WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the March 2016 issue of *CERN Courier*.

This month we have been captivated by the wonderful images of the Very Large Telescope, ESO's breathtaking installation, which made the cover, and the article is as inspiring as the accompanying photographs. We also collect a series of "firsts" in this issue. The first Viewpoint by CERN's new Director-General, Fabiola Gianotti, as well as the first article about the newly proposed SHiP facility, designed to explore the hidden world. And the idea that two researchers had to use the sonification technique (well known in particle physics) to develop novel investigation methods to study the body motor also comes under the "first" label. In addition to a great collection of features, we have a rich body of news articles, with new information published on antimatter and nuclear physics.

To sign up to the new-issue alert, please visit:
http://cerncourier.com/cws/sign-up.

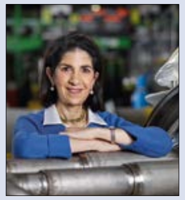
To subscribe to the magazine, the e-mail new-issue alert, please visit:
http://cerncourier.com/cws/how-to-subscribe.

EDITOR: ANTONELLA DEL ROSSO, CERN
DIGITAL EDITION CREATED BY JESSE KARJALAINEN/IOP PUBLISHING, UK

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERNCOURIER

VOLUME 56 NUMBER 2 MARCH 2016

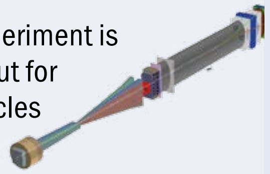


CERN

Introducing the Organization's new management **p21**

INTENSITY FRONTIER

The SHiP experiment is on the lookout for hidden particles **p25**



ANTIHYDROGEN CHARGE

ALPHA presents new results **p9**

Contents

Covering current developments in high-energy physics and related fields worldwide

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

Editor Antonella Del Rosso
Books editor Virginia Greco
CERN, 1211 Geneva 23, Switzerland
E-mail cern.courier@cern.ch
Fax +41 (0) 22 76 69070
Web cerncourier.com

Advisory board Luis Alvarez-Gaume, Peter Jenni, Christine Sutton, Claude Amsler, Roger Bailey, Philippe Bloch, Roger Forty

Laboratory correspondents:
Argonne National Laboratory (US) Tom LeCompte
Brookhaven National Laboratory (US) P Yamin
Cornell University (US) D G Cassel
DESY Laboratory (Germany) Till Mundzeck
EMFCSC (Italy) Anna Cavallini
Enrico Fermi Centre (Italy) Guido Piragino
Fermi National Accelerator Laboratory (US) Katie Yurkewicz
Forschungszentrum Jülich (Germany) Markus Buescher
GSI Darmstadt (Germany) I Peter
IHEP, Beijing (China) Tongzhou Xu
IHEP, Serpukhov (Russia) Yu Ryabov
INFN (Italy) Antonella Varaschin
Jefferson Laboratory (US) Steven Corneliussen
JINR Dubna (Russia) B Starchenko
KEK National Laboratory (Japan) Saeko Okada
Lawrence Berkeley Laboratory (US) Spencer Klein
Los Alamos National Laboratory (US) Rajan Gupta
NCSL (US) Ken Kingery
Nikhef (Netherlands) Robert Fleischer
Novosibirsk Institute (Russia) S Eidelman
Orsay Laboratory (France) Anne-Marie Lutz
PSI Laboratory (Switzerland) P-R Kettle
Saclay Laboratory (France) Elisabeth Locci
Science and Technology Facilities Council (UK) Jane Binks
SLAC National Accelerator Laboratory (US) Farnaz Khadem
TRIUMF Laboratory (Canada) Marcello Pavan

Produced for CERN by IOP Publishing Ltd
IOP Publishing Ltd, Temple Circus, Temple Way,
Bristol BS1 6HG, UK
Tel +44 (0)117 929 7481

Publisher Susan Curtis
Production editor Lisa Gibson
Technical illustrator Alison Tovey
Group advertising manager Chris Thomas
Advertisement production Katie Graham
Marketing & Circulation Angela Gage

Head of B2B & Marketing Jo Allen
Art director Andrew Giaquinto

Advertising
Tel +44 (0)117 930 1026 (for UK/Europe display advertising)
or +44 (0)117 930 1164 (for recruitment advertising);
E-mail: sales@cerncourier.com; fax +44 (0)117 930 1178

General distribution Courrier Adressage, CERN, 1211 Geneva 23, Switzerland
E-mail: courrier-adressage@cern.ch
In certain countries, to request copies or to make address changes, contact:
China Jiang Ya'ou, Library, Institute of High Energy Physics,
PO Box 918, Beijing 100049, People's Republic of China
E-mail: jiangyo@ihep.ac.cn
Germany Antje Brandes, DESY, Notkestr. 85, 22607 Hamburg, Germany
E-mail: desypr@desy.de
UK Mark Wells, Science and Technology Facilities Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1SZ
E-mail: mark.wells@stfc.ac.uk
US/Canada Published by Cern Courier, 6N246 Willow Drive,
St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US
Fax 630 377 1569. E-mail: creative_mailing@att.net
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147,
St Charles, IL 60174, US

Published by European Organization for Nuclear Research, CERN,
1211 Geneva 23, Switzerland
Tel +41 (0) 22 767 61 11. Telefax +41 (0) 22 767 65 55

Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

 ISSN 0304-288X

IOP Publishing   CERN

CERNCOURIER

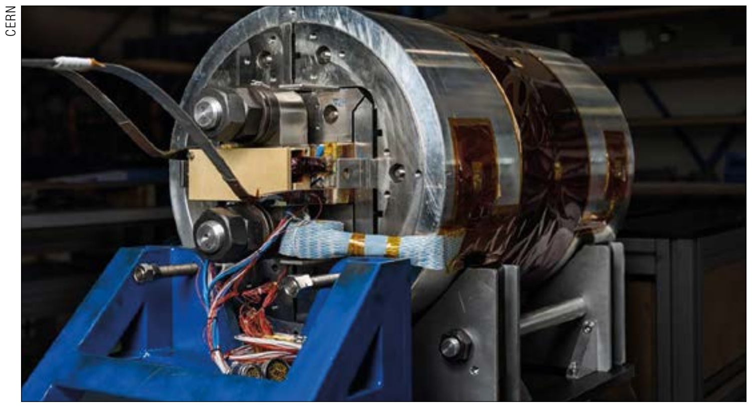
VOLUME 56 NUMBER 2 MARCH 2016

On the cover: One of the four gigantic (30 m-tall) fixed-unit telescope of ESO's Very Large Telescope observatory, at Cerro Paranal, Northern Chile. (Image credit: Mike Struik.)

Charting the future of CERN

The coming years will be crucial for the long-term future of particle physics.

CERN



This model magnet recently achieved a field of 16.2 T at CERN, twice the nominal field of the LHC dipoles, offering promise for a long-term accelerator-based future for the laboratory.

By Fabiola Gianotti

Over the next five years, key events shaping the future of particle physics will unfold. We will have results from the second run of the LHC, and from other particle and astroparticle physics projects around the world. These will help us to chart the future scientific road map for our field. The international collaboration that is forming around the US neutrino programme will crystallise, bringing a new dimension to global collaboration in particle physics. And initiatives to host major high-energy colliders in Asia should become clear. All of this will play a role in shaping the next round of the European Strategy for Particle Physics, which will in turn shape the future of our field in Europe and at CERN.

CERN is first and foremost an accelerator laboratory. It is there that we have our greatest experience and concentration of expertise, and it is there that we have known our greatest successes. I believe that it is also there that CERN's future lies. Whether or not new physics emerges at the LHC, and whether or not a new collider is built in Asia, CERN should aim to maintain its pre-eminence as an accelerator lab exploring fundamental physics.

CERN's top priority for the next five years is ensuring a successful LHC Run 2, and securing the financial and technical development and readiness of the High-Luminosity LHC project. This does not mean that CERN should compromise its scientific diversity. Quite the opposite: our diversity underpins our strength. CERN's programme today is vibrant, with unique facilities such as the Antiproton Decelerator and ISOLDE, and experiments studying topics ranging from kaons to axions. This is vital to our intellectual life, and it is a programme that will evolve and develop as physics needs dictate. Furthermore, with the new neutrino platform, CERN is contributing to projects hosted outside of Europe, notably the exciting neutrino programme underway at Fermilab.

If CERN is to retain its position as a focal point for accelerator-based physics in the decades to come, we must continue to play a leading role in global efforts to develop technologies to serve a range of possible physics scenarios. These include R&D on superconducting high-field magnets, high-gradient, high-efficiency accelerating structures, and novel acceleration technologies. In this context, AWAKE is a unique project using CERN's high-energy, high-intensity proton beams to investigate the potential of proton-driven plasma wakefield acceleration for the very-long-term future. In parallel, CERN is playing a leading role in international design studies for future high-energy colliders that could succeed the LHC in the medium-to-long term. Circular options, with colliding electron–positron and proton–proton beams, are covered by the Future Circular Collider (FCC) study, while the Compact Linear Collider (CLIC) study offers potential technology for a linear electron–positron option reaching the multi-TeV range. To ensure a future programme that is compelling, and scientifically diverse, we are putting in place a study group that will investigate future opportunities other than high-energy colliders, making full use of the unique capabilities of CERN's rich accelerator complex, while being complementary to other endeavours around the world. Along with the developments I mention above, these studies will also provide valuable input into the next update of the European Strategy, towards the end of this decade.

Global planning in particle physics has advanced greatly over recent years, with European, US and Japanese strategies broadly aligning, and the processes that drive them becoming ever more closely linked. For particle physics to secure its long-term future, we need to continue to promote strong worldwide collaborations, develop synergies, and bring new and emerging players, for example in Asia, into the fold.

Within that broad picture, CERN should steer a course towards a future based on accelerators. Any future accelerator facility will be an ambitious undertaking, but that should not deter us. We should not abandon our exploratory spirit just because the technical and financial challenges are intimidating. Instead, we should rise to the challenge, and develop the innovative technologies needed to make our projects technically and financially feasible.

Fabiola Gianotti started her five-year mandate as CERN Director-General on 1 January.

News

LHC

CERN sets accelerator objectives for 2016

CERN

The 2016 LHC Performance Workshop participants.

The LHC Performance Workshop took place in Chamonix from 25 to 28 January. Attended by representatives from across the accelerator sector, including members of the CERN Machine Advisory Committee, and the LHC experiments, the programme covered a review of the 2015 performance and a look forward to 2016, as well as the status of both the LHC injector upgrade (LIU) and the High Luminosity LHC (HL-LHC) projects. It finished with a session dedicated to the next long shutdown (LS2), planned for 2019–2020.

For the LHC, 2015 was the first year of operation following the major interventions carried out during the long shutdown (LS1) of 2013–2014. At Chamonix, an analysis of the year's operations and operation efficiency was performed, with the aim to identify possible improvements for 2016. The performance of key systems (e.g. machine protection, collimation, radio frequency, transverse dampers, magnetic circuits, and beam diagnostics) has been good, but nonetheless a push is still being made for better reliability, improved functionality and more effective monitoring.

The first year of operation also revealed a number of challenges, including the now-famous unidentified falling objects (UFOs), and an unidentified aperture restriction in an arc dipole called the unidentified lying object (ULO). Both problems are under control and there should be no surprises in 2016.

A dominating feature of 2015 was the electron cloud. The worst effects were suppressed by a systematic scrubbing campaign and a strategy that allowed continued scrubbing in physics conditions at 6.5 TeV. This strategy delivered 2244 bunches and encouraging luminosity performance. The electron cloud has side effects such as heat load to the cold sectors of the machine and beam instabilities. These have to be effectively handled to avoid compromising operations. In particular, the heat load to the beam screens that shield the walls of the beam pipes was a major challenge for the cryogenics teams, who were forced to operate their huge system close to its cooling-power limit. Plans for tackling the electron cloud in 2016 were discussed at the Chamonix meeting, including a short scrubbing run that should allow the conditions at the end of 2015 to be re-established. Further staged improvement will be obtained by further scrubbing while delivering luminosity to the experiments.

The machine configuration, planning and potential performance for 2016 and Run 2 were outlined. The LHC has shaken off the after effects of LS1, and the clear hope is to enter into a production phase in the coming years. Besides luminosity production, 2016 will include the usual mix of machine development, technical stops, special physics runs and an ion run. The special runs will include the commissioning of a machine configuration that will allow TOTEM and ALFA to probe very-low-angle elastic scattering.

Machine availability is key to efficient luminosity production, and a day was spent examining availability tracking and the performance of all key systems. Possible areas for improvement in the short and medium term were identified.

The LIU project has the job of upgrading the injectors to deliver the extremely challenging beams for the HL-LHC. The status of Linac4 and the necessary upgrades to the Booster, PS and SPS were presented. Besides the completion of Linac4 and its connection to the Booster, the upgrade programme comprises an impressive and extensive number of projects. The energy upgrade to the Booster will involve the replacement of its entire radio-frequency (RF) system with a novel solution based on a new magnetic alloy (Finemet). The PS will have to tackle the increased injection energy from the Booster, as well as upgrades to its RF and damper systems. The SPS foresees a major RF upgrade, a new ▷

Sommaire en français

beam dump, an extensive campaign of impedance reduction, and the deployment of electron-cloud reduction measures. The upgrade programme also targets ions as it plans improvements to Linac3 and LEIR, and looks at implementing new techniques to produce a higher number of intense ion bunches in the PS and SPS.

An in-depth survey of the potential performance limitations of the HL-LHC and means to mitigate or circumvent them were discussed. Although it is clear that the electron cloud will remain an issue, the experts gathered at Chamonix proposed a number of measures including *in-situ* amorphous-carbon (a-C) coating and *in-situ* laser-engineered surface structures (LESS) as a way of tackling the electron cloud in the magnets at the insertion regions.

Besides the complete re-working of the high-luminosity insertions, key upgrades to the RF and collimation systems are also required. Here, plans have been base-lined and work is in progress to develop and produce the required hardware. An important novel contribution from RF is the production of crab cavities, which are designed to mitigate the effort of the large crossing angle at the high-luminosity interaction points. The preparation for the installation of test crab cavities in the SPS is well under way.

Ions will be an integral part of the HL-LHC programme, and the means to deliver the required beams and luminosity are taking shape. The recent successful Pb–Pb run at 5.02 TeV centre-of-mass energy per colliding nucleon pair and the quench tests performed during the same run have provided very useful input.

Although it will only start in 2019, planning for LS2 is already under way, and a dedicated session looked at the considerable amount of work foreseen for the next two-year stop of the accelerator complex. A major part of the effort will be devoted to the deployment of the LIU injector upgrade discussed previously. Looking at the experiments, ALICE and LHCb will perform major upgrades to their detectors and read-out systems. An impressive amount of consolidation work is also foreseen. Of note is major work in the much-solicited PS and SPS experimental areas.

