WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the March/April 2019 issue of *CERN Courier*.

In March 1989, Tim Berners-Lee, while working at CERN, released his proposal for a new information-management system. Within two years, the web was born. CERN's subsequent agreement in 1993 to place the underlying software in the public domain (reproduced in this issue) shapes the web's character to this day. It is part of a culture of sharing and collaboration that was set out in the CERN Convention 40 years earlier, and which is deeply engrained in the software and particle-physics worlds. The features in this issue – from open-source software, to open-access publishing, open data and entirely open analysis procedures – show how far ahead our field is in the growing open-science movement. Our Viewpoint, meanwhile, argues that we have only begun to harness the full potential of the web to benefit humanity.

On other pages of this issue – the second in the Courier's new format – theorist Nima Arkani-Hamed explains why the world needs a new collider, physicists reflect on 40 years of fixed-target experiments at CERN's North Area, sterile neutrinos come under increasing pressure from experiment, a survey assesses the impact of working at CERN on your career, supersymmetric lasers demonstrate advanced theoretical physics in action, and more.

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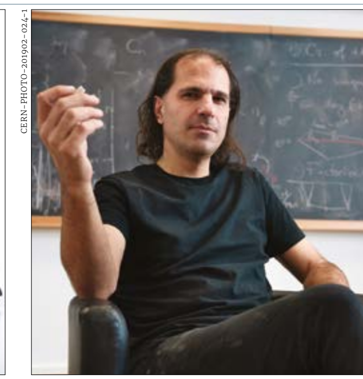

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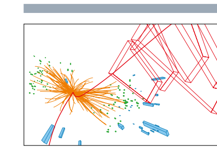

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FROM THE EDITOR

Web at 30: celebrating a culture of openness

Matthew Chalmers
Editor

It is 30 years since Tim Berners-Lee, while working at CERN, released his proposal for a new information-management system. Two years and a lot of coding later, this vision of universal connectivity had become the World Wide Web. For those born too late to have enjoyed those first double-click hyperlinks, CERN has teamed up with developers to recreate the experience for you by emulating the NeXT browser on which the software was written (https://worldwideweb.cern.ch). This is part of a series of 30th anniversary celebrations worldwide taking place in March in partnership with the World Wide Web Consortium and the World Wide Web (WWW) Foundation.

Openness is the soul of the web, and CERN's 1993 agreement to place the software in the public domain shapes the web's character to this day (p39). It is part of a culture of sharing and collaboration that was set out in the CERN Convention 40 years earlier, and which is deeply engrained in the software and particle-physics worlds. The articles in this issue – from open-source software (p27), to open-access publishing (p29), open data (p31) and entirely open analysis procedures (p25) – show how far ahead our field is in the growing open-science movement.

The articles in this issue show how far ahead our field is in the growing open-science movement

Beyond science, the WWW Foundation, established by Berners-Lee a decade ago, advocates an "open web" as a means to build a just and thriving society. In November 2018 the foundation published a report that reflected on what the web has allowed humanity to accomplish over the past 30 years and outlined the threats that it now faces. The report notes that more than half of the world's population is still offline, with online take-up slowing dramatically, continuing: "The distributed power of the web has shifted to lay in the hands of just a few, online abuse is on the rise, and the content we see is increasingly susceptible to manipulation." This issue's Viewpoint, arguing for a "humanised internet" (p43), suggests that we have so far tapped only a fraction of the web's potential for good.

Happy anniversary *The historic web logo created by CERN systems engineer Robert Cailliau, Berners-Lee's first partner on the WWW project.*

Theoretical therapy

For anyone feeling down about the lack of discoveries of new elementary particles since the Higgs boson, redemption may be found in an extensive interview with theorist Nima Arkani-Hamed (p45). Known for his deep and original thinking, Arkani-Hamed explains why this is the most privileged time in centuries to be working in fundamental physics, and how the next collider after the LHC will guarantee progress. Elsewhere in this issue, the second in the *Courier*'s redesigned format (do keep the feedback coming!): feast on 40 years of physics at the North Area (p34), learn about CERN's impact on your career (p55), get the latest on the search for the sterile neutrino (p7), delve into the weird world of supersymmetric lasers (p10), and more.

Reporting on international high-energy physics

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NEWS ANALYSIS


Fermilab

Null result *The MINOS+ experiment completed data taking in June 2016 and has since been dismantled, but much of its data remains to be analysed.*

NEUTRINOS

MINOS squeezes sterile neutrino's hiding ground

Newly published results from the MINOS+ experiment at Fermilab in the US cast fresh doubts on the existence of the sterile neutrino – a hypothetical fourth neutrino flavour that would constitute physics beyond the Standard Model. MINOS+ studies how muon neutrinos oscillate into other neutrino flavours as a function of distance travelled, using magnetised-iron detectors located 1 and 735 km downstream from a neutrino beam produced at Fermilab.

Neutrino oscillations, predicted more than 60 years ago, and finally confirmed in 1998, explain the observed transmutation of neutrinos from one flavour to another as they travel. Tantalising hints of new-physics effects in short-baseline accelerator-neutrino experiments have persisted since 1995, when the Liquid Scintillator Neutrino Detector (LSND) at Los Alamos National Laboratory reported an 88±23 excess in the number of electron antineutrinos emerging from a muon-antineutrino beam. This suggested that muon antineutrinos were oscillating into electron antineutrinos along the way, but not in the way expected if there are only three neutrino flavours.

LSND, MiniBooNE and the reactor data are fairly compatible in terms of sterile neutrinos, but in stark conflict with the null results from MINOS+ and IceCube

The plot thickened in 2007 when another Fermilab experiment, MiniBooNE, an 818 tonne mineral-oil Cherenkov detector located 541 m downstream from Fermilab's Booster neutrino beamline, began to see a similar effect. The excess grew, and last November the MiniBooNE collaboration reported a 4.5σ deviation from the predicted event rate for the appearance of electron neutrinos in a muon neutrino beam. In the meantime, theoretical revisions in 2011 meant that measurements of neutrinos from nuclear reactors also show deviations suggestive of sterile-neutrino interference: the so-called "reactor anomaly".

Tensions have been running high. The latest results from MINOS+, first reported in 2017 and recently accepted for publication in *Physical Review Letters*, fail to confirm the MiniBooNE signal. The MINOS+ results are also consistent with those from a comparable analysis of atmospheric neutrinos in 2016 by the IceCube detector at the South Pole. "LSND, MiniBooNE and the reactor data are fairly compatible when interpreted in terms of sterile neutrinos, but they are in stark conflict with the null results from MINOS+ and IceCube," says theorist Joachim Kopp of CERN. "It might be possible to come up with a model that allows compatibility, but the simplest sterile neutrino models do not allow this." In late February, the long-baseline T2K experiment in Japan joined the chorus of negative searches for the sterile neutrino, although excluding a different region of parameter space.

Whereas MiniBooNE and LSND sought to observe a second-order flavour transition (in which a muon neutrino morphs into a sterile and then electron neutrino), MINOS+ and IceCube are sensitive to a first-order muon-to-sterile transition that would reduce the expected flux of muon neutrinos. Such "disappearance" experiments are potentially more sensitive to sterile neutrinos, provided systematic errors are carefully modelled.

"The MiniBooNE observations interpreted as a pure sterile neutrino oscillation signal are incompatible with the muon-neutrino disappearance data," says MINOS+ spokesperson Jenny ▷

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Thomas of University College London. "In the event that the most likely MiniBooNE signal were due to a sterile neutrino, the signal would be unmissable in the MINOS/MINOS+ neutral-current and charged-current data sets." Taking into account simple unitarity arguments, adds Thomas, the latest MINOS+ analysis is incompatible with the MiniBooNE result at the 2σ level and at 3σ sigma below a "mass-splitting" of 1 eV² (see figure 1).

The sterile-neutrino hypothesis is also in tension with cosmological data, says theorist Silvia Pascoli of Durham University. "Sterile neutrinos with these masses and mixing angles would be copiously produced in the early universe and would make up a significant fraction of hot dark matter. This is somewhat at odds with cosmological observations."

One possibility for the surplus electron-neutrino-like events in MiniBooNE is insufficient accuracy in the way neutrino–nucleus interactions in the detector are modelled – a challenge for neutrino-oscillation experiments generally. According to MiniBooNE collaborator Teppei Katori, one effect proposed to account for the MiniBooNE anomaly is neutral-current single-gamma production. "This rare process has many theoretical interests, both within and beyond the Standard Model, but the calculations are not yet tractable at low energies (around 1 GeV) as they are in the non-perturbative QCD region," he says.

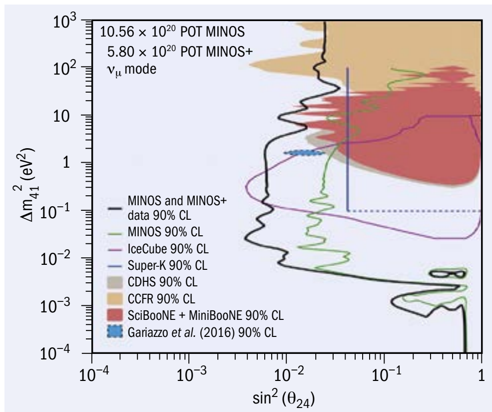


Fig. 1. *New MINOS+ exclusion limits (black). The plot shows the coupling and mass splitting of sterile neutrinos with the established neutrinos. Parameter space to the right is excluded with 90% confidence.*

MINOS+ is now analysing its final data-set and working on a direct comparison with MiniBooNE to look for electron-neutrino appearance as well as the present study on muon-neutrino disappearance. Clarification could also come from other short-baseline experiments at Fermilab, in particular MicroBooNE, which has been operating since 2015, and two liquid-argon detectors ICARUS and SBND (*CERN Courier* June 2017 p25). The most exciting possibility is that new physics is at play. "One viable explanation requires a new neutral-current interaction mediated by a new GeV-scale vector boson and sterile neutrinos with masses in the hundreds of MeV," explains Pascoli. "So far this has not been excluded. And it is theoretically consistent. We have to wait and see."

Further reading

MINOS+ Collaboration 2017 arXiv: 1710.06488 (accepted in *Phys. Rev. Lett.*).
MiniBooNE Collaboration 2018 *Phys. Rev. Lett.* **121** 221801.

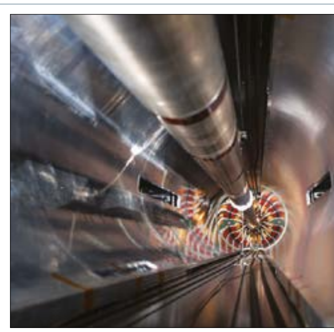
MONOPOLES

CMS beam pipe to be mined for monopoles

On 18 February the CMS and MoEDAL collaborations at CERN signed an agreement that will see a 6 m-long section of the CMS beam pipe cut into pieces and fed into a SQUID in the name of fundamental research. The 4 cm diameter beryllium tube – which was in place (right) from 2008 until its replacement by a new beampipe for LHC Run 2 in 2013 – is now under the proud ownership of MoEDAL spokesperson Jim Pinfold and colleagues, who will use it to search for the existence of magnetic monopoles.

Magnetic monopoles with multiple magnetic charge, if produced in high-energy particle collisions at the LHC, are so highly ionising that they could stop in the material surrounding the collision points and bind there with the beryllium nuclei of the beam pipe. To detect the trapped monopoles, Pinfold and coworkers will pass the beam-pipe material through superconducting loops and look for a non-decaying current using highly precise SQUID-based magnetometers.

Materials from the CDF and D0 detectors at the Tevatron and from the H1 detector at HERA were subjected to such searches during the 1990s, and the first pieces of beam pipe from the



Pipe dreams *The original CMS beampipe, in use during LHC Run 1.*

LHC experiments, taken from the CMS region, were tested in 2012. But these were from regions far from the collision point, whereas the new study will use material surrounding the CMS central-interaction region. "It's the most directly exposed piece of material of the experiment that the monopoles encounter when produced and moving away from the collision point," says Albert De Roeck of CMS and MoEDAL, who was involved in the previous LHC and HERA studies. "Although no signs of monopoles have shown up in data so far, this new study pushes the search for monopoles with magnetic charge well beyond the five Dirac charges currently achievable with the MoEDAL detector."

MoEDAL technical coordinator Richard Soluk and a small team of technicians will first cut the beampipe into bite-sized pieces at a special facility constructed at the Centre for Particle Physics at the University of Alberta, Canada, where they have to be especially careful because beryllium is highly toxic. The resulting pieces, carefully enshrined in plastic, will then be shipped back to Europe to the SQUID Magnetometer Laboratory at ETH Zurich, where the freshly sliced beam pipe will undergo a short measurement campaign planned for early summer. "On the analysis front we have to estimate how many monopoles would have been trapped in the beam pipe during its deployment at CMS as a function of monopole mass, spin, magnetic charge, kinetic energy and production mechanism," says Pinfold.

The latest search is complementary to general monopole searches that have already been carried out by the ATLAS and MoEDAL collaborations. Deployed at LHC Point 8, MoEDAL contains more than 100 m² of nuclear-track detectors that are sensitive only to new physics and has a dedicated trapping detector consisting of around one tonne of aluminum.

"Most modern theories such as GUTs and string theory require the existence of monopoles," says Pinfold. "The monopole is the most important particle not yet found."

Most modern theories such as GUTs and string theory require the existence of monopoles

Further reading

J Pinfold 2019 *Universe* **5** 47.
A de Roeck *et al.* 2012 *Eur. Phys. J. C* **72** 2212.

HL-LHC

Report reveals full reach of LHC programme

The High-Luminosity LHC (HL-LHC), scheduled to operate from 2026, will increase the instantaneous luminosity of the LHC by at least a factor of five beyond its initial design luminosity. The analysis of a fraction of the data already delivered by the LHC – a mere 6% of what is expected by the end of HL-LHC in the late-2030s – led to the discovery of the Higgs boson and a diverse set of measurements and searches that have been documented in some 2000 physics papers published by the LHC experiments. "Although the HL-LHC is an approved and funded project, its physics programme evolves with scientific developments and also with the physics programmes planned at future colliders," says Aleandro Nisati of ATLAS, who is a member of the steering group for a new report quantifying the HL-LHC physics potential.

The 1000+ page report, published in January, contains input from more than 1000 experts from the experimental and theory communities. It stems from an initial workshop at CERN held in late 2017 (*CERN Courier* January/February 2018 p44) and also addresses the physics opportunities at a proposed high-energy upgrade (HE-LHC). Working groups have carried out hundreds of projections for physics measurements within the extremely challenging HL-LHC collision environment, taking into account the expected evolution of the theoretical landscape in the years ahead. In addition to their experience with LHC data analysis, the report factors in the improvements expected from the newly upgraded detectors and the likelihood that new analysis techniques will be developed. "A key aspect of this report is the involvement of the whole LHC community, working closely together to ensure optimal scientific progress," says theorist and steering-group member Michelangelo Mangano.

Physics streams

The physics programme has been distilled into five streams: Standard Model (SM), Higgs, beyond the SM, flavour and QCD matter at high density. The LHC results so far have confirmed the validity of the SM up to unprecedented energy scales and with great precision in the strong, electroweak and flavour sectors. Thanks to a 10-fold larger data set, the HL-LHC will probe the SM with even greater precision, give access to previously unseen rare processes, and will extend the experiments' sensitivity to new physics in direct and indirect searches for processes with low-production cross sections and more elusive signatures. The precision of key measurements, such as the coupling of the Higgs boson to SM particles, is expected to reach the percent level, where effects of new physics could be seen. The experimental uncertainty on the top-quark mass will be reduced to a few hundred MeV, and vector-boson scattering – recently observed in LHC data – will be studied with an accuracy of a few percent using various diboson processes.

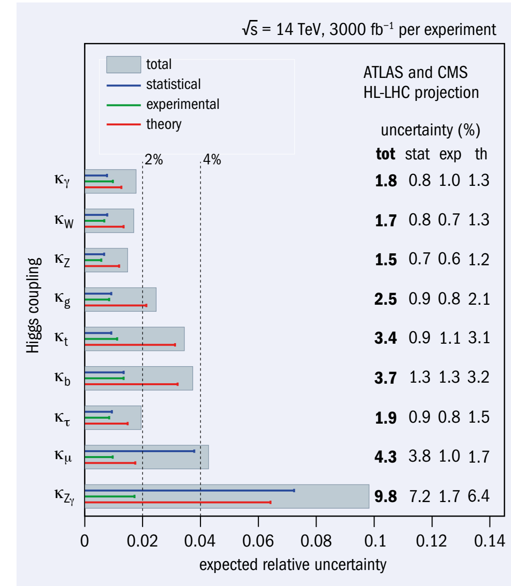


Fig. 1. *Projected uncertainties on the Higgs-boson couplings to SM particles, within the so-called k-framework, with the full HL-LHC programme.*

The 2012 discovery of the Higgs boson opens brand-new studies of its properties, the SM in general, and of possible physics beyond the SM. Outstanding opportunities have emerged for measurements of fundamental importance at the HL-LHC, such as the first direct constraints on the Higgs trilinear self-coupling and the natural width. The experience of LHC Run 2 has led to an improved understanding of the HL-LHC's ability to probe Higgs pair production, a key measure of its self-interaction, with a projected combined ATLAS and CMS sensitivity of four standard deviations. In addition to significant improvements on the precision of Higgs-boson measurements (figure 1), the HL-LHC will improve searches for heavier Higgs bosons motivated by theories beyond the SM and will be able to probe very rare exotic decay modes thanks to the huge dataset expected.

The new report considers a large variety of new-physics models that can be probed at HL-LHC. In addition to searches for new heavy resonances and supersymmetry models, it includes results on dark matter and dark sectors, long-lived particles, leptoquarks, sterile neutrinos, axion-like particles, heavy scalars, vector-like quarks, and more. "Particular attention is placed on the potential opened by the LHC detector upgrades, the assessment of future systematic uncertainties, and new experimental techniques," says steering-group member Andreas Meyer of CMS. "In addition to extending the present LHC mass and coupling reach by 20–50% for most new-physics scenarios, the HL-LHC will be able to potentially discover, or constrain, new physics that is not in reach of the current LHC dataset."

Pushing for precision

The flavour-physics programme at the HL-LHC comprises many different probes – the weak decays of beauty, charm, strange and top quarks, as well as of the τ lepton and the Higgs boson – in which the experiments can search for signs of new physics. ATLAS and CMS will push the measurement precision of Higgs couplings and search for rare top decays, while the proposed second phase of the LHCb upgrade will greatly enhance the sensitivity with a range of beauty-, charm-, and strange-hadron probes. "It's really exciting to see the full potential of the HL-LHC as a facility for precision flavour physics," says steering-group member Mika Vesterinen of LHCb. "The projected experimental advances are also expected to be accompanied by improvements in theory, enhancing the current mass-reach on new physics by a factor as large as four."

Finally, the report identifies four major scientific goals for future high-density QCD studies at the LHC, including detailed characterisation of the quark-gluon plasma and its underlying parton dynamics, the development of a unified picture of particle production, and QCD dynamics from small to large systems. To address these goals, high-luminosity lead–lead and proton–lead collision programmes are considered as priorities, ▷

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while high-luminosity runs with intermediate-mass nuclei such as argon could extend the heavy-ion programme at the LHC into the HL-LHC phase.

High-energy considerations

One of the proposed options for a future collider at CERN is the HE-LHC, which would occupy the same tunnel but be built from advanced high-field dipole magnets that could support roughly double the LHC's energy. Such a machine would be expected to deliver an integrated proton–proton luminosity of 15,000 fb^{-1} at a centre-of-mass energy of 27 TeV, increasing the discovery mass-reach beyond anything possible at the HL-LHC. The HE-LHC would provide precision access to rare Higgs boson (H) production modes, with approximately a 2% uncertainty on the ttH coupling, as well as an unambiguous observation of the HH signal and a precision of about 20% on the trilinear coupling. An HE-LHC would enable a heavy new Z′ gauge boson discovered at the HL-LHC to be studied in detail, and in general double the discovery reach of the HL-LHC to beyond 10 TeV.

The HL/HE-LHC reports were submitted to the European Strategy for Particle Physics Update in December 2018, and are also intended to bring perspective to the physics potential of future projects beyond the LHC. "We now have a better sense of our potential to characterise the Higgs boson, hunt for new particles and make Standard Model measurements that restrict the opportunities for new physics to hide," says Mangano. "This report has made it clear that these planned 3000 fb^{-1} of data from HL-LHC, and much more in the case of a future HE-LHC, will play a central role in particle physics for decades to come."

A Panté, www.antoninopante.com

Digging for success *The excavation of the two new shafts for the HL-LHC at points 1 and 5 of the accelerator has recently been completed.*

Further reading

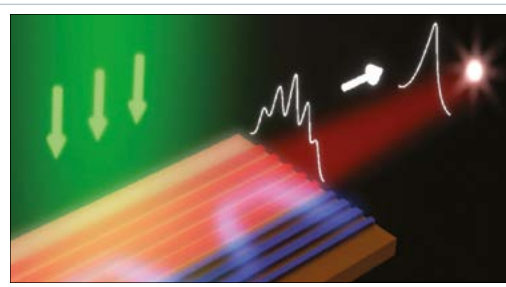
P Azzi *et al.* 2019 arXiv:1902.04070.
M Cepeda *et al.* 2019 arXiv:1902.00134.
A Cerri *et al.* 2018 arXiv:1812.07638.
X Cid Vidal *et al.* 2018 arXiv:1812.07831.
Z Citron *et al.* 2018 arXiv:1812.06772.

Optics

First light for supersymmetry

Ideas from supersymmetry have been used to address a longstanding challenge in optics – how to suppress unwanted spatial modes that limit the beam quality of high-power lasers. Mercedeh Khajavikhan at the University of Central Florida in the US and colleagues have created a first supersymmetric laser array, paving the way towards new schemes for scaling up the radiance of integrated semiconductor lasers.

Supersymmetry (SUSY) is a possible additional symmetry of space–time that would enable bosonic and fermionic degrees of freedom to be "rotated" between one another. Devised in the 1970s in the context of particle physics, it suggests the existence of a mirror-world of supersymmetric particles and promises a unified description of all fundamental interactions. "Even though the full ramification of SUSY in high-energy physics is still a matter of debate that awaits experimental validation, supersymmetric techniques have already found their way into low-energy physics, condensed matter, statistical mechanics, nonlinear dynamics and soliton theory as well as in stochastic processes and BCS-type theories, to mention a few," write Khajavikhan and collaborators in *Science*.



Science 363 623

SUSY engineering *Schematic representation of a supersymmetric laser array involving a primary active lattice (red) coupled to its lossy superpartner (blue), emitting exclusively in the fundamental in-phase mode.*

The team applied the SUSY formalism first proposed by Ed Witten of the Institute for Advanced Study in Princeton to force a semiconductor laser array to operate exclusively in its fundamental transverse mode. In contrast to previous schemes developed to achieve this, such as common antenna-feedback methods, SUSY introduces a global and systematic method that applies to any type of integrated laser array, explains Khajavikhan. "Now that the proof of concept has been demonstrated, we are poised to develop high-power electrically pumped laser arrays based on a SUSY design. This can be applicable to various wavelengths, ranging from visible to mid-infrared lasers."

To demonstrate the concept, the Florida-based team paired the unwanted modes of the main laser array (comprising five coupled ridge-waveguide cavities etched from quantum wells on an InP wafer) with a lossy superpartner (an array of four waveguides left unpumped). Optical strategies were used to build a superpartner index profile with propagation constants matching those of the four higher-order modes associated with the main array, and the performance of the SUSY laser was assessed using a custom-made optical setup. The results indicated that the existence of an unbroken SUSY phase (in conjunction with a judicious pumping of the laser array) can promote the in-phase fundamental mode and produce high-radiance emission.

"This is a remarkable example of how a fundamental idea such as SUSY may have a practical application, here increasing the power of lasers," says SUSY pioneer John Ellis of King's College London. "The discovery of fundamental SUSY still eludes us, but SUSY engineering has now arrived."

