different chapters of each subtopic.

▲ **FIG 5:** Calculated abundance distribution of nuclides during r-process nucleosynthesis (*Astrophys. J.* **606** (2004)1057).

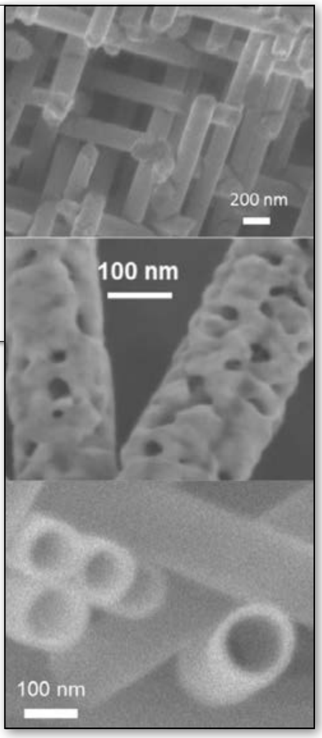
In the introduction chapter one can find special mention to the contribution received by the European Commission to the different facilities, the ones focussing on hadron physics (the last integrated activity being HP3) and the ones on nuclear structure and astrophysics (presently in the ENSAR2 integrated activity). Concerning the more general scientific context, in which the Nuclear Physics infrastructures are placed, the relation of NuPECC with ESFRI (the European Strategy Forum for Research Infrastructure) is very important and fruitful.

Last but not least, in the introduction and also in various chapters, the role of international collaborations worldwide, outside Europe (the largest fraction being in USA and Japan), is underlined, resulting in major achievements in the field. These collaborations are expected to continue and to be reinforced in the future.

The release of the long range plan was possible thanks to the work of several researchers involved directly or more indirectly in this process. Now these active players in the field are expected to further enhance the vitality of the field by using this long range plan as key tool for this purpose. Indeed, it will be very important in the next years to implement the goals outlined in the recommendations, in particular also those that go beyond the capabilities of an individual country. ■



▲ **FIG 6:** Illustration of the comparison of the gravitational mass of an antiproton and a proton, which was obtained by comparing the cyclotron frequency of an antiproton and a H^- ion in a Penning trap (From Georg Schneider, BASE collaboration)



▶ **FIG 7:** Novel ion-track technology based nanostructures such as nanowire networks (top), porous wires (center) and nanotubes (bottom) with tailored diameter, length and surface (From C. Trautmann, GSI).

About the Author

Angela Bracco is full professor in experimental physics at the Università degli Studi di Milano and is associated to INFN. Her research field is nuclear structure mainly addressed via gamma spectroscopy and using nuclear reactions with stable and radioactive ion beams. She is member of the steering committe of AGATA, the last generation detector system for gamma-ray spectroscopy, used in several European laboratories. In 2017 she was scientific associated at CERN. She chaired in 2012-2017 NuPECC the expert board for European Nuclear Science. She is in the executive committee of EPS. She also served as member and chair of several advisory and review panels for different institutions in Europe, USA and Japan.

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Ring lasers – a brief history

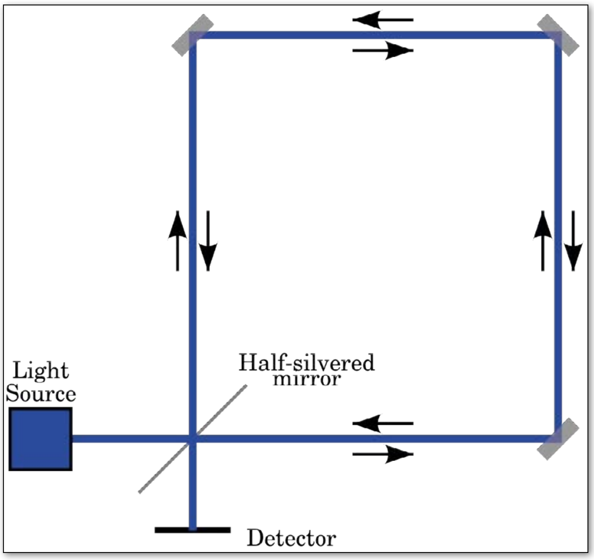
Used these days in inertial navigation, ring lasers are also used in recording the tiniest variations in the Earth's spin, as well in detecting earthquakes and even the drift of continents. How did it all begin?