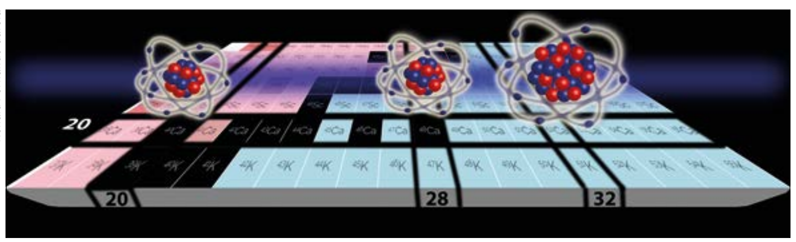
Besides the exploitation of the LHC in the short term, the workshop revealed that there is a huge amount of work going on to anticipate and assure the mid-term future of the laboratory, both at the high-energy frontier and in the extensive non-LHC physics programmes. The LIU upgrade and the consolidation effort will help to guarantee the future for, and offer potential performance improvements to, the extensive fixed-target facilities, including the Antiproton Decelerator and the new Extra Low ENergy Antiproton ring (ELENA), HIE-ISOLDE, nTOF and AWAKE.

Further reading
Material and detailed information about the summary session of Chamonix 2016 can be found at https://indico.cern.ch/event/486336/.
https://indico.cern.ch/event/448109.
https://espace.cern.ch/be-dep/BEDepartmentalDocuments/BE/LHC_Schedule_2016.pdf.

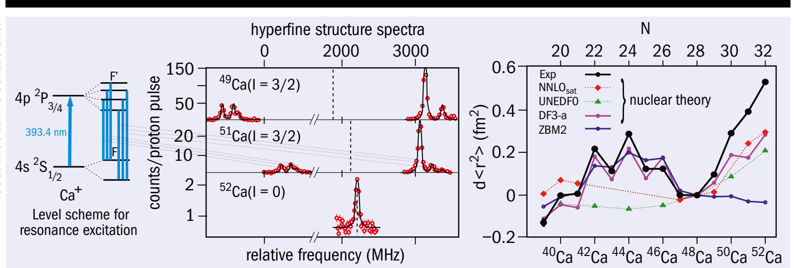
Nuclear physics

Exploring the nature of the proposed magic number $N = 32$

Ronald Fernando Garcia



ISOLDE/COLLAPS Collaboration



Top: The region of the chart of nuclei including the $^{40-52}$Ca isotopes studied at ISOLDE. Bottom, left to right: The atomic excitation scheme used to study the Ca isotopes. The measured hyperfine structure for ^{49}Ca, ^{51}Ca and ^{52}Ca isotopes; dashed lines indicate the centroid of the hyperfine structure. The charge radii for the $^{39-52}$Ca isotopes are shown and compared with the best-performing models. The large radius of ^{52}Ca ($Z = 20$, $N = 32$) challenges theory and questions its magicity nature.

Magic numbers appear in nuclei in which protons or neutrons completely fill a shell. The existence of magic numbers to explain certain regularities observed in nuclei was discovered in 1949 independently by M Goeppert-Mayer and J D Jensen, who were awarded the Nobel prize in 1963. Nuclei containing a magic number of nucleons, namely 2, 8, 20, 28, 50 and 82, are spherical, and present a very high degree of stability, which makes them very difficult to excite. The degree of "magicity" of a nucleus can be determined by precisely determining its shape, mass, excitation energy and electromagnetic observables – properties that can be precisely studied with dedicated experiments at ISOLDE.

The calcium-isotopic chain ($Z = 20$, magic proton number) is a unique nuclear system to study how protons and neutrons interact inside of the atomic nucleus: two of its stable isotopes are magic in both their proton and neutron number (^{40}Ca with $N = 20$ and ^{48}Ca with $N = 28$). Despite an excess of eight neutrons, ^{48}Ca exhibits the striking feature that it has an identical mean square charge radius as ^{40}Ca. In addition, experimental evidence of doubly magic features in a short-lived calcium isotope, ^{52}Ca ($N = 32$), was obtained in 2013 (Wienholtz *et al.* 2013 *Nature* **498** 346). Therefore, to determine the radius beyond ^{48}Ca was crucial from an experimental and theoretical point of view. The new determination of the nuclear radius is now challenging the magicity of the ^{52}Ca isotope.

The measurements were performed by using high-resolution bunched-beam collinear laser spectroscopy in the COLLAPS installation at ISOLDE, CERN. The charge radii for $^{40-52}$Ca isotopes were obtained from the measured optical isotope shifts extracted from the fit of the hyperfine experimental spectra. Indeed, although the average distance between the electrons and the nucleus in an atom is about 5000 times larger than the nuclear radius, the size of the nuclear-charge distribution is manifested as a perturbation of the atomic energy levels. A change in the nuclear size between two isotopes gives rise to a shift of the atomic hyperfine structure (hfs) levels. This shift between two isotopes, one million times smaller than the absolute transition frequency, commonly known as the isotope shift, includes a part that is proportional to the change in the nuclear mean square charge radii. Measurement of such a tiny change is only possible by using ultra-high-resolution techniques. With a production yield of only a few hundred ions per second, the measurement on ^{52}Ca represents one of the highest sensitivities ever reached using fluorescence-detection techniques. The collinear laser spectroscopy technique developed at ISOLDE has been established as a unique method to reach such high resolution, and has been applied with different detection schemes to study a variety of nuclear chains.

The resulting charge radius of ^{52}Ca is found to be much larger than expected for a doubly magic nucleus, and largely exceeds the theoretical predictions. The large and unexpected increase of the size of the neutron-rich calcium isotopes beyond $N = 28$ challenges the doubly magic nature of ^{52}Ca, and opens new and intriguing questions on the evolution of nuclear size away from stability, which are of importance for our understanding of neutron-rich atomic nuclei.

Further reading
Nature Physics 2016 10.1038/nphys3645.

Antimatter

New ALPHA measurement of the charge of antihydrogen

CERN

The ALPHA experiment installed at CERN's Antiproton Decelerator.

The ALPHA collaboration has just published a new measurement of the charge of the antihydrogen atom. Although the Standard Model predicts that antihydrogen must be strictly neutral, only a few actual direct measurements have been performed so far to test this conjecture.

A glance at the Particle Data Book reveals that, according to the latest measurements, the antiproton charge can differ from the charge of the electron by at most 7×10^{-10} times the fundamental charge. The comparable number for the positron is somewhat larger, at 4×10^{-8}. Note that studies with atoms of normal matter show that they are neutral to about one part in 10^{21}. We are, therefore, unsurprisingly, way behind in our ability to study antimatter. Given that we still do not understand the baryon asymmetry, it is generally a good idea to take a hard look at antimatter, if you can get your hands on some.

Antihydrogen is unique in the laboratory in that it should be neutral, stable antimatter. Indeed, the charge–parity–time (CPT) symmetry requires antihydrogen to have the same properties as hydrogen, including charge neutrality. In ALPHA, we can produce antihydrogen atoms and catch them in a trap formed by superconducting magnets, and we can hold them for at least 1000 s.

The current article in *Nature* results from experiments in the recently commissioned ALPHA-2 machine, and uses a new technique proposed by ALPHA member Joel Fajans and colleagues at UC Berkeley. The new method, known as stochastic acceleration, involves subjecting the trapped antihydrogen atoms to electric-field pulses at various time intervals. If the antihydrogen is not really neutral, it will be "heated" by the repeated pulses until it finally escapes the trap and annihilates. Comparing the results of trials with and without the pulsed field, we can derive a limit on how "charged" antihydrogen might be. The answer so far: antihydrogen is neutral to 0.7 ppb (one standard deviation) of the fundamental charge. This is a factor of 20 improvement over our previous limit, set by using static electric fields to try to deflect antihydrogen when it is released from the trap.

If we take another approach and assume that antihydrogen is indeed neutral, we can combine this result with ASACUSA'S measurement of the antiproton charge anomaly to improve the limit on the positron charge anomaly by a factor of about 25. Of course, we are looking for signs of new physics in the antihydrogen system – it is probably best not to assume anything.

Further reading
C Amole *et al.* 2014 *Nature Commun.* **5** 3955
G B Andresen *et al.* 2010 *Nature* **468** 673–676.
G B Andresen *et al.* 2011 *Nature Phys.* **7** 558–564
M Hori *et al.* *Nature* **475** 484–488 dx.doi.org/10.1038/nature10260.

Les physiciens des particules du monde entier sont invités à apporter leurs contributions aux CERN Courier, en français ou en anglais. Les articles retenus seront publiés dans la langue d'origine. Si vous souhaitez proposer un article, faites part de vos suggestions à la rédaction à l'adresse cern.courier@cern.ch.

CERN Courier welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send proposals to the editor at cern.courier@cern.ch.

LHC EXPERIMENTS

ATLAS searches for strong SUSY production at Run 2

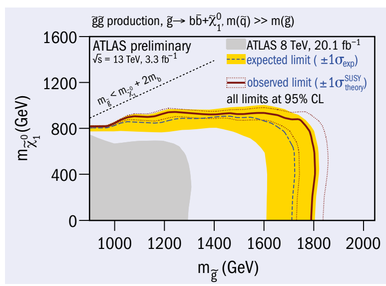
As the LHC delivered proton–proton collisions at the record energy of 13 TeV during the summer and autumn of last year, the experiments were eagerly scrutinising the new data. They were on alert for the signatures that would be left by new heavy particles, indicating a breakdown of the Standard Model in the new energy regime. A few days before CERN closed for the Christmas break, and only six weeks after the last proton–proton collisions of 2015, the ATLAS collaboration released the results of seven new searches for supersymmetric particles.

Supersymmetry (SUSY) predicts that, for every known elementary particle, there is an as-yet-undiscovered partner whose spin quantum number differs by half a unit. In most models, the lightest SUSY particle (LSP) is stable, electrically neutral and weakly interacting, hence it is a good dark-matter candidate. SUSY also protects the Higgs boson mass from catastrophically large quantum corrections, because the contributions from normal particles and their partners cancel each other out. The cancellation is effective only if some of the SUSY particles have masses in the range probed by the LHC. There are therefore well-founded hopes that SUSY particles might be detected in the higher-energy collisions of LHC Run 2.

The data collected by the ATLAS detector in 2015 are just an appetiser. The 3.2 fb^{-1} of integrated luminosity available are an order of magnitude less that collected in Run 1, and a small fraction of that expected by 2018. The first Run 2 searches for SUSY particles have focused on the partners of the quarks and gluons (called squarks and gluinos). They would be abundantly produced through strong interactions with cross-sections up to 40 times larger than in Run 1. The sensitivity has also been boosted by detector upgrades (in particular, the new "IBL" pixel layer installed near to the beam pipe) and improvements in the data analysis.

Squarks and gluinos would decay to quarks and the undetectable LSP, producing an excess of events with energetic jets and missing transverse momentum. The seven searches looked for such a signature, with different selections depending on the number of jets, b-tagged jets and leptons, to be sensitive to different production and decay modes. Six of the searches found event rates in good agreement with the Standard Model prediction, and placed new limits on squark and gluino masses. The figure shows the new limits for a gluino decaying to two b quarks and a neutralino LSP. For a light neutralino, the Run 1 limit of 1300 GeV on the gluino mass has been extended to 1780 GeV by the new results.

The seventh search looked for events with a Z boson, jets and missing transverse momentum, a final state where a 3σ was observed in the Run 1 data. Intriguingly, the new data show a modest 2σ excess over the background prediction. This intriguing excess, and a full investigation of all SUSY channels, make the upcoming 2016 data eagerly awaited.



The gluino (x-axis) and neutralino (y-axis) masses to the bottom left of the red line are excluded by the latest results, under the assumption that the gluino decays to two b quarks and a neutralino. The grey area is the corresponding Run 1 limit.

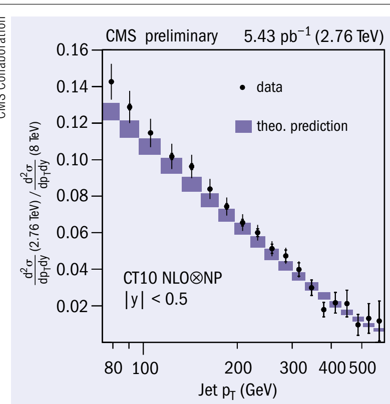
Further reading

"Search for gluino-mediated stop and sbottom pair production in events with b-jets and large missing transverse momentum in √s = 13 TeV pp collisions with the ATLAS detector", ATLAS-CONF-2015-067, https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-067/.

"A search for supersymmetry in events containing a leptonically decaying Z boson, jets and missing transverse momentum in √s = 13 TeV pp collisions with the ATLAS detector", ATLAS-CONF-2015-082, https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-082/.

CMS bridges the gap in jet measurements

The LHC Run 1, famed for its discovery of the Higgs boson, came to a conclusion on Valentine's Day (14 February) 2013. The little-known fact is that the last three days of the run were reserved neither for the highest energies nor for the heaviest ions, but for relatively low-energy proton–proton collisions at 2.76 TeV centre-of-mass energy. Originally designed as a reference run for heavy-ion studies, it also provided the perfect opportunity to bridge the wide gap in jet measurements between the Tevatron's 1.96 TeV and the LHC's 7 and 8 TeV.



Ratio of the inclusive jet-production cross-section at $\sqrt{s} = 2.76$ TeV to the one at $\sqrt{s} = 8$ TeV, shown as a function of jet p_T in rapidity of $|y| < 0.5$. The measurements are compared with the NLO QCD prediction using the CT10 PDFs.

Jet measurements are often plagued by large uncertainties arising from the jet-energy scale, which itself is subject to changes in detector conditions and reconstruction software. Because the 2.76 TeV run was an almost direct continuation of the 8 TeV proton–proton programme, it provided a rare opportunity to measure jets at two widely separated collision energies with almost identical detector conditions and with the same analysis software. CMS used this Valentine's Day gift from the LHC to measure the inclusive jet cross-section over a wide range of angles (absolute rapidity $|y| < 3.0$) and for jet transverse momenta p_T from 74 to 592 GeV, nicely complementing the measurements performed at 8 TeV. The data are compared with the theoretical prediction at next-to-leading-order QCD (the theory of the strong force) using different sets of parameterisations for the structure of the colliding protons. This measurement tests and confirms the predictions of QCD at 2.76 TeV, and extends the kinematic range probed at this centre-of-mass energy beyond those available from previous studies.