Further reading

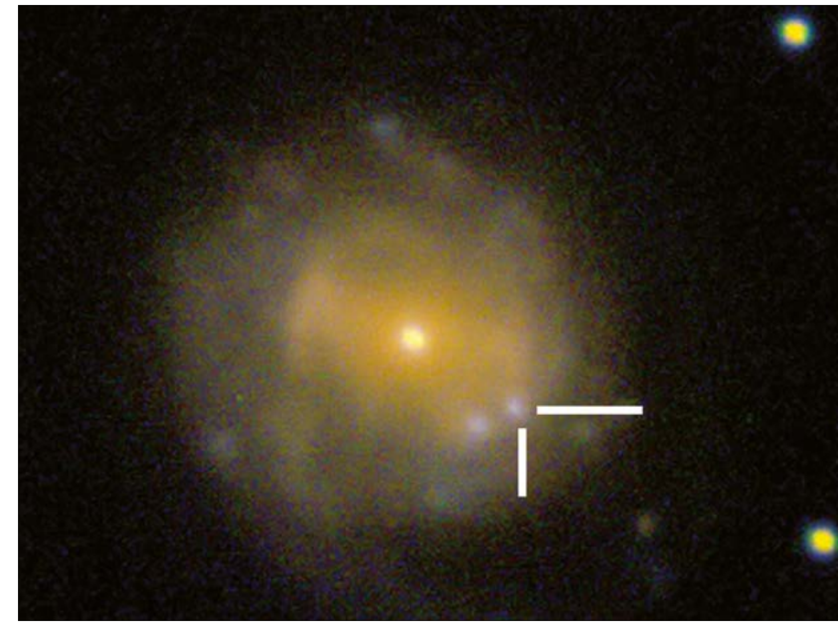
M Hokmabadi *et al.* 2019 *Science* **363** 623.

Astrowatch: Multi-messenger astronomy

Mysterious burst confounds astrophysicists

On 16 June 2018, a bright burst of light was observed by the Asteroid Terrestrial-impact Last Alert System (ATLAS) telescope in Hawaii, which automatically searches for optical transient events. The event, which received the automated catalogue name "AT2018cow", immediately received a lot of attention and acquired a shorter name: "the Cow". While transient objects are observed on the sky every day – caused, for example, by nearby asteroids or supernovae – two factors make the Cow intriguing. First, the very short time it took for the event to reach its extreme brightness and fade away again indicates that this event is nothing like anything observed before. Second, it took place relatively close to Earth, 200 million light years away in a star-forming arm of a galaxy in the Hercules constellation, making it possible to study the event in a wide range of wavelengths.

Soon after the ATLAS detection, the object was observed by more than 20 different telescopes around the world, revealing it to be 10–100 times brighter than a typical supernova. In addition to optical measurements, the object was observed for several days by space-based X- and gamma-ray telescopes such as NuSTAR, XMM-Newton, INTEGRAL and Swift, which also observed it in the UV energy range, as well as by radio telescopes on Earth. The IceCube observatory in Antarctica also identified two possible neutrinos coming from the Cow, although the detection is still compatible with a background fluctuation. The combination of all the data – demonstrating the power of multi-messenger astronomy – confirmed that this was not an ordinary supernova, but potentially something completely different.



Sloan Digital Sky Survey

Holy cow! *An optical image of "the Cow" (bottom right) and its host galaxy.*

Bright spark

While standard supernovae take several days to reach maximum brightness, the Cow did so in just 1.5 days, after which the brightness also started to decrease much faster than a typical supernova. Another notable feature was the lack of heavy-element decays. Normally, elements such as ^{56}Ni produced during the explosion are the main source of supernova brightness, but the Cow only revealed signs of lighter elements such as hydrogen and helium. Furthering the event's mystique is the variability of the X-ray emission several days after its discovery, which is a clear sign of an energy source at its centre. Half a year after its discovery, two opposing theories aim to explain these features.

The first theory states that an unlucky compact object was destroyed when coming too close to a black hole – a phenomenon called a tidal disruption event. The fast increase in brightness excludes normal stars. On the other hand, a smaller object (such as a neutron star, a very dense star consisting of neutron matter) cannot explain the hydrogen and helium observed in the remnant, since it contains no proper elements. The remaining possibility is a white dwarf, a dense star remaining after a normal star has ceased fusion but kept from gravitational collapse into a neutron star or black hole by the electron-degeneracy pressure in its core. The observed emission from the Cow could be explained if a white dwarf was torn apart by tidal forces in the vicinity of a massive black hole. One problem with this theory, however, is the event's location, since black holes with the sizes required for such an event are normally not found in the spiral arms of galaxies.

The very short time it took for the event to reach its extreme brightness and fade away again indicates that this event is nothing like anything observed before

The opposing theory is that the Cow was a special type of supernova in which either a black hole or a quickly rotating highly magnetic neutron star, a magnetar, is produced. While the bright emission in the optical and UV bands are produced by the supernova-like event, the variable X-ray emission is produced by radiating gas falling into the compact object. Normally the debris of a supernova blocks most of the light from reaching us, but the progenitor of the Cow was likely a relatively low-mass star that caused little debris. A hint of its low mass was also found in the X-ray data. If so, the observations would constitute the first observation of the birth of a compact object, making these data very valuable for further theoretical development. Such magnetar sources could also be responsible for ultra-high-energy cosmic rays as well as high-energy neutrinos, two of which might have been observed already. The debate on the nature of the Cow continues, but the wealth of information gathered so far indicates the growing importance of multi-messenger astronomy.

Further reading

R Margutti *et al.* 2018 arXiv:1810.10720.
K Fang *et al.* 2018 arXiv:1812.11673.
N Paul and M Kuin 2018 arXiv:1808.08492.

CERNCOURIER

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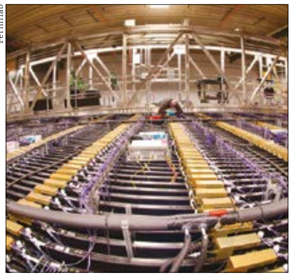
NEWS DIGEST



Fermilab

The NOvA far detector.

NOvA joins supernova watch

The NOvA experiment in the US, designed to study neutrino oscillations in a beam produced at Fermilab, has joined the Supernova Early Warning System (SNEWS). SNEWS is a global network of neutrino experiments that has been running in automated mode since 2005 to catch core-collapse supernovae in our galaxy – which occur a handful of times each century. NOvA joins other detectors including Super-K in Japan, Ice Cube at the South Pole, Borexino in Italy, Daya Bay in China, and HALO in Canada. The next step for SNEWS is to embrace the world of multi-messenger astronomy by linking with the LIGO and VIRGO gravitational-wave detectors. Potential collaborators are invited to join a SNEWS workshop at SNOLAB, Canada, in June.

ϕ boson where art thou

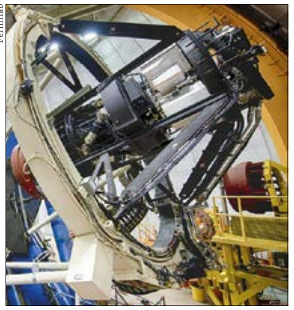
The CDF collaboration at Fermilab in the US has set the most stringent limits to date on the existence of a spin-zero particle called the ϕ boson. Such bosons arise, for example, in minimal supersymmetric extensions of the Standard Model and would be expected to decay predominantly into a pair of b quarks. A previous CDF analysis observed a 3σ excess of events with respect to the expected background at a ϕ mass of 150 GeV/c^2. The new CDF search excludes such a signal at 95% confidence, setting upper limits ranging from 20 to 2 pb for the product of production cross-sections times branching fraction for a ϕ boson with mass between 100 and 300 GeV/c^2 (arXiv.org/1902.04683).

ADMX Sidecar explores ALPs

The Axion Dark Matter Experiment (ADMX) at the University of Washington in the US has reported results from a pathfinder experiment, ADMX "Sidecar", which is designed to pave the way for future, higher mass, searches. Axions are cold dark-matter candidates that were originally postulated to solve the strong CP problem of the Standard Model. ADMX searches for them by looking for the resonant conversion of dark-matter axions to microwave photons in a strong magnetic field (known as the inverse Primakoff effect). The experiment has already excluded axion masses near 3 μeV, and its Sidecar pathfinder has now demonstrated that the same technique can be used to search for axion-like particles with masses up to 30 μeV (arXiv:1901.00920).

DES completes data-taking

The Dark Energy Survey (DES) – which began mapping a 5000-square-degree area of the sky in August 2013 – completed taking data on 9 January. Using the 520-megapixel Dark Energy Camera (below) mounted on the 4-metre Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile, the Fermilab-hosted project took data on 758 nights over six years, recording data from more than 300 million distant galaxies. The DES collaboration has already released a full range of papers based on its first year of data, and will now focus on producing results from its six years of data.



Fermilab

The Dark Energy Camera is mounted on the 4-metre Blanco telescope.

BESIII amasses record J/ψ dataset

On 11 February, the BESIII experiment at the Beijing Electron Positron Collider in China finished accumulating a sample of 10 billion J/ψ events – the world's largest dataset produced directly from electron–positron annihilations. Decays of the J/ψ particle offer a clean laboratory for studying exotic hadrons composed of light quarks and gluons, including those composed of pure gluons. With 1.3 billion J/ψ events collected in 2009 and 2012, BESIII has reported many such studies. The record J/ψ-event data sample – which adds the 8.7 billion events collected in 2017, 2018 and 2019 – will improve the precision of such studies.

New kaon decay observed

The NA48/2 experiment at CERN's North Area has reported the first observation of the decay $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}e^{+}e^{-}$, based on data recorded in 2003–2004. This radiative decay proceeds via a virtual photon which converts into an electron–positron pair, where the photon can be produced either by inner bremsstrahlung, where it is emitted by one of the charged mesons, or by direct emission at the weak vertex. The experimenters observed decays in a 60 GeV/c kaon beam passing through a 114 m tank, and used 4919 candidates to measure the branching ratio to be $4.24 \pm 0.14 \times 10^{-6}$. Several CP-violating asymmetries were investigated and found to be consistent with zero (arXiv:1809.02873).

Skyrmion model revised

The skyrmion model in nuclear physics offers a way to determine the properties of nuclei from QCD, by describing the nucleus in terms of pions and linking the number of twists – or skyrmions – in the quantum field that the pions create with the number of nucleons. But the model yields nuclear binding energies that are an order of magnitude larger than nuclear data, and predicts shapes for nuclei that don't match the clustering structure of light nuclei. Carlos Naya and Paul Sutcliffe of Durham University in the UK have now shown that a modified version of the model that includes rho mesons, the next lightest subatomic mesons, can improve both of these features (*Phys. Rev. Lett.* **121** 232002).

FAIR progress with heavy ions

After a two-year-long shut down, the SIS18 heavy-ion synchrotron is back in action at GSI, Darmstadt, with upgraded cavities (below), power converters and shielding. SIS18 is the new fast-cycling booster synchrotron for FAIR, the international Facility for Antiproton and Ion Research (*CERN Courier* July/August 2017 p41). FAIR will use beams from protons up to uranium ions with a wide range of intensities and energies to garner insights into the nuclear reactions that underpin the synthesis of heavy elements and other processes.

FAIR

Three new radio-frequency cavities enable the acceleration of intermediate-charge-state heavy ions.

Dark photon search begins

A new dark-matter experiment, the Heavy Photon Search at Jefferson Lab in Virginia, is preparing to take first data. If dark matter is part of a hidden sector, it could couple to ordinary matter via so-called heavy photons. During a two-month run this summer, the collaboration hopes to create dark photons in bremsstrahlung radiation from 4.5 GeV electrons impinging on a heavy target. The experiment will search for bumps in the invariant mass spectrum of electron–positron pairs with vertices separated from the target, with sensitivity to masses of the order of a few hundred MeV.

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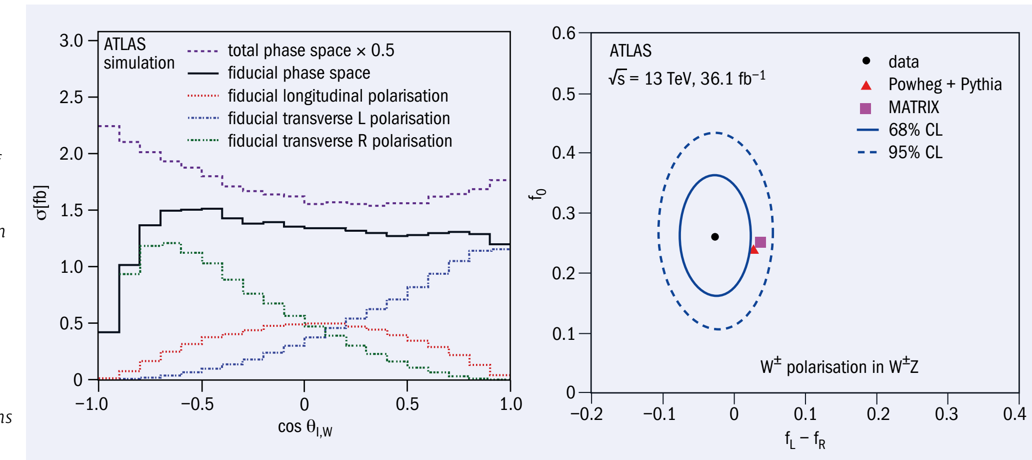
IOP Publishing

Reports from the Large Hadron Collider experiments

ATLAS

Probing gauge-boson polarisation

Fig. 1. *Left: simulated distributions of the cosine of the angle between the momentum of the W boson and that of its decay lepton for each W-boson polarisation state in WZ-production events. Right: new ATLAS measurements of longitudinal versus left minus right polarisation fractions of W bosons in WZ-production events.*



Precision measurements of diboson processes at the LHC are powerful probes of the gauge structure of the Standard Model at the multi-TeV energy scale. Among the most interesting directions in the diboson physics programme is the study of gauge-boson polarisation. The existence of three polarisation states is predicted by the Standard Model. The transverse polarisation is composed of right- and left-handed states, with spin either parallel or antiparallel to the momentum vector of the boson. The third state, a longitudinally-polarised component, is generated when the W and Z bosons acquire mass through electroweak symmetry breaking, and is therefore under particular scrutiny.

New phenomena can alter the polarisation predicted by the Standard Model due to interference between new-physics amplitudes and diagrams with gauge-boson self-interactions. WZ production, with its clean experimental signature, offers a sensitive way to search for such anomalies by providing a direct probe of the WWZ gauge coupling, due to the s-channel "Z-strahlung" contribution, where the W radiates a Z.

Building on precision WZ measurements previously reported by the ATLAS and CMS collaborations, a recent ATLAS result constitutes the most precise WZ measurement at a centre-of-mass energy of 13 TeV, and provides the first measurement of the polarisation of pair-produced vector bosons in hadron collisions. Based on 36.1 fb^{-1} of data collected in 2015 and 2016 by the ATLAS detector, and using leptonic decay modes of the gauge bosons to electrons or muons, ATLAS has achieved a precision of 4.5% for the WZ cross section measured in a fiducial phase space closely matching the detector acceptance. The kinematics of WZ events, including the underlying dynamics of accompanying hadronic jets, has been studied in detail by measuring the cross section as a function of several observables.

The polarisation states for W and Z bosons can be probed through distributions of the angle of the leptons relative to the bosons from which they decayed (figure 1, left). A binned profile-likelihood fit of templates describing the three helicity states allowed ATLAS to extract the W and Z polarisations in the fiducial measurement region. Because of the incomplete

The longitudinally-polarised component is generated when the W and Z bosons acquire mass through electroweak symmetry breaking

knowledge of the neutrino momentum originating from the W-boson decay, it is more difficult to measure the helicity fractions of the W than of the Z. The fraction of a longitudinally-polarised W boson in WZ events is found to be 0.26 ± 0.06 (figure 1, right), while the longitudinal fraction of the Z boson is found to be 0.24 ± 0.04. The analysis leads to an observed significance of 4.2 standard deviations for the presence of longitudinally-polarised W bosons, and 6.5 standard deviations for longitudinally-polarised Z bosons.

Improved precision

The measurements are dominated by statistical uncertainties, but future datasets will improve precision and allow the collaboration to probe new-physics effects in events where both the Z and the W are longitudinally polarised. The ultimate target is to measure the scattering of longitudinally polarised vector bosons: this would be a direct test of electroweak symmetry breaking.

Further reading

ATLAS Collaboration 2019 arXiv 1902.05759 (submitted to *Eur. Phys. J. C*).

LHCb

Charm mixing tests the Standard Model

The Standard Model (SM) allows neutral flavoured mesons such as the D^0 to oscillate into their antiparticles. Having first observed this process in 2012, the LHCb collaboration has recently made some of the world's most precise measurements of this behaviour, which is potentially sensitive to new physics. The oscillation of the D^0 ($c\bar{u}$) into its antiparticle, the $\bar{D}^0$ ($\bar{c}u$), occurs through the exchange of massive virtual particles. These might include as-yet undiscovered particles, so the measurements are sensitive to non-Standard Model dynamics at large energy scales. By examining D^0 and $\bar{D}^0$ mesons separately, it is also possible to search for the violation of charge-parity (CP) symmetry in the charm sector. Such effects are predicted to be very small. Therefore, given LHCb's current level of experimental precision, any sign of CP violation would be a clear indication of physics beyond the Standard Model.

Due to quantum-mechanical mixing between the neutral charm meson's mass and flavour eigenstates, the probabilities of observing either it or its antiparticle vary as a function of time. This mixing can be described by two parameters, x and y, which relate the properties of the mass eigenstates: x is the normalised difference in mass, and y is the normalised difference in width, or inverse lifetime. The mixing rate is very slow, making these parameters difficult to measure. Isolating the differences between the D^0 and $\bar{D}^0$ mesons is an even greater challenge. For these two papers, LHCb was able to achieve small statistical uncertainties thanks to the large samples of charm mesons collected during Run 1, and minimised systematic uncertainties by measuring ratios of yields to cancel detector effects.

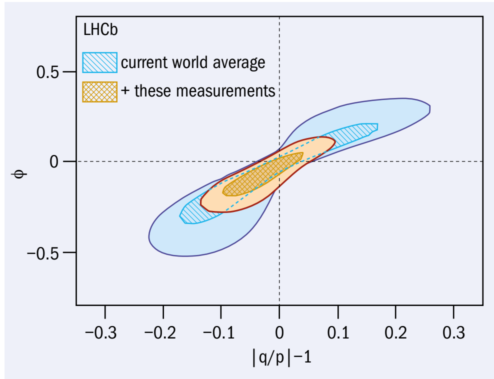


Fig. 1. *Constraints on the parameters describing CP violation in charm mixing, showing the impact of LHCb measurements (orange). The 68% and 95% confidence regions are shown. Under the hypothesis of CP conservation, the expected value is (0,0).*

In the first paper, LHCb physicists studied the effective lifetime of the mesons. As a consequence of mixing, the effective decay width to CP-even final states, such as K^+K^- and $\pi^+\pi^-$, differs from the average width measured in decays such as $D^0 \to K^- \pi^+$. The parameter y_{CP}, which in the limit of CP symmetry is equal to y, can be deduced from the ratio of decay rates to these two final states as a function of time. LHCb measured y_{CP} with the same precision as all previous measurements combined, obtaining a value consistent with the world-average value of y.

In the second analysis, LHCb reconstructed D^0 decays into the final state $K^0_S\pi^+\pi^-$ to measure the parameter x, which had not previously been shown to differ from zero. In this mode, mixing manifests as small variations in the decay rate in different parts of phase space as a function of time. Measuring it requires good control over experimental effects as a function of both phase space and decay time. LHCb achieved this by measuring the ratios of the yields in complementary regions of phase space (mirrored in the Dalitz plane) as a function of time. The measured value of x is the world's most precise, and in combination with previous measurements there is now evidence that it differs from zero.

As well as the mixing itself, both analyses are also sensitive to mixing-induced CP violation. While CP violation was not observed, the limits on its parameters were greatly improved (figure 1). This is a good example of how different decay modes give complementary information and, when taken together, can have a big impact. LHCb will continue to perform measurements with additional modes and the larger samples collected in Run 2.

Further reading

LHCb Collaboration 2019 *Phys. Rev. Lett.* **122** 011802.
LHCb Collaboration 2019 LHCb-PAPER-2019-001 (in preparation).

CMS

CASTOR calorimetry delves into gluon saturation

The fundamental structure of nucleons is described by the properties and dynamics of their constituent quarks and gluons, as described by QCD. The gluon's self-interaction complicates this picture considerably. Non-linear recombination reactions, where two gluons fuse, are predicted to lead to a saturation of the gluon density. This largely unexplored phenomenon is expected to occur when the gluons in a hadron overlap transversally, and is enhanced for hadrons with high atomic numbers. Gluon saturation may be studied in lead-proton collisions at the LHC in the kinematic region where the gluon density is high and the gluons have sizable transverse dimensions.

Gluon saturation has been at the focal point of the heavy-ion community for decades. Precision measurements at HERA, RHIC and previously at the LHC agree with the predictions made by saturation models, however, the measurements do not allow an unambiguous interpretation of whether gluon saturation occurs in nature. This is a strong motivation both for the LHC experiments and for the planned Electron Ion Collider (*CERN Courier* October 2018 p31).

Non-linear recombination reactions, where two gluons fuse, are predicted to lead to a saturation of the gluon density

The CMS collaboration recently submitted a paper on gluon saturation in proton-lead collisions to the *Journal of High Energy Physics* (*JHEP*). The collisions that were used for this analysis occurred in 2013 at a centre-of-mass energy of 5 TeV and were detected using the CMS experiment's CASTOR calorimeter. This is a very forward calorimeter of CMS, where "forward" refers to regions of the detector that are close to the beam pipe. Therefore, unlike any other LHC experiment, CMS can measure jets at very forward angles ($-6.6<|\eta|<-5.2$) and with transverse momenta (p_T) as low as 3 GeV. This is the first time that a jet-energy spectrum measurement from the CASTOR calorimeter has been submitted to a journal.

Forward jets with a small p_T can target high-density-regime gluons with ample transverse dimensions, making ▷ CASTOR ideal for a study of gluon saturation. By colliding protons with lead ions, the sensitivity of the CASTOR jet spectra to saturation effects was further enhanced. This enabled CASTOR to overcome the ambiguity associated with the interpretation of the previous measurements.

The jet-energy spectrum obtained using CASTOR was compared to two saturation models (figure 1, left). These were the "Katie KS" model and predictions from the AAMQS collaboration; the latter are based on the colour-glass-condensate model. In the Katie KS model, the strength of the non-linear gluon recombination reactions can be varied. Upon comparison with the model, it was seen that the linear and non-linear predictions differed by an order of magnitude for the lowest energy bins of the spectrum, which correspond to low-p_T jets. Meanwhile, they converged at the highest energies, confirming the high sensitivity of the measurement to gluon saturation. The AAMQS predictions underestimated the data progressively, up to an order of magnitude, in the region most strongly affected by saturation. Overall, neither model described the spectrum correctly.

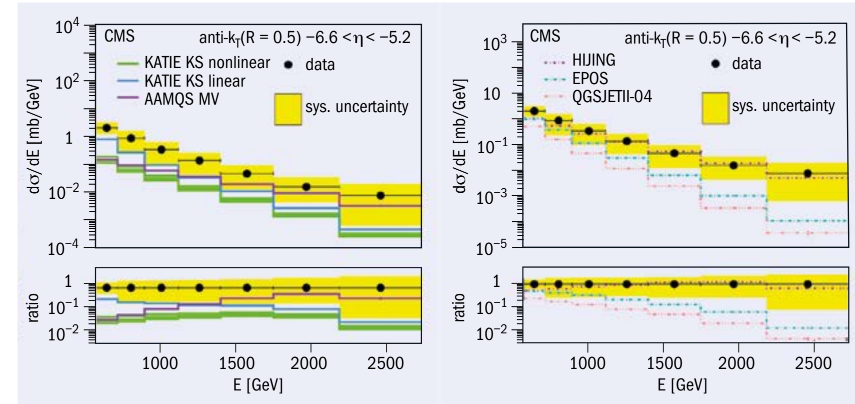


Fig. 1. *Left: The differential jet cross section as a function of jet energy as measured in the CASTOR calorimeter, for data, the Katie KS model and AAMQS predictions. Right: The differential jet cross section as a function of jet energy as measured in the CASTOR calorimeter, for data, cosmic ray models and HIJING.*

The spectrum was also compared to two cosmic ray models (EPOS-LHC and QGSJetII-04) and to the HIJING event generator (figure 1, right). The former models underestimated the data by over two orders of magnitude while HIJING, which incorporates an implementation of nuclear shadowing, agreed well with the data. Nuclear shadowing is an interference effect between the nucleons of a heavy ion. Like gluon saturation, it is expected to lead to a decrease in the probability for a proton-lead collision to occur, however further data analysis is required for more definite conclusions on nuclear shadowing.

These results establish CASTOR jets as an experimental reality and their sensitivity to saturation effects is encouragement for further, more refined CASTOR jet studies.