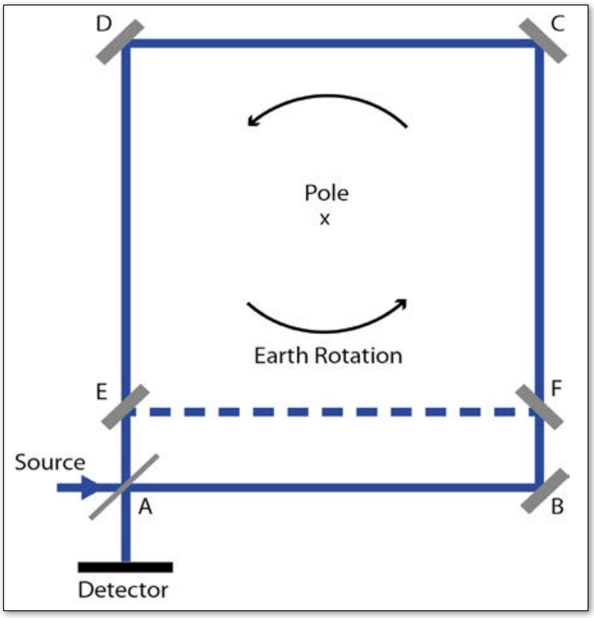
Back in 1914, Frenchman Georges Sagnac [1] built an interferometer in the shape of a polygon of mirrors in which counter-propagating waves from the same intense light-source could demonstrate a phase shift between the clockwise and the anticlockwise propagating waves (see figure 1).

When stationary, the two modes are degenerate, but if set into rotation, one lot of light waves from the beam-splitter are chasing the mirrors while the other lot are running into them, thereby producing a phase difference between the two beams. What Sagnac had intended to demonstrate was the speed of light relative to the "Luminiferous Ether" (which was shown to be non-existent by Einstein's Special Relativity).

The time difference effect, now named after Sagnac, may be shown to be given by [2]: $\Delta t = 4\boldsymbol{A} \,.\, \boldsymbol{\Omega}/c^2$ where $\boldsymbol{A}$ is the area (vector) of the polygon enclosed by the interferometer mirrors, $\boldsymbol{\Omega}$ (vector) is the angular velocity of the interferometer, and c is the velocity of light. In a passive interferometer, the time difference shows up as a phase difference: $\Delta\phi = 8\,\pi\boldsymbol{A}\,.\,\boldsymbol{\Omega}/\,\lambda c$ where λ is the wavelength of

▾ **FIG. 1:** Schematic of a Sagnac Interferometer. If set into rotation, a phase difference between the two beams will show up. (Image credit Krishnavedala, CC BY-SA 3.0.)



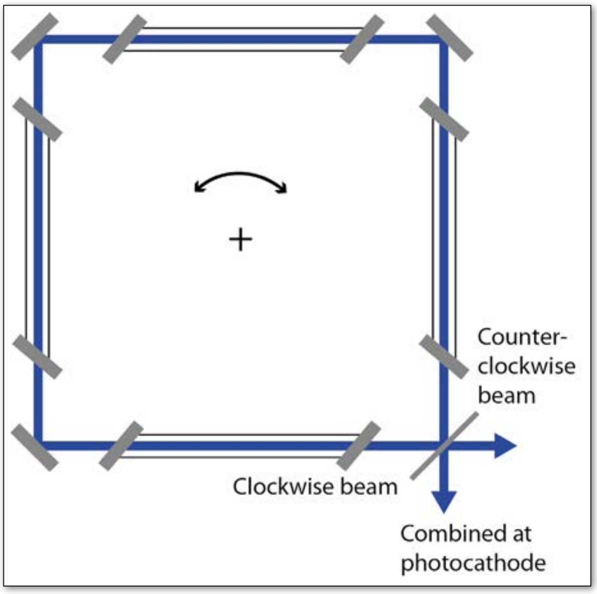


▴ **FIG. 2:** Schematic of the Michelson-Gale Experiment. Here the phase difference between light waves exiting the large and the small rectangles is detected. With a perimeter of 1.9 km, this set-up was large enough to detect the angular velocity of the Earth.