Calculating ratios of the jet cross-sections at different energies allows particularly high sensitivity to certain aspects of the proton structure. The main theory scale-uncertainties from missing orders of perturbative calculations mostly cancel out in the ratio, leaving exposed the nearly pure, so-called DGLAP, evolution of the proton parton density functions (PDFs). In particular, one can monitor directly the evolution of the gluon density as a function of the energy of the collisions. This lays a solid foundation for future searches for new physics, for which the parametrisations of the PDFs are the leading uncertainty. Also, the experimental uncertainties cancel out in the ratio if the conditions are stable enough, as indeed they were for this period of data-taking. This principle was proven by ATLAS with 2.76 TeV data collected in 2011 (2013 *Eur. Phys. J.* **C** 73 2509), but with a data set 20 times smaller.

The figure demonstrates the excellent agreement of the ratio of 2.76 and 8 TeV data with the QCD predictions, laying a solid foundation for future searches for new physics through smaller QCD uncertainties. This opportunistic use of the 2.76 GeV data by CMS has again proven the versatility and power of the LHC programme – a true Valentine's Day for jet aficionados.

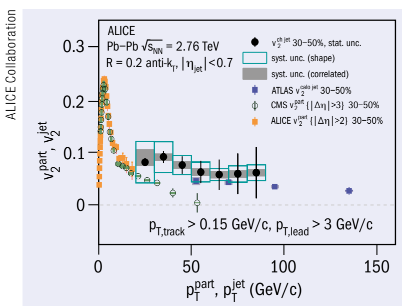
Further reading

CMS Collaboration 2015 CMS PAS SMP-14-017, cds.cern.ch/record/2033773.

Jet v_2 measurements with ALICE

High-energy scattering of partons (quarks and gluons) produces collimated cones of particles called jets, the production rate of which can be calculated using perturbative QCD techniques. In heavy-ion collisions, partons lose energy in the hot, dense quark–gluon plasma (QGP), leading to a modification of the jet-energy distribution. Measurement of the jet characteristics can therefore be used to probe QGP properties.

In non-central heavy-ion collisions, the overlap region between the two nuclei where nucleon–nucleon scattering takes place has a roughly elliptic shape, resulting in a longer average path length – and therefore larger energy loss – for jets and particles that are emitted along the major axis, than for those emitted along the minor axis of the interaction region. The resulting variation of the azimuthal jet distribution can be expressed as jet v_2, the second coefficient of a Fourier expansion of the angular distribution. The magnitude of jet v_2 depends on the path-length dependence of the jet energy loss, which differs among



Positive v_2 for both jets and charged hadrons is observed up to high p_T in semi-central collisions (30–50% collision centrality), for single particles (ALICE and CMS), charged-particle jets (ALICE) and calorimetrically measured jets (ATLAS).

proposed energy-loss mechanisms and can be studied via model comparisons.

The figure shows the new jet v_2 measurement of ALICE, using only charged particles for jet reconstruction, in semi-central collisions (30–50% collision centrality) compared with earlier jet v_2 results of ATLAS, using both charged and neutral fragments, and v_2 of ALICE and CMS, using single charged particles. The ALICE measurement covers the p_T range between the charged-particle results and the ATLAS jet measurements. Jet measurements in this momentum range (20–50 GeV/c) are challenging due to the large background of soft particles in the event. This background is itself subject to azimuthal variations, which have to be carefully separated from the jet v_2 signal.

The significant positive v_2 for both jets and single charged particles indicates that in-medium parton energy loss is large, and that sensitivity to the collision geometry persists up to high p_T. For a more quantitative interpretation in terms of density and path-length dependence, the experimental results will need to be interpreted within theoretical models that include the effects of parton energy loss as well as jet fragmentation. Larger data samples from Run 2 will further improve the measurement, giving more precise information about the nature of the QGP and its interactions with high-momentum quarks and gluons.

Further reading

ALICE Collaboration 2016 *Phys.Lett. B* **753** 511, arxiv.org/abs/1509.07334.

LHCb brings charm physics to the frontier of experimental knowledge

Owing to the large cross-section for charm production at the LHC, LHCb collected the world's largest sample of charmed hadrons, allowing for stringent tests of the Cabibbo–Kobayashi–Maskawa (CKM) mechanism in the Standard Model (SM). The search for violation of the charge-parity (CP) symmetry in weak interactions is among the most relevant of such tests.

In recent years, LHCb confirmed unequivocally that CP violation occurs in the B^0 system, and observed, for the first time, the same mechanism in B^0_s decays. All of the results match the SM predictions well. Although an outstanding experimental precision in the charm sector has been achieved, clear evidence of CP violation has not been seen yet. Mesons composed of a charm and an anti-up quark, so-called D^0 particles, constitute an interesting laboratory for this search. The D^0 meson is the only particle in nature containing an up-type quark that gives rise to the phenomenon of matter–antimatter oscillation.

In the SM, in contrast to the case of beauty mesons, the weak decays of charmed mesons are not expected to produce large CP-violating effects. However, CP violation can be enhanced by transitions involving new particles beyond those already known.

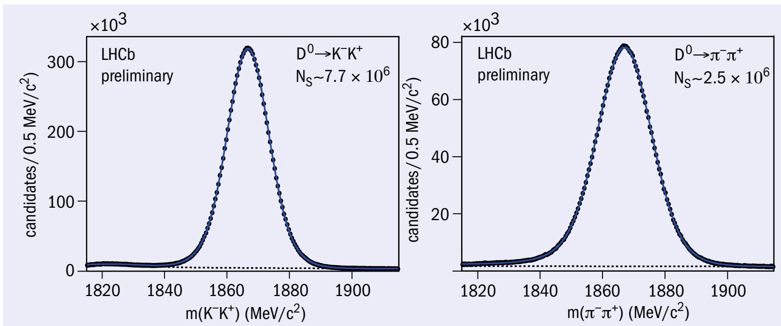
In 2011, LHCb reported the first ▷

evidence for CP violation in the charm sector, measuring the difference of the time-integrated CP asymmetries in $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$ decays to differ significantly from zero, $\Delta A_{CP} = [-0.82 \pm 0.21\ (\mathrm{stat.}) \pm 0.11\ (\mathrm{syst.})]\%$. This result was reinforced later by new measurements from the CDF and Belle experiments. On the other hand, in 2014, LHCb published a more precise measurement, $\Delta A_{CP} = [+0.14 \pm 0.16\ (\mathrm{stat.}) \pm 0.08\ (\mathrm{syst.})]\%$, with a central value closer to zero than that obtained previously, with a precision of 2×10^{-3}.

Now, using the full data sample collected in Run 1, LHCb breaks the wall of 10^{-3} for the first time ever, reaching a precision of 9×10^{-4}. The measured value of ΔA_{CP} is $[-0.10 \pm 0.08\ (\mathrm{stat.}) \pm 0.03\ (\mathrm{syst.})]\%$.

Although the evidence for CP violation in the charm sector is not confirmed, LHCb brings charm physics to the frontier of experimental knowledge. The experiment plans to collect an integrated luminosity of 50 inverse femtobarn, owing to an upgraded detector, in about 10 years from now. This will improve the precision of these results by an order of magnitude.

LHCb Collaboration



Invariant mass spectra for $D^0 \rightarrow K^-K^+$ (left) and $D^0 \rightarrow \pi^-\pi^+$ (right), showing the high-statistics samples of cleanly reconstructed decays in these suppressed modes.

● **Further reading**
LHCb-PAPER-2015-055 (cds.cern.ch).

Neutrino physics

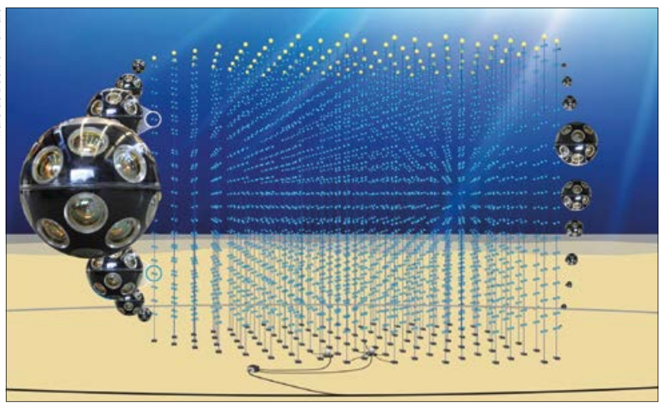
Construction of KM3NeT, a next-generation neutrino telescope, has begun

In the early morning of 3 December, scientists and engineers started the installation of KM3NeT (*CERN Courier* July/August 2012 p31). Once completed, it will be the largest detector of neutrinos in the Northern Hemisphere. Located in the depths of the Mediterranean Sea, the infrastructure will be used to study the fundamental properties of neutrinos and to map the high-energy cosmic neutrinos emanating from extreme cataclysmic events in space.

Neutrinos are the most elusive of elementary particles and their detection requires the instrumentation of enormous volumes: the KM3NeT neutrino telescope will occupy more than a cubic kilometre of seawater. It comprises a network of several hundred vertical detection strings, anchored to the seabed and kept taut by a submerged buoy. Each string hosts 18 light-sensor modules, equally spaced along its length. In the darkness of the abyss, the sensor modules register the faint flashes of Cherenkov light that signal the interaction of neutrinos with the seawater surrounding the telescope.

On board the Ambrosius Tide deployment boat, the first string – wound, like a ball of wool, around a spherical frame – arrived at the location of the KM3NeT-Italy site, south of Sicily. It was anchored to the seabed at a depth of 3500 m and connected to a junction box, already present on the sea floor, using a remotely operated submersible. The junction box is connected by a 100 km cable to the shore station located in Portopalo di Capo Passero in the south of Sicily.

Marc de Boer/Ori Ginale



A building block of KM3NeT comprises 115 detection strings; the full detector has many building blocks, with a total of a few hundred strings.

After verification of the quality of the power and fibre-optic connections to the shore station, the go-ahead was given to trigger the unfurling of the string to its full 700 m height. During this process, the deployment frame is released from its anchor and floats towards the surface while slowly rotating. In doing so, the string unwinds from the spherical frame, eventually leaving behind a vertical string. The string was then powered on from the shore station, and the first data from the sensor modules started streaming to shore.

The successful acquisition of data from the abyss with the novel technology developed by the KM3NeT collaboration is a major milestone for the project. It represents the culmination of more than 10 years of research and development by the many research institutes that make up the international collaboration.

● **Further reading**
arxiv.org/abs/1601.07459.

New facilities

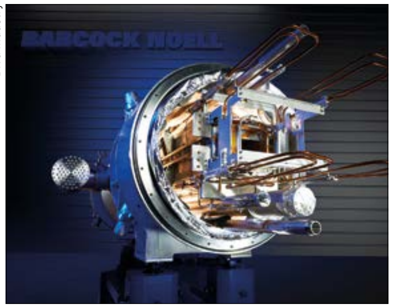
Manufacturing and delivery of components for the new heavy-ion synchrotron SIS100 at FAIR has begun

The international Facility for Antiproton and Ion Research in Europe (FAIR) (*CERN Courier* May 2007 p23) is currently under construction at GSI, in Darmstadt, Germany. The FAIR accelerators will deliver antiproton and ion beams of unprecedented intensities and qualities to perform heavy-ion and antimatter research. The driver accelerator of FAIR is a fast-ramping, superconducting synchrotron, SIS100, which allows the acceleration of high-intensity beams of stable elements from protons (29 GeV) to uranium (11 GeV/u). SIS100 will be installed in an underground tunnel and all of the services will be installed in a parallel supply tunnel.

The delivery of components for SIS100 commenced at the end of 2015. On 21 December, AURION in Seeligenstadt delivered the first of nine magnetic-alloy bunch-compression cavities. In a combined site/factory acceptance test at GSI, approval for series production is now in preparation.

As the first Polish in-kind contribution, the first piece of cryogenic-bypass line, made at the Wroclaw University of Technology, was delivered in February. After delivery, the bypass line will undergo acceptance tests at GSI.

BNG Industry



The first fast-ramped superconducting dipole for the SIS100 accelerator is currently being tested at GSI.

The site acceptance test of the first of a series of fast-ramped, dipole magnets is in its final stage (see figure). The results available so far indicate high mechanical precision and excellent performance of the superconducting coil. Following successful results, series production has started, and the first devices are expected to be delivered by the middle of 2016. The series devices will be tested at the new test facility at GSI, which has been set up for cold testing of FAIR magnets. In accordance with the contracts, many other SIS100 components will be delivered in 2016, including the first of a series of superconducting quadrupoles from JINR (Dubna, Russia), resonance sextupole magnets, acceleration cavities, magnet chambers, cryo-catcher and cryo-absorption pumps, and many others.

The realisation phase of the SIS100 project is fully under way, and the work is proceeding according to schedule. The production of accelerator components is expected to take a maximum of four years.

Underground laboratories

LUNA observes a rare nuclear reaction that occurs in giant red stars

In December, the Laboratory for Underground Nuclear Astrophysics (LUNA) experiment (*CERN Courier* October 2004 p31) reported the first direct observation of sodium production in giant red stars, one of the nuclear reactions that are fundamental to the formation of the elements that make up the universe.

LUNA is a compact linear accelerator for light ions (maximum energy 400 keV). A unique facility, it is installed in a deep-underground laboratory and shielded from cosmic rays. The experiment aims to study the nuclear reactions that take place inside stars, where elements that make up matter are formed and then driven out by gigantic explosions and scattered as cosmic dust.

For the first time, LUNA has observed three low-energy resonances in the neon-sodium cycle, the $^{22}Ne(p,\gamma)^{23}Na$ reaction, responsible for sodium production in red giants and energy generation. LUNA recreates the energy ranges of nuclear reactions and, with its accelerator, goes back in time to one hundred million years after the Big Bang, when the first stars formed and the processes that gave rise to the huge variety of elements in the universe started.

This result is an important piece in the puzzle of the origin of the elements in the universe, which LUNA has been studying for 25 years. Stars assemble atoms through a complex system of nuclear reactions. A very small fraction of these reactions have been studied at the energies existing inside of the stars, and a large part of those few cases have been observed using LUNA.

A high-purity germanium detector with relative efficiency up to 130% was used for this particular experiment, together with a windowless gas target filled with enriched gas. The rock surrounding the underground facility at the Gran Sasso National Laboratory and additional passive shielding protected the experiment from cosmic rays and ambient radiation, making the direct observation of such a rare process possible.