Further reading

CMS Collaboration 2018 arXiv 1812.01691 (submitted to *JHEP*).

ALICE

Bottomonium suppression in lead-lead collisions

The study of the production of quarkonia, the bound states of heavy quark-antiquark pairs, is an important goal of the ALICE physics programme. The quarkonium yield is suppressed in heavy-ion collisions when compared with proton-proton collisions because the binding force is screened by the hot and dense medium. This suppression is expected to be greatest for events with high "centrality", when the heavy ions collide head-on.

The ALICE collaboration has recently analysed the suppression of inclusive bottomonium ($b\bar{b}$) production in lead-lead collisions relative to proton-proton collisions. This reduction is quantified in terms of the nuclear modification factor R_{AA}, which is the ratio of the measured yield in lead-lead to proton-proton collisions corrected by the number of binary nucleon-nucleon collisions. An R_{AA} value of unity would indicate no suppression whereas zero indicates full suppression. The bottomonium states ϒ(1S) and ϒ(2S) were measured via their decays to muon pairs at a centre-of-mass energy per nucleon-nucleon pair of 5.02 TeV, in the rapidity range $2.5 < \eta < 4$, with a maximum transverse momentum of 15 GeV/c. No significant variation of R_{AA} is observed as a function of transverse momentum and rapidity, however, production is suppressed with increasing centrality (figure 1). A decrease in R_{AA} from 0.60±0.10(stat)±0.04(syst) for the peripheral 50–90% of collisions to 0.34±0.03(stat)±0.02(syst) for the 0–10% most central collisions was observed.

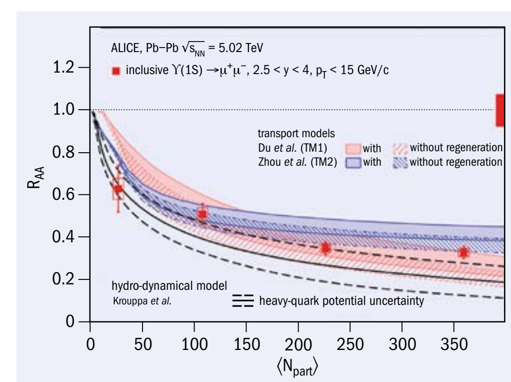


Fig. 1. *Inclusive ϒ(1S) R_{AA} as a function of centrality. The vertical error bars and the boxes represent the statistical and uncorrelated systematic uncertainties, respectively. The relative correlated uncertainty is shown as a red box at unity. The results are compared with predictions from two transport models and a hydrodynamical model.*

Theoretical models must deal with the competing effects of melting and (re)generation of the ϒ within the quark-gluon plasma, the shadowing of parton densities in the initial state and "feed-down" from higher resonance states. Due to uncertainties on the parton density, it is not yet known whether the direct production of ϒ(1S) is suppressed, or merely the feed-down from ϒ(2S) and other higher-mass states. Nevertheless, the precision of these measurements imposes significant new constraints on the modelling of ϒ production in lead-lead collisions.

Further reading

ALICE Collab. 2019 *Phys. Lett. B* **790** 89.

FIELD NOTES

Reports from events, conferences and meetings

BABAR COLLABORATION

BaBar celebrates its 25th anniversary

On 11 December 2018, 25 years after its inaugural meeting, the BaBar collaboration came together at the SLAC National Accelerator Laboratory in California to celebrate its many successes. David Hitlin, BaBar's first spokesperson, described the inaugural meeting of what was then called the Detector Collaboration for the PEP-II "asymmetric" electron–positron collider, which took place at SLAC at the end of 1993. By May 1994 the collaboration had chosen the name BaBar in recognition of its primary goal to study CP violation in the neutral B–$\bar{B}$ meson system. Jonathan Dorfan, PEP-II project director, recounted how PEP-II was constructed by SLAC, LBL and LLNL. Less than six years later, PEP-II and the BaBar detector were built and the first collision events were collected on 26 May 1999. Twenty-five years on, and BaBar has now chalked up more than 580 papers on CP violation and many other topics.

D Harmer, SLAC

Collegial team *Participants of the BaBar 25th anniversary event.*

The "asymmetric" descriptor of the collider refers to Pier Oddone's concept of using unequal electron and positron beam energies – tuned to 10.58 GeV, the mass of the $\Upsilon(4S)$ meson and just above the threshold for producing a pair of B mesons. This relativistic boost enabled measurements of the distance between the points where the mesons decay, which is critical for the study of CP violation. Equally critical was the entanglement of the B meson and anti-B meson produced in the $\Upsilon(4S)$ decay, as it marked whether it was the B^0 or $\bar{B}^0$ that decayed to the same CP final state by tagging the flavour of the other meson.

By October 2000 PEP-II had achieved its design luminosity of $3 \times 10^{33}\,cm^{-2}\,s^{-1}$ and less than a year later BaBar published its observation of CP violation in the B^0 meson system based on a sample of 32×10^6 pairs of B^0–$\bar{B}^0$ mesons – on the same day that Belle, its competitor at Japan's KEK laboratory, published the same observation. These results led to Makoto Kobayashi and Toshihide Maskawa sharing the 2008 Nobel Prize in Physics. The ultimate luminosity achieved by PEP-II, in 2006, was $1.2 \times 10^{34}\,cm^{-2}s^{-1}$. BaBar continued to collect data on or near the $\Upsilon(4S)$ meson until 2007 and in 2008 collected large samples of $\Upsilon(2S)$ and $\Upsilon(3S)$ mesons before PEP-II was shut down. In total, PEP-II produced 471×10^6 B–$\bar{B}$ pairs for BaBar studies – as well as a myriad of other for other investigations.

The BaBar collaboration made the first direct observation of time-reversal violation

The anniversary event also celebrated technical innovations, including "trickle injection" of beam particles into PEP-II, which provided a nearly 40% increase in integrated luminosity; BaBar's impressive particle identification, made possible by the DIRC detector; and the implementation of a computing model – spurred by PEP-II delivering significantly more than design luminosity – whereby countries provided in-kind computing support via large "Tier-A" centres. This innovation paved the way for CERN's Worldwide LHC Computing Grid.

Notable physics results from BaBar include the first observation in 2007 of D–$\bar{D}$ mixing, while in 2008 the collaboration discovered the long-sought η_b, the lowest energy particle of the bottomonium family. The team also searched for lepton-flavour violation in tau-lepton decays, publishing in 2010 what remain the most stringent limits on $\tau \to \mu\gamma$ and $\tau \to e\gamma$ branching fractions. In 2012, making it onto *Physics World*'s top-ten physics results of the year, the BaBar collaboration made the first direct observation of time-reversal violation by measuring the rates at which the B^0 meson changes quantum states. Also published in 2012 was evidence for an excess of $\bar{B} \to D^{(*)}\tau^- \bar{\nu}_\tau$ decays, which challenges lepton universality and is an important part of the current Belle II and LHCb physics programmes. Several years after data-taking ended, it was recognised that BaBar's data could also be mined for evidence of dark-sector objects such as dark photons, leading to the publication of two significant papers in 2014 and 2017. Another highlight, published last year, is a joint BaBar–Belle paper that resolved an ambiguity concerning the quark-mixing unitarity triangle.

Although BaBar stopped collecting data in 2008, this highly collegial team of researchers continues to publish impactful results. Moreover, BaBar alumni continue to bring their experience and expertise to subsequent experiments, ranging from ATLAS, CMS and LHCb at the LHC, Belle II at SuperKEKB, and long-baseline neutrino experiments (T2K, DUNE, HyperK) to dark-matter (LZ, SCDMS) and dark-energy (LSST) experiments in particle astrophysics.

J Michael Roney *University of Victoria and* **David MacFarlane** *SLAC.*

Physics Beyond Colliders

PBC initiative presents main findings

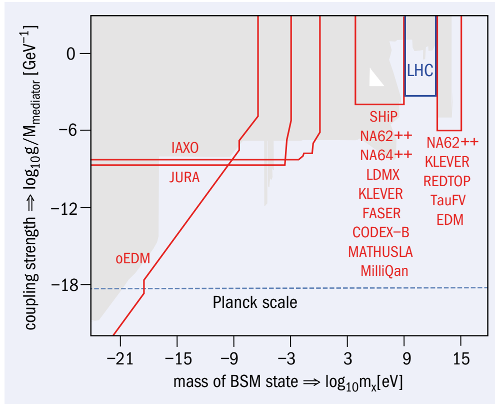
In a workshop held at CERN on 16–17 January, researchers presented the findings of the Physics Beyond Colliders (PBC) initiative, which was launched in 2016 to explore the opportunities at CERN via projects complementary to the LHC and future colliders (*CERN Courier* November 2016 p28). PBC members have weighed up the potential for such experiments to explore open questions in QCD and the existence of physics beyond the Standard Model (BSM), in particular including searches for signatures of hidden-sector models in which the conjectured dark matter does not couple directly to Standard Model particles.

The BSM and QCD groups of the PBC initiative have developed detailed studies of CERN's options and compared them to other worldwide possibilities. The results show the international competitiveness of the PBC options.

The Super Proton Synchrotron (SPS) remains a clear attraction, offering the world's highest-energy beams to fixed-target experiments in the North Area (see p34). The SPS high-intensity muon beam could allow a better understanding of the theoretical prediction of the muon anomalous magnetic moment (MUonE project), and a significant contribution to the resolution of the proton radius puzzle by COMPASS(R_p). The NA61 experiment could explore QCD in the interesting region of "criticality", while upgrades of NA64 and a few months of NA62 operation in beam-dump mode (whereby a target absorbs most of the incident protons and contains most of the particles generated by the primary beam interactions) would explore the hidden-sector parameter space. In the longer term, the KLEVER experiment could probe rare decays of neutral kaons, and NA60 and DIRAC could enhance our understanding of QCD.

A novel North Area proposal is the SPS Beam Dump Facility (BDF). Such a facility could, in the first instance, serve the SHiP experiment, which would perform a comprehensive investigation of the hidden sector with discovery potential in the MeV–GeV mass range, and the TauFV experiment, which would search for forbidden τ decays. The BDF team has made excellent progress with the facility design and is preparing a comprehensive design study report. Options for more novel exploitation of the SPS have also been considered: proton-driven plasma-wakefield acceleration of electrons for a dark-matter experiment (AWAKE++); the acceleration and slow extraction of electrons to light-dark-matter experiments (eSPS); and the production of well-calibrated neutrinos via a muon decay ring (nuSTORM).

Fixed-target studies at the LHC are also considered within PBC, and these could improve our understanding of QCD in regions where it is relevant for new-physics searches at the high-luminosity LHC upgrade. The LHC could also be supplemented with new experiments to search for long-lived particles, and PBC support for a small experiment called FASER has helped pave the way for its installation in the ongoing long shutdown of CERN's accelerator complex.



New domains *The new-physics domains explored by PBC-proposed projects as a function of mass scale and coupling strength, showing full complementarity between precision measurements and rare decays at high mass, SPS beam-dump-like experiments at intermediate mass, and non-accelerator axion experiments at low mass.*

The Super Proton Synchrotron remains a clear attraction

2018 was a notable year for the gamma factory, a novel concept that would use the LHC to produce intense gamma-ray beams for precision measurements and searches (*CERN Courier* November 2017 p7). The team has already demonstrated the acceleration of partially stripped ions in the LHC, and is now working towards a proof-of-principle experiment in the SPS. Meanwhile, the Electric Dipole Moment (CPEDM) collaboration has continued studies, supported by experiments at the COSY synchrotron in Germany (*CERN Courier* September 2016 p27), towards a prototype storage ring to measure the proton EDM.

The PBC technology team has also been working to leverage CERN's skills base to novel experiments, for example by exploring synergies across experiments and collaboration in technologies – in particular, concerning light-shining-through-walls experiments and QED vacuum-birefringence measurements.

Finally, some PBC projects are likely to flourish outside CERN: the IAXO axion helioscope, now under consideration at DESY; the proton EDM ring, which could be prototyped at the Jülich laboratory, also in Germany; and the REDTOP experiment devoted to η meson rare decays, for which Fermilab in the US seems better suited.

The PBC groups have submitted their full findings to the European Particle Physics Strategy Update (http://pbc.web.cern.ch/).

Joerg Jaeckel *Heidelberg University,* **Mike Lamont** *CERN and* **Claude Vallée** *CPPM Marseille.*

COMHEP

Colombian students analyse LHC data

Masterclass *The students from the Cali Tecnocentro with coordinator Carlos Sandoval of ATLAS (fifth from right).*

C H Rueda

The annual Colombian national high-energy physics conference (COMHEP), held this year in the city of Cali, provided an opportunity for youngsters from the Tecnocentro "Somos Pacifico", an out-of-school activity centre, to participate in a one-off masterclass analysing data from the LHC. The masterclass used the tools and setup from the International Particle Physics Outreach Group (IPPOG) international masterclasses, and was coordinated by ATLAS member Carlos Sandoval from the Universidad Antonio Nariño in Bogotá, and included a virtual visit to the ATLAS control room. The Tecnocentro is in a disadvantaged area of Cali, many of whose inhabitants have been displaced from the countryside by civil conflict.

CLIC workshop

CLIC collaboration considers collider's potential

The annual workshop of the Compact Linear Collider (CLIC), a proposed multi-TeV linear electron–positron collider at CERN, attracted more than 200 participants to CERN on 21–25 January. CLIC occupies a unique position in both the precision and energy frontiers, combining the benefits of electron–positron collisions with the possibility of multi-TeV collision energies. It uses a two-beam acceleration scheme based on novel, high-gradient X-band accelerating structures, and envisions a three-stage implementation with a collision energy stepping from 380 GeV to 3 TeV and a diverse physics programme spanning 30 years (*CERN Courier* November 2016 p21).

M Volpi

Facing the future *Participants of the CLIC workshop in January 2019.*

Key CLIC concepts such as drive-beam production and operation of high-efficiency radio-frequency cavities have all been demonstrated, reported Steinar Stapnes, CLIC project leader. "The CLIC project offers a cost-effective and innovative technology, and is ready to proceed towards a Technical Design Report, enabling the start of construction for the first stage by 2026 and realising electron–positron collisions at 380 GeV as soon as 2035," he said.

A major focus for the CLIC collaboration during 2018 was the completion of a project implementation plan, as well as several comprehensive CERN Yellow Reports describing the accelerator, detector and physics studies. A central point was an updated cost and power estimate, which for the 380 GeV stage amount to around 5.9 billion Swiss francs and 168 MW. Workshop participants also discussed the next important step for CLIC: a preparatory phase focusing on large-scale tests, industrial production and civil-engineering aspects including siting and infrastructure.

An overview of potential industrial involvement in CLIC's core technologies is also being compiled. Several partner agreements support technical developments for smaller X-band accelerators, including the European Commission's CompactLight study and the recently proposed eSPS project that would see a 3.5 GeV X-band electron linac feeding the Super Proton Synchrotron for further acceleration, followed by slow extraction to study dark-sector physics. The linear tunnel of CLIC also provides a natural infrastructure for long-term future projects based on plasma-wakefield and other acceleration techniques.

Concerning CLIC detector R&D, the latest test-beam analysis and simulation results show promise for meeting the challenging CLIC vertex and tracker requirements. The next generation of detector assemblies will be tested at DESY in Hamburg, where the CLICdp vertex and tracker group will be welcomed for several weeks during the current long shutdown of CERN's accelerators.

CLIC's physics programme generated rich discussions at the January workshop. In particular the Higgs self-coupling, which determines the shape of the Higgs potential, can be directly accessed at the multi-TeV collisions at CLIC via double-Higgs production. A dedicated mini-workshop jointly set up by theorists and experimentalists covered CLIC's potential to extend our knowledge of physics beyond the Standard Model, including possible compositeness of the Higgs boson and dark-matter candidates such as the thermal Higgsino and axion-like particles. The full physics case, designs, costs and timescales for CLIC were submitted to the European Strategy for Particle Physics Update in December.

Rickard Ström *CERN.*

CUWiP

Supporting future female physicists

Northwestern Local Organizing Committee

Thirst for knowledge *Attendees of the 2019 CUWiP conference for women in physics.*

The Conferences for Undergraduate Women in Physics (CUWiP) are three-day regional events for undergraduate physics students run by the American Physical Society and many volunteers. Their goal is to provide female students with resources and motivation to support their pursuit of a degree and a career in physics, and is addressed in many ways, including inspirational talks by female physicists and workshops and panel discussions on graduate school and physics careers. This year's CUWiP took place on 18–20 January at 12 universities across the US and Canada, which collectively hosted a record number of attendees. The keynote speaker, CERN Director-General Fabiola Gianotti, delivered her talk from CERN titled "Why a Professional Life in Physics?" She gave details of her path to becoming a physicist – which included her study of humanities, constant curiosity as a child, and continuous thirst for knowledge – and expressed that it does not matter if you had a late start in physics as long as you have a passion.

Kai Wright *and* **Theodore Hodapp** *American Physical Society.*

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HIGGS COUPLINGS

Higgs workshop returns to Tokyo

G Tateno

Higgs highlights *Participants of Higgs Couplings 2018.*

The seventh in the series of Higgs Couplings workshops, which began in Tokyo in 2012, returned to the Japanese capital on 26–30 November 2018. Lively discussions between experimentalists and theorists have been a strength of the meeting since the beginning. The 2018 workshop attracted more than 130 participants and included 49 plenary talks, 35 parallel talks and 18 talks by young scientists, covering a broad range of Higgs-boson physics.

On the experiments side, measurements of the Higgs-boson mass, width, couplings, spin and parity were discussed. In particular, the recent confirmation of the top and bottom Yukawa couplings was presented, and effective field theory was described as the next phenomenological framework for parametrising measurements of the couplings. Additional Higgs-boson searches including dark-matter aspects were discussed, as were new data-analysis techniques such as boosted topology and machine learning. On the theory side, recent advances in higher-order calculations in precision Higgs phenomenology were presented.

The importance of future colliders for the measurement of Higgs-boson properties, including its self-coupling, was also highlighted. The high-luminosity LHC, the high-energy LHC, linear colliders such as the ILC, as well as future circular colliders, were discussed. Many prospective results from these colliders were documented in CERN Yellow Reports submitted to the European Strategy for Particle Physics Update, and were reported for the first time at the workshop.

There was also a special session on "beyond collider" studies, which underlined the synergies with collider experiments and featured recent results from gravitational-wave observatories and cosmic-microwave-background experiments.

The conference also included a young scientists' forum, which saw many excellent talks. Finally, the Japanese traditional ceremony of Kagami biraki, in which a cask of sake is opened at a party or ceremony, celebrated the measurement of the top and bottom Yukawa couplings and of a new era in Higgs measurements.

The next Higgs Couplings workshop will be held in Oxford in the UK from 30 September to 4 October 2019.

Yuji Enari *chair of the local organising committee of Higgs Couplings 2018.*

HISTORY OF THE NEUTRINO

Paris event reflects on the history of the neutrino

N Bleurvacq, APC Laboratory, Paris

History makers *Participants of the first International Conference on the History of the Neutrino.*

Neutrinos, discovered in 1956, play an exceptional role in particle and nuclear physics, as well as astrophysics, and their study has led to the award of several Nobel prizes. In recognition of their importance, the first International Conference on the History of the Neutrino took place at the Université Paris Diderot in Paris on 5–7 September 2018.

The purpose of the conference, which drew 120 participants, was to cover the main steps in the history of the neutrino since 1930, when Wolfgang Pauli postulated its existence to explain the continuous energy spectrum of the electrons emitted in beta decay. Specifically, for each topic in neutrino physics, the aim was to pursue an historical approach and follow as closely as possible the discovery or pioneering papers. Speakers were chosen as much as possible for their roles as authors or direct witnesses, or as players in the main events.

The first session, "Invention of a new particle", started with the prehistory of the neutrino – that is, the establishment of the continuous energy spectrum in beta decay – before moving into the discoveries of the three flavour neutrinos. The second session, "Neutrinos in nature", was devoted to solar and atmospheric neutrinos, as well as neutrinos from supernovae and Earth. The third session covered neutrinos from reactors and beams including the discovery of neutral-current neutrino interactions, in which the neutrino is not transformed into another particle like a muon or an electron. This discovery was made in 1973 by the Gargamelle bubble chamber team at CERN after a race with the HPWF experiment team at Fermilab.

The major theme of neutrino oscillations from the first theoretical ideas of Bruno Pontecorvo (1957) to the Mikheyev–Smirnov–Wolfenstein effect (1985), which can modify the oscillations when neutrinos travel through matter, was complemented by talks on the discovery of neutrino oscillations by Nobel laureates Takaaki Kajita and Art McDonald. In 1998, the Super-Kamiokande experiment, led by Kajita, observed the oscillation of atmospheric neutrinos, and in 2001 the Sudbury Neutrino Observatory experiment, led by McDonald, observed the oscillation of solar neutrinos.

The role of the neutrino in the Standard Model was discussed, as was its intrinsic nature. Although physicists have observed the rare process of double beta decay with neutrinos in the final state, neutrinoless double beta decay with no neutrinos produced has been searched for for more than 30 years because its observation would prove that the neutrino is Majorana-type (its own antiparticle) and not Dirac-type.

To complete the panorama, the conference discussed neutrinos as messengers from the wider universe, from the Big Bang to violent phenomena such as gamma-ray bursts or active galactic nuclei. Delegates also discussed wrong hints and tracks, which play a positive role in the development of science, and the peculiar sociological aspects that are common to particle physics and astrophysics.

Following the conference, a website dedicated to the history of this fascinating particle was created: https://neutrino-history.in2p3.fr.

Michel Cribier *APC Laboratory, Paris and CEA-Saclay, and* **Daniel Vignaud** *APC Laboratory, Paris.*

iStock/Nastco

OPEN SCIENCE

A vision for collaborative, reproducible and reusable research

Solving the challenges of sharing, reproducing and reusing results in particle physics seems more feasible than ever thanks to recent technological developments.

The goal of practising science in such a way that others can collaborate, question and contribute – known as "open science" – long predates the web. One could even argue that it began with the first academic journal 350 years ago, which enabled scientists to share knowledge and resources to foster progress. But the web offered opportunities way beyond anything before it, quickly transforming academic publishing and giving rise to greater sharing in areas such as software. Alongside the open-source (p27), open-access (p29) and open-data (p31) movements grew the era of open science, which aims to encompass the scientific process as a whole.

Today, numerous research communities, political circles and funding bodies view open science and reproducible research as vital to accelerate future discoveries. Yet, to fully reap the benefits of open and reproducible research, it is necessary to start implementing tools to power a more profound change in the way we conduct and perceive research. This poses both sociological and technological challenges, starting from the conceptualisation of research projects, through conducting research, to how we ensure peer review and assess the results of projects and grants. New technologies have brought open science within our reach, and it is now up to scientific communities to agree on the extent to which they want to embrace this vision.

Particle physicists were among the first to embrace the open-science movement, sharing preprints and building a deep culture of using and sharing open-source software. The cost and complexity of experimental particle physics,

THE AUTHORS
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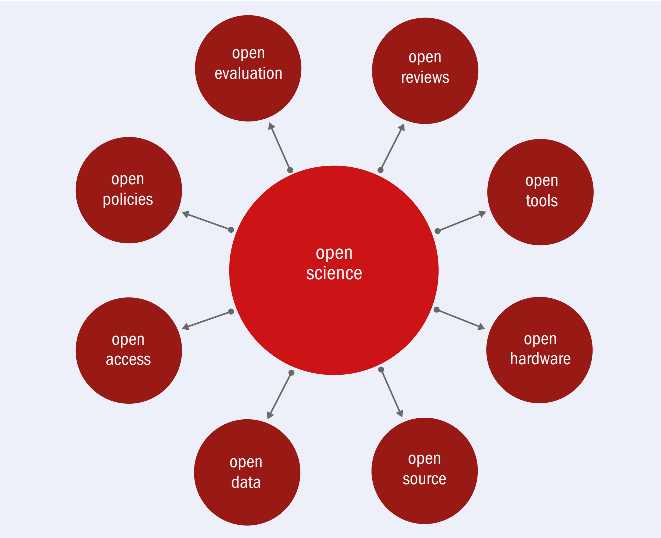
T Šimko



Open movements *Open science encompasses all aspects of how scientific research is governed, performed, shared, published and evaluated.*

making complete replication of measurements unfeasible, presents unique challenges in terms of open data and scientific reproducibility. It may even be considered that openness itself, in the sense of having an unfettered access to data from its inception, is not particularly advantageous.