the light source. The irony is that these formulae are true in both an ether-theoretic picture and in Special Relativity, so that the experiment didn't, in fact, demonstrate anything. This was recognised by Albert Michelson who proceeded to build his well-known Michelson-Morley experiment that did, of course, demonstrate the correctness of the Einstein theory.

However, in 1925, many years after the more famous Michelson-Morley experiment, Michelson and Gale [3] did indeed perform a "heroic" experiment aimed at detecting the Earth's rotation, by means of a huge rectangular Sagnac interferometer 612 × 339 meters in size, built in the countryside near Chicago, from evacuated 12-inch sewer pipes. I say "heroic" because the observed fringe-shift was only 0.230 ± 0.005 of a fringe, but in good agreement with the theoretical prediction (see figure 2).

(In case you were wondering, they observed the difference in fringe-shifts between the interferometers (ABCDA) and (ABFEA), *i.e.*, changing the area enclosed). There are of course other ways of proving that the Earth rotates, even



▲ **FIG. 3:** Schematic of a Ring laser.

without reference to the fixed stars, including the famous Foucault pendulum.

There matters stood until the year 1962 when a very interesting paper by Rosenthal [4] appeared in the Journal of the Optical Society of America proposing the insertion of active media (*e.g.*, Helium-Neon) inside a Sagnac (*i.e.*, a polygonal) interferometer which would then turn into a Ring Laser- see figure 3.

In such a laser, two modes would co-exist, namely the clockwise and the anticlockwise – normally degenerate in a stationary frame. However, when in a rotating frame, the phase difference between the two modes would turn into a frequency difference, *i.e.*, a detectable beat note. The optical frequency difference between the two modes in the polygonal laser (which may be triangular or square) is given by [2]: $\delta f = 4A\,\Omega\cos\theta/\lambda P$ where A is the area enclosed, as before, Ω is the rotation rate; while θ is the angle between the rotation axis and the normal to the polygon of mirrors, and P is the perimeter of the polygon.

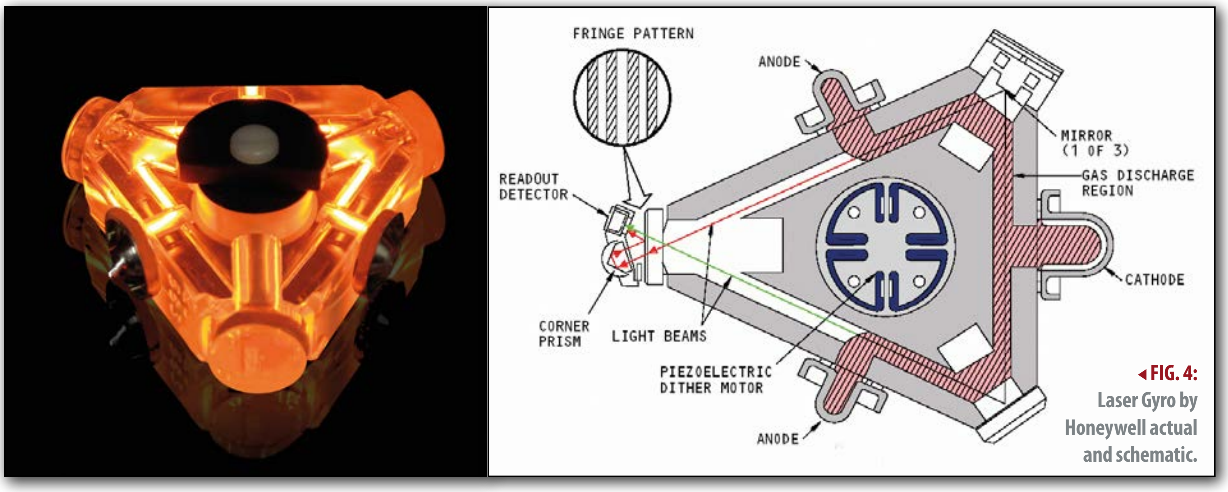
($A\,\Omega\cos\theta$) is of course, ($A\,.\,\Omega$), showing θ explicitly, so that the beat frequency is seen to be sensitive to both Ω and to θ, and can thus measure variations in either.