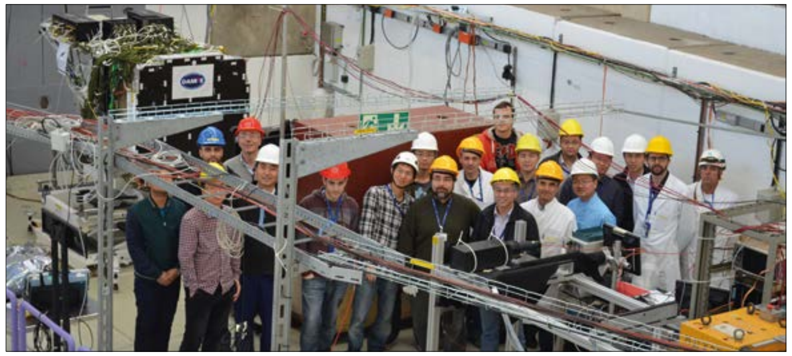
INFN

Members of the LUNA collaboration pictured next to the facility.

● **Further reading**
F Cavanna *et al.* (The LUNA Collaboration) 2015 *Phys. Rev. Lett.* **115** 252501

ASTROPARTICLES

DAMPE joins the search for dark matter in space



The DAMPE detector (far left) installed in the CERN PS T9 beamline.

On 17 December, the Chinese Academy of Sciences (CAS) successfully launched the DArk Matter Particle Explorer (DAMPE) satellite from the Jiuquan Satellite Launch Center in northwest China, marking the entrance of a new player in the global hunt for dark matter.

The nature of dark matter is one of the most fundamental questions of modern science, and many experiments have been set up to unravel this mystery, using either large underground detectors or at colliders (for example at the LHC), or with space missions (for example, AMS, *CERN Courier* November 2014 p6, or CALET, *CERN Courier* November 2015 p11).

DAMPE is the first science satellite launched by CAS. Built with advanced particle-detection technologies, DAMPE will extend the dark-matter search in space into the multi-TeV region. It will measure electrons and photons in the 5 GeV–10 TeV range with unprecedented energy resolution (1.5% at 100 GeV), to find dark-matter annihilation in these channels. It will also measure precisely the flux of nuclei up to above 100 TeV, which will bring new insights into the origin and propagation of high-energy cosmic rays. With its excellent photon-detection capability, the DAMPE mission is also well placed for new discoveries in high-energy γ-ray astronomy. The DAMPE collaboration consists of Chinese (Purple Mountain Observatory, University of Science and Technology, Institute of High Energy Physics, Institute of Modern Physics, Lanzhou, National Space Science Center) and European (University of Geneva, INFN Perugia, Bari and Lecce) institutes.

The DAMPE detector weighs 1.4 tonnes and consumes 400 W. It consists of, from top to bottom, a plastic scintillator detector (PSD) that serves as an anti-coincidence detector, a silicon-tungsten tracker-converter (STK), a BGO imaging calorimeter of about 31 radiation lengths, and a neutron detector (NUD). The STK, which improves the tracking and photon detection capability of DAMPE greatly, was proposed and designed by the European team and was constructed in Europe, in collaboration with IHEP, in a record time of two years. DAMPE became a CERN-recognised experiment in March 2014 and has profited greatly from the CERN test-beam facilities, both in the Proton Synchrotron and the Super Proton Synchrotron. In fact, CERN provided more than 60 days of beam from July 2012 to December 2015, allowing DAMPE to calibrate its detector extensively with various types of particles, with energy raging from 1 to 400 GeV.

Three days after the launch, on 20 December, the STK was powered on, and four days later, the high voltage of the calorimeter was also turned on. To the satisfaction of the collaboration, all of the detector sub-systems functioned very well, and in-orbit commissioning is now well under way to tune the detector to optimal condition for the three-year observation period. A great deal of data collection, process and analysis lie ahead, but thanks to CERN, we can look forward to a well-callibrated DAMPE detector to produce exciting new measurements in the very near future.

Sciencewatch

Compiled by John Swain, Northeastern University

Low-cost diamonds?

A novel, new form of carbon, dubbed "Q-carbon", is harder than diamond. The new phase, discovered by Jagdish Narayan and Anagh Bhaumik of North Carolina State University in Raleigh, US, results from the rapid quenching of liquid carbon produced by high-power nanosecond laser pulses on amorphous carbon. The material can be a semiconductor or metallic, depending on temperature. It is ferromagnetic and, depending on the cooling rate, can be formed with tiny diamonds. The process takes place under normal temperatures and pressures and is inexpensive, making bulk, low-cost diamond production look very feasible, in addition to there now being a very interesting new form of carbon.

● **Further reading**
J Narayan and A Bhaumik 2015 *J. Appl. Phys.* **118** 215303.


Steve Jurvetson

A synthetic diamond obtained by industry using a patented production process.

Seventh-row complete

Four new elements have been discovered, completing the seventh row of the periodic table. The RIKEN collaboration in Japan takes the credit for element 113 (ununtrium, Uut), and they will be invited to propose a more interesting name. For elements 115, 117 and 118 (ununpentium, Uup; ununseptium, Uus; and ununoctium, Uuo), credit goes to JINT in Dubna, LLNL in California and ORNL in Tennessee. New names and two letter symbols will also be proposed for these. Now it's time to try for the eighth row.

● **Further reading**
IUPAC, 30 December 2015, announcement at www.iupac.org/news/news-detail/article/discovery-and-assignment-of-elements-with-atomic-numbers-113-115-117-and-118.html.

Chameleon tongues

Chameleons are able to lash out with their sticky tongues that extend more than twice their body lengths, and achieve incredible accelerations of 25490 m/s^2 or 264 g, corresponding to peak power outputs of more than 14,000 W/kg, outperforming any other amniotes. Christopher V Anderson of Brown University in Rhode Island, US, has tracked the mechanism back to stretching elastic tissues, similar to the stretching of a bow. This energy can then be released rapidly – much more so than muscles could provide directly.

● **Further reading**
C V Anderson 2016 *Scientific Reports* **6** 18625 and video at news.brown.edu/articles/2016/01/chameleon.

Multicellular life from a single accident

Early life was unicellular, and we now know that it took just one random but crucial mutation, 600 million years ago, which changed the function of one key protein, to make multicellular life possible. In multicellular organisms, adjoining cells have to co-ordinate, and key to this at division is the orientation of the mitotic spindle, which segregates chromosomes into daughter cells. Using a technique called ancestral protein reconstruction, which is based on gene sequencing and computer modelling, Kenneth Prehoda of the University of Oregon, US, and colleagues tracked things back to a mutation in the GK protein-interaction domain (GKPID). Even more remarkable, the reason that a single mutation could have such a huge effect is a lucky resemblance between two seemingly unrelated molecules – so we're lucky to be here at all.

● **Further reading**
D P Anderson *et al.* 2016 *eLife* **5** e10147.

Best test of charge conservation

We all think that electric charge is conserved, but physics is an experimental subject, so it's always good to check. The Borexino collaboration has now used a liquid scintillation detector to search for the decay of an electron into a neutrino and a photon. The new bound is a lifetime greater than 6.6×10^{28} years at 90% CL, two orders of magnitude better than the previous limit.

● **Further reading**
M Agostini *et al.* 2015 *Phys. Rev. Lett.* **115** 231802.

Separating hydrogen and deuterium

Hydrogen and deuterium are, chemically, quite similar, but without their electrons, a proton is less than half the radius of a deuteron. M Lozada Hidalgo and colleagues of the University of Manchester in the UK used this fact to provide a new and novel way to separate them. Both can diffuse through monolayers of graphene and boron nitride, but deuterons go through much more slowly, allowing a separation factor of about 10 to be achieved at room temperature. The isotope effect is explained by a roughly 60 meV difference in zero-point energies, which affect the activation barriers to pass through the monolayers – a surprising application of the uncertainty principle.

● **Further reading**
M Lozada-Hidalgo *et al.* 2016 *Science* **351** 68.

Bell loophole closed

Tests of local realism based on Bell's inequality have, up to now, always had a small loophole, but that has now been closed. Lynden K Shalm of NIST in Boulder, Colorado, US, and colleagues looked at entangled photon pairs, ensuring that the events used were space-like separated and using fast random-number generators and high-speed polarisation measurements. The results: local realism is rejected with a p value of 5.9×10^{-9}.

● **Further reading**
L K Shalm *et al.* 2015 *Phys. Rev. Lett.* **115** 250402.

CERNCOURIER
Volume 56 Number 2 March 2016
www.
IOP Publishing
CERN

Astrowatch

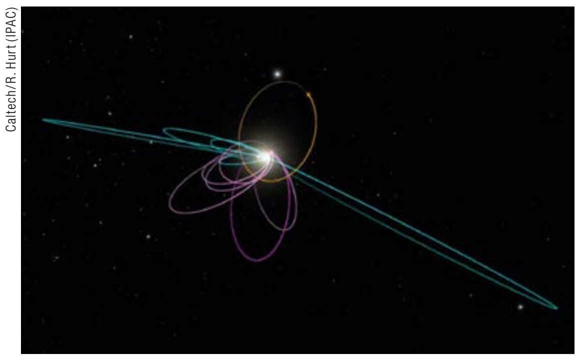
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva, and CHIPP, University of Zurich

Is there a 'ninth planet' after all?

Pluto was considered to be the ninth planet of the solar system, until it was relegated to a "dwarf planet" by the International Astronomical Union (IAU) in 2006. It was judged to be too small among many other trans-Neptunian objects to be considered a real planet. Almost 10 years later, two astronomers have now found indications of the presence of a very distant heavy planet orbiting the Sun. While it is still to be detected, it is already causing a great deal of excitement in the scientific community and beyond.

Pluto was discovered in 1930 by a young American astronomer, Clyde Tombaugh, who tediously looked at innumerable photographic plates to detect an elusive planet moving relative to background stars. With the progressive discovery – since the 1990s – of hundreds of objects orbiting beyond Neptune, Pluto is no longer alone in the outer solar system. It even lost its status of the heaviest trans-Neptunian object with the discovery of Eris in 2003. This forced the IAU to rethink the definition of a planet and led to the exclusion of Pluto from the strict circle of eight planets.

Eris is not the only massive trans-Neptunian object found by Mike Brown, an astronomer of the California Institute of Technology (Caltech), US, and colleagues. There are also Quaoar (2002), Sedna (2003), Haumea (2004) and Makemake (2005), all only slightly smaller than Pluto and Eris. Despite these discoveries, almost nobody during recent years would have thought that there could still be a much bigger real planet in the outskirts of our solar system. But this is what Mike Brown and one of his colleagues, the theorist Konstantin Batygin, now propose.



Caltech/R. Hurt (IPAC)

Diagram of the orbit around the Sun of the predicted ninth planet (orange), maintaining the orbits of the six most distant Kuiper-belt objects on the opposite side (pink), and also forcing five known objects into elongated perpendicular orbits (blue). The diagram was created using WorldWide Telescope.

The two astronomers deduced the existence of a ninth planet through mathematical modelling and computer simulations, but have not yet observed the object directly. The evidence comes from an unexpected clustering of perihelion positions and orbital planes of a group of objects just outside of the orbit of Neptune, in the so-called Kuiper belt. All six objects with the most elongated orbits – with semi-major axes greater than 250 AU – share similar perihelion positions and pole orientations. The combined statistical significance of this clustering is 3.8σ, assuming that Sedna and the five other peculiar planetoids have the same observational bias as other known Kuiper-belt objects.

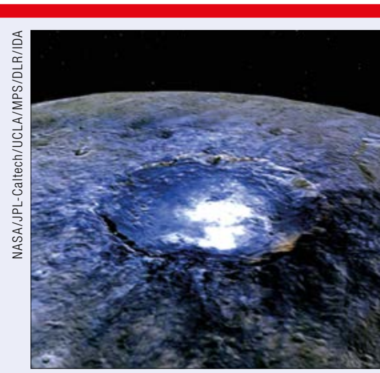
Batygin and Brown then show that a planet with more than about 10 times the mass of the Earth in a distant eccentric orbit anti-aligned with the six objects would maintain the peculiar configuration of their orbits. This possible ninth planet would rotate around the Sun about 20 times further out than Neptune, therefore completing one full orbit only approximately once every 10,000 years. Batygin's simulations of the effect of this new planet further predict the existence of a population of small planetoids in orbits perpendicular to the plane of the main planets. When Brown realised that such peculiar objects exist and have indeed already been identified, he became convinced about the existence of Planet Nine.

Observers now know along which orbit they should look for Planet Nine. If it happens to be found, this would be a major discovery: the third planet to be discovered since ancient times after Uranus and Neptune and, as with the latter, it would have been first predicted to exist via calculations.

Further reading

K Batygin and M Brown 2016 *The Astronomical Journal* **151** 22.

Picture of the month



NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

This impressive crater is located on Ceres, the largest object in the asteroid belt between Mars and Jupiter. With a diameter of 950 km, Ceres has been considered, since 2006, a "dwarf planet", as Pluto. And, as this former ninth planet, it has also been visited for the first time by a spacecraft, in 2015. While the New Horizons mission sent back amazing views of Pluto (Picture of the Month, *CERN Courier* September 2015 p17 and November 2015 p17), NASA's Dawn spacecraft was already in orbit around Ceres. Dawn's camera has revealed more than 100 bright spots on the surface of Ceres. The brightest is in the 90 km-wide Occator Crater shown in this false-colour image combining near-infrared and visible observations. The mysterious spots are thought to be a type of salt – a magnesium sulphate called hexahydrate – rather than ice or snow, according to a new study published in *Nature*. An accompanying paper reports ammonia-rich clays, which are usually to be found in the outer solar system. Did Ceres migrate to the asteroid belt from a region near Neptune? Maybe. The solar system is still full of surprises and mysteries.

CERN's new management begins a five-year term

Fabiola Gianotti took the reins on 1 January, alongside several incoming directors who complete the new structure of the laboratory.

Several challenges lie ahead for CERN during the years 2016–2020. With the winter technical stop of the accelerators coming to an end in March, the voyage of true post-Higgs physics exploration can start at the LHC. In the meantime, all of the other accelerators and experiments will continue to ensure that the scientific programme of the laboratory remains as diverse and compelling as it has always been.

For CERN, this means ensuring that the High-Luminosity LHC project and injector upgrades remain technically on track and financially secure, for both the accelerators and the experiments.

The rich programme of collaboration with the worldwide scientific community will be enhanced through studies and projects like the FCC study, CLIC and AWAKE. Beyond the lab, CERN will contribute to neutrino research outside of Europe through the CERN neutrino platform.

In the words of the Director-General, these years will be crucial "to start building the long-term future of particle physics".