Take the existing data-management policies of the LHC collaborations: while physicists generally strive to be open in their research, the complexity of the data and analysis procedures means that data become publicly open only after a certain embargo period that is used to assess its correctness. The science is thus born "closed". Instead of thinking about "open data" from its inception, it is more useful to speak about FAIR (findable, accessible, interoperable and reusable) data, a term coined by the FORCE11 community. The data should be FAIR throughout the scientific process, from being initially closed to being made meaningfully open later to those outside the experimental collaborations.

True open science demands more than simply making data available: it needs to concern itself with providing information on how to repeat or verify an analysis performed over given datasets, producing results that can be reused by others for comparison, confirmation or simply for deeper understanding and inspiration. This requires runnable examples of how the research was performed, accompanied by software, documentation, runnable scripts, notebooks, workflows and compute environments. It is often too late to try to document research in such detail once it has been published.

True open science demands more than simply making data available

FAIR data repositories for particle physics, the "closed" CERN Analysis Preservation portal and the "open" CERN Open Data portal emerged five years ago to address the community's open-science needs. These digital repositories enable physicists to preserve, document, organise and share datasets, code and tools used during analyses. A flexible metadata structure helps researchers to define everything from experimental configurations to data samples, from analysis code to software libraries and environments used to analyse the data, accompanied by documentation and links to presentations and publications. The result is a standard way to describe and document an analysis for the purposes of discoverability and reproducibility.

Recent advancements in the IT industry allow us to encapsulate the compute environments where the analysis was conducted. Capturing information about how the analysis was carried out can be achieved via a set of runnable scripts, notebooks, structured workflows and "containerised" pipelines. Complementary to data repositories, a third service named REANA (reusable analyses) allows researchers to submit parameterised computational workflows to run on remote compute clouds. It can be used to reinterpret preserved analyses but also to run "active" analyses before they are published and preserved, with the underlying philosophy that physics analyses should be automated from inception so that they can be executed without manual intervention. Future reuse and reinterpretation starts with the first commit of the analysis code; altering an already-finished analysis to facilitate its eventual reuse after publication is often too late.

Full control

The key guiding principle of the analysis preservation and reuse framework is to leave the decision as to when a dataset or a complete analysis is shared, privately or publicly, in the hands of the researchers. This gives the experiment collaborations full control over the release procedures, and thus fully supports internal processing and review protocols before the results are published on community services, such as arXiv, HEPData and INSPIRE.

The CERN Open Data portal was launched in 2014 amid a discussion as to whether primary particle-physics data would find any use outside of the LHC collaborations. Within a few years, the first paper based on open data from the CMS experiment was published (see p31).

Three decades after the web was born, science is being shared more openly than ever and particle physics is at the forefront of this movement. As we have seen, however, simple compliance with data and software openness is not enough: we also need to capture, from the start of the research process, runnable recipes, software environments, computational workflows and notebooks. The increasing demand from funding agencies and policymakers for open data-management plans, coupled with technological progress in information technology, leads us to believe that the time is ripe for this change.

Sharing research in an easily reproducible and reusable manner will facilitate knowledge transfer within and between research teams, accelerating the scientific process. This fills us with hope that three decades from now, even if future generations may not be able to run our current code on their futuristic hardware platforms, they will be at least well equipped to understand the processes behind today's published research in sufficient detail to be able to check our results and potentially reveal something new. ●

Further reading

X Chen *et al.* 2019 *Nat. Phys.* **15** 113.

S Kulkarni

INSPIRED BY SOFTWARE

The well-established governance, licensing and collaborative mechanisms of open-source software set a standard for open-science movements.

THE AUTHORS
Giacomo Tenaglia *and* **Tim Smith** *CERN.*

Of all the movements to make science and technology more open, the oldest is "open source" software. It was here that the "open" ideals were articulated, and from which all later movements such as open-access publishing derive. Whilst it rightly stands on this pedestal, from another point of view open-source software was simply the natural extension of academic freedom and knowledge-sharing into the digital age.

Open-source has its roots in the free software movement, which grew in the 1980s in response to monopolising corporations and restrictions on proprietary software. The underlying ideal is open collaboration: peers freely, collectively and publicly build software solutions. A second ideal is recognition, in which credit for the contributions made by individuals and organisations worldwide is openly acknowledged. A third ideal concerns rights, specifically the so-called four freedoms granted to users: to use the software for any purpose; to study the source code to understand how it works; to share and redistribute the software; and to improve the software and share the improvements with the community. Users and developers therefore contribute to a virtuous circle in which software is continuously improved and shared towards a common good, minimising vendor lock-in for users.

Today, 20 years after the term "open source" was coined, and despite initial resistance from traditional software companies, many successful open-source business models exist. These mainly involve consultancy and support services for software released under an open-source licence and extend beyond science to suppliers of everyday tools such as the WordPress platform, Firefox browser and the Android operating system. A more recent and unfortunate business model adopted by some companies is "open core", whereby essential features are deemed premium and sold as proprietary software on top of existing open-source components.

Founding principles

Open collaboration is one of CERN's founding principles, so it was natural to extend the principle into its software. The web's invention brought this into sharp focus. Having experienced first-hand its potential to connect physicists around the globe, in 1993 CERN released the web software into the public domain so that developers could collaborate and improve on it (see p39). The following year, CERN released the next web-server version under an open-source licence with the explicit goal of preventing private compa-

Being a scientist in the digital age means being a software producer and a software consumer

nies from turning it into proprietary software. These were crucial steps in nurturing the universal adoption of the web as a way to share digital information, and exemplars of CERN's best practice in open-source software.

Nowadays, open-source software can be found in pretty much every corner of CERN, as in other sciences and industry. Indico and Invenio – two of the largest open-source projects developed at CERN to promote open collaboration – rely on the open-source framework Python Flask. Experimental data are stored in CERN's Exascale Open Storage system, and most of the servers in the CERN computing centre are running on Openstack – an open-source cloud infrastructure to which CERN is an active contributor. Of course, CERN also relies heavily on open-source GNU/Linux as both a server and desktop operating system. On the accelerator and physics analysis side, it's all about open source. From C2MON, a system at the heart of accelerator monitoring and data acquisition, to ROOT, the main data-analysis framework used to analyse experimental data, the vast majority of the software components behind the science done at CERN are released under an open-source licence.

Open hardware

The success of the open-source model for software has inspired CERN engineers to create an analogous "open hardware" licence, enabling electronics designers to collaborate and use, study, share and improve the designs of hardware components used for physics experiments. This approach has become popular in many sciences, and has become a lifeline for teaching and research in developing countries.

Being a scientist in the digital age means being a software producer and a software consumer. As a result, collaborative software-development platforms such as GitHub and GitLab have become as important to the physics department as they are to the IT department. Until recently, the software underlying an analysis has not been easily shared. CERN has therefore been developing research data-management tools to enable the publication of software and data, forming the basis of an open-data portal (see p31). Naturally, this software itself is open source and has also been used to create the worldwide open-data service Zenodo, which is connected to GitHub to make the publication of open-source software a standard part of the research cycle.

Interestingly, as with the early days of open source, many corners of the scientific community are hesitant about open science. Some people are concerned that their software and data are not of sufficient quality or interest to be shared, or that they will be helping others to the next discovery before them. To triumph over the sceptics, open science can learn from the open-source movement, adopting standard licences, credit systems, collaborative development techniques and shared governance. In this way, it too will be able to reap the benefits of open collaboration: transparency, efficiency, perpetuity and flexibility. ●

A TURNING POINT FOR OPEN-ACCESS PUBLISHING

The European Commission is embarking on an ambitious project called Plan S to make all scientific publications open access from 2020, but particle physics is ahead of the game.

THE AUTHOR
Cristina Agrigoroae
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High-energy physics (HEP) has been at the forefront of open-access publishing, the long-sought ideal to make scientific literature freely available. An early precursor to the open-access movement in the late 1960s was the database management system SPIRES (Stanford Physics Information Retrieval System), which aggregated all available (paper-copy) preprints that were sent between different institutions. SPIRES grew to become the first database accessible through the web in 1991 and later evolved into INSPIRE-HEP, hosted and managed by CERN in collaboration with other research laboratories.

The electronic era

The birth of the web in 1989 changed the publishing scene irreversibly. Vast sums were invested to take the industry from paper to online and to digitise old content, resulting in a migration from the sale of printed copies of journals to electronic subscriptions. From 1991, helped by the early adoption by particle physicists, the self-archiving repository arXiv.org allowed rapid distribution of electronic preprints in physics and, later, mathematics, astronomy and other sciences. The first open-access journals then began to sprout up and in early 2000 three major international events – the Budapest Open Access Initiative, Bethesda Statement on Open Access Publishing and the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities – set about leveraging the new technology to grant universal free access to the results of scientific research.

Today, roughly one quarter of all scholarly literature in sciences and humanities is open access. In HEP, the figure is almost 90%. The Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP3), a global partnership between libraries, national funding agencies and publishers of HEP journals, has played an important role in HEP's success. Designed at CERN, SCOAP3 started operation in 2014 and removes subscription fees for journals and any expenses scientists might incur to publish their articles open access by paying publishers directly. Some 3000 institutions from 43 countries (figure 1) contribute financially according to their scientific output in the field, re-using funds previously spent on subscription fees for journals that are now open access.

"SCOAP3 has demonstrated how open access can increase the visibility of research and ease the dissemination of scientific results for the benefit of everyone," says SCOAP3 operations manager Alex Kohls of CERN. "This initiative was made possible by a strong collaboration of the worldwide library community, researchers, as well as commercial and society publishers, and it can certainly serve as an inspiration for open access in other fields."

Plan S

On 4 September 2018, a group of national funding agencies, the European Commission (EC) and the European Research Council – under the name "cOAlition S" – launched a radical initiative called Plan S. Its aim is to ensure that, by 2020, all scientific publications that result from research funded by public grants must be published in compliant open-access journals or platforms. Robert-Jan Smits, the EC's open-access envoy and one of the architects of Plan S, cites SCOAP3 as an inspiration for the project and says that momentum for Plan S has been building for two decades. "During those years many declarations, such as the Budapest and Berlin ones, were adopted, calling for a rapid transition to full and immediate open access. Even

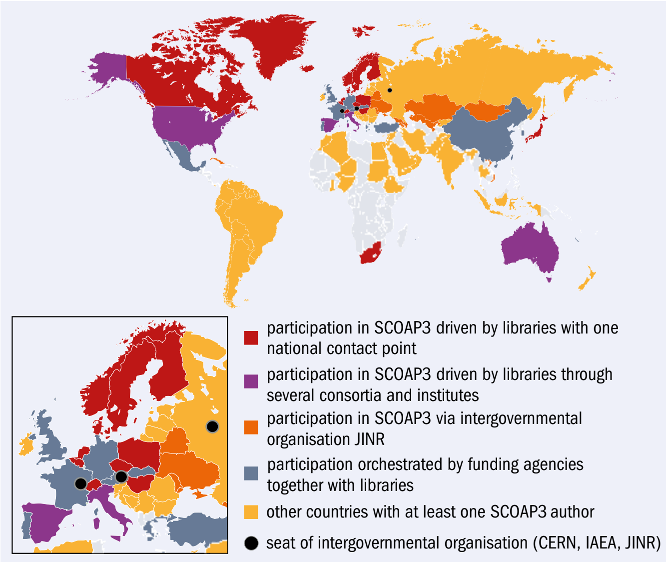

Fig. 1. *Participating countries in SCOAP3, which has helped take the percentage of particle-physics articles that are published open access to 90%.*

the 28 science ministers of the European Union issued a joint statement in 2016 that open access to scientific publications should be a reality by 2020," says Smits. "The current situation shows, however, that there is still a long way to go."

Recently, China released position papers supporting the efforts of Plan S, which could mark a key moment for the project. But the reaction of scientists around the world has been mixed. An open letter published in September by biochemist Lynn Kamerlin of Uppsala University in Sweden, attracting more than 1600 signatures at the time of writing, argues that Plan S would strongly reduce the possibilities to publish in suitable scientific journals of high quality, possibly splitting the global scientific community into two separate systems. Another open letter, published in November by biologist Michael Eisen at University of California Berkeley with around 2000 signatures, backs the principles of Plan S and supports its commitment "to continue working with funders, universities, research institutions and other stakeholders until we have created a stable, fair, effective and open system of scholarly communication."

The reaction of scientists around the world has been mixed

Challenges ahead

High-energy physics is already aligned to the Plan S vision thanks to SCOAP3, says Salvatore Mele of CERN, who is one of SCOAP3's architects. But for other disciplines "the road ahead is likely to be bumpy". "Funders, libraries and publishers have cooperated through CERN to make SCOAP3 possible. As most of the tens of thousands of scholarly journals today operate on a different model, with access mostly limited to readers paying subscription fees, this vision implies systemic challenges for all players: funders, libraries, publishers and, crucially, the wider research community," he says.

It is publishers who are likely to face the biggest impact from Plan S. However, the Open Access Scholarly Publishers Association (OASPA) – which includes, among others, the American Physical Society, IOP Publishing (which publishes *CERN Courier*) and The Royal Society – recently published a statement of support, claiming OASPA "would welcome the opportunity to provide guidance and recommendations for how the funding of open-access publications should be implemented within Plan S", while emphasising that smaller publishers, scholarly societies and new publishing platforms need to be included in the decision-making process.

Responding to an EC request for Plan S feedback that was open until 8 February, however, publishers have expressed major concerns about the pace of implementation and about the consequences of Plan S for hybrid journals. In a statement on 12 February, the European Physical Society, while supportive of the Plan S rationale, wrote that "several of the governing principles proposed for its implementation are not conducive to a transition to open access that preserves the important assets of today's scientific publication system". In another statement, the world's largest open-access publisher, Springer Nature, released a list of six recommendations for funding bodies worldwide to adopt in order for full open-access to become a reality, highlighting the differences between "geographic, funder and disciplinary needs". In parallel, a group of learned societies in mathematics and science in Germany has reacted with a statement citing a "precipitous process" that infringes the freedom of science, and urged cOAlition S to "slow down and consider all stakeholders".

Global growth

Smits thinks traditional publishers, which are a critical element in quality control and rigorous peer review in scholarly literature, should adopt a fresh look, for example by implementing more transparent metrics. "It is obvious that the big publishers that run the subscription journals and make enormous profits prefer to keep the current publishing model. Furthermore, the dream of each scientist is to publish in a so-called prestigious high-impact journal, which shows that the journal impact factor is still very present in the academic world," says Smits. "To arrive at the necessary change in academic culture, new metrics need to be developed to assess scientific output. The big challenge for cOAlition S is to grow globally, by having more funders signing up."

Undoubtedly we are at a turning point between the old and new publishing worlds. The EC already requires that all publications from projects receiving its funding be made open access. But Plan S goes further, proposing an outright shift in scholarly publication. It is therefore crucial to ensure a smooth shift that takes into account all the actors, says Mele. "Thanks to SCOAP3, which has so far supported the publication of more than 26,000 articles, the high-energy physics community is fortunate to meet the vision of Plan S, while retaining researcher choice of the most appropriate place to publish their results." ●

Further reading

www.coalition-s.org.

scoap3.org.

Through the looking glass *A student studying ALICE data during a particle-physics masterclass in 2011.*

PRESERVING THE LEGACY OF PARTICLE PHYSICS

While poring over increasingly voluminous datasets, the LHC collaborations are making sure that students and scientists of tomorrow can revisit the ground-breaking analyses of today.

In the 17th century, Galileo Galilei looked at the moons of Jupiter through a telescope and recorded his observations in his now-famous notebooks. Galileo's notes – his data – survive to this day and can be reviewed by anyone around the world. Students, amateurs and professionals can replicate Galileo's data and results – a tenet of the scientific method.

In particle physics, with its unique and expensive experiments, it is practically impossible for others to attempt to reproduce the original work. When it is impractical to gather fresh data to replicate an analysis, we settle for reproducing the analysis with the originally obtained data. However, a 2013 study by researchers at the University of British Columbia, Canada, estimates that the odds of scientific data existing in an analysable form reduce by about 17% each year.

Indeed, just a few years down the line it might not even be possible for researchers to revisit their own data due to changes in formats, software or operating systems. This has led to growing calls for scientists to release and archive their data openly. One motivation is moral: society funds research and so should have access to all of its outputs. Another is practical: a fresh look at data could enable novel research and lead to discoveries that may have eluded earlier searches.

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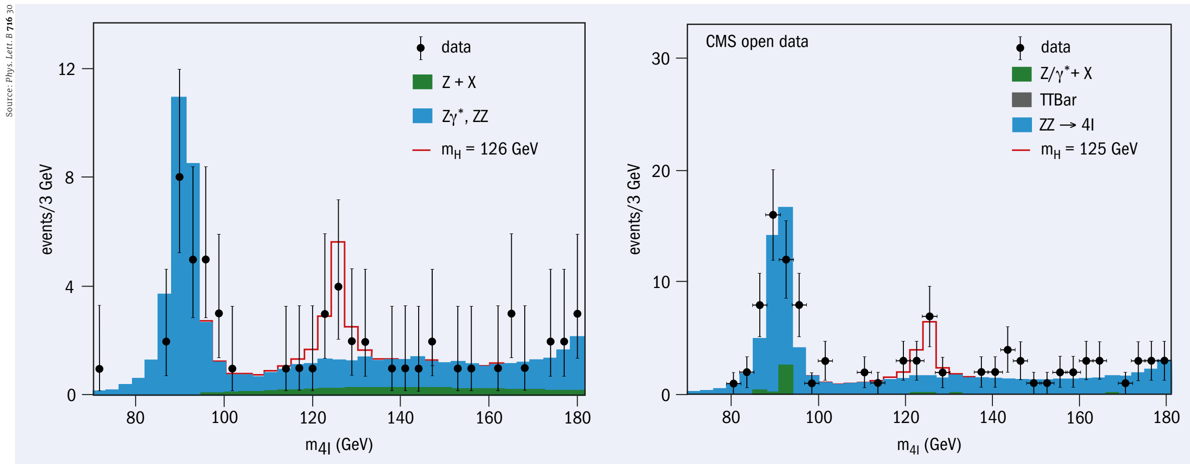

Fig. 1. *The official CMS plot for the Higgs-to-four-lepton channel shown during the Higgs-boson discovery announcement (left), and a similar plot (right) produced using CMS open data that contains more data but has not been scrutinised by CMS experts.*

Like open-access publishing (see p29), governments have started to impose demands on scientists regarding the availability and long-term preservation of research data. The European Commission, for example, has piloted the mandatory release of open data as part of its Horizon 2020 programme and plans to invest heavily in open data in the future. An increasing number of data repositories have been established for life and medical sciences as well as for social sciences and meteorology, and the idea is gaining traction across disciplines. Only days after they announced the first observation of gravitational waves, the LIGO and VIRGO collaborations made public their data. NASA also releases data from many of its missions via open databases, such as exoplanet catalogues. The Natural History Museum in London makes data from millions of specimens available via a website and, in the world of art, the Rijksmuseum in Amsterdam provides an interface for developers to build apps featuring historic artworks.

Data levels

The open-data movement is of special interest to particle physics, owing to the uniqueness and large volume of datasets involved in discoveries such as that of the Higgs boson at the Large Hadron Collider (LHC). The four main LHC experiments have started to periodically release their data in an open manner, and these data can be classified into four levels. The first consists of the data shown in final publications, such as plots and tables, while the second concerns datasets in a simplified format that are suitable for "lightweight" analyses in educational or similar contexts. The third level involves the data being used for analysis by the researchers themselves, requiring specialised code and dedicated computing resources, and the final level with the highest complexity is the raw data generated by the detectors, which requires petabytes of storage and, uncalibrated, is not of much use without being fed to the third tier.

Governments have started to impose demands on scientists regarding the availability of research data

In late 2014 CERN launched an open-data portal and released research data from the LHC for the first time. The data, collected by the CMS experiment, represented half the level-three data recorded in 2010. The ALICE experiment has also released level-three data from proton–proton as well as lead–lead collisions, while all four collaborations – including ATLAS and LHCb – have released subsets of level-two data for education and outreach purposes.

Proactive policy

The story of open data at CMS goes back to 2011. "We started drafting an open-data policy, not because of pressure from funding agencies but because defining our own policy proactively meant we did not have an external body defining it for us," explains Kati Lassila-Perini, who leads the collaboration's data-preservation project. CMS aims to release half of each year's level-three data three years after data taking, and 100% of the data within a ten-year window. By guaranteeing that people outside CMS can use these data, says Lassila-Perini, the collaboration can ensure that the knowledge of how to analyse the data is not lost, while allowing people outside CMS to look for things the collaboration might not have time for. To allow external re-use of the data, CMS released appropriate metadata as well as analysis examples. The datasets soon found takers and, in 2017, a group of theoretical physicists not affiliated with the collaboration published two papers using them. CMS has since released half its 2011 data (corresponding to around 200 TB) and half its 2012 data (1 PB), with the first releases of level-three data from the LHC's Run 2 in the pipeline.

The LHC collaborations have been releasing simpler datasets for educational activities from as early as 2011, for example for the International Physics Masterclasses that involve thousands of high-school students around the globe each year. In addition, CMS has made available several Jupyter notebooks – a browser-based analysis platform named with a nod to Galileo – in assorted languages (programming and human) that allow anyone with an internet connection to perform a basic analysis. "The real impact of open data in terms of numbers of users is in schools," says Lassila-Perini. "It makes it possible for young people with no previous contact with coding to learn about data analysis and maybe discover how fascinating it can be." Also available from CMS are more complex examples aimed at university-level students.

Open-data endeavours by ATLAS are very much focused on education, and the collaboration has provided curated datasets for teaching in places that may not have substantial computing resources or internet access. "Not even the documentation can rely on online content, so everything we produce needs to be self-contained," remarks Arturo Sánchez Pineda, who coordinates ATLAS's open-data programme. ATLAS datasets and analysis tools, which also rely on Jupyter notebooks, have been optimised to fit on a USB memory stick and allow simplified ATLAS analyses to be conducted just about anywhere in the world. In 2016, ATLAS released simplified open data corresponding to 1 fb^{-1} at 8 TeV, with the aim of giving university students a feel for what a real particle-physics analysis involves.

ATLAS open data have already found their way into university theses and have been used by people outside the collaboration to develop their own educational tools. Indeed, within ATLAS, new members can now choose to work on preparing open data as their qualification task to become an ATLAS co-author, says Sánchez Pineda. This summer, ATLAS will release 10 fb^{-1} of level-two data from Run 2, with more than 100 simulated physics processes and related resources. ATLAS does not provide level-three data openly and researchers interested in analysing these can do so through a tailored association programme, which 80 people have taken advantage of so far. "This allows external scientists to rely on ATLAS software, computing and analysis expertise for their project," says Sánchez Pineda.

The real impact of open data in terms of numbers of users is in schools

Fundamental motivation

CERN's open-data portal hosts and serves data from the four big LHC experiments, also providing many of the software tools including virtual machines to run the analysis code. The OPERA collaboration recently started sharing its research data via CERN and other particle-physics collaborations are interested in joining the project.

Although high-energy physics has made great strides in providing open access to research publications, we are still in the very early days of open data. Theorist Jesse Thaler of MIT, who led the first independent analysis using CMS open data, acknowledges that it is possible for people to get their hands on coveted data by joining an experimental collaboration, but sees a much brighter future with open data. "What about more exploratory studies where the theory hasn't yet been invented? What about engaging undergraduate students? What about examining old data for signs of new physics?" he asks. These provocative questions serve as fundamental motivations for making all data in high-energy physics as open as possible. ●

Further reading
opendata.cern.ch.

THE AUTHOR
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CERN COURIER
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FIXED TARGET, STRIKING PHYSICS

A strong tradition of innovation and ingenuity shows that, for CERN's North Area, life really does begin at 40.

As generations of particle colliders have come and gone, CERN's fixed-target experiments have remained a backbone of the lab's physics activities. Notable among them are those fed by the Super Proton Synchrotron (SPS). Throughout its long service to CERN's accelerator complex, the 7 km-circumference SPS has provided a steady stream of high-energy proton beams to the North Area at the Prévessin site, feeding a wide variety of experiments. Sequentially named, they range from the pioneering NA1, which measured the photoproduction of vector and scalar bosons, to today's NA64, which studies the dark sector. As the North Area marks 40 years since its first physics result, this hub of experiments large and small is as lively and productive as ever. Its users continue to drive developments in detector design, while reaping a rich harvest of fundamental physics results.