This exciting idea, for *active* Sagnac Interferometry, made everyone sit up and take notice and sure enough, it was followed less than a year later by a paper by Macek and Davis [5] demonstrating its feasibility. Thus was born the Ring Laser.

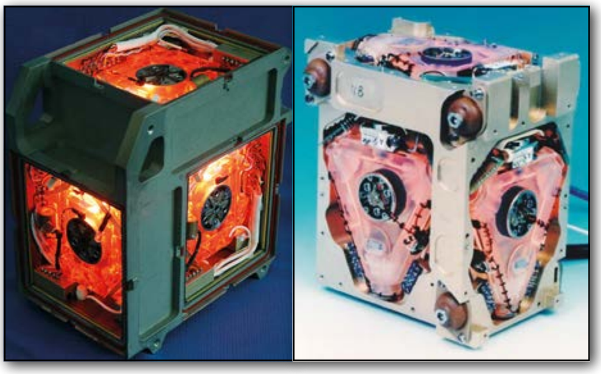
The military potential of a rotation sensor (with no moving parts), *i.e.*, a Laser Gyro, was promptly recognised and further development became classified secret, so the scientific literature on the subject went completely silent! Rapid progress followed all over the world and by the 1970s the Ring Laser Gyro became patented and openly published again in various forms, see figure 4a and b.

One of the shortcomings of compact ring lasers is the phenomenon of mode locking at low rotation rates. There is a minimum angular velocity below which the clockwise and anticlockwise modes simply lock together, causing zero frequency difference in the output. This is caused by parasitic phenomena, *e.g.*, back-scattering from imperfect mirrors, and places a lower limit on measurable rotation rates. What emerged as the standard solution to this problem was in the form of motor-driven "dithering" about each of the axes, *i.e.*, artificial rotation back and forth through a small angle about zero. The resultant sinusoidal modulation of the output is easily subtracted from the signal. Highly refined complete inertial navigation packages (see figure 5a and b) became commercially available and have been in widespread use since the 1980's, for example in the Boeing 747 and all airliners since (and in all missile guidance systems, of course).

An interesting variant of the Sagnac interferometer is the Fibre Optic interferometer in which the polygon of mirrors is replaced by a large number of turns of optical fibre in which the contra-rotating beams propagate, as in figure 6. Thus a very large included area A is made possible in a compact size, allowing the realisation of compact Fibre Optic Gyros – also available commercially.



◀ **FIG. 4:** Laser Gyro by Honeywell actual and schematic.



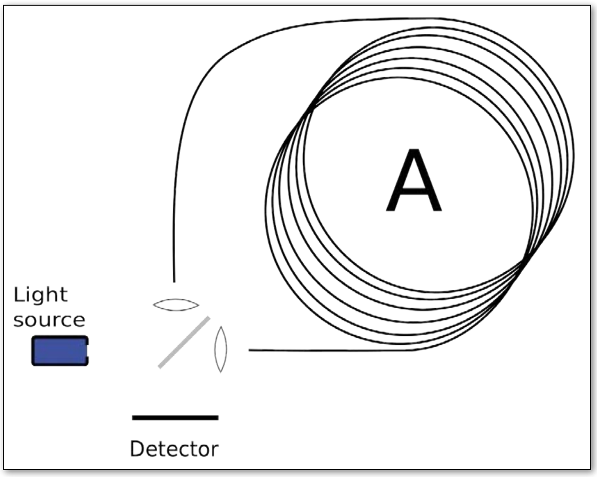
▲ **FIG. 5:** Complete inertial navigation systems (note in the middle of each triangular ring laser the "dithering" motor).