Résumé

La nouvelle Direction du CERN entame un mandat de cinq ans

Plusieurs défis attendent le CERN entre 2016 et 2020. L'arrêt technique hivernal des accélérateurs se terminant fin mars, l'étude de la physique de l'après-Higgs va pouvoir commencer au LHC. Parallèlement, les autres accélérateurs et expériences vont permettre au Laboratoire de conserver un programme scientifique diversifié et passionnant. Pour le CERN, cela voudra dire maintenir le cap sur les plans technique et financier pour le projet HL-LHC et les améliorations des injecteurs, aussi bien pour les accélérateurs que pour les expériences. Le vaste programme de collaboration avec la communauté scientifique mondiale sera enrichi grâce à des études et des projets comme l'étude FCC, le CLIC et AWAKE. Le CERN contribuera aussi à la recherche sur les neutrinos en dehors de l'Europe grâce à la «plateforme neutrino». Selon la Directrice générale du CERN, ces années seront décisives pour « commencer à bâtir l'avenir à long terme de la physique des particules ».

Fabiola Gianotti – Director-General

In 1989, Fabiola Gianotti was awarded a PhD in experimental particle physics from the University of Milan, and went on to become an eminent physicist with more than 500 authored or co-authored publications in peer-reviewed scientific journals.

A member of the CERN community since 1994, Fabiola Gianotti is the first female Director-General of CERN.

Gianotti has been a research physicist in the Physics Department of CERN since 1994 – when she joined as a fellow – and since then has been involved in several CERN experiments, detector R&D and construction, as well as software development and data analysis.

From 2009 to 2013, she held the elected position of spokesperson for the ATLAS experiment, and was honoured to announce the discovery of the Higgs boson in a seminar at CERN on 4 July 2012.

During her career she has also been a member of several international committees, such as the Scientific Council of the CNRS (France), the Physics Advisory Committee of the Fermilab Laboratory (USA), the Council of the European Physical Society, the Scientific Council of the DESY Laboratory (Germany), and the Scientific Advisory Committee of NIKHEF (Netherlands). She is also a member of the Scientific Advisory Board of the UN secretary-general, Mr Ban Ki-moon, and of both the US National and the Italian Academy of Sciences (Accademia Nazionale dei Lincei).

Since 2012, Gianotti has been bestowed with several awards, including the Special Fundamental Physics Prize of the Milner Foundation (2012), the Enrico Fermi Prize of the Italian Physical Society (2013) and the Medal of Honour of the Niels Bohr Institute of Copenhagen (2013). She was also awarded the honour of "Cavaliere di Gran Croce dell'ordine al merito della Repubblica" by the Italian President.

Gianotti's influence and success have also led to her being ranked 5th in *Time* magazine's "Personality of the Year 2012", included in the *Guardian*'s 2011 "Top 100 most inspirational women" and *Forbes* magazine's 2013 "Top 100 most inspirational women" lists, and is considered one of the "Leading Global Thinkers of 2013" by *Foreign Policy* magazine (USA, 2013).

On 1 January, she became the first female Director-General of CERN.

Frédérick Bordry – Director for Accelerators and Technology

Frédérick Bordry was head of the Technology Department before being appointed as CERN's Director for Accelerators and Technology.

In 1978, Frédérick Bordry graduated with a PhD in electrical engineering from the Institut National Polytechnique in Toulouse, and went on to gain his higher doctorate in science from the same institute in 1985.

Bordry's early career was spent teaching and conducting energy conversion research. Then he moved to Brazil, where he spent two years as a professor at the Federal University of Santa Catarina (Florianópolis). In 1981, he was appointed senior lecturer at the Institut National Polytechnique in Toulouse.

Bordry came to CERN in 1986, joining the group working on power converters for the Large Electron–Positron Collider (LEP), before moving in 1988 to the Operations Group as an engineer in charge of the Super Proton Synchrotron and LEP.

In 1994, the year that the LHC was approved, he joined the Power Converter Group as the head of power converters design and construction for the LHC. He was appointed leader of the Power Converter Group in 2002, a position he held until December 2008.

In 2009, Bordry was promoted to head of the CERN Technology Department – responsible for technologies specific to existing particle accelerators, facilities and future projects – where he has remained until 2013.

From 2014, he acted as the director for accelerators and technology, where he is responsible for the operation and exploitation of the whole CERN accelerator complex, with particular emphasis on the LHC and for the development of new projects and technologies. He was re-appointed CERN's Director for Accelerators and Technology.

Eckhard Elsen – Director for Research and Computing

Particle physicist Eckhard Elsen has held many committee positions, including chairing the LHC experiments committee from 2011 to 2014.

Eckhard Elsen obtained his PhD in particle physics from Hamburg University in 1981.

Elsen's research focused initially on e^+e^- collider particle physics and led him to prominent postdoctoral positions at Hamburg University, SLAC National Accelerator Laboratory, and Heidelberg University, where he first made contact with CERN as a member of the OPAL collaboration.

In 1990, Elsen was promoted to senior scientist for the Deutsches Elektronen-Synchrotron (DESY), in Germany. During this time, he became the spokesperson for the H1 experiment (an international collaboration that developed and built the H1 detector at the ep-collider HERA at DESY), and later – after a sabbatical at the BaBar experiment at Stanford – project manager for the International Linear Collider (ILC) project team at DESY, when Elsen continued his relationship with CERN.

In 2006, Elsen was made a professor at Hamburg University, where he taught both general physics courses and accelerator physics, and supervised students.

Elsen has co-authored two books (the most recent on the physics harvest of the LHC Run 1), worked on more than 450 publications in various fields of particle physics, and participated in many scientific committees – including chairing the LHC experiments committee from 2011 to 2014.

Martin Steinacher – Director for Finance and Human Resources

Martin Steinacher has held high-level roles in the ESO and ESRF Councils and in the CERN Finance Committee.

Martin Steinacher studied physics, mathematics and astronomy before going on to gain his doctorate in experimental physics at the University of Basel.

After completing his studies, Steinacher moved to the University of Berne, where he worked for seven years as a scientific collaborator on space-research projects.

Then he continued as a civil servant at the Foreign Ministry, where he acted as a delegate for Switzerland and was responsible for planning the Swiss financial contribution to the European Space Agency (ESA), European Southern Observatory (ESO) and other international organisations.

These skills led to Steinacher being appointed the scientific adviser for the Federal Office for Education and Science, before being appointed the deputy head of international co-operation at the State Secretariat for Education and Research.

In his role as chairman of the CERN Finance Committee, Steinacher worked closely with CERN member states, which led to the unanimous approval of a new method to calculate the annual scale of contribution.

In 2013, Steinacher was promoted to head of the International Research Organisations Unit, giving him high-level roles as senior scientific administrator in the ESO and ESRF Councils. His achievements while in this position include helping to negotiate Poland's accession to ESO and also securing a funding agreement for the Swiss participation in the European Spallation Source project, until 2026.

Charlotte Lindberg Warakaulle – Director for International Relations

Charlotte Warakaulle has held a variety of posts at the United Nations, and was a key focal point for relations between CERN and the UN Office at Geneva.

Since 2001, Charlotte Warakaulle has held a variety of posts at the United Nations, from associate speechwriter to chief of the Political Affairs and Partnerships Section of the United Nations Office at Geneva.

During her time in this post, she was a key focal point for relations between CERN and the United Nations Office at Geneva, and was closely involved in the first-ever UNOG-CERN Co-operation Agreement, signed in 2011.

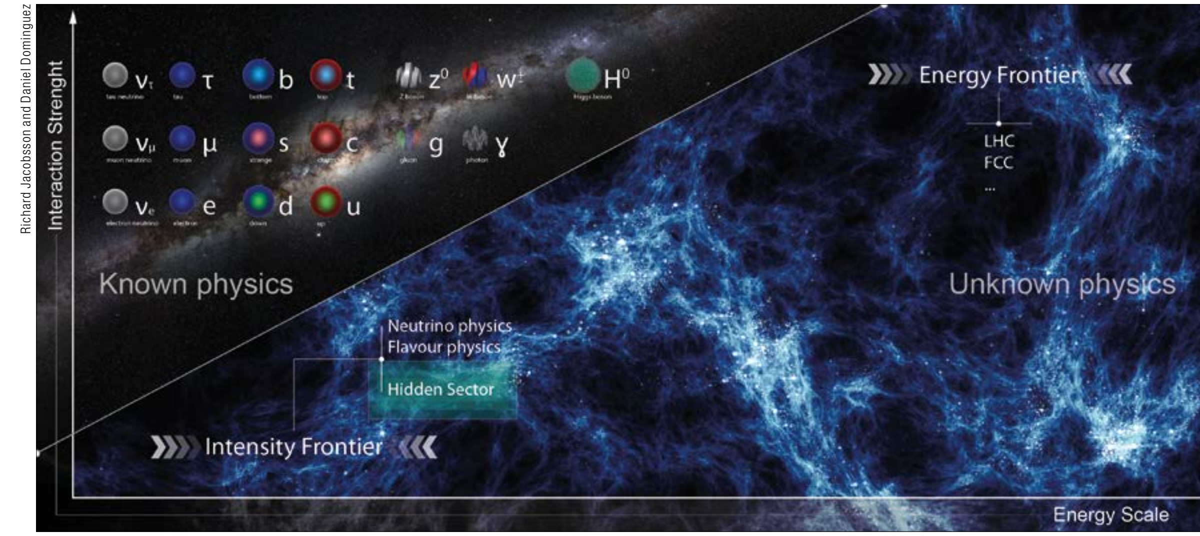
She was also a linchpin in the preparations for CERN obtaining observer status with the General Assembly at the United Nations in 2012.

Most recently, she took on the position of chief of the United Nations Library in Geneva, where she was responsible for library services, knowledge management, cultural diplomacy and intellectual outreach.

Prior to her work with the United Nations, Warakaulle held a Carlsberg visiting research fellowship at Lucy Cavendish College at the University of Cambridge from 1998 to 2001.

During her time at the University of Cambridge, she also served as editor-in-chief of the *Cambridge Review of International Affairs*, a peer-reviewed international affairs journal then published by the Centre of International Studies at the University of Cambridge.

She gained her MPhil in international relations at the University of Cambridge (Pembroke College), and also holds an MA in history (cand.mag.) from the University of Copenhagen, as well as an MA in history (coursework) from the University of Sydney and a BA in history from the University of Copenhagen.



SHiP is a new experiment at the intensity frontier aimed at exploring the hidden sector.

SHiP sets a new course in intensity-frontier exploration

SHiP (Search for Hidden Particles) is a newly proposed experiment for CERN's Super Proton Synchrotron accelerator. Its challenging goals include the direct search for hidden non-Standard Model particles.

A Golutvin, Imperial College London/CERN, and **R Jacobsson**, CERN, on behalf of SHiP.

SHiP is an experiment aimed at exploring the domain of very weakly interacting particles and studying the properties of tau neutrinos. It is designed to be installed downstream of a new beam-dump facility at the Super Proton Synchrotron (SPS). The CERN SPS and PS experiments Committee (SPSC) has recently completed a review of the SHiP Technical and Physics Proposal, and it recommended that the SHiP collaboration proceed towards preparing a Comprehensive Design Report, which will provide input into the next update of the European Strategy for Particle Physics, in 2018/2019.

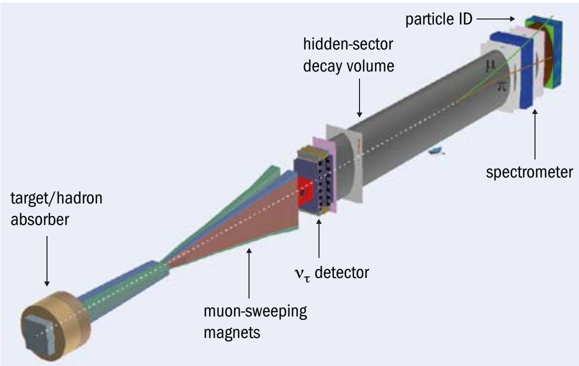
Why is the SHiP physics programme so timely and attractive? We have now observed all the particles of the Standard Model, however it is clear that it is not the ultimate theory. Some yet unknown particles or interactions are required to explain a number of observed phenomena in particle physics, astrophysics and cosmology, the so-called beyond-the-Standard Model (BSM) problems, such as dark matter, neutrino masses and oscillations, baryon asymmetry, and the expansion of the universe.

While these phenomena are well-established observationally, they give no indication about the energy scale of the new physics. The analysis of new LHC data collected at √ = 13 TeV will soon have directly probed the TeV scale for new particles with couplings at O(%) level. The experimental effort in flavour physics, and searches for charged lepton flavour violation and electric dipole moments, will continue the quest for specific flavour symmetries to complement direct exploration of the TeV scale.

However, it is possible that we have not observed some of the particles responsible for the BSM problems due to their extremely feeble interactions, rather than due to their heavy masses. Even in the scenarios in which BSM physics is related to high-mass scales, many models contain degrees of freedom with suppressed couplings that stay relevant at much lower energies.

Given the small couplings and mixings, and hence typically long lifetimes, these hidden particles have not been significantly ▷

SHiP Collaboration



Overview of the SHiP experimental set-up. The typical signature of a hidden particle decay is also shown, in this case a heavy neutral lepton decaying to a muon and a pion.

constrained by previous experiments, and the reach of current experiments is limited by both luminosity and acceptance. Hence the search for low-mass BSM physics should also be pursued at the intensity frontier, along with expanding the energy frontier.

SHiP is designed to give access to a large class of interesting models. It has discovery potential for the major observational puzzles of modern particle physics and cosmology, and can explore some of the models down to their natural "bottom line". SHiP also has the unique potential to test lepton flavour universality by comparing interactions of muon and tau neutrinos.

SPS: the ideal machine

SHiP is a new type of intensity-frontier experiment motivated by the possibility to search for any type of neutral hidden particle with mass from sub-GeV up to O(10) GeV with super-weak couplings down to 10^{-10}. The proposal locates the SHiP experiment on a new beam extraction line that branches off from the CERN SPS transfer line to the North Area. The high intensity of the 400 GeV beam and the unique operational mode of the SPS provide ideal conditions. The current design of the experimental facility and estimates of the physics sensitivities assume the SPS accelerator in its present state. Sharing the SPS beam time with other SPS fixed-target experiments and the LHC should allow 2×10^{20} protons on target to be produced in five years of nominal operation.

The key experimental parameters in the phenomenology of the various hidden-sector models are relatively similar. This allows common optimisation of the design of the experimental facility and of the SHiP detector. Because the hidden particles are expected to be predominantly accessible through the decays of heavy hadrons and in photon interactions, the facility is designed to maximise their production and detector acceptance, while providing the cleanest possible environment. As a result, with 2×10^{20} protons on target, the expected yields of different hidden particles greatly exceed those of any other existing and planned facility in decays of both charm and beauty hadrons.