Specialised and precise

In fixed-target experiments, a particle beam collides with a target that is stationary in the laboratory frame, in most cases producing secondary particles for specific studies. High-energy machines like the SPS, which produces proton beams with a momentum up to 450 GeV/c, give the secondary products a large forward boost, providing intense sources of secondary and tertiary particles such as electrons, muons and hadrons. With respect to collider experiments, fixed-target experiments tend to be more specialised and focus on precision measurements that demand very high statistics, such as those involving ultra-rare decays.

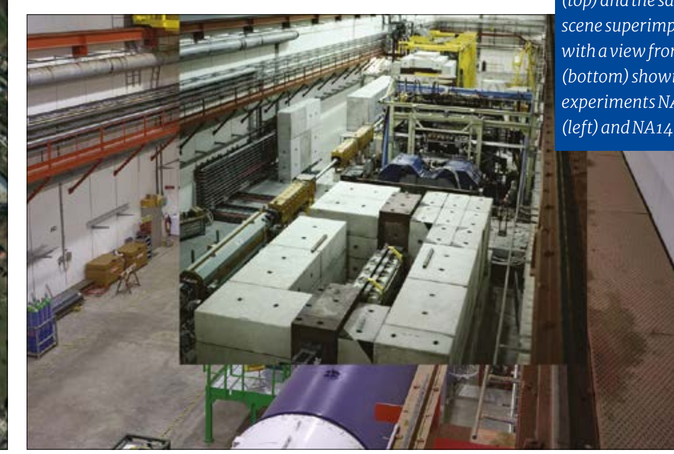
Fixed-target experiments have a long history at CERN, forming essential building blocks in the physics landscape in parallel to collider facilities. Among these were the first studies of the quark–gluon plasma, the first evidence of direct CP violation and a detailed understanding of how nucleon spin arises from quarks and gluons. The first muons in CERN's North Area were reported at the start of the commissioning run in March 1978, and the first physics publication – a measurement of the production rate of muon pairs by quark–antiquark annihilation as predicted by Drell and Yan – was published in 1979 by the NA3 experiment. Today, the North Area's physics programme is as vibrant as ever.

The longevity of the North Area programme is explained by the unique complex of proton accelerators at CERN, where each machine is not only used to inject the protons into the next one but also serves its own research programme (for example, the Proton Synchrotron Booster serves the ISOLDE facility, while the Proton Synchrotron serves the Antiproton Decelerator and the n_TOF experiment). Fixed-target experiments using protons from the SPS started taking data while the ISR collider was already in operation in the late 1970s, continued during SPS operation as a proton–antiproton collider in the early 1980s, and again during the LEP and now LHC eras. As has been the case with collider experiments, physics puzzles and unexpected results were often at the origin of unique collaborations and experiments, pushing limits in several technology areas such as the first use of silicon-microstrip detectors.

THE AUTHORS

Augusto Ceccucci, Gerhard Mallot *and* **Lau Gatignon** *CERN.*

North Area *Protons leaving the SPS enter a target station (bottom left), leading to 6 km of secondary beamlines for experiments in three halls.*



M Brice

Past times *The ECN3 underground hall today, showing experiment NA62 (top) and the same scene superimposed with a view from 1980 (bottom) showing experiments NA10 (left) and NA14 (right).*

The initial experimental programme in the North Area involved two large experimental halls: EHN1 for hadronic studies and EHN2 for muon experiments. The first round of experiments in EHN1 concerned studies of: meson photoproduction (NA1); electromagnetic form factors of pions and kaons (NA7); hadronic production of particles with large transverse momentum (NA3); inelastic hadron scattering (NA5); and neutron scattering (NA6). In EHN2 there were experiments devoted to studies with high-intensity muon beams (NA2 and NA4). A third, underground, area called ECN3 was added in 1980 to host experiments requiring primary proton beams and secondary beams of the highest intensity (up to 10^{10} particles per cycle).

Experiments in the North Area started a bit later than those in CERN's West Area, which started operation in 1971 with 28 GeV/c protons supplied by the PS. Built to serve the last stage of the PS neutrino programme and the Omega spectrometer, the West Area zone was transformed into an SPS area in 1975 and is best known for seminal neutrino experiments (by the CDHS and CHARM collaborations, later CHORUS and NOMAD) and hadron-spectroscopy experiments with Omega. We are now used to identifying experimental collaborations by means of fancy acronyms such as ATLAS or ALICE, to mention two of the large LHC collaborations. But in the 1970s and the 1980s, one could distinguish between the experiments (identified by a sequential number)

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Forty years of fixed-target physics at CERN's North Area

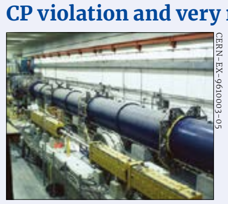
Probing nucleon structure with high-energy muons

High-energy muons are excellent probes with which to investigate the structure of the nucleon. The North Area's EHN2 hall was built to house two sets of muon experiments: the sequential NA2/NA9/NA28 (also known as the European Muon Collaboration, EMC), which made the observation that nucleons bound in nuclei are different from free nucleons; and NA4 (pictured above), which confirmed the electroweak effects between the weak and electromagnetic interactions. A particular success of the North Area's muon experiments concerned the famous "proton spin crisis". In the late-1980s, contrary to the expectation by the otherwise successful quark–parton model, data showed that the proton's spin is not carried by the quark spins. This puzzle interested the community for decades, compelling CERN to further investigate by building the NA47 Spin Muon collaboration experiment in the early 1990s (which established the same result for the neutron) and, subsequently, the COMPASS experiment (which studied the contribution of the gluon spins to the nucleon spin). A second phase of COMPASS still ongoing today, is devoted to nucleon tomography using deeply virtual Compton scattering and, for the first time, polarised Drell–Yan reactions. Hadron spectroscopy is another area of research at the North Area, and among recent important results from COMPASS is the measurement of pion polarisability, which is an important test of low-energy QCD.

Hadroproduction and photoproduction at high energy

Following the first experiment to publish data in the North Area (NA3) concerning the production of $\mu^+\mu^-$ pairs from hadron collisions, the ingenuity to combine bubble chambers and electronic detectors led to a series of experiments. The European Hybrid Spectrometer facility housed NA13, NA16, NA22, NA23 and NA27, and studied charm production and many aspects of hadronic physics, while photoproduction of heavy bosons was the primary aim of NA1. A measurement of the charm lifetime using the first ever microstrip silicon detectors was pioneered by the ACCMOR collaboration (NA11/NA32; see image of Robert Klanner next to the ACCMOR spectrometer in 1977), and hadron spectroscopy with neutral final states was studied by NA12 (GAMS), which employed a large array of lead glass counters, in particular a search for glueballs. To study $\mu^+\mu^-$ pairs from pion interactions at the highest possible intensities, the toroidal spectrometer NA10 was housed in the ECN3 underground cavern. Nearby in the same cavern, NA14 used a silicon active target and the first big microstrip silicon detectors (10,000 channels) to study charm photoproduction at high intensity. Later, experiment NA30 enabled a direct measurement of the π^0 lifetime by employing thin gold foils to convert the photons from the π^0 decays. Today, electron beams are used by NA64 to look for dark photons while hadron spectroscopy is still actively pursued, in particular at COMPASS.

CP violation and very rare decays



The discovery of CP violation in the decay of the long-lived neutral kaon to two pions at Brookhaven National Laboratory in 1964 was unexpected. To understand its origin, physicists needed to make a subtle comparison (in the form of a double ratio) between long- and short-lived neutral kaon decays in pairs of neutral and charged kaons. In 1987 an ambitious experiment (NA31) showed a deviation from one of the double ratios, providing the first evidence of direct CP violation (that is, it happens in the decay of the neutral mesons, not only in the mixing between neutral kaons). A second-generation experiment (NA48, pictured above in 1996), located in ECN3 to accept a much higher primary-proton intensity, was able to measure the four decay modes concurrently thanks to the deflection of a tiny fraction of the primary proton beam into a downstream target via channelling in a "bent" crystal. NA48 was approved in 1991 when it became evident that more precision was needed to confirm the original observation (a competing programme at Fermilab called E731 did not find a significant deviation from the unity of the double ratio). Both KTeV (the follow-up Fermilab experiment) and NA48 confirmed NA31's results, firmly establishing direct CP violation. Continuations of the NA48 experiments studied rare decays of the short-lived neutral kaon and searched for direct CP violation in charged kaons. Nowadays the kaon programme continues with NA62, which is dedicated to the study of very rare $K^+ \to \pi^+\nu\bar{\nu}$ decays and is complementary to the B-meson studies performed by the LHCb experiment.

Heavy-ion experiments

In the mid-1980s, with a view to reproduce in the laboratory the plasma of free quarks and gluons predicted by QCD and believed to have existed in the early universe, the SPS was modified to accelerate beams of heavy ions and collide them with nuclei. The lack of a single striking signature of the formation of the plasma demands that researchers look for as many final states as possible, exploiting the evolution of standard observables (such as the yield of muon pairs from the Drell–Yan process or the production rate of strange quarks) as a function of the degree of overlap of the nuclei that participate in the collision (centrality). By 2000 several experiments had, according to *CERN Courier* in March that year, found "tantalising glimpses of mechanisms that shaped our universe". The experiments included NA44, NA45, NA49, NA50, NA52 and NA57, as well as WA97 and WA98 in the West Area. Among the most popular signatures observed was the suppression of the J/ψ yield in ion–nucleus collisions with respect to proton–proton collisions, which was seen by NA50. Improved sensitivity to muon pairs was provided by the successor experiment NA60. The current heavy-ion programme at the North Area includes NA61/SHINE (see image above), the successor of NA49, which is studying the onset of phase transitions in dense quark–gluon matter at different beam energies and for different beam species. Studies of the quark–gluon plasma continue today, in particular at the LHC and at RHIC in the US. At the same time, NA61/SHINE is measuring the yield of mesons from replica targets for neutrino experiments worldwide and particle production for cosmic-ray studies.

Then and now *EHN1, the largest of the North Area's halls, photographed in 1980 (left) and today (right) showing the NA64 experiment.*

and the collaborations (identified by the list of the cities hosting the collaborating institutes). For instance CDHS stood for the CERN–Dortmund–Heidelberg–Saclay collaboration that operated the WA1 experiment in the West Area. Los Alamos, SLAC, Fermilab and Brookhaven National Laboratory in the US, JINR and the Institute for High Energy Physics in Russia, and KEK in Japan, for example, also all had fixed-target programmes, some of which date back to the 1960s. As fixed-target programmes got into their stride, however, colliders were commanding the energy frontier. In 1980 the CERN North Area experimental programme was reviewed in a special meeting held in Cogne, Italy, and it was not completely obvious that there was a compelling physics case ahead. But it also led to highly optimised installations thanks to strong collaborations and continuous support from the CERN management. Advances in detectors and innovations such as silicon detectors and aerogel Cherenkov counters, plus the hybrid integration of bubble chambers with electronic detectors, led to a revamp in the study of hadron interactions at fixed-target experiments, especially for charmed mesons.

Nucleon tomography *The COMPASS experiment in EHN2 pictured in late 2018 (see panel, left).*

Physics landscape

Experiments at CERN's North Area began shortly after the Standard Model had been established, when the scale of experiments was smaller than it is today. According to the 1979 CERN annual report, there were 34 active experiments at the SPS (West and North areas combined) and 14 were completed in 1978. This article cannot do justice to all of them, not even to those in the North Area. But over the past 40 years the experimental programme has clearly evolved into at least four main themes: probing nucleon structure with high-energy muons; hadroproduction and photoproduction at high energy; CP violation in very rare decays; and heavy-ion experiments (see page left).

Aside from seminal physics results, fixed-target experiments at the North Area have driven numerous detector innovations. This is largely a result of their simple geometry and ease of access, which allows more adventurous technical solutions than might be possible with collider experiments. Examples of detector technologies perfected at the North Area include: silicon microstrips and active targets (NA11, NA14); rapid-cycling bubble chambers (NA27); holographic bubble chambers (NA25); Cherenkov detectors (CEDAR, RICH); liquid-krypton calorimeters (NA48); micromegas gas detectors (COMPASS); silicon pixels with 100 ps time resolution (NA62); time-projection chambers with dE/dx measurement (ISIS, NA49); and many more. The sheer amount of data to be recorded in these experiments also led to the very early adoption of PC farms for the online systems of the NA48 and COMPASS experiments.

Another key function of the North Area has been to test and calibrate detectors. These range from the fixed-target experiments themselves to experiments at colliders (such as LHC, ILC and CLIC), space and balloon experiments, and bent-crystal applications (such as UA9 and NA63). New detector concepts such as dual-readout calorimetry (DREAM) and particle-flow calorimetry (CALICE) have also been developed and optimised. Recently the huge EHN1 hall was extended by 60 m to house two very large liquid-argon prototype detectors to be tested for the Deep Underground Neutrino Experiment under construction in the US.

If there is an overall theme concerning the development of the fixed-target programme in the North Area, one could say that it was to be able to quickly evolve and adapt to address the compelling questions of the day. This looks set to remain true, with many proposals for new experiments appearing on the horizon, ranging from the study of very rare decays and light dark matter to the study of QCD with hadron and heavy-ion beams. There is even a study under way to possibly extend the North Area with an additional very-high-intensity proton beam serving a beam dump facility. These initiatives are being investigated by the Physics Beyond Collider study (see p20), and many of the proposals explore the high-intensity frontier complementary to the high-energy frontier at large colliders. Here's to the next 40 years of North Area physics! ●

As fixed-target programmes got into their stride, colliders were commanding the energy frontier

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CERN'S ULTIMATE ACT OF OPENNESS

The seed that led CERN to relinquish ownership of the web in 1993 was planted when the Organization formally came into being.

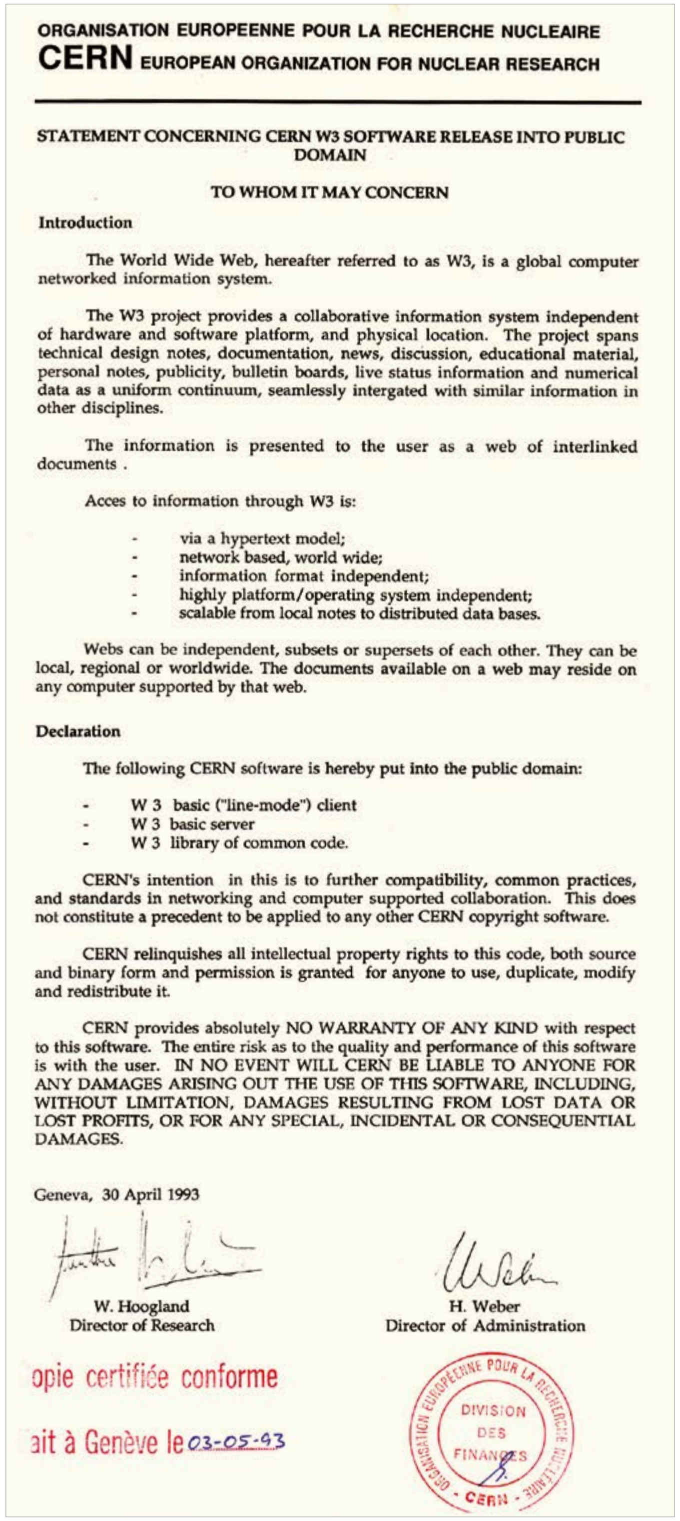
At a mere 30 years old, the World Wide Web already ranks as one of humankind's most disruptive inventions. Developed at CERN in the early 1990s, it has touched practically every facet of life, impacting industry, penetrating our personal lives and transforming the way we transact. At the same time, the web is shrinking continents and erasing borders, bringing with it an array of benefits and challenges as humanity adjusts to this new technology.

This reality is apparent to all. What is less well known, but deserves recognition, is the legal dimension of the web's history. On 30 April 1993, CERN released a memo (pictured right) that placed into the public domain all of the web's underlying software: the basic client, basic server and library of common code. The document was addressed "To whom it may concern" – which would suggest the authors were not entirely sure who the target audience was. Yet, with hindsight, this line can equally be interpreted as an unintended address to humanity at large.

The legal implication was that CERN relinquished all intellectual property rights in this software. It was a deliberate decision, the intention being that a no-strings-attached release of the software would "further compatibility, common practices, and standards in networking and computer supported collaboration" – arguably modest ambitions for what turned out to be such a seismic technological step. To understand what seeded this development you need to go back to the 1950s, at a time when "software" would have been better understood as referring to clothing rather than computing.

European project

CERN was born out of the wreckage of World War II, playing a role, on the one hand, as a mechanism for reconciliation between former belligerents, while, on the other, offer-



ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

STATEMENT CONCERNING CERN W3 SOFTWARE RELEASE INTO PUBLIC DOMAIN

TO WHOM IT MAY CONCERN

Introduction

The World Wide Web, hereafter referred to as W3, is a global computer networked information system.

The W3 project provides a collaborative information system independent of hardware and software platform, and physical location. The project spans technical design notes, documentation, news, discussion, educational material, personal notes, publicity, bulletin boards, live status information and numerical data as a uniform continuum, seamlessly intergated with similar information in other disciplines.

The information is presented to the user as a web of interlinked documents .

Acces to information through W3 is:

- via a hypertext model;
- network based, world wide;
- information format independent;
- highly platform/operating system independent;
- scalable from local notes to distributed data bases.

Webs can be independent, subsets or supersets of each other. They can be local, regional or worldwide. The documents available on a web may reside on any computer supported by that web.

Declaration

The following CERN software is hereby put into the public domain:

- W 3 basic ("line-mode") client
- W 3 basic server
- W 3 library of common code.

CERN's intention in this is to further compatibility, common practices, and standards in networking and computer supported collaboration. This does not constitute a precedent to be applied to any other CERN copyright software.

CERN relinquishes all intellectual property rights to this code, both source and binary form and permission is granted for anyone to use, duplicate, modify and redistribute it.

CERN provides absolutely NO WARRANTY OF ANY KIND with respect to this software. The entire risk as to the quality and performance of this software is with the user. IN NO EVENT WILL CERN BE LIABLE TO ANYONE FOR ANY DAMAGES ARISING OUT THE USE OF THIS SOFTWARE, INCLUDING, WITHOUT LIMITATION, DAMAGES RESULTING FROM LOST DATA OR LOST PROFITS, OR FOR ANY SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES.

Geneva, 30 April 1993

W. Hoogland
Director of Research

H. Weber
Director of Administration

opie certifiée conforme

ait à Genève le 03-05-93

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
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ing European nuclear physicists the opportunity to conduct their research locally. The hope was that this would stem the "brain drain" to the US, from a Europe still recovering from the devastating effects of war.

In 1953, CERN's future Member States agreed on the text of the organisation's founding Convention, defining its mission as providing "for collaboration among European States in nuclear research of a pure scientific and fundamental character". With the public acutely aware of the role that destructive nuclear technology had played during the war, the Convention additionally stipulated that CERN was to have "no concern with work for military requirements" and that the results of its work, were to be "published or otherwise made generally available".

THE AUTHORS
Maarten Wilbers *and* **Jonathan Drakeford**
CERN legal service.

In the early years of CERN's existence, the openness resulting from this requirement for transparency was essentially delivered through traditional channels, in particular through publication in scientific journals. Over time, this became the cultural norm at CERN, permeating all aspects of its work both internally and with its collaborating partners and society at large. CERN's release of the WWW software into the public domain, arguably in itself a consequence of the openness requirement of the Convention, could be seen as a precursor to today's web-based tools that represent further manifestations of CERN's openness: the SCOAP3 publishing model, open-source software and hardware, and open data (see pp25–33).

CERN's release of the WWW software into the public domain could be seen as a precursor to today's web-based tools

Perhaps the best measure for how ingrained openness is in CERN's ethos as a laboratory is to ask the question: "if CERN would have known then what it knows now about the impact of the World Wide Web, would it still have made the web software available, just as it did in 1993?" We would like to suggest that, yes, our culture of openness would provoke the same response now as it did then, though no doubt a modern, open-source licensing regime would be applied.

A culture of openness

This, in turn, can be viewed as testament and credit to the wisdom of CERN's founders, and to the CERN Convention, which remains the cornerstone of our work to this day.

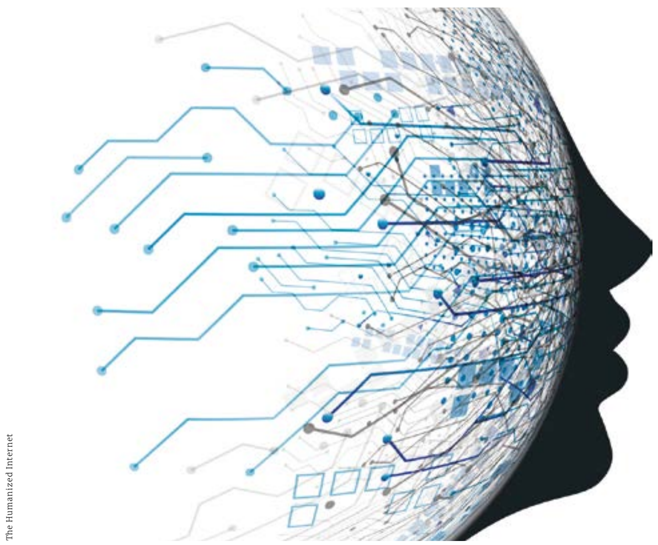
OPINION VIEWPOINT

Harnessing the web for humanity

New technologies can be used to give every human being secure and sovereign control over their own digital identity, argues Monique Morrow.

TEDxGeneva

Monique Morrow, *a former CTO at Cisco, is president and co-founder of The Humanized Internet. This article is based on her forthcoming book* The Humanized Internet *(River Publishers, Denmark).*



The Humanized Internet

What would you do if you were thrust into a world where suddenly you lacked control over who you were? If you had no way to prove where you were from, who you were related to, or what you had accomplished? If you lost all your documentation in a natural disaster, or were forced to leave your home without taking anything with you? Without proof of identity, people are unable access essential systems such as health, education and banking services, and they are also exceedingly vulnerable to trafficking and incarceration. Having and owning your identity is an essential human right that too many people are lacking.

More than 68 million people worldwide have been displaced by war and conflict, and over 25 million have fled their countries and gone from the designation of "citizen" to "refugee". They are often prevented from working in their new countries, and, even if they are allowed to work, many nations will not let personal credentials, such as licences to practise law or medicine, follow these people across their borders. We end up stripping away fundamental human dignities and leaving exorbitant amounts of untapped potential on the table. Countries need to recognise not just the right to identity but also that identity is portable across nation states.

The issue of sovereign identities extends much further than documentation. All over the world, individuals are becoming commodified by companies offering "free" services because their actual products are the users and their data. Every individual should have the right to decide to monetise their data if they want. But the speed, scale and stealth of such practises is making it increasingly difficult to retain control of our data.