But the story of the ring laser as a rotation sensor doesn't end there. In the early 1990s, Professor Geoff Stedman of Canterbury University in Christchurch, New Zealand, decided to investigate its potential in measuring tiny variations in the Earth's spin caused by various geophysical sources, such as earthquakes, tidal effects, and diurnal polar motion [6].

He built a series of large area ring lasers (with higher and higher sensitivities), first in the Physics building and later in a Second World War bunker, in the New Zealand countryside, 30m below the ground. The first instrument, with an enclosed area of ~0.85 m^2, built in 1992, was followed by larger and larger rings, with enclosed areas of 1 m^2, then 3.5 m^2 the latter (first of a series) built in collaboration with the Technical University of Munich (TUM) and the German Federal Institute of Geodesy (BKG) (see figure 7 a and b).

A large instrument, built in the German countryside with input from the famous optical firm of Zeiss, was of 16 m^2 area and included various technical improvements, principally better mirrors and better laser beam control. In this way better and better performance was obtained, initially from 1 part in a million of the Earth's angular velocity to more recently approaching 1 part per billion. In this way not only could earthquakes be detected in detail but also their aftershocks. This is because of changes in the earth's moment of inertia caused by the slippage of blocks and other subtle seismic and geodetic effects. Other effects came to be investigated in detail such as the precession of the equinoxes, the Earth's Eulerian wobble - a consequence of the departure from its spherical shape - changes in the length of the day (measured in fractions of a millisecond per day) and so forth [7].

▼ **FIG. 6:** Schematic of a Fibre Optic interferometer. (Image credit D. Mcfadden, CC BY-SA 3.0.)



Ironically, the great earthquake of September 2010, and its aftershocks, that caused devastation in Christchurch were accurately documented by the underground interferometers and caused some damage at the installation in the cave. But the work continues, there and in Germany and elsewhere, with the aim of improving sensitivity to the point of being able to detect fundamental physical effects, *e.g.*, General Relativistic precessions of the rotating Earth, such as the Lense-Thiring effect. But basically, these large ring lasers may be regarded as components of an inertial navigation system for 'spaceship Earth'. ■

▲ **FIG. 7: (a)** The north arm of the University of Canterbury's UG-2 ring laser, situated in the Cashmere Caverns, New Zealand. **(b)** G (for "*Grossring*") Ring Laser in Bavaria, Germany. Both are situated underground to give thermal stability.

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Anthony Klein (AM, BEE, PhD, DSc, FAA) is an Emeritus Professor in the School of Physics of the University of Melbourne, where he held a Personal Chair in Physics until his retirement in 1998. He served as Head of the School of Physics, as President of the Australian Institute of Physics and as President of the Australian Optical Society.

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Opinion: Trump, climate change and the EPS

Gerard van der Steenhoven – Director General of the Royal Netherlands' Meteorological Institute (KNMI), and Former chair of the Netherlands Physical Society (NNV, 2007-2013)

US Energy Secretary Rick Perry announced on June 19th of this year – while being interviewed on CNBC – that "CO_2 is not the primary driver of climate change". You may argue that such a statement, which is not only wrong but plainly misleading, should not come as a surprise given the stance of the Trump administration on climate change. Still, it is a shock when the person heading a department in the US that has been in the lead of so much excellent science comes with such an anti-scientific statement. What has happened to our society that political leaders are making such statements and what should our response be?

I will address these questions below, but let me first remind you of the scientific facts: (i) the average ice-cover in the arctic is down by 30-40% as compared to 30 years ago; (ii) the sea-level has risen by 20 cm since 1900; (iii) the average global temperature has increased by more than 1 °C since pre-industrial times; (iv) extreme weather conditions are occurring more frequently than in the past – up to a factor 3 in some countries. These phenomena are caused by the rapid increase of CO_2 (and several other trace gases) in the atmosphere rising from about 300 to 400 ppm in less than 100 years. The physical mechanism describing this so-called greenhouse effect was first published in 1896 (!) by the Swedish Nobel Prize winner Svante Arrhenius and can now be considered as text-book science.