As shown in the figure (left), the next critical component of SHiP after the target is the muon shield, which deflects the high flux of muon background away from the detector. The detector for the hidden particles is designed to fully reconstruct the exclusive decays of hidden particles and to reject the background down to below 0.1 events in the sample of 2×10^{20} protons on target. The detector consists of a large magnetic spectrometer located downstream of a 50 m-long and 5 × 10 m-wide decay volume. To suppress the background from neutrinos interacting in the fiducial volume, the decay volume is maintained under a vacuum. The spectrometer is designed to accurately reconstruct the decay vertex, mass and impact parameter of the decaying particle at the target. A set of calorimeters followed by muon chambers provide identification of electrons, photons, muons and charged hadrons. A dedicated high-resolution timing detector measures the coincidence of the decay products, which allows the rejection of combinatorial backgrounds. The decay volume is surrounded by background taggers to detect neutrino and muon inelastic scattering in the surrounding structures, which may produce long-lived SM V^0 particles, such as K_L, etc. The experimental facility is also ideally suited for studying interactions of tau neutrinos. The facility will therefore host a tau-neutrino detector largely based on the Opera concept, upstream of the hidden-particle decay volume (*CERN Courier* November 2015 p24).

Global milestones and next steps

The SHiP experiment aims to start data-taking in 2026, as soon as the SPS resumes operation after Long Shutdown 3 (LS3). The 10 years consist, globally, of three years for the comprehensive design phase and then, following approval, a bit less than five years of civil engineering, starting in 2021, in parallel with four years for detector production and staged installation of the experimental facility, and two years to finish the detector installation and commissioning.

The key milestones during the upcoming comprehensive design phase are aimed at further optimising the layout of the experimental facility and the geometry of the detectors. This involves a detailed study of the muon-shield magnets and the geometry of the decay volume. It also comprises revisiting the neutrino background in the fiducial volume, together with the background detectors, to decide on the required type of technology for evacuating the decay volume. Many of the milestones related to the experimental facility are of general interest beyond SHiP, such as possible improvements to the SPS extraction, and the design of the target and the target complex. SHiP has already benefitted from seven weeks of beam time in test beams at the PS and SPS in 2015, for studies related to the Technical Proposal (TP). A similar amount of beam time has been requested for 2016, to complement the comprehensive design studies.

The experimental facility is also ideally suited for studying interactions of tau neutrinos.

The SHiP collaboration currently consists of almost 250 members from 47 institutes in 15 countries. In only two years, the collaboration has formed and taken the experiment from a rough idea in the Expression of Interest to an already mature design in the TP. The CERN task force, consisting of key experts from CERN's different departments, which was launched by the CERN management in 2014 to investigate the implementation of the experimental facility, brought a fundamental contribution to the TP. The SHiP physics case was demonstrated to be very strong by a collaboration of more than 80 theorists in the SHiP Physics Proposal.

SHiP Collaboration

The SHiP collaboration has just received the green light to prepare a Comprehensive Design Report for the proposed experiment and facility.

The intensity frontier greatly complements the search for new physics at the LHC. In accordance with the recommendations of the last update of the European Strategy for Particle Physics, a multi-range experimental programme is being actively developed all over the world. Major improvements and new results are expected during the next decade in neutrino and flavour physics, proton-decay experiments and measurements of the electric dipole moments. CERN will be well-positioned to make a unique contribution to exploration of the hidden-particle sector with the SHiP experiment at the SPS.

● For further reading, see cds.cern.ch/record/2007512.

Résumé

SHiP ouvre une nouvelle voie pour explorer les frontières de l'intensité

Conçue pour être installée en aval d'un nouveau dispositif d'arrêt de faisceau auprès du Supersynchrotron à protons (SPS), l'expérience SHiP (Search for Hidden Particles)*, récemment proposée, vise à explorer le territoire des particules interagissant très faiblement, ainsi qu'à étudier les propriétés des neutrinos tau. Le Comité SPSC du CERN a recommandé à la collaboration SHiP de préparer un rapport de conception complet, lequel fournira des éléments d'informations pour la prochaine mise à jour de la stratégie européenne pour la physique des particules en 2018–2019.*

Aerial (drone) view of the Very Large Telescope observatory in Cerro Paranal, Northern Chile.

The eye that looks at galaxies far, far away

The Very Large Telescope, ESO's breathtaking installation, is the world's largest optical instrument, and among the most productive in terms of scientific papers generated.

Paola Catapano, with photos and video by **Mike Struik**, CERN.

Night is falling over Cerro Paranal, a 2600 m peak within the mountain range running along Chile's Pacific coastline. As our eyes gradually become accustomed to total obscurity and we start to catch a glimpse of the profile of the domes on top of the Cerro, we are overwhelmed by the breathtaking view of the best starry sky we have ever seen. The centre of the Milky Way is hanging over our heads, together with the two Magellanic Clouds and the four stars of the Southern Cross. The galactic centre is so star-dense that it looks rather like a 3D object suspended in the sky.

Not a single artificial light source is polluting the site, which is literally in the middle of nowhere, because the closest inhabited area is about 130 km away. The air in the austral winter in the Atacama desert is cold, but there is almost no wind, and no noise can be heard as I walk in the shadow of four gigantic (30 m tall) metal domes housing the four 8.2 m-diameter fixed unit telescopes (UTs) and four 1.8 m-diameter movable auxiliary telescopes (ATs), that make up the Very Large Telescope (VLT). Yet dozens of astronomers are working not far away, in a building right below the platform on top of the Cerro, overlooking the almost permanent cloud blanket over the Pacific Ocean.

As we enter the control room, I immediately feel a sense of *déjà vu*: a dozen busy and mostly young astronomers are drinking coffee, eating crisps and talking in at least three different languages, grouped around five islands of computer terminals.

Welcome to the nerve centre of the most complex and advanced optical telescope in the world. From here, all of the instrumentation is remotely controlled through some 100 computers connected to the telescopes by bunches of optical fibres. Four islands are devoted to the operation of all of the components of the VLT telescopes, from their domes to the mirrors and the imaging detectors, and the fifth is entirely devoted to the controls of interferometry.

Highly specialised ESO astronomers take their night shifts in this room 300 nights per year, on average. Most observations are done in service mode (60–70% of the total time), with ESO staff doing observations for other astronomers within international projects that have gone through an evaluation process and have been approved. The service mode guarantees full flexibility to reschedule observations and match them with the most suitable atmospheric conditions. The rest of the time is "visitor mode", with the astronomer in charge of the project leading the observations, which is particularly useful whenever any real-time decision is needed.

The shift leader tonight is an Italian from Padova. He swaps from one screen to the next, trying to ignore the television crew's microphones and cameras, while giving verbal instructions to a young Australian student. He is activating one of the VLT's adaptive-optics systems, hundreds of small pistons positioned under the mirrors to change their curvature up to thousands of times per second, to counteract any distortion caused by atmospheric turbulence. "Thanks to adaptive optics, the images obtained with the VLT are as sharp as if we were in space," he explains briefly, before leaning back on one of the terminals.

Complex machinery

Adaptive optics is not the only astronomers' dream come true at the VLT. The VLT's four 8.2 m-diameter mirrors are the largest single-piece light-collecting surface in the world, and the best application of active optics – the trick ESO scientists use to correct for gravitationally induced deformations as the telescope changes its orientation and so maintain the optics of the vast surface. The telescope mirrors are controlled by an active support system powered by more than 250 computers, working in parallel and positioned locally in each structure, to apply the necessary force to the mirrors to maintain their alignment with one another. The correcting forces have a precision of 5 g and keep the mirror in the ideal position, changing it every 3 minutes with 10 nm precision. The forces are applied on the basis of the analysis of the image of a real star, taken during the observations, so that the telescope is self-adjusting. The weight of the whole structure is incredibly low for its size. The 8.2 m-diameter reflecting surface is only 17 cm thick, and the whole mirror weighs 22 tonnes; its supporting cell weighs only 10 tonnes. Another technological marvel is the secondary mirror, a single-piece lightweight hyperbolic mirror that can move in all directions along five degrees of freedom. With its 1.2 m diameter, it is the second largest object entirely made in beryllium, after the Space Shuttle doors.

But the secret of the VLT's uniqueness lies in a tunnel under the platform. Optical interferometry is the winning idea that enables ▷

Astronomy

Drone-shot over Cerro Armazones, 3060 m altitude and 20 km from Paranal, the site where the construction of the European Extremely Large Telescope has started. The Argentinian Cordillera with the Llullaillaco volcano are visible in the background.

Striking night skies are not unusual at the VLT's experimental site.

the VLT to achieve yet unsurpassed ultra-high image resolution, by combining the light collected by the main 8.2 m UTs and the 1.8 m ATs. The physics principle behind the idea stems from Young's 19th century two-slit experiment, and was first applied to radio astronomy, where wavelengths are long. But in the wavelength domains of visible and infrared light, interferometry becomes a much greater challenge. It is interesting to note that the idea of using optical interferometry became a real option for the VLT at the ESO conference held at CERN in 1977 (cf Claus Madsen *The Jewel on the Mountain Top* Wiley-VCH).

With special permission from the director and taking advantage of a technical stop to install a new instrument, we are able to visit the interferometry instrumentation room and tunnel under the platform – a privilege granted to few. The final instrument that collects and analyses all of the light coming from the VLT telescopes, after more than 25 different reflections, is kept like a jewel in a glass box in the instrumentation room. Nobody can normally get this close to it, because even the turbulence generated by a human presence can disturb its high-precision work. Following the path of the light, we enter the interferometry tunnel. The dominant blue paint of the metal rails and the size of the tunnel trigger once again an inevitable sense of *déjà vu*. Three horizontal telescopes travel seamlessly on two sets of four 60 m-long rails – the "delay lines" where the different arrival times of photons on each of the telescopes is compensated for with ultra precision. These jewels of technology move continuously along the rails without electric contact, thanks to linear engines with coils interacting directly with the magnets in the engine; no cable is connected to the telescopes on the rails because the signals are transmitted by laser, and electricity is conveyed by the rails themselves to enable precision and smooth movement. The system is so precise that it can detect and automatically adapt to earthquakes, and measure the vibrations provoked in the mountain by the waves of the Pacific Ocean 12 km away. Nowhere else has interferometry reached such complexity and been pushed so far.

Delivering science at a high rate

The resolution obtained by the Very Large Telescope Interferometer (VLTI – the name given to the telescopes when they function in this mode) is equivalent to the resolution of a 100 m-diameter mirror. Moreover, the Auxiliary Telescopes are mounted on tracks, and can move over the entire telescope platform, enabling the VLTI to obtain an even better final resolution. The combined images of the 4+4 telescopes allow the same light collection capacity as a much larger individual mirror, therefore making the VLT the largest optical instrument in the world.

Another revolution introduced by the VLT has to do with e-science. The amount of data generated by the new high-capacity VLT science instruments drove the development of end-to-end models in astronomy, introducing electronic proposal submission and service observing with processed and raw science and engineering data fed back to everyone involved. The expansion of the data links in Latin America enabled the use of high-speed internet connections spanning continents, and ESO has been able to link its observatories to the data grid. "ESO practises an open-access policy (with regulated, but limited propriety rights for science proposers) and holds public-survey data as well. Indeed, it functions as a virtual observatory on its own," says Claus Madsen, senior counsellor for international relationships at ESO. Currently, up to 15% of refereed science papers based on ESO data are authored by researchers not involved in the original data generation (e.g. as proposers), and an additional 10% of the papers are partly based on archival data. Thanks also to this open-access policy, the VLT has become the most productive ground-based facility for astronomy operating at visible wavelengths, with only the Hubble Space Telescope generating more scientific papers.

Watch the video at https://cds.cern.ch/record/2128425.

Résumé

Un œil ouvert sur des galaxies très, très lointaines

Le Très Grand Télescope (VLT, Very Large Telescope*) est le plus grand instrument optique du monde. Ce qui le rend unique se cache dans le tunnel situé sous la plate-forme. Le recours à l'interférométrie optique est en effet l'idée lumineuse qui permet au VLT d'atteindre une résolution d'image inégalée ; cette technique combine en effet la lumière recueillie par les télescopes de l'unité principale et celle reçue par les télescopes auxiliaires. Le VLT est aujourd'hui l'un des centres d'astronomie les plus productifs en termes d'articles scientifiques publiés. Lancez-vous dans une visite virtuelle pour découvrir tous les secrets de cette installation extraordinaire.*

Data sonification enters the biomedical field

Music and life sciences share an incredibly strong link: both are dependent on the idea of cycles, periodicity, fluctuations, transitions and, in a fascinating sense, harmony.

Domenico Vicinanza, Department of Computing and Technology, Anglia Ruskin University and GÉANT, Cambridge, UK, and **Genevieve Williams**, Department of Life Sciences, Anglia Ruskin University, Cambridge, UK.

Piotr Traczyk

Researchers Genevieve Williams (centre) and Domenico Vicinanza (left), with physicist and flute-player Chiara Mariotti (CMS, INFN Torino), working on a real-time sonification prototype at CERN.

Resonances, periodicity, patterns and spectra are well-known notions that play crucial roles in particle physics, and that have always been at the junction between sound/music analysis and scientific exploration. Detecting the shape of a particular energy spectrum, studying the stability of a particle beam in a synchrotron, and separating signals from a noisy background are just a few examples where the connection with sound can be very strong, all sharing the same concepts of oscillations, cycles and frequency.

In 1619, Johannes Kepler published his *Harmonices Mundi* (the "harmonies of the world"), a monumental treatise linking music, geometry and astronomy. It was one of the first times that music, an artistic form, was presented as a global language able to describe relations between time, speed, repetitions and cycles.

The research we are conducting is based on the same ideas and principles: music is a structured language that enables us to examine and communicate periodicity, fluctuations, patterns and relations. Almost every notion in life sciences is linked with the idea of cycles, periodicity, fluctuations and transitions. These properties are naturally related to musical concepts such as pitch, timbre and modulation. In particular, vibrations and oscillations play a crucial role, both in life sciences and in music. Take, for example, the regulation of glucose in the body. Insulin is produced from the pancreas, creating a periodic oscillation in blood insulin that is thought to stop the down-regulation of insulin receptors in target cells. Indeed, these oscillations in the metabolic process are so key that constant inputs of insulin can jeopardise the system.

Oscillations are also the most crucial concept in music. What we call "sound" is the perceived result of regular mechanical vibrations happening at characteristic frequencies (between 20 and 20,000 times per second). Our ears are naturally trained to recognise the shape of these oscillations, their stability or variability, the way they combine and their interactions. Concepts such as pitch, timbre, harmony, consonance and dissonance, so familiar to musicians, all have a formal description and characterisation that can be expressed in terms of oscillations and vibrations.