Having and owning your identity is an essential human right that too many people in today's world are lacking

All of this is happening as we celebrate the 30th anniversary of the web. While there is no doubt that the web has been incredibly beneficial for humanity, it has also turned people into pawns and opened them up to new security risks. I believe that we can not only remedy these harms, but that we've yet to harness even a small fraction of the good that the web can do. Enter The Humanized Internet – a non-profit movement founded in 2017 that is working to use new technologies to give every human being secure, sovereign control over their own digital identity.

New technologies like blockchain, which allows digital information to be distributed but not copied, can allow us to tackle this issue. Blockchain has some key differences with today's databases. First, it allows participants to see and verify all data involved, minimising chances of fraud. Second, all data is verified and encrypted before being added to an individual block in such a way that a hacker would need to have exponentially more computing power to break in than is required in today's systems. These characteristics allow blockchain to provide public ledgers that participants trust based on the agreed-upon consensus protocol. Once data transactions are on a block, they cannot be overwritten, and no central institution holds control, as these ledgers are visible to all the users connected to them. Users' identities within a ledger are known only to the users themselves.

The first implication of this technology is that it can help to establish a person's citizenship in their state of origin and enable registration of official records. Without this many people would be considered stateless and granted almost no rights or diplomatic protections. For refugees, digital identities also allow peer-to-peer donation and transparent public transactions. Additionally, digital identities create the ability to practise selective disclosure, where individuals can choose to share their records only at their own discretion.

We now need more people to get on board. We are already working with experts to discuss the potential of blockchain to improve inclusion in state-authenticated identity programmes and how to combat potential privacy challenges, in addition to e-voting systems that could allow inclusive participation in voting at all policy levels. We should all be the centre of our universe; our identity should be wholly and irrevocably our own.

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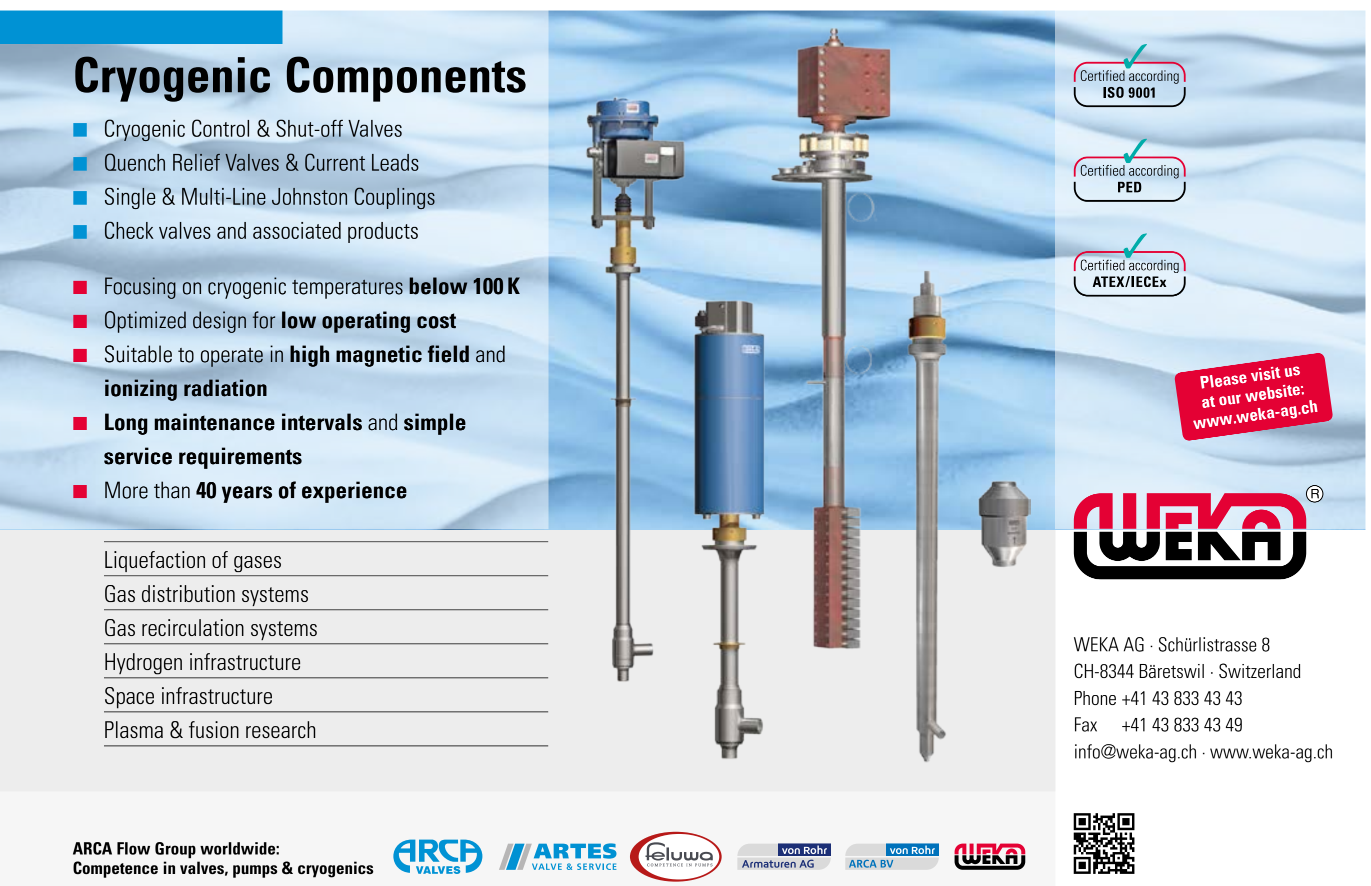
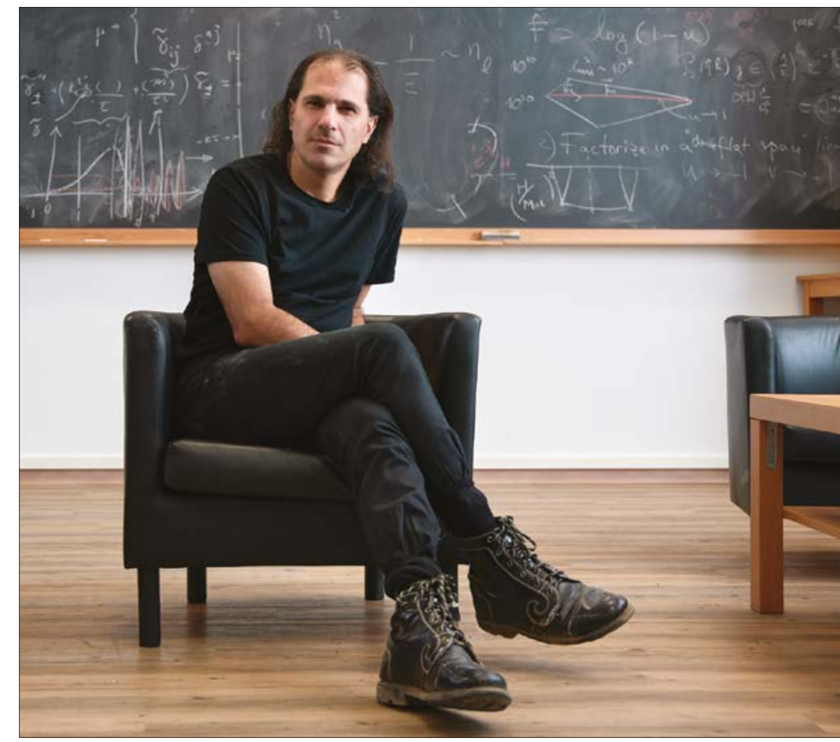


OPINION
INTERVIEW

In it for the long haul

We have conquered the easiest challenges in fundamental physics, says Nima Arkani-Hamed. The case for building the next major collider is now more compelling than ever.



Nima Arkani-Hamed *of the Institute for Advanced Study in Princeton (photographed at CERN) spoke to CERN Courier in February while attending the CERN Winter School on Supergravity, Strings and Gauge Theory.*

How do you view the status of particle physics?

There has never been a better time to be a physicist. The questions on the table today are not about this-or-that detail, but profound ones about the very structure of the laws of nature. The ancients could (and did) wonder about the nature of space and time and the vastness of the cosmos, but the job of a professional scientist isn't to gape in awe at grand, vague questions – it is to work on the *next* question. Having ploughed through all the "easier" questions for four centuries, these very deep questions finally confront us: what are space and time? What is the origin and fate of our enormous universe? We are extremely fortunate to live in the era when human beings first get to meaningfully attack these questions. I just wish I could adjust when I was born so that I could be starting as a grad student today! But not everybody shares my enthusiasm. There is cognitive dissonance. Some people are walking around with their heads hanging low, complaining about being disappointed or even depressed that we've "only discovered the Higgs and nothing else".

So who is right?

It boils down to what you think particle physics is really about, and what motivates you to get into this business. One view is that particle physics is the study of the building blocks of matter, in which "new physics" means "new particles". This is certainly the picture of the 1960s leading to the development of the Standard Model, but it's not what drew me to the subject. To me, "particle physics" is the study of the fundamental laws of nature, governed by the still mysterious union of space–time and quantum mechanics. Indeed, from the deepest theoretical perspective, the very definition of what a particle *is* invokes both quantum mechanics and relativity in a crucial way. So if the biggest excitement for you is a cross-section plot with a huge bump in it, possibly with a ticket to Stockholm attached, then, after the discovery of the Higgs, it makes perfect sense to take your ball and go home, since we can make no guarantees of this sort whatsoever. We're in this business for the long haul of decades and centuries, and if you don't have the stomach for it, you'd better do something else with your life!

Isn't the Standard Model a perfect example of the scientific method?

Sure, but part of the reason for the rapid progress in the 1960s is that the intellectual structure of relativity and quantum mechanics was already sitting there to be explored and filled in. But these more revolutionary discoveries took much longer, involving a wide range of theoretical and experimental

results far beyond "bump plots". So "new physics" is much more deeply about "new phenomena" and "new principles". The discovery of the Higgs particle – especially with nothing else accompanying it so far – is unlike anything we have seen in any state of nature, and is profoundly "new physics" in this sense. The same is true of the other dramatic experimental discovery in the past few decades: that of the accelerating universe. Both discoveries are easily accommodated in our equations, but theoretical attempts to compute the vacuum energy and the scale of the Higgs mass pose gigantic, and perhaps interrelated, theoretical challenges. While we continue to scratch our heads as theorists, the most important path forward for experimentalists is completely clear: measure the hell out of these crazy phenomena! From many points of view, the Higgs is the most important actor in this story amenable to experimental study, so I just can't stand all the talk of being disappointed by seeing nothing but the Higgs; it's completely backwards. I find that the physicists who worry about not being able to convince politicians are (more or less secretly) not able to convince *themselves* that it is worth building the next collider. Fortunately, we do have a critical mass of fantastic young experimentalists who believe it is worth studying the Higgs to death, while also exploring whatever might be at the energy frontier, with no preconceptions about what they might find.

What makes the Higgs boson such a rich target for a future collider?

It is the first example we've seen of the simplest possible type of elementary particle. It has no spin, no charge, only mass, and this extreme simplicity makes it theoretically perplexing. There is a striking difference between massive and massless particles that have spin. For instance, a photon is a massless particle of spin one; because it moves at the speed of light, we can't "catch up" with it, and so we only see it have two "polarisations", or ways it can spin. By contrast the Z boson, which also has spin one, is massive; since you can catch up with it, you can see it spinning in any of three directions. This "two not equal to three" business is quite profound. As we collide particles at ever increasing energies, we might think that their masses are irrelevant tiny perturbations to their energies, but this is wrong, since something must account for the extra degrees of freedom.

Had the LHC discovered supersymmetric particles, then the case for the next circular collider would be somewhat weaker

The whole story of the Higgs is about accounting for this "two not equal to three" issue, to explain the extra spin states needed for massive W and Z particles mediating the weak interactions. And this also gives us a good understanding of why the masses of the elementary particles should be pegged to that of the Higgs. But the huge irony is that we don't have any good understanding for what can explain the mass of the Higgs itself. That's because there is no difference in the number of degrees of freedom between massive and massless spin-zero particles, and related to this, simple estimates for the Higgs mass from its interactions with virtual particles in the vacuum are wildly wrong. There are also good theoretical arguments, amply confirmed in analogous condensed-matter systems and elsewhere in particle physics, for why we shouldn't have expected to see such a beast lonely, unaccompanied by other particles. And yet here we are. Nature clearly has other ideas for what the Higgs is about than theorists do.

Is supersymmetry still a motivation for a new collider?

Nobody who is making the case for future colliders is invoking, as a driving motivation, supersymmetry, extra dimensions or any of the other ideas that have been developed over the past 40 years for physics beyond the Standard Model. Certainly many of the versions of these ideas, which were popular in the 1980s and 1990s, are either dead or on life support given the LHC data, but others proposed in the early 2000s are alive and well. The fact that the LHC has ruled out some of the most popular pictures is a fantastic gift to us as theorists. It shows that understanding the origin of the Higgs mass must involve an even larger paradigm change than many had previously imagined. Ironically, had the LHC discovered supersymmetric particles, the case for the next circular collider would be somewhat weaker than it is now, because that would (indirectly) support a picture of a desert between the electroweak and Planck scales. In this picture of the world, most people wanted a linear electron–positron collider to measure the superpartner couplings in detail. It's a picture people very much loved in the 1990s, and a picture that appears to be wrong. Fine. But when theorists are more confused, it's the time for more, not less experiments.

What definitive answers will a future high-energy collider give us?

First and foremost, we go to high energies because it's the frontier, and we look around for new things. While there is absolutely no guarantee we will produce new particles, we will definitely stress test our existing laws in the most extreme environments we have ever probed. Measuring the properties of the Higgs, however, is guaranteed to answer some burning questions. All the drama revolving around the existence of the Higgs would go away if we saw that it had substructure of any sort. But from the LHC, we have only a fuzzy picture of how point-like the Higgs is. A Higgs factory will decisively answer this question via precision measurements of the coupling of the Higgs to a slew of other particles in a very clean experimental environment. After that the ultimate question is whether or not the Higgs looks point-like even when interacting with itself. The simplest possible interaction between elementary particles is when three particles meet at a space–time point. But we have actually never seen any single elementary particle enjoy this simplest possible interaction. For good reasons going back to the basics of relativity and quantum mechanics, there is always some quantum number that must change in this interaction – either spin or charge quantum numbers change. The Higgs is the only known elementary particle allowed to have this most basic process as its dominant self-interaction. A 100 TeV collider producing billions of Higgs particles will not only detect the self-interaction, but will be able to measure it to an accuracy of a few per cent. Just thinking about the first-ever probe of this simplest possible interaction in nature gives me goosebumps.

What are the prospects for future dark-matter searches?
Beyond the measurements of the Higgs properties, there are all sorts of exciting signals of new particles that can be looked for at both Higgs factories and 100 TeV colliders. One I find especially important is WIMP dark matter. There is a funny perception, somewhat paralleling the absence of supersymmetry at the LHC, that the simple paradigm of WIMP dark matter has been ruled out by direct-detection experiments. Nope! In fact, the very simplest models of WIMP dark matter are perfectly alive and well. Once the electroweak quantum numbers of the dark-matter particles are specified, you can unambiguously compute what mass an electroweak charged dark-matter particle should have so that its thermal relic abundance is correct. You get a number between 1–3 TeV, far too heavy to be produced in any sizeable numbers at the LHC. Furthermore, they happen to have miniscule interaction cross sections for direct detection. So these very simplest theories of WIMP dark matter are inaccessible to the LHC and direct-detection experiments. But a 100 TeV collider has just enough juice to either see these particles, or rule out this simplest WIMP picture.

What is the cultural value of a 100 km supercollider?
Both the depth and visceral joy of experiments in particle physics is revealed in how simple it is to explain: we smash things together with the largest machines that have ever been built, to probe the fundamental laws of nature at the tiniest distances we've ever seen. But it goes beyond that to something more important about our self-conception as people capable of doing great things. The world has all kinds of long-term problems, some of which might seem impossible to solve. So it's important to have a group of people who, generation after generation, give a concrete template for how to go about grappling with seemingly impossible problems, and who are driven by a calling far larger than themselves. Furthermore, suppose it's 200 years from now, and there are no big colliders on the planet. How can humans be sure that the Higgs or top particles exist? Because it says so in dusty old books? There is an argument to be made that as we advance we

The scientific issues at stake are more profound than they have been for many decades

should be able to do the things we did in the past. After all, the last time that fundamental knowledge was shoved in old dusty books was in the dark ages, and that didn't go very well for the West.

What about justifying the cost of the next collider?
There are a number of projects and costs we could be talking about, but let's call it \$5–25 billion. Sounds like a lot, right? But the global economy is growing, not shrinking, and the cost of accelerators as a fraction of GDP has barely changed over the past 40 years – even a 100 TeV collider is in this same ballpark. Meanwhile the scientific issues at stake are more profound than they have been for many decades, so we certainly have an honest science case to make that we need to keep going.

People sometimes say that if we don't spend billions of dollars on colliders, then we can do all sorts of other experiments instead. I am a huge fan of small-scale experiments, but this argument is silly because science funding is infamously not a zero-sum game. So, it's not a question of, "do we want to spend tens of billions on collider physics or something else instead", it is rather "do we want to spend tens of billions on fundamental physics experiments at all".

Another argument is that we should wait until some breakthrough in accelerator technology, rather than just building bigger machines. This is naïve. Of course miracles can always happen, but we can't plan doing science around miracles. Similar arguments were made around the time of the cancellation of the Superconducting Super Collider (SSC) 30 years ago, with prominent condensed-matter physicists saying that the SSC should wait for the development of high-temperature superconductors that would dramatically lower the cost. Of course those dreamed-of practical superconductors never materialised, while particle physics continued from strength to strength with the best technology available.

What do you make of claims that colliders are no longer productive?
It would be only to the good to have a no-holds barred, public discussion about the pros and cons of future colliders, led by people with a deep understanding of the relevant technical and scientific issues. It's funny that non-experts don't even make the best arguments for not building colliders; I could do a much better job than they do! I can point you to an awesomely fierce debate about future colliders that already took place in China two years ago: (*Int. J. Mod. Phys. A* **31** 1630053 and 1630054). C N Yang, who is one of the greatest physicists of the 20th century and enormously influential in China, came out with a strong attack on colliders, not only in China but more broadly. I was delighted. Having a serious attack meant there could be a serious response, masterfully provided by David Gross. It was the King Kong vs Godzilla of fundamental physics, played out on the pages of major newspapers in China, fantastic!

What are you working on now?
About a decade ago, after a few years of thinking about the cosmology of "eternal inflation" in connection with solutions to the cosmological constant and hierarchy problems, I concluded that these mysteries can't be understood without reconceptualising what space–time and quantum mechanics are really about. I decided to warm up by trying to understand the dynamics of particle scattering, like collisions at the LHC, from a new starting point, seeing space-time and quantum mechanics as being derived from more primitive notions. This has turned out to be a fascinating adventure, and we are seeing more and more examples of rather magical new mathematical structures, which surprisingly appear to underlie the physics of particle scattering in a wide variety of theories, some close to the real world. I am also turning my attention back to the goal that motivated the warm-up, trying to understand cosmology, as well as possible theories for the origin of the Higgs mass and cosmological constant, from this new point of view. In all my endeavours I continue to be driven, first and foremost, by the desire to connect deep theoretical ideas to experiments and the real world.

Interview by **Matthew Chalmers** *editor.*

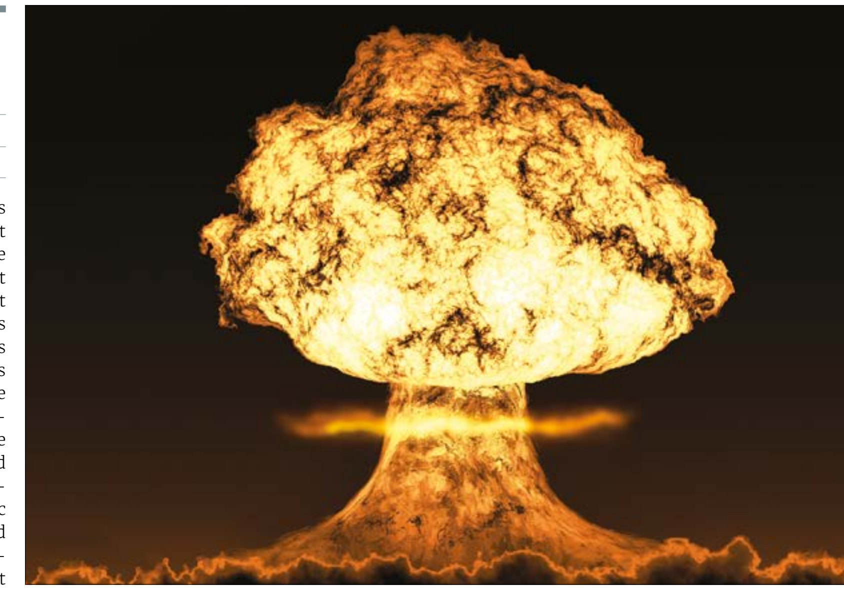
OPINION REVIEWS

Political intrigue and the arms race

The Soviet Atomic Project: How the Soviet Union Obtained the Atomic Bomb

By Lee G Pondrom

World Scientific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"Leave them in peace. We can always shoot them later." Thus spoke Soviet Union leader Josef Stalin, in response to a query by Soviet security and secret police chief Lavrentiy Beria about whether research in quantum mechanics and relativity (considered by Marxists to be incompatible with the principles of dialectical materialism) should be allowed. With these words, a generation of Soviet physical scientists were spared a disaster like the one perpetrated on Soviet agriculture by Trofim Lysenko's politically correct, pseudoscientific theories of genetics. The reason behind this judgement was the successful development of nuclear weapons by Soviet physical scientists and the recognition by Stalin and Beria of the essential role that these "*bourgeois*" sciences played in that development.

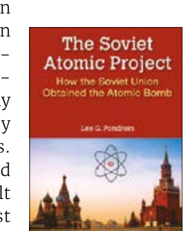
Gripping account

Political intrigue, the arms race, early developments of nuclear science, espionage and more are all present in this gripping book, which provides a comprehensive account of the intensive programme the Soviets embarked on in 1945, immediately after Hiroshima, to catch up with the US in the area of nuclear weapons. A great deal is known about the Manhattan project, from the key scientists involved, to the many Los Alamos incidents – such as Fermi's determination of the Alamogordo test-blast energy using scraps of paper and Feynman's ability to crack his Los Alamos colleagues' safes – that are intrinsic parts of the US nuclear/particle-physics community's culture. On the contrary, little is known, at least in the West, about the huge effort made by the war-ravaged Soviet Union in less than five years to reach strategic parity with the US.

Pondrom, a prominent experimental particle physicist with a life-long interest in Russia and its language, provides an intriguing narrative. It is based on a thorough study of available literature plus a number of original documents – many of which he translated himself – that gives a fascinating insight into this history-changing enterprise and into the personalities of the exceptional people behind it.

The success of the Soviet programme was primarily due to Igor Kurchatov, a gifted experimental physicist and outstanding scientific administrator, who was equally at ease with laboratory workers, prominent theoretical physicists and the highest leaders in government, including Beria and Stalin himself. Saddled with developing several huge and remotely located laboratories from scratch, he remained closely involved in many important nitty-gritty scientific and engineering problems. For example, Kurchatov participated hands-on and full-time in the difficult commissioning of Reactor A, the first full-scale reactor for plutonium-239 production at the sprawling Combine #817 laboratory, receiving, along the way, a radiation dose that was 100 times the safe limit that he had established for laboratory staff members.

Catching up
The Soviets embarked on an intensive programme in 1945 to catch up with the US in the area of nuclear weapons.



Beria was the overall project controller and ultimate decision-maker. Although best known for his role as Stalin's ruthless enforcer – Pondrom describes him as "supreme evil," Sakharov as a "dangerous man" – he was also an extraordinary organiser and a practical manager. When asked in the 1970s, long after Beria's demise, how best to develop a Soviet equivalent of Silicon Valley, Soviet Academy of Sciences president A P Alexandrov answered "Dig up Beria." Beria promised project scientists improved living conditions and freedom from persecution if they performed well (and that they would "be sent far away" if they didn't). His daily access to Stalin was critical for keeping the project on track. Most of the project's manual construction work used slave labour from Beria's gulag.

Both the US and Soviet projects were monumental in scope; Pondrom estimates the Manhattan project's scale to be about 2% of the US economy. The Soviet's project scale was similar, but in an economy one-tenth the size. The Soviets had some advantage from the information gathered by espionage (and the simple fact that they knew the Manhattan project succeeded). Also, German scientists interned in Russia for the project played important support roles, especially in the large-scale purification of reactor-grade natural uranium. In addition, there was a nearly unlimited supply of unpaid labourers, as well as German prisoners of war with scientific and engineering backgrounds whose participation in the project was rewarded by better living conditions.