Serious people who deny the role of greenhouse gases have a different way of thinking than most physicists have, as I learned from a recent documentary on Dutch TV. While for us data and established scientific theories are a starting point, several professors supporting the position of the Trump administration argued that the unlimited growth of governmental activities is a major threat, and limiting this growth and possibly reversing it is their starting point. As an illustration they gave the following example. State funding of climate research leads to ideas about the reduction of greenhouse gas emissions, and expensive infrastructural measures. By fighting climate change this unwanted growth of government can be prevented. The measured data, the scientific evidence, the threat for many people in Small-Island-States: it does not enter the equation for them. It will be clear that a discussion or compromise is almost impossible between the two groups as the two starting points are essentially orthogonal.

It will be clear that a discussion or compromise is almost impossible between the two groups as the two starting points are essentially orthogonal.

What can we do? What can the European Physical Society do? The great value of Physical Societies is their independence. We receive our budget from our members (mainly through the national societies of course), *i.e.* individual physicists throughout Europe. No government can tell us what we should do or think. This independence becomes important once the foundations of our field, of our work are under attack. The EPS can give a voice to physicists whose jobs are in jeopardy, only because they adhere to the principles of physics. This may seem far-fetched, but it has already been announced earlier this year that several thousands of employees will lose their job in the US Environmental Protection Agency (EPA).

Some people believe that a statement on climate change by a physical society is a hollow gesture. I disagree. Given the rise of anti-scientific sentiments worldwide, an unambiguous statement by EPS can be very helpful. As a signal to politicians and in support of all those physicists suffering under local political uncertainty. ■

▲ Picture: R. Jorksveld

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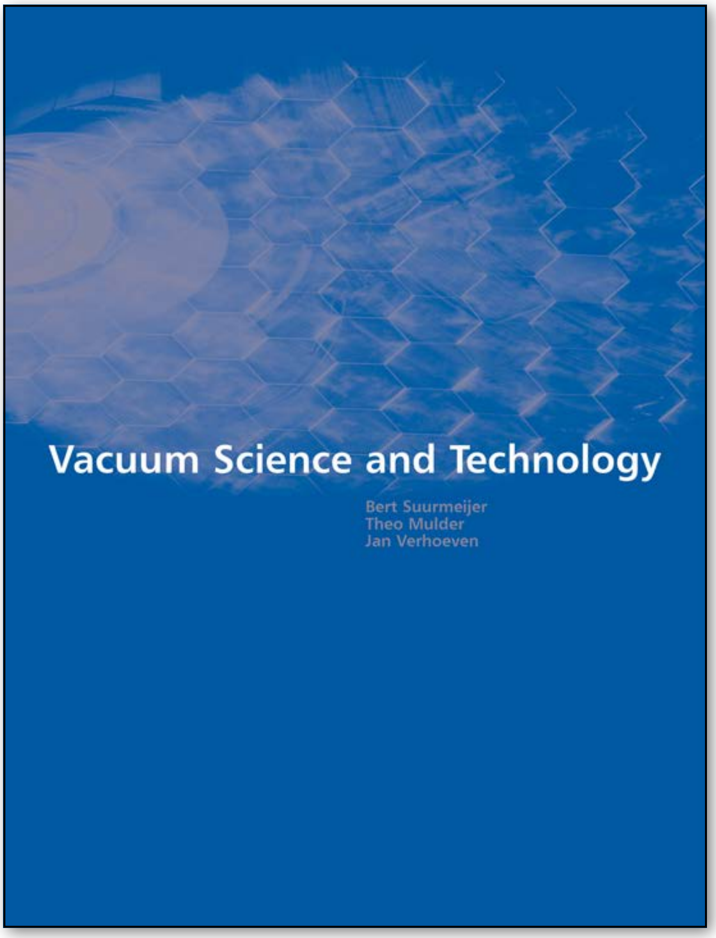

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