Many human movements are cyclic in nature. An important example is gait – the manner of walking or running. If we track the position of any point on the body in time, for example the shoulder or the knee, we would see it describing a regular, cyclic movement. If the gait is stable, as in walking at a constant speed, the frequency associated would be regular, with small variations due to the inherent variability of the system. By measuring, for example, the vertical displacement of the centre of each joint while walking or running, we would have a series of one-dimensional oscillating waveforms. The collection of these waveforms provides a representation of co-ordinated movement of the body. Studying their properties, such as phase relations, frequencies and amplitudes, then provides a way to investigate the order parameters that define modes of co-ordination.

Previous methods of examining the relation between components of the body have included statistical techniques such as ▷

principal-component analysis, or analysis of coupled oscillators through vector coding or continuous relative phase. However, a problem is that data are lost using statistical techniques, and small variations due to the inherent variability of the system are ignored. Conversely, a coupled oscillator can cope only with two components contributing to the co-ordination.

Sonograms to study body movements

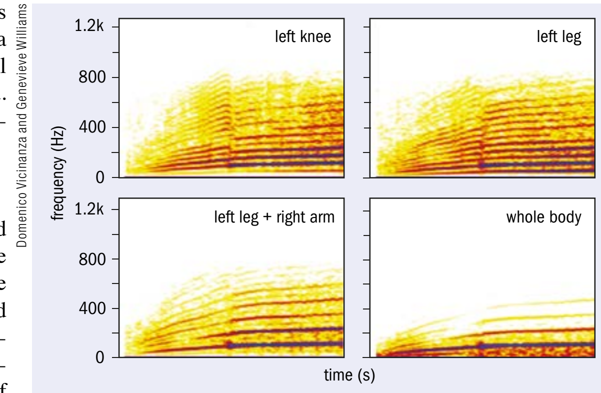
Our approach is based on the idea of analysing the waveforms and their relations by translating them into audible signals and using the natural capability of the ear to distinguish, characterise and analyse waveform shapes, amplitudes and relations. This process is called data sonification, and one of the main tools to investigate the structure of the sound is the sonogram (sometimes also called a spectrogram). A sonogram is a visual representation of how the spectrum of a certain sound signal changes with time, and we can use sonograms to examine the phase relations between a large collection of variables without having to reduce the data. Spectral analysis is a particularly relevant tool in many scientific disciplines, for example in high-energy physics, where the interest lies in energy spectra, pattern and anomaly detections, and phase transitions.

Using a sonogram to examine the movement of multiple markers on the body in the frequency domain, we can obtain an individual and situation-specific representation of co-ordination between the major limbs. Because anti-phase frequencies cancel, in-phase frequencies enhance each other, and a certain degree of variability in the phase of the oscillation results in a band of frequencies, we are able to represent the co-ordination within the system through the resulting spectrogram.

In our study, we can see exactly this. A participant ran on a treadmill that was accelerating between speeds of 0 and 18 km/h for two minutes. A motion-analysis system was used to collect 3D kinematic data from 24 markers placed bilaterally on the head, neck, shoulders, elbows, wrists, hand, pelvis, hips, knees, heels, ankles and toes of the participant (sampling frequency 100 Hz, trial length 120 s). Individual and combined sensor measurements were resampled to generate audible waveforms. Sonograms were then computed using moving-frequency Hanning analysis windows for all of the sound signals computed for each marker and combination of markers.

Sonification of individual and combined markers is shown above right. Sonification of an individual marker placed on the left knee (top left in the figure) shows the frequencies underpinning the marker movement on that particular joint-centre. By combining the markers, say of a whole limb such as the leg, we can examine the relations of single markers, through the cancellation and enhancement of frequencies involved. The result will show some spectral lines strengthening, others disappearing and others stretching to become bands (top right). The nature of the collective movements and oscillations that underpin the mechanics of an arm or a leg moving regularly during the gait can then be analysed through the sound generated by the superposition of the relative waveforms.

The final result of this cancellation is a globally simpler dynamical system.



Sonograms of vertical components of (top left) a left-knee marker; (top right) the left leg = left-knee, ankle and hip markers; (bottom left) the left leg combined with the right arm = right-wrist, elbow and shoulder markers; and (bottom right) the whole body = combined left-leg, right-leg, left-arm, right-arm and head markers.

A particularly interesting case appears when we combine audifications of marker signals coming from opposing limbs, for example left leg/right arm or right leg/left arm. The sonogram bottom left in the figure is the representation of the frequency content of the oscillations related to the combined sensors on the left leg and the right arm (called additive synthesis, in audio engineering). If we compare the sonogram of the left leg alone (top right) and the combination with the opposing arm, we can see that some spectral lines disappear from the spectrum, because of the phase opposition between some of the markers, for example the left knee and the right elbow, the left ankle and the right hand.

The final result of this cancellation is a globally simpler dynamical system, described by a smaller number of frequencies. The frequencies themselves, their sharpness (variability) and the point of transition provide key information about the system. In addition, we are able to observe and hear the phase transition between the walking and running state, indicating that our technique is suitable for examining these order-parameter states. By examining movement in the frequency domain, we obtain an individual and situation-specific representation of co-ordination between the major limbs.

Sonification of movement as audio feedback

Sonification, as in the example above, does not require data reduction. It can provide us with unique ways of quantifying and perceiving co-ordination in human movement, contributing to our knowledge and understanding of motor control as a self-organised dynamical system that moves through stable and unstable states in response to changes in organismic, task and environmental constraints. For example, the specific measurement described above is a tool to increase our understanding of the adaptability of human motor control to something like a prosthetic limb. The application of this technique will aid diagnosis and tracking of pathological and perturbed gait, for example highlighting key changes in gait with ageing or leg surgeries.

In addition, we can also use sonification of movements as a novel form of audio feedback. Movement is key to healthy ageing and recovery from injuries or even pathologies. Physiotherapists and practitioners prescribe exercises that take the human body through certain movements, creating certain forces. The precise execution of these exercises is fundamental to the expected benefits, and while this is possible under the watchful eye of the physiotherapist, it can be difficult to achieve when alone at home.

In precisely executing exercises, there are three main challenges. First, there is the patient's memory of what the correct movement or exercise should look like. Second, there is the ability of the patient to execute correctly the movement that they are required to do, working the right muscles to move the joints and limbs through the correct space, over the right amount of time or through an appropriate amount of force. Last, finding the motivation to perform sometimes painful, strenuous or boring exercises, sometimes many times a day, is a challenge.

Sonification can provide not only real-time audio feedback but also elements of feed-forward, which provides a quantitative reference for the correct execution of movements. This means that the patient has access to a map of the correct movements through real-time feedback, enabling them to perform correctly. And let's not forget about motivation. Through sonification, in response to the movements, the patient can generate not only waveforms but also melodies and sounds that are pleasing.

Another possible application of generating melodies associated with movement is in the artistic domain. Accelerometers, vibration sensors and gyroscopes can turn gestures into melodic lines and harmonies. The demo organised during the public talk of the International Conference on Translational Research in Radio-Oncology – Physics for Health in Europe (ICTR-PHE), on 16 February in Geneva, was based on that principle. Using accelerometers connected to the arm of a flute player, we could generate melodies related to the movements naturally occurring when playing, in a sort of duet between the flute and the flutist. Art and science and music and movement seem to be linked in a natural but profound way by a multitude of different threads, and technology keeps providing the right tools to continue the investigation just as Kepler did four centuries ago.

Résumé

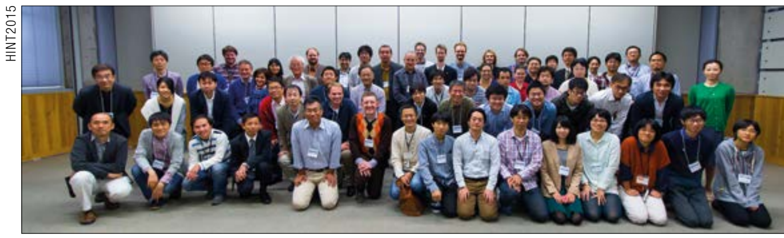
La sonification des données fait son entrée dans le domaine biomédical

La musique et les sciences de la vie ont beaucoup d'affinités : les deux disciplines font intervenir les concepts de cycles, de périodicité, de fluctuations, de transition et même, curieusement, d'harmonie. En utilisant la technique de la sonification, les scientifiques sont capables de percevoir et de quantifier la coordination des mouvements du corps humain, ce qui permet d'améliorer notre connaissance et notre compréhension du contrôle moteur en tant que système dynamique auto-organisé passant par des états stables et instables en fonction de changements dans les contraintes s'exerçant au niveau de l'organisme, des tâches et de l'environnement.

Interactions & Crossroads

FUTURE FACILITIES

Any hints for new physics ?


HINT2015

Participants at the International Workshop on Future Potential of High Intensity Proton Accelerator for Particle and Nuclear Physics, held in Japan in October 2015.

The International Workshop on Future Potential of High Intensity Proton Accelerator for Particle and Nuclear Physics, HINT2015, was held from 13 to 15 October at the Japan Proton Accelerator Research Complex (J-PARC). The purpose of the workshop was to discuss future prospects for high-intensity proton accelerators and beams with megawatt (MW) beam power, and new frontiers in particle and nuclear physics enabled by the high-intensity beams. 129 scientists from 12 countries participated in the workshop. The workshop covered a broad range of topics, from technical challenges to the science potential of MW high-intensity proton accelerators to be used for neutrino, kaon, muon, hypernuclei, hadron and neutron physics.

In his welcome address, Naohito Saito, director of J-PARC since April, emphasised the importance of flavour physics as a guiding light in particle and nuclear physics. Following that, Ryuichiro Kitano, a theorist from KEK, presented a grand picture of the precision/intensity frontier in particle physics, and Taku Yamanaka, an experimentalist from Osaka University, addressed the issues in designing new experiments for the intensity frontier. In addition, the status and future of the accelerator facilities at J-PARC, Fermilab, CERN, GSI/FAIR and PSI were reported. Tadashi Koseki reported that 500 kW stable operation had been realised, and a design power of 1 MW equivalent shot was successfully demonstrated at the J-PARC 3 GeV Rapid Cycling Synchrotron (RCS), and the J-PARC Main Ring (MR) synchrotron achieved 350 kW stable operation for the T2K neutrino experiment. After a shutdown lasting two years, beam for the Hadron Experimental Facility was resumed in April, and 33 kW beam power had been provided at the time of HINT2015. He also presented that the next goal of the MR beam power at J-PARC for neutrino experiments is 1.3 MW. The technical issues on ion sources, RF cavities, beam instrumentation, beamlines, beam windows, production targets, focusing devices and remote maintenance were overviewed and discussed by the experts.

A variety of physics research topics were covered by theorists and experimentalists. The T2K experiment presented the possibility to extend the measurement to accumulate up to 2×10^{22} protons on target to find evidence of CP violation at $>3\sigma$. The KOTO experiment for $K_L \to \pi^0 \nu\bar{\nu}$ decay will soon reach the sensitivity of the so-called Grossman-Nir bound, and start the search for new physics. The COMET experiment for μ-e conversion completed construction of the experimental hall and will continue the construction of the beamline and detector. The muon g-2/EDM experiment has completed the technical design report. Results from the hadron–nuclear experiments with high-intensity kaon beams are superseding the achievements at BNL-AGS and INFN-DAΦNE in the past, and new experiments with the beams of primary protons and high-energy mesons will open up a new era of hadron physics. The concluding remark were provided by Tsuyoshi Nakaya, an experimentalist from Kyoto University, who shared his memory with the late Yoji Totsuka, who contributed significantly on the construction of Super-Kamiokande and J-PARC.

A poster session was held in the afternoon of the first day, and young scientists enjoyed discussions.

- More details are available at j-parc.jp/pn/HINT2015/.

Annual meeting takes the pulse of EuroCirCol

June 2015 saw the start of the EU-funded EuroCirCol project, a design study for a post-LHC hadron collider that is part of the wider Future Circular Collider (FCC) study. The study has received €3 million within the Horizon 2020 Research and Innovation Framework programme to produce a conceptual design of a 100 TeV hadron collider by 2019, in time for the next update of the European Strategy for Particle Physics.

The project is co-ordinated by CERN and brings together an international consortium of 16 beneficiary organisations. Five work packages have been established within EuroCirCol to deal with the huge challenge of designing a cost-effective 100 km-long energy frontier accelerator with high-luminosity experimental insertion regions. Moreover, EuroCirCol will study the development of a cryogenic beam vacuum system to cope with unprecedented synchrotron light power, and an innovative design for superconducting accelerator magnets, to achieve high-quality dipole fields up to 16 T.

On 19–20 November, a meeting was held at the Institute of Nuclear Physics in Orsay (France), gathering more than 50 EuroCirCol scientists and engineers to review the progress made in the first six months of the study in each of the work packages.

One of the priorities established in the kick-off meeting in June was to recruit the necessary highly qualified research staff. Most positions have been filled, but some are still available (https://fcc.web.cern.ch/Pages/Oportunities-For-Individuals.aspx). ▷

All of the work packages are advancing at a good pace. For the lattice design, many versions have been considered and tested in simulations, working in close collaboration with the team in charge of the experimental insertion-regions design.

Several options for the cryogenic beam vacuum system have also been studied, considering both 1.9 K and 4.5 K operation temperature of the magnets, and a beam-screen prototype will be tested at a later stage at the ANKA synchrotron in Karlsruhe. Regarding the 16 T superconducting magnets, design optimisation based on different coil geometries is ongoing and a review will take place in spring, to identify the preferred options. In parallel to the EuroCirCol design activity, a complementary FCC Magnets Technology programme has been set up at CERN, to launch the development of the required high-performance Nb_3Sn superconducting wire with industry and to carry out magnet-prototyping work.

The discussions held during the meeting evidenced how much the EuroCirCol project is pushing the limits of technology and entering uncharted territory. They also demonstrated the strong interdependence of the characteristics of the different elements of the accelerator. Both aspects of the project define the enormous challenge that lies ahead in the FCC study.

An international FCC conference will be held in Rome from 11 to 15 April (fccw2016.web.cern.ch/fccw2016/), to follow up on the design progress and set the goals for the coming year. Dedicated technology R&D programmes will be presented, and an open poster session will provide a platform to showcase new concepts and technologies related to the FCC study. A satellite meeting concerning the EuroCirCol project in particular will also take place during the FCC week. The participation of industry and potential future partners is highly encouraged.