The book is crisply written and well worth the read. The text includes a number of translated segments of official documents plus extracts from memoirs of some of the people involved. So, although Pondrom sprinkles his opinions throughout, there is sufficient material to permit readers to make their own judgements. He doesn't shirk from explaining some of the complex technical issues, which he (usually) addresses clearly and concisely. The appendices expand on technical issues, some on an elementary level for non-physicists, and others, including isotope extraction techniques, nuclear reaction issues and encryption, in more detail, much of which was new to me.

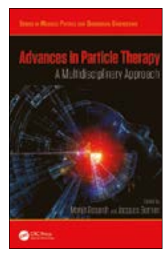
On the other hand, the confusing assortment of laboratories, their locations, leaders and primary tasks begged for some kind of summary or graphics. The simple chart describing the Soviet's complex espionage network in the US was useful for keeping track of the roles of the persons involved; a similar chart for the laboratories and their roles would have been equally valuable. The book would also have benefited from a final edit that might have eliminated some of the repetition and caught some obvious errors. But these are minor faults in an engaging, informative book.

Stephen L Olsen *University of Chinese Academy of Sciences.*

Advances in Particle Therapy: A multidisciplinary approach

By Manjit Dosanjh and Jacques Bernier (eds)

CRC Press, Taylor and Francis Group



A new volume in the CRC Press series on Medical Physics and Biomedical Engineering, this interesting book on particle therapy is structured in 19 chapters, each written by one or more co-authors out of a team of 49 experts (including the two editors). Most are medical physicists, radiation oncologists and radiobiologists who are well renowned in the field.

The opening chapter provides a brief and useful summary of the evolution of modern radiation oncology, starting from the discovery of X rays up to the latest generation of proton and carbon-ion accelerators. The second and third chapters are devoted to the radiobiological aspects of particle therapy. After an introductory part where the concepts of relative biological effectiveness (RBE) and oxygen-enhancement ratio are defined, this section of the book goes on to review the most recent knowledge gained in the field, from DNA structure to the production of radiation-induced damage, to secondary cancer risk. The conclusion is that, as biological effects and clinical response are functions of a broad range of parameters, we are still far from a complete understanding of all radiobiological aspects underlying particle therapy, as well as from a universally accepted RBE model providing the optimum RBE value to be used for any given treatment.

Chapter 4 and, later, chapter 18 are dedicated to particle-therapy technologies. The first provides a simple explanation of the operating principles of particle accelerators and then goes into the details of beam delivery systems and dose conformation devices. Chapter 18 recalls the historical development of particle therapy in Europe, first with the European Light Ion Medical Accelerator (EULIMA) study and Proton-Ion Medical Machine Study (PIMMS), and then with the design and construction of the HIT, CNAO and MedAustron clinical facilities (*CERN Courier* January/February 2018 p25). It then provides an outlook on ongoing and expected future technological developments in accelerator design.

Extensive review

Chapter 5 discusses the general requirements for setting up a particle therapy centre, while the following chapter provides an extensive review of imaging techniques for both patient positioning and treatment verification. These are made necessary by the rapid spread of active beam delivery technologies (scanning) and robotic patient positioning systems, which have strongly improved dose delivery. Chapter 7 reviews therapeutic indications for particle therapy and explains the necessity to integrate it with all other treatment modalities so that oncologists can decide on the best combination of therapies for each individual patient. Chapter 8 reports on the history of the European Network of Light Ion Hadron Therapy (ENLIGHT) and its role in boosting collaborative efforts in particle therapy and in training specialists.

The central part of the book (chapters 9 to 15) reviews worldwide clinical results and indications for particle therapy from different angles, pointing out the inherent difficulties in comparing conventional radiation therapy and particle therapy. It analyses the two perspectives under which the dosimetric properties of particles can translate into clinical benefit: decreasing the dose to normal tissue to reduce complications, or scaling the dose to the tumour to improve tumour control without increasing the dose to normal tissue.

A useful compendium of state-of-the-art particle therapy

Chapter 16 discusses the economic aspects of particle therapy, such as cost-effectiveness and budget impact, while the following chapter describes the benefits of a "rapid learning health care" system. The last chapter discusses global challenges in radiation therapy, such as how to bring medical electron linac technology to low- and middle-income countries (*CERN Courier* March 2017 p31). I found this last chapter slightly confusing as I did not understand what is meant by "radiation rotary" and I could not fully grasp the mixing-up of different topics, such as particle therapy and nuclear detonation-terrorism. This part also seemed too US-focussed when discussing the various initiatives, and I was not in agreement with some of the statements (e.g. that particle therapy has undergone a cost reduction by an order of magnitude or more in the past 10 years).

Overall, this book provides a useful compendium of state-of-the-art particle therapy and each chapter is supported by an extensive bibliography, meeting the expectations of both experts and readers interested in gaining an overview of the field. The essay is well structured, and enables readers to go through only selected chapters and in the order that they prefer. Some knowledge of radiobiology, clinical oncology and accelerator technology is assumed. It is disappointing that clinical dosimetry and treatment planning are not addressed other than in a brief mention in chapter 5, but perhaps this is something to consider for a second edition.

Marco Silari *CERN.*

Mad maths

Theatre, CERN Globe, 24 January 2019

Do you remember your maths high-school teachers? Were they strict? Funny? Extraordinary? Boring? The theatre comedy "Mad maths" presents the two most unusual teachers you can imagine. Armed with chalk and measuring tapes, Mademoiselle X and Mademoiselle Y aim to heal all those with maths phobia, and teach the audience more about their favourite subject.

Math therapy *Mademoiselle X and Mademoiselle Y can cure any maths phobia.*

On 24 January CERN's fully booked Globe of Science and Innovation turned into a bizarre classroom. Marching along well-defined 90° angles, and meticulously measuring everything around them, the comedians Sophie Leclercq and Garance Legrou play with numbers and fight at the blackboard to make maths entertaining. The dialogues are juiced up with rap and music, spiced by friendly maths jargon, and seasoned with a hint of craziness. Bumping with trigonometry, philosophising about the number zero, and inventing new counting systems with dubious benefits, the rhythm grows exponentially. For example, did you know that some people's mood goes up and down like a sine function? That you can make music with fractions? And that some bureaucratic steps are noncommutative?

This comedy show originated from an idea by Olivier Faliez and Kevin Lapin from the French theatre company *Sous un autre angle*. First studying maths at the university, then attending theatre school, Faliez combined his two passions in 2003 to create an entertaining programme based on maths-driven jokes and turns of event.

Perfect for families with children, this French play has already been performed more than 500 times, especially at science festivals and schools. The topics are customised depending on the level of the students. Future showings are scheduled in Castanet (15 March), Les Mureaux (22 March) and in several schools in France and other countries. Teachers and event organisers who are interested in the show are advised to contact Sophie Leclercq.

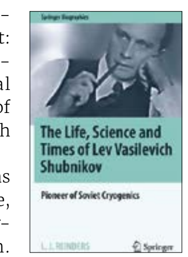
At times foolish, at times witty, it is worth watching if and only if you want to unwind and rediscover maths from a different perspective.

Letizia Diamante *CERN.*

The Life, Science and Times of Lev Vasilevich Shubnikov, Pioneer of Soviet Cryogenics

By L J Reinders

Springer



This book is a biography of Russian physicist Lev Vasilevich Shubnikov, whose work is scarcely known despite its importance and broad reach. It is also a portrayal of the political and ideological environment existing in the Soviet Union in the late 1930s under Stalin's repressive regime.

While at Leiden University in the Netherlands, which at the time had the most advanced laboratory for low-temperature physics in the world, Shubnikov co-discovered the Shubnikov–De Haas effect: the first observation of quantum-mechanical oscillations of a physical quantity (in this case the resistance of bismuth) at low temperatures and high magnetic fields.

In 1930 Shubnikov went to Kharkov (as it is called in Russian) in the Ukraine, where he built up the first low-temperature laboratory in the Soviet Union. There he led an impressive scientific programme and, together with his team, he discovered what is now known as type-II superconductivity (or the Shubnikov phase) and nuclear paramagnetism. In addition, independently of and almost simultaneously with Meissner and Ochsenfeld, they observed the complete diamagnetism of superconductors (today known as the Meissner effect).

In 1937, aged just 36, Shubnikov was arrested, processed by Stalin's regime and executed "for no other reason than that he had shown evidence of independent thought", as the author states.

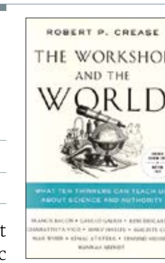
Based on thorough document research and a collection of memories from people who knew Shubnikov, this book will appeal not only to those curious about this physicist, but also to readers interested in the history of Soviet science, especially the development of Soviet physics in the 1930s and the impact that Stalin's regime had on it.

Virginia Greco *CERN.*

The Workshop and the World, what ten thinkers can teach us about science and authority

By Robert P Crease

W. W. Norton & Company



In this book, science historian Robert Crease discusses the concept of scientific authority, how it has changed along the centuries, and how society and politicians interact with scientists and the scientific process – which he refers to as the "workshop".

Crease begins with an introduction about current anti-science rhetoric and science denial – the most evident manifestation of which is probably the claim that "global warming is a hoax perpetrated by scientists with hidden agendas".

Four sections follow. In part one, the author introduces the first articulation of scientific authority through the stories of three renowned scientists and philosophers: Francis Bacon, Galileo Galilei and René Descartes. Here, some vulnerabilities of the authority of the scientific workshop emerge, but they are discussed further in the second section of the book through the stories of thinkers like Giambattista Vico, Mary Shelley and Auguste Comte.

Part three attempts to understand the deeply complicated relationship between the workshop and the world, described through the stories of Max Weber, Kemal Atatürk and his precursors, and Edmund Husserl. The final section is all about reinventing authority and is discussed through the work of Hannah Arendt, a thinker who barely escaped the Holocaust and who provided a deep analysis of authority as well as provding clues as to how to restore it.

With this brilliantly written essay, Crease aims to explore what practising science for the common good means and to understand what makes a social and political atmosphere in which science denial can flourish. Finally, Crease tries to suggest what can be done to ensure that science and scientists regain the trust of the people.

Virginia Greco *CERN.*

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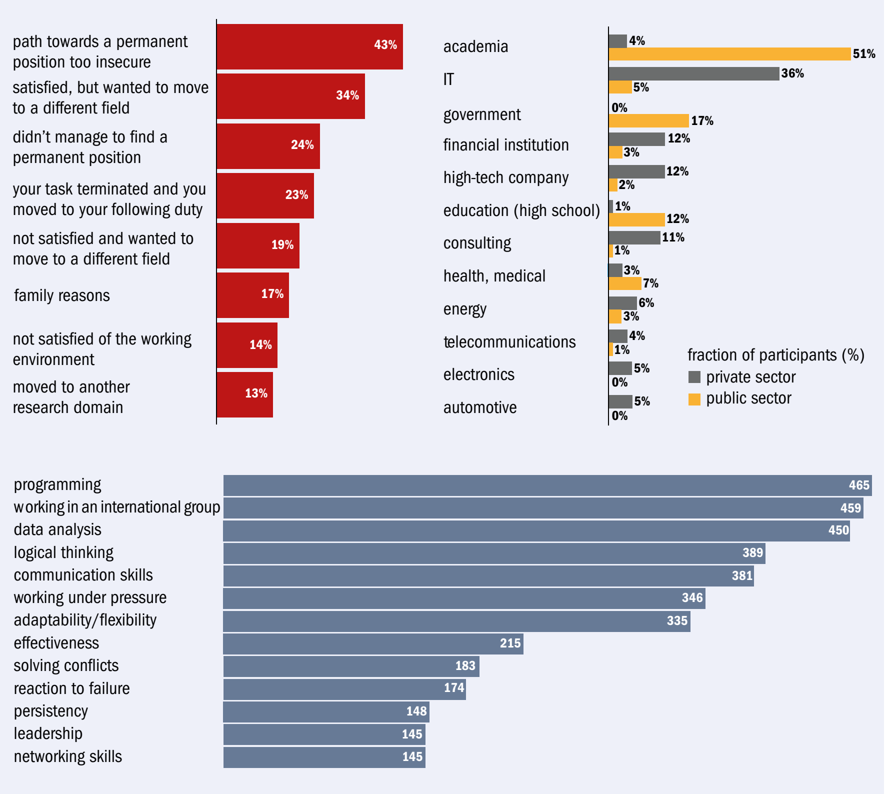
PEOPLE CAREERS

Assessing CERN's impact on careers

Results from a new survey show the important impact of working at CERN on an individual's career.

Since the advent of the Large Hadron Collider (LHC), CERN has been recognised as the world's leading laboratory for experimental particle physics. More than 10,000 people work at CERN on a daily basis. The majority are members of universities and other institutions worldwide, and many are young students and postdocs. The experience of working at CERN therefore plays an important role in their careers, be it in high-energy physics or a different domain.



Moving on *Top left: the reasons given for leaving high-energy physics, with multiple answers allowed. Top right: the sectors in which former CERN users continue their career. Bottom: the skills acquired at CERN that are deemed important for working outside the field, with multiple answers allowed.*

The value of education

In 2016 the CERN management appointed a study group to collect information about the careers of students who have completed their thesis studies in one of the four LHC experiments. Similar studies were carried out in the past, also including people working on the former LEP experiments, and were mainly based on questionnaires sent to the team leaders of the various collaborator institutes. The latest study collected a larger and more complete sample of up-to-date information from all the experiments, with the aim of addressing young physicists who have left the field. This allows a quantitative measurement of the value of the education and skills acquired at CERN in finding jobs in other domains, which is of prime importance to evaluate the impact and role of CERN's culture.

Following an initial online questionnaire with 282 respondents, the results were presented to the CERN Council in December 2016. The experience demonstrated the potential for collecting information from a wider population and also to deepen and customise the questions. Consequently, it was decided to enlarge the study to all persons who had been or are still involved with CERN, without any particular restrictions. Two distinct communities were polled with separate questionnaires: past and current CERN users (mainly experimentalists at any stage of their career), and theorists who had collaborated with the CERN theory department. The questionnaires were opened for a period of about four months and attracted 2692 and 167 participants from the experimental and theoretical communities, respectively. A total of 84 nationalities were represented, with German, Italian and US nationals making up around half, and the distribution of participants by experiments was: ATLAS (994); CMS (977); LHCb (268) ALICE (102); and "other" (87), which mainly included members of the NA62 collaboration. ▷

The latest study addressed young physicists who have left the field

The questionnaires addressed various professional and socio-logical aspects: age, nationality, education, domicile and working place, time spent at CERN, acquired expertise, current position, and satisfaction with the CERN environment. Additional points were specific to those who are no longer CERN users, in relation to their current situation and type of activity. The analysis revealed some interesting trends.

For experimentalists, the CERN environment and working experience is considered as satisfactory or very satisfactory by 82% of participants, which is evenly distributed across nationalities. In 70% of cases, people who left high-energy physics mainly did so because of the long and uncertain path for obtaining a permanent position. Other reasons for leaving the field, although quoted by a lower percentage of participants, were: interest in other domains; lack of satisfaction at work; and family reasons. The majority of participants (63%) who left high-energy physics are currently working in the private sector, often in information technology, advanced technologies and finance domains, where they occupy a wide range of positions and responsibilities. Those in the ▷

Appointments and awards

New DESY director for astroparticle physics

Effective from 1 January, Christian Stegmann (below) has been appointed the first director in charge of astroparticle physics at DESY in Germany – a new role designed to strengthen astroparticle physics at DESY and in Germany as a whole. Stegmann completed his PhD in experimental particle physics at the OPAL experiment at LEP in 1995 and was a professor at the University of Erlangen-Nürnberg, working on cosmic-ray studies


DESY

with the HESS experiment. From October 2011 he became head of DESY in Zeuthen and professor of astroparticle physics at the University of Potsdam, and his new role also entails responsibility for managing the Zeuthen site.

Denisov joins Brookhaven Lab

Dmitri Denisov of Fermilab in the US has been appointed deputy associate laboratory director for high-energy physics at Brookhaven National Laboratory (BNL), effective from 19 February. An expert in detector development, and in large-experiment operation and data analysis, Denisov has been the spokesperson of the D0 experiment at Fermilab's


Fermilab

Tevatron collider since 2006 and has most recently served as the lab's head of the particle physics initiatives department. The new role for Denisov (above) at BNL comes with responsibilities including advancing BNL goals in particle physics and providing regular monitoring and oversight of all high-energy physics projects at BNL.

Mariotti wins Emmy Noether award

Chiara Mariotti (below), a member of the CMS collaboration at CERN, has been awarded the 2018 EPS Emmy Noether Distinction for


G Brown

Women in Physics. Announced twice per year, the award was established to bring noteworthy women physicists to the wider attention of the scientific community, policymakers and the general public, and to identify role models that will help to attract women to a physics career. Mariotti is recognised "for her outstanding contributions to the discovery and characterisation of the Higgs boson, for her leading role as founder and coordinator of the LHC-wide Higgs Cross Section Working Group, and for her impressive capacities and achievements in outreach, in particular towards the young generation of physicists."

SESAME pioneers bag AAAS award

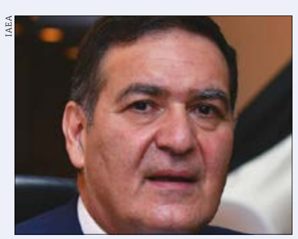
Five people who have played instrumental roles in the establishment of the third-generation light-source SESAME in Jordan have been awarded the 2019 AAAS Award for Science Diplomacy. Officially inaugurated in May 2017, SESAME is the first major international scientific centre in the Middle East. The recipients are: former CERN DG Chris Llewellyn-Smith (top right), who served as SESAME's second president of council; SESAME council member Eliezer Rabinovici (second from top); former Scientific Advisory Committee chair Zehra Sayers (third from top); former CERN DG Herwig Schopper (second from bottom), who was also the first president of SESAME council; and SESAME director Khaled Toucan (bottom). The award recognises an individual or group making an outstanding contribution to furthering science diplomacy, and has an honorarium of $5000, which this year's awardees have decided to use to help fund the work of a young scientist at SESAME.


C Llewellyn-Smith


YBM2000


Sabancı University


H Schopper


IAEA

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PEOPLE CAREERS

public sector are mainly involved in academia or education.

For persons who left the field, several skills developed during their experience at CERN are considered important in their current work. The overall satisfaction of participants with their current position was high or very high for 78% of respondents, while 70% of respondents considered CERN's impact on finding a job outside high-energy physics as positive or very positive. CERN's services and networks, however, are not found to be very effective in helping finding a new job – a situation that is being addressed, for example, by the recently launched CERN alumni programme.

Theorists participating in the second questionnaire mainly have permanent or tenure-track positions. A large majority of them spent time at CERN's theory department with short- or medium-term contracts, and this experience seems to improve participants' careers when leaving CERN for a national institution. On average, about 35% of a theorist's scientific publications originate from collaborations started at CERN, and a large fraction of theorists (96%) declared that they are satisfied or highly satisfied with their experience at CERN.

The impact of CERN on people's careers is considered by a large majority to be mostly positive

Conclusions

As with all such surveys, there is an inherent risk of bias due to the formulation of the questions and the number and type of participants. In practice, only between 20 and 30% of the targeted populations responded, depending on the addressed community, which means the results of the poll cannot be considered as representative of the whole CERN population. Nevertheless, it is clear that the impact of CERN on people's careers is considered by a large majority of the people polled to be mostly positive, with some areas for improvement such as training and supporting the careers of those who choose to leave CERN and high-energy physics.

In the future this study could be made more significant by collecting similar information on larger samples of people, especially former CERN users. In this respect, the CERN alumni programme could help build a continuously updated database of current and former CERN users and also provide more support for people who decide to leave high-energy physics.

The final results of the survey, mostly in terms of statistical plots, together with a detailed description of the methods used to collect and analyse all the data, have been documented in a CERN Yellow Report, and will also be made available through a dedicated web page.

Paolo Giacomelli *INFN Bologna, on behalf of the survey study group.*

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INSTITUTO DE FÍSICA
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Pontificia Universidad Catolica de Chile

Tenure-track faculty positions at the Assistant Professor level

$Attractive | South America | To start as early as August 2019

The Institute of Physics of the Pontificia Universidad Católica de Chile invites applications for tenure-track faculty positions at the Assistant Professor level, to start as early as August 2019. A Ph.D. degree in Physics (or closely related areas) is required and postdoctoral experience is highly desirable. The open positions are in the following areas:

i) High Energy Physics: we are looking for an experimental particle physicist who will be able to take a leading role in our ongoing activities in the ATLAS experiment. Applicants who could also help maintain our current effort in neutrino physics with the JUNO experiment are particularly encouraged to apply.

ii) Mathematical Physics: we are looking for candidates having the potential of interaction with the established research areas in Mathematical Physics at the institute such as Analysis, PDE, Quantum Physics, and Non-linear Physics.

iii) Medical Physics: we are looking for candidates with a strong background and research expertise in the field.

iv) Quantum Optics & Photonics: we are looking for strong candidates with theoretical or experimental research expertise in either of the following fields: photonics, nano-photonics, non-linear optics, optical metrology, novel laser technologies and similar topics.

v) Plasma Physics: we are looking for candidates having a proven background or research expertise in experimental plasma physics in any of the following areas: Pulsed power Zpinch plasmas, high energy density physics, radiofrequency discharges, laser-produced plasmas, atmospheric and other non-Maxwellian plasmas or plasma diagnostics. Candidates performing theoretical and/or computer modeling research related to some of the previously mentioned experiments are also welcome.

The successful candidates are expected to establish a leading research program as well as to teach in Spanish at the undergraduate and graduate levels.

Applications must include two recommendation letters, curriculum vitae, list of publications, and statements of past and proposed research and teaching interests. The two recommendation letters must be sent separately to the application's e-mail address. All the documents should be sent by email before April 30, 2019 to the Head of the Search Committee at **concurso2019@fis.puc.cl**.

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Accelerators | Photon Science | Particle Physics

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

DESY

For our location in Hamburg we are seeking:

DESY-Fellowships – experimental particle physics

DESY

DESY is one of the world's leading research centres for photon science, particle and astroparticle physics as well as accelerator physics. More than 2400 employees work at our two locations Hamburg and Zeuthen in science, technology and administration.

Particle physics and the investigation of the fundamental building blocks of nature and their interactions are at the core of the DESY mission. The lab is among the globally leading research institutions in this field. We take significant responsibility in internationally leading projects, e.g. at CERN and at KEK, and on our campus. We develop detectors and technologies relevant for our experimental activities, and we engage in scientific computing and in the development of future accelerators for particle physics.

The position

You are invited to take an active role in one or more of the following areas at Hamburg.

- Our involvements at CERN (ATLAS, CMS) and at KEK (Belle II)
- On-site experimental activities (ALPS II) and preparations for IAXO, MADMAX, LUXE
- Detector and technology development for future applications in particle physics
- Scientific computing
- Accelerator development

Requirements

- Ph.D. in physics completed within the last four years
- Interest in particle physics
- Expertise relevant for at least one of the areas listed above

DESY-Fellowships are awarded for a duration of 2 years with the possibility of prolongation by one additional year.

Futher informations and a link to the submission system for your application and the references can be found here: www.desy.de/FellowFH

Please note that it is the applicants responsibility that all material, including letter of references, reach DESY before the deadline for the application to be considered.

Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. Handicapped persons will be given preference to other equally qualified applicants. DESY operates flexible work schemes. DESY is an equal opportunity, affirmative action employer and encourages applications from women. Vacant positions at DESY are in general open to part-time- work. During each application procedure DESY will assess whether the post can be filled with part-time employees.

We are looking forward to your application via our application system: www.desy.de/onlineapplication

Deutsches Elektronen-Synchrotron DESY
Human Resources Department I Code: FHFE001/2019
Notkestraße 85 I 22607 Hamburg I 22607 Hamburg Germany
Phone: +49 40 8998-3392
http://www.desy.de/career

Deadline for applications: 2019/03/31

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

PAUL SCHERRER INSTITUT PSI

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Head of the Division of Large Research Facilities

at the Paul Scherrer Institute (PSI)

and

Professor of Particle Accelerator Physics

at the Ecole Polytechnique Fédérale de Lausanne (EPFL)

PSI is a large center for multi-disciplinary research and one of the world's leading user laboratories. It develops and operates large accelerator-driven research infrastructures requiring exceptionally high standards of know-how and experience. With its 2100 employees it is an autonomous institution of the Swiss ETH domain.

EPFL is a leading university with strong emphasis on basic, engineering and life sciences. Research and teaching within its School of Basic Sciences includes high-energy physics, particle accelerator physics and plasma physics.

Together, we are seeking to appoint a dynamic person with strategic thinking, jointly as Head of the Division for Large Research Facilities at PSI and as tenured Professor of Particle Accelerator Physics at EPFL. This is a full-time position.

The Challenge

As Head of the Division for Large Research Facilities you will provide vision and leadership in technical, scientific and management aspects of all accelerator-based facilities at PSI, such as the SINQ neutron source, the Swiss Light Source (SLS), the SμS muon source, and the X-ray free electron laser SwissFEL. This division ensures the operation and future development of these facilities, which serve a large user community and Switzerland's sole Center for Proton Therapy.

As Professor of Particle Accelerator Physics, you will lead the EPFL participation in the Swiss Accelerator Research and Technology (CHART) collaboration between major Swiss institutions and CERN, develop your own CHART-related research activity at EPFL, direct PhD students in their research, and promote collaboration in your field with other laboratories and centers at EPFL. You will also provide teaching in the field of particle accelerator science at Master and graduate levels.

With its Large Hadron Collider, CERN is the world-leading research laboratory providing accelerator infrastructure at the energy frontier. CHART has ambitious R&D plans for the technical design of CERN's Future Circular Collider (FCC) in the next five years (2019–2023), which will further foster synergies between CERN, EPFL and PSI towards a strategically important and vigorous R&D program in accelerator science and technology. CHART is hosted by PSI.

For this position we are seeking a scientist of international standing, with proven records of scientific and technological achievements in the field of particle accelerators. Leadership capabilities as well as a strong interest for teaching and education are essential requirements.

Applications including a motivation letter, a curriculum vitae with a list of research outputs, a statement of research (max. 3 pages) and teaching interests (max. 1 page), as well as the contact information of at least five references, should be submitted in PDF format, by **31 March 2019** via https://facultyrecruiting.epfl.ch/position/17104896

Enquiries may be addressed to:

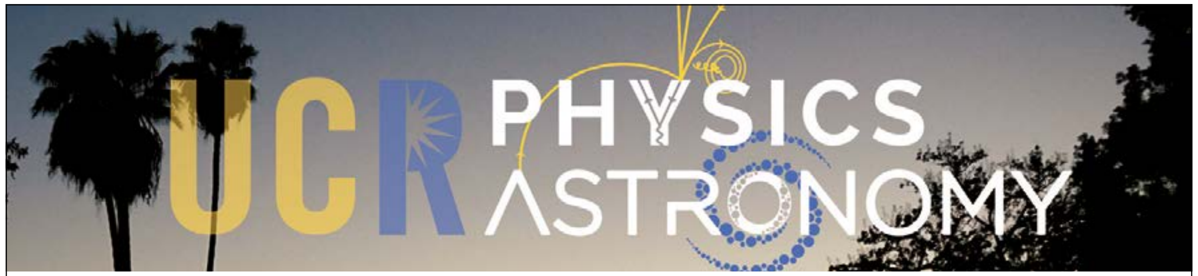
Dr. Thierry Strässle, Director PSI a.i., Chair of the Search Committee
e-mail: thierry.straessle@psi.ch

Or to:

Prof. Harald Brune, Director of the Institute of Physics
e-mail: iphysdirector@epfl.ch

Additional information is available at www.psi.ch, www.epfl.ch, sb.epfl.ch, iphys.epfl.ch

EPFL and PSI are equal opportunity employers, they are committed to increasing the diversity of their members. Women are strongly encouraged to apply.



Tenure-track Assistant Professor Level Faculty Position in Experimental Medium or High Energy Nuclear Physics
Department of Physics and Astronomy
University of California, Riverside

The Department of Physics and Astronomy at the University of California, Riverside (https://www.physics. ucr.edu/) invites highly qualified individuals to apply for an Academic-year tenure-track faculty positionin the field of experimental medium or high energy nuclear physics. The appointment will be made at the assistant professor level.

Candidates should possess a record of demonstrated excellence in research. The successful candidate is expected to establish an outstanding and well-funded research program involving graduate students and postdoctoral scientists, and to contribute to departmental teaching at all levels. Under an agreement between UCR and the Thomas Jefferson National Accelerator Facility (JLab), this position will be partially funded by JLab for the first four years. As such, a significant portion of the research program is expected to include work at JLab. The candidate is expected to complement our existing program in medium energy spin physics and high energy nuclear physics and play a significant role in preparations for a future Electron-Ion Collider being planned in the US.

Candidates for this position are required to have a Ph.D. or equivalent degree in physics or a related field. Salary will be competitive and commensurate with qualifications. Applicants should submit a cover letter, curriculum vitae, list of publications, a statement of research and teaching objectives, a statement addressing the candidate's past and potential future contributions to promote academic diversity and arrange to have at least four referees submit their letter of recommendation directly via the AP Recruit site at **https://apptrkr.com/1400215**.

For inquiries regarding the position, please contact the search committee Chair, **Prof. Richard Seto (richard.seto@ucr.edu)**, or **Kenneth Barish (kenneth.barish@ucr.edu)**. For inquiries regarding the application process, please contact Andrew Herrera, Academic Personnel, at andrew.herrera@ucr.edu.

Review of applications will commence on April 15, 2019, and proceed until the position is filled. For full consideration, applicants should submit their complete applications by the above date. Advancement through the faculty ranks at the University of California is through a series of structured, merit-based evaluations, occurring every 2-3 years, each of which includes substantial peer input. Minorities and members of underrepresented groups are particularly encouraged to apply.

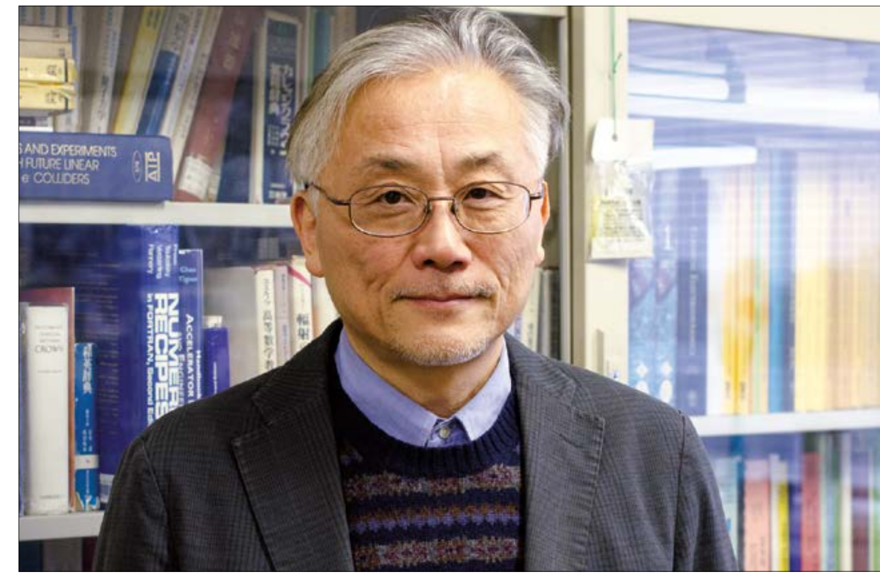
The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, age, disability, protected veteran status, or any other characteristic protected by law.

UCR is a world-class research university with an exceptionally diverse undergraduate student body. Its mission is explicitly linked to providing routes to educational success for underrepresented and firstgeneration college students. A commitment to this mission is a preferred qualification.

PEOPLE OBITUARIES

Yong Ho Chin 1958–2019

A foremost accelerator physicist



KEK

Yong Ho Chin was chair of the beam dynamics panel of the International Committee for Future Accelerators.

Yong Ho Chin, a leading theoretical accelerator physicist at the High Energy Accelerator Research Organization (KEK) in Japan and chair of the beam dynamics panel of the International Committee for Future Accelerators (ICFA) since November 2016, unexpectedly passed away on 8 January.

In 1984, Yong Ho received his PhD in accelerator physics from the University of Tokyo for studies performed at KEK under the supervision of Masatoshi Koshiba, who won the Nobel Prize in Physics jointly with Raymond Davis Jr and Riccardo Giacconi in 2002. Yong Ho participated in the design and commissioning of the TRISTAN accelerator, and later in the designs of the KEKB and J-PARC accelerators, along with major contributions to JLC (the Japan Linear Collider) and ILC (the International Linear Collider). In the 1980s and 1990s he spent several years abroad, at DESY and CERN in Europe, and at LBL (now LBNL) in the US.

Distinguished career

In his long and distinguished career, Yong Ho made numerous essential contributions in the fields of beam-coupling impedances, coherent beam instabilities, radio-frequency klystron development, space-charge and beam–beam collective effects. He considered his "renormalisation theory for the beam–beam interaction", developed during his last six months at DESY in the 1980s, as his greatest achievement. However, in the accelerator community, Yong Ho Chin's name is linked, in particular, to two computer codes he wrote and maintained, and which have been widely used over the past decades.

The first of these codes, developed by Yong Ho in the 1980s, is MOSES (MOde-coupling Single bunch instabilities in an Electron Storage ring), which computes the complex transverse coherent betatron tune shifts as a function of the beam current for a bunch interacting with a resonator impedance. The second well-known code, written by Yong Ho in the 1990s, is the ABCI (Azimuthal Beam Cavity Interaction) code for impedance and wakefield calculations. This served as a time-domain solver of electromagnetic fields when a bunched beam with arbitrary charge distribution goes through an axisymmetric structure, on or off axis.

In the mid-1990s, Yong Ho's work expanded to two-stream beam instabilities. He rightly foresaw that such instabilities could potentially limit the performance of KEKB and organised and co-organised several international workshops to address this issue early on. Subsequently, he was put in charge of the development and modelling of the X-band klystron for the JLC. He also greatly contributed to the development of the multi-beam klystron now in use for large superconducting linacs, and to the optimisation of the J-PARC accelerators.

Yong Ho returned to the field of collective effects more than 10 years ago and he remained extremely active there. Over the past few years, together with two other renowned accelerator physicists, Alexander W Chao and Michael Blaskiewicz, he developed a two-particle model to study the effects of space-charge force on transverse coherent beam instabilities. The purpose of this model was to obtain a simple picture of some of the essence of the physics of this intricate subject and at the same time provide a good starting point for newcomers joining the effort to solve this long-lasting issue.

As illustrated by his role as chair of an ICFA panel, and by his co-organisation of a large number of international workshops and conferences (including PAC and LINAC), Yong Ho was devoted to serving the international physics community. He was a productive author, diligent referee and esteemed editor for several journals. In 2015 he was recognised with an Outstanding Referee Award by the American Physical Society, and just a few months ago, in the summer of 2018, Yong Ho was appointed associate editor of *Physical Review Accelerators and Beams*.

Yong Ho was a very good lecturer, teaching at different accelerator schools, including the CERN Accelerator School. He was also in charge of a collaboration programme in which young accelerator scientists were invited to spend a few weeks at KEK.

Yong Ho was a wonderful person and an outstanding scientist. We are very proud to have had the chance to work and collaborate with him. His passing away is a great loss to the community and he will be sorely missed.

His friends and colleagues *at CERN.*

ALBERT HOFMANN 1933–2018

An expert in all things colliders

Albert Hofmann, a brilliant accelerator physicist with a worldwide reputation and a distinguished career in the US and Europe, passed away on 28 December 2018.

Hofmann finished his studies at ETH Zurich in the mid-1960s and went on to work at the Cambridge Electron Accelerator (CEA) at Harvard University. The team at CEA was a highly reputed one, making seminal contributions including the invention of the low-beta scheme, which converted the CEA 6 GeV electron synchrotron into an electron–positron collider where the first indications of the charm quark were revealed. This scheme, used in the accelerator's by-pass, became a basic ingredient of modern colliders.

A major element of this conversion was a Robinson damping wiggler – a series of magnets that supresses a beam instability brought about by synchrotron radiation. Hofmann led the design, installation and commissioning of this complex device. This was the first multipole wiggler to be used in an electron synchrotron ring, and led to Hofmann's subsequent lifelong interest in the new discipline of synchrotron radiation and his monumental book *The Physics of Synchrotron Radiation*.

When the CEA closed Hofmann moved to CERN in 1973, where he made significant contributions to the performance of the Intersecting Storage Rings (ISR) collider, including proposing the use of a higher harmonic cavity to control beam stability as had been done at CEA.


CERN-GE-9612005

Albert Hofmann made significant contributions to the performance of colliders in the US and Europe.

Hofmann also served as advisor for a number of synchrotron-radiation facilities

When the ISR was closed a decade later, Hofmann returned to the US, accepting a professorship at Stanford University. He worked on the damping rings for the SLC electron–positron linear collider and on synchrotron-radiation devices such as the wiggler and undulator magnets to be inserted into the PEP and SPEAR electron–positron circular colliders.

Hofmann was then invited to return to CERN to take joint responsibility for the commissioning of the large electron–positron collider (LEP), and made remarkable contributions to its performance throughout the collider's 11 years of operations. As at the ISR, he was especially fond of subtle effects such as those of tidal forces on the collider's beam energy, which was crucial for the precision of the experimental programme.

He subsequently returned to California to work on a compact light source based on inverse Compton scattering that was under development by Lyncean Technologies Inc in Palo Alto. Here, he brought his deep knowledge of accelerator physics to bear on the unusual situation of a very-low-energy electron storage ring. This knowledge was key to the success of this light source.

Hofmann gave many inspiring lectures at the CERN Accelerator School, simplifying, as only he could, some of the most difficult concepts in accelerator physics. He also served as advisor for a number of synchrotron-radiation facilities, spanning from the European Synchrotron Radiation Facility (ESRF) in Grenoble to the Synchrotron Radiation Research Centre (SRRC) in Taiwan. In 1996 he was awarded the prestigious Robert R. Wilson Prize of the American Physical Society for his achievements in accelerator physics and teaching.

Albert Hofmann was always over-generous in giving scientific credit to colleagues who had in some cases only made a minor contribution. He also had an impish, tongue-in-cheek sense of humour and told fascinating stories about the early days of colliders. We say goodbye to this generous, modest, inspiring and unpretentious role model.

His friends and colleagues *at CERN and SLAC.*

VLADIMIR RITTENBERG 1934–2018

Striving for essentials

Vladimir Rittenberg, a distinguished theoretical physicist, passed away on 15 April 2018. Vladimir was born in 1934 in Bucharest, Romania, to a mother from Galati, eastern Romania, and a father, an engineer, from Bessarabia, now Moldavia. He attended the French School in Bucharest, after which he earned a diploma in technology from the Bucharest Electrotechnical School. Starting in 1952, Vladimir studied theoretical physics at the University of Bucharest, passing the MSc exam in 1957. Due to political upheaval, Vladimir was forced to leave the university in 1958 and accept a job in a laboratory for crystal growth. It was only in 1963 that he was able to return to theoretical physics, joining the high-energy physics group of the Romanian Academy. In 1966 he received a PhD and became the leader of the group.

In 1969 Vladimir finally left Romania. This was facilitated through an invitation to Oxford University arranged by Bruno Renner. In the same year he immigrated to Israel, where he was a visiting scientist at the Weizmann Institute until 1972. Thereafter, for three years, he worked at the Rockefeller University in New York. In 1975 Vladimir was appointed professor at the University of Bonn in Germany. He kept this position for more than 40 years, but also followed many invitations to spend time abroad: ▷

for example, once more at Rockefeller University, several times at the International School for Advanced Studies (SISSA) in Trieste, at the University of Melbourne, the Dubna Laboratories and various places in France. In his later years he also visited the Federal University of São Carlos in Brazil many times.

Vladimir's early papers – 19 in total between 1966 and 1969, mostly with Ladislaus Banyai as co-author – were devoted to particle theory and the related group theory. In the following five years Vladimir collaborated with various colleagues from the Weizmann Institute and Rockefeller University, producing 25 papers on phenomenological high-energy physics. On his arrival in Bonn, his main interest turned to the mathematics of representations of superalgebras related to supersymmetrical quantum field theories. With Werner Nahm and Manfred Scheunert, and later with Daniel Wyler, he published several papers that were seminal to the subject and relevant for string theory.

At the beginning of the 1980s Vladimir successfully conquered the new domain of spin field models, in particular those related to the then newly revived two-dimensional conformal field theories. In this area of mathematical physics he produced more than 50 articles, partially in collaboration with his students or colleagues in Bonn, or visitors to the Bonn physics department. He obtained several first results about the level structure of quantum spin chains using conformal invariance, which were useful in the early stages of string theory.


G v Gehlen

Vladimir Rittenberg's impact spanned mathematical, statistical and high-energy physics.

From 1993 Vladimir turned his attention to non-equilibrium statistical processes such as reaction–diffusion phenomena. He showed how in one dimension, similar to equilibrium processes, some of these non-equilibrium processes can be described through quantum spin chain models too, partly exploiting quadratic algebras. This resulted in 25 articles written with various collaborators, in particular Francisco Alcaraz. With Francisco he constructed the first stochastic model that is integrable and conformally invariant. Vladimir was also the founding editor of the *Journal of Statistical Mechanics*, which launched in 2004.

Vladimir was very passionate in scientific discussions, always striving to get a better understanding of the underlying physics. He had an extraordinary gift of connecting with people, which was clearly visible through the huge number of researchers who were his co-authors. He also inspired young people to enthusiastically follow his guide into the adventure of scientific research.

Vladimir is survived by his daughter Vivian and three grandchildren.

Rainald Flume *and* **Günter v Gehlen** *the University of Bonn.*

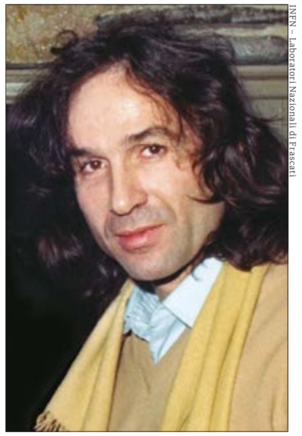
PIO PICCHI 1942–2019

A leader in detector development

Pio Picchi, a prominent Italian particle physicist, suddenly passed away on 23 January. It was a shock for everyone who knew him as a mentor and as a splendid friend.

We had the great honour and pleasure of collaborating with Pio over the past few decades. He had an honest and unbiased scientific approach to experimental particle physics, often along the lines of his exceptional intuition, and had many insightful ideas at the frontiers of detector technologies.

Pio spent most of his life as a physicist, first at the INFN Frascati National Laboratories in Italy, and then at the University of Turin, where he was appointed full professor at the age of 34. In his research, mostly conducted at CERN, he gave visible contributions to the design and construction of several experiments such as FRAMM and ALEPH at CERN, NUSEX in the Mont Blanc underground laboratory, and LVD and ICARUS at the INFN Gran Sasso National Laboratory.


INFN - Laboratori Nazionali di Frascati

Pio Picchi was appointed full professor at the age of 34.

To mention a few of his achievements, it was under Pio's leadership that the first tonne-scale liquid-argon time-projection chamber detector was successfully operated at CERN within the ICARUS R&D programme; he pioneered, also at CERN, the double-phase operation mode of xenon and argon time-projection chambers, which nowadays is widely used in dark-matter experiments; and he actively participated in R&D on new micropattern detectors.

Picchi had the gift of always recognising and valuing the best skills

Since a relatively young age, Pio was affected by Parkinson's disease. Thanks to his courage and tenacity against his evolving illness, he continued to work at his best. CERN was a place of joy for him. On days with physicians' visits, he would be upset because that prevented him from going to work. For us, his presence provided an anchor to hear the latest news and to discuss not only physics but also life. Even on his very last day at CERN, Pio was discussing with students new ideas on single-photon detection in liquid argon and the way to test them. He had the gift of always recognising and valuing the best skills of every person around him: students, technical personnel, colleagues and friends. And he always did so without asking for anything in return.

We will remember Pio as a generous man with a strong sense of friendship. Those who needed help found a friend that was always available and discreet: if he could help, he would do it with modesty and confidentiality.

His friends and colleagues *at CERN and beyond.*

CERNCOURIER
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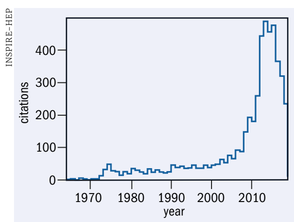
BACKGROUND

Notes and observations from the high-energy physics community

Higgs hits 5000 citations



Peter Higgs' 1964 paper "Broken Symmetries and the Masses of Gauge Bosons" (*Phys. Rev. Lett.* **13** 508) has reached 5000 citations in the INSPIRE-HEP database, having made only a modest stir during most of its existence (see figure). Just 1.5-pages long, it showed that the spin-one quanta of some of the gauge fields acquire mass, forever connecting Higgs to the scalar boson discovered at CERN in 2012. The paper is catching up with those of ATLAS and CMS reporting the actual Higgs discovery, which, at around 7000 citations each, are currently ranked in the top-10 cited works. Only time will tell if Higgs' paper can ascend to the bibliometric heights of Steven Weinberg's related "A Model of Leptons" (almost 10,000 core citations), or Juan Maldacena's pole-position (> 12,000) "The Large N Limit of Superconformal Field Theories and Supergravity".

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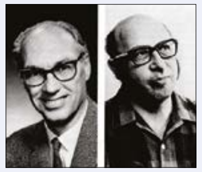
11,637 Unofficial world record for the number of attendees at a physics talk – *Brian Cox's Universal*, Arena Birmingham, UK, 23 February 2019

Scraping the barrel

In the name of frivolity, Sweden-based ATLAS physicists Caterina Doglioni, Will Kalderon, Geoffrey Mullier and Nathan Simpson, all of Lund University, Rebeca Gonzalez Suarez of Uppsala University and engineer David Cox have launched the Meatball Accelerator (MEAL) – billed as a "revolutionary linear collider concept, synchronised by a human trigger". The team achieved first collisions on 9 February, having overcome challenges such as keeping the beam pipe meat-free. The spectacle was part of the 2019 Stupid Hackathon Sweden.

From the archive: March 1976

Physics is fun



At the February Meeting of the American Physical Society, some of our colleagues put on a cabaret called "The Physical Revue". Master of Ceremonies was Marvin Goldberger from Princeton, whose wife Mildred was Producer. Stars included Val Telegdi from Chicago (image, right) doing a travel agent sketch advising a young physicist on the choice of a European Summer School. He dismissed schools in Sweden because of the danger from women, in Italy because of the danger from food poisoning, in France because of the danger of having to work at physics and recommended Switzerland, where the only danger was linguistics – the school was to be conducted in Romansch! Arthur Roberts from Fermilab (image, left), who has had a dual physicist/musician career with works played by several orchestras, also had a prominent role, singing a medley of songs with sharply observed lyrics. Stage hands included past APS Presidents – I I Rabi, Robert Serber, Philip Morse and Chieng-Shung Wu.

Compiler's note

The physics-world-renowned Christmas plays put on by CERN's Theory Department date back 30 or more years, but it seems that APS got there first. CERN has links with their show nonetheless, with roads on site named after APS stagehands, I I Rabi and Chieng-Shung Wu. Crew member Rabi is acknowledged as being the father of CERN, while Madame Wu is honoured for her scene-setting 1956 experiment demonstrating parity violation in beta decay, for which she was awarded the first Wolf prize in 1978.

Media corner

"Colliders are expensive, but so was the government shutdown. Only one of these will yield lasting insights into the nature of matter."

Lisa Randall of Harvard University in a letter to *The New York Times* on 1 February in response to an article arguing against the construction of future colliders.

"Both CLIC and the FCC would be realized in several stages so that the cost will be spread over decades."

CERN Director-General ***Fabiola Gianotti***, interviewed in the March issue of *Physics World*, responding to a question about the potential cost of a post-LHC collider.

"I think we'd have no chance; we just need one [circular facility] in the world."

Wang Yifang, director of IHEP in Beijing, reflecting on the prospects for China's Circular Electron–Positron Collider were a 100 km collider to get the green light in Europe (*Science Business* 21 February).

"My own sons' alma mater has just built a cloud-chamber particle detector and its new sixth-form common room resembles an Apple store. Nonetheless the school relentlessly taps me up for donations. For what? A Hadron collider, a helipad, a spa?"

Times journalist ***Janice Turner*** reviewing *Engines of Privilege: Britain's Private School Problem* (Bloomsbury) in *New Statesman*, 1 February.