Big data

DS@LHC2015: bringing together the HEP and machine-learning communities

Bruno Mazoyer

A mosaic of the distinguished data scientists invited to CERN for the workshop.

High-energy physicists have been doing data science without realising it. Over the last decade, the field of machine learning has developed outside of high-energy physics (HEP), thanks to key algorithmic developments and increased computing power, driven by the needs of industry. A workshop took place at CERN on 9–13 November, which brought together top data scientists and high-energy physicists to discuss possible synergies for data processing and analysis. The workshop was a great success in terms of the quality of talks, discussions and attendance (more than 200 participants), both in person and remotely. The programme was designed so that both communities could learn each other's language.

Morning sessions were dedicated to plenary talks and were organised to introduce the fields of HEP and data science. Several optimisation methods and applications for the high-energy field were presented, including experience with the matrix element method. Renowned speakers lectured on the state-of-the-art in deep learning. Online data processing at the LHC was presented and potential hardware solutions were discussed. Promising results from recent HEP machine-learning projects were shown. Early-afternoon symposiums hosted speakers in other scientific domains that make use of promising data-science techniques. Applications in artificial intelligence (are we moving towards an artificial scientist?), urban science (what to do with a two-year-long time lapse of the New York skyline), astronomy (discovering hundreds of exoplanets) and genomics (deciphering the genome code with sparse data) were discussed. Late-afternoon tutorial sessions offered talks and hands-on session on tools and techniques from both fields. Notably, participants could gain practical experience in the latest improvements of multivariate analysis in the CERN TMVA ROOT package. A dense agenda on the matrix-element method guided the audience through the state-of-the-art of using theoretical calculations in HEP data analysis. Three well-attended tutorials were dedicated to machine-learning analysis software: Caffe (a popular image recognition toolbox), pylearn (one of many deep-neural-network training software) and an analysis pipeline constructed in the scikit-learn python framework (widely used in the machine-learning community).

The workshop ended with a panel on open data and reproducibility. It was noted that the CERN experiments are fairly advanced on this matter compared with other domains of science. The parting vow was to hold a dedicated workshop on science reproducibility in HEP. The workshop was the first of a series of conferences that will alternate generic and topical events. The next topical event will take place in summer 2016, and then again in spring 2017.

● Talks and videos from the 2015 workshop are available at cern.ch/DataScienceLHC2015.

Materials science

Magnet-technology conference features techniques for the FCC

The International Conference on Magnet Technology took place in Seoul, Korea, from 18 to 23 October. CERN's Amalia Ballarino gave a plenary talk on "Superconductors for future circular colliders". After presenting the current status of the HiLumi LHC project, she explained the technical challenges generated by the Future Circular Collider (FCC) study, and the need for future R&D in superconducting materials that would allow reaching higher magnetic fields. She discussed both low-temperature superconducting (Nb_3Sn) and high-temperature superconducting (HTS) materials. She outlined the ongoing studies on Nb_3Sn that aim to increase the performance of the material to meet the need for 16 T fields, as well as to start production.

One of the techniques that can be used to tackle these challenges is the implementation of artificial pinning in materials, although this has today only been tried on a laboratory scale for short lengths of conductor. Ballarino explained that the HiLumi LHC exploits the performance of state-of-the-art high-field Nb_3Sn, but a future FCC collider requires further improvements in the performance of the conductor and production of large quantities of affordable wire. More effort is needed from the perspective of both material science and manufacturing techniques, to understand how artificial pinning can be implemented to improve the in-field properties of this material.

In the framework of the FCC study, several collaborations involving industry and laboratories are being launched. The main focus is to establish a worldwide effort to develop and produce high-field Nb_3Sn conductors and involve industrial partners from Europe, Japan, Korea, Russia and the US. These are the countries where Nb_3Sn industry exists, and large quantities of Nb_3Sn were indeed produced for the ITER project. ITER today represents the first large-scale production (~ 500 tonnes) of Nb_3Sn wire. The FCC will require thousands of tonnes, with far higher performance.

It is important to forge synergies between laboratories and industrial partners to promote collaboration and co-ordination of efforts at a global scale. Fundamental research can provide the necessary feedback to industry, which can in turn profit from industrial production of advanced materials. It is an interactive process, and the FCC study requirements extend the boundaries of our present knowledge.

● For more information, see www.mt24.org/index.php?userAgent=PC&.

CERN

CERN's Amalia Ballarino presented an overview of the current studies on superconducting materials for future circular colliders.

Events calendar

23–25 April
IoTBD 2016
Rome, Italy
The conference will discuss the best strategies to deal with large amounts of data in different formats, and content that needs to be processed efficiently, quickly and intelligently through advanced algorithms, techniques, models and tools.
www.iotbd.org/

2–6 May
BEAUTY 2016
Marseille, France
The aim of this conference is to review the latest theoretical and experimental results in heavy-flavour physics. The scientific programme covers a wide range of research, including the study of CP violation and rare-decay properties of beauty and charm hadrons.
https://indico.cern.ch/event/352928/

8–13 May
IPAC 2016
Busan, Korea
IPAC brings together accelerator scientists, engineers, students and industrial vendors from across the globe to share ideas and exchange information on cutting-edge accelerator science and technology.
www.ipac16.org/

13–18 June
LHCP 2016
Lund, Sweden
The programme will be devoted to a detailed review of the latest experimental and theoretical results on collider physics, particularly the results of the Large Hadron Collider Run II.
https://indico.cern.ch/event/442390/

Faces & Places

Awards

Carlo Rubbia awarded China's highest scientific prize

Carlo Rubbia, Nobel laureate for physics in 1984 and CERN's Director-General from 1989 to 1994, has been awarded the International Scientific and Technological Co-operation Award by the People's Republic of China.

The award honours the significant contributions that Rubbia has made to China's scientific development in the field of high-energy physics.

During the last 30 years, Rubbia has been devoted to promoting co-operation in science and technology between China and Europe. Particularly since 1989, when serving as Director-General of CERN, he promoted collaboration between CERN and the Institute of High Energy Physics, Chinese Academy of Sciences (IHEPCAS), helped to construct the experimental high-energy physics base in China, and supported IHEPCAS in accessing the internet.

Under his leadership, in 1993 CERN proposed free internet protocols and procedures, which had important significance for the development of the internet as well as its application in China. Moreover, he enhanced co-operation in the fields of energy and the environment between Italy and China, and supported China's research in accelerator-driven systems, with significant achievements.

Rubbia, who was appointed a senator-for-life of the Italian Republic in 2013, is currently a president of the Chinese University of Mining and Technology's Institute of Sustainable Energy. The institute's main research focus is on zero-emission energy systems, energy-storage systems, and transmitting electric power over long distances using superconductors.

This work follows his recent research on finding solutions to the world's energy crisis through renewable sources. As a result of this, Rubbia has held several positions on energy advisory boards, including the United Nations Economic Commission for Latin America. He is currently a professor at the Gran Sasso Science Institue (INFN) and spokesman of the ICARUS experiment (one of the three SBN experiments at Fermilab).

The prize – considered to be the top honour for foreign individuals – is awarded to several scientists each year for their contributions to China's social, technological and economic development.

CERN is extremely proud of this new recognition for Rubbia, whose contribution to the history of both particle physics and CERN itself has been critical.

Rubbia was presented with the award by president Xi Jinping and premier Li Keqiang in Beijing on 8 January.


CERN

Carlo Rubbia, Nobel laureate for physics and former CERN Director-General, has been awarded the International Scientific and Technological Co-operation Award by the People's Republic of China.

Appointments

New director for Lawrence Berkeley National Laboratory

Michael Witherell, vice chancellor for research at the University of California Santa Barbara (UCSB), has been appointed the new director of the Lawrence Berkeley National Laboratory (Lawrence Berkeley National Lab), in the US.

Witherell is a leading particle physicist with a highly distinguished career in teaching, research and managing complex organisations. He has received numerous honours and recognitions for his scientific contributions and achievements. Witherell is the former director of the Fermi National Accelerator Laboratory (Fermilab) and currently holds the presidential chair in physics at UCSB.

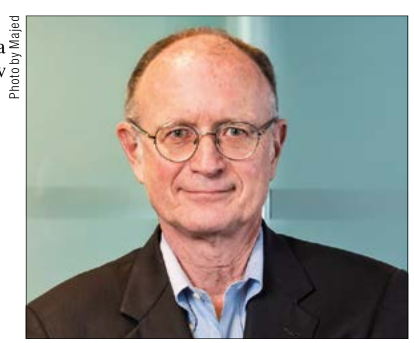


Photo by Majed

Michael Witherell.

Witherell is a member of the LUX collaboration (*CERN Courier* December 2013 p8) and he was also a member of the CMS collaboration. Before that, he studied e^+e^- collisions with the BaBar, CLEO and SLD detectors, and charm production in fixed-target experiments at Fermilab E-691, with a particular interest in heavy-quark physics.

Lawrence Berkeley National Lab, the internationally renowned institution whose scientific expertise has been recognised with 13 Nobel prizes, is managed by the University of California on behalf of the US Department of Energy (DOE) since it was founded in 1931.

New leadership structure accelerates TRIUMF

TRIUMF

Reiner Krücken.

With a fresh leadership structure at TRIUMF, the laboratory's new deputy director (DD), Reiner Krücken, will guide the realisation of TRIUMF's scientific vision.

TRIUMF recently instituted changes to the laboratory's management structure, as the organisation enters into its latest five-year plan (FYP), 2015–2020. Changes included renaming the Science Division the Physical Sciences Division, and creating the Life Science Division, into which the current Nuclear Medicine Division will be integrated as a department. All divisions will be under the leadership of associate laboratory directors (ALDs, replacing division heads). Most significantly, a DD position was created, with Dr Reiner Krücken being appointed to the new role by director Jonathan Bagger. All changes were effective as of 1 October 2015.

The DD's responsibilities include supporting the director in driving TRIUMF's projects in the current FYP, such as the Advanced Rare IsotopE Laboratory (ARIEL) and the upcoming Institute for Advanced Medical Isotopes (IAMI). The DD will work across TRIUMF's divisions – accelerator, physical sciences, life sciences, and engineering – to realise the FYP in a safe and effective manner, as well as to develop the laboratory's long-term science strategy.

Krücken is ready for the job. He developed a profound knowledge of TRIUMF's research programme while leading the laboratory's (now) Physical Sciences Division since 2011, co-editing TRIUMF's 2010–2015 FYP, and creating the ARIEL science workshop series. Moreover, he founded the Isotopes for Science and Medicine (IsoSiM) programme, a joint venture between TRIUMF and the University of British Columbia under the Natural Sciences and Engineering Research Council of Canada (NSERC) Collaborative Research and Training Experience (CREATE) programme umbrella. IsoSiM will expose students and postdocs to the interdisciplinary nature and applications of isotope science, providing them with a unique training opportunity within UBC and TRIUMF's diverse research programmes. His broad scientific interests, which have evolved from experimental nuclear physics to applications of nuclear physics in medicine and other scientific fields, are particularly well suited for his role, interacting with all of the associate lab directors.

As the new DD, Krücken declares his primary goal to be achieving TRIUMF's FYP vision. He emphasises that ARIEL is a key priority upon which the laboratory's future is based, because it will solidify TRIUMF's position as a world-leading isotope-production facility for studies in particle physics, nuclear physics, materials science and nuclear medicine.

With both Bagger and Krücken at the helm, and a new management structure in place, TRIUMF is well poised to navigate the challenges facing the laboratory in the exciting times ahead.

CELEBRATIONS

Aleksandr Skrinsky celebrates his 80th birthday

Valentin Baev

Aleksandr Skrinsky.

Aleksandr (Sasha) Skrinsky, currently the scientific leader of Budker Institute of Nuclear Physics (Russia), turned 80 on 15 January.

Skrinsky is well-known for his contribution to the development of colliding beams in storage rings. At the VEP-1 and VEPP-2 colliders in Novosibirsk, Skrinsky and colleagues conducted a series of pioneering tests of quantum electrodynamics and studies of vector mesons. Studies on the beams in storage rings led to the discovery of the longitudinal and transverse coherent instabilities and, subsequently, to the development of methods for their suppression. Skrinsky was also the first to show the nonlinear nature of the beam–beam effects in circular accelerators. In particular, he showed the role of nonlinear resonances and stochastic instability in reducing the luminosity of colliders.

In the 1970s, Skrinsky played a leading role in the development of the theory of spin motion in circular accelerators, based on the invention of the periodic spin precession axis. Together with colleagues, he proposed a method for the precise measurement of elementary particle mass by resonant depolarisation of electron–positron beams. In 1974, Skrinsky and colleagues developed the theory of "electron cooling" (proposed by G I Budker in 1967), and confirmed it experimentally. The method has been widely used at many laboratories around the world, including CERN, GSI (Germany), and IMP (China).

During the past few years, Skrinsky has worked on the ionisation cooling of muons for muon colliders. Skrinsky is an expert on free-electron lasers (FELs), for which he proposed the optical klystron. Largely through his efforts, a number of Russian laboratories have been involved in the LHC programme.

Today, while he continues to ski and run regularly, Skrinsky participates in experiments at the VEPP-4M and VEPP-2000 colliders, and is involved in the design of the Super-tau-charm factory, one of the most ambitious scientific projects in the field of high-energy physics.

JINR celebrates 90th birthday of academician Alexander Baldin

JINR

Alexander Mikhailovich Baldin.

On 26 February, the scientific community of the Joint Institute for Nuclear Research (JINR) celebrated Alexander Mikhailovich Baldin, who was born on the same day in 1926 in the Krasnaja Presnja district of Moscow.

Baldin's youth and student years were lived during the Second World War and post-war reconstruction. In 1946, he was invited to continue his studies at the newly established Moscow Mechanics Institute of Ammunition – later named the Moscow Engineering Physics Institute (MEPhI) – from which he graduated in 1949.

Baldin's first research work was on the theory of particle motion in a cyclic accelerator. These investigations allowed him to develop a method that was used to improve the performance of JINR's Synchrophasotron, and it is still being widely used in calculations for the design of new accelerators. In the early 1950s, Baldin developed the theory of meson photoproduction off nucleons and nuclei, and in 1973 he was awarded the USSR State Prize for pioneering research in pi-meson photoproduction.

In 1968, in his capacity as a scientific leader of JINR, Baldin set nuclear interactions at relativistic energies as a major research activity. Under his guidance, the Synchrophasotron was modified to become a specialised accelerator of relativistic and polarised nuclei, which led to the discovery of the nuclear cumulative effect predicted by Baldin. The results of the first period of studies with relativistic nuclei enabled Baldin to suggest the idea of a new, superconducting accelerator – the Nuclotron.

Baldin's scientific and organisational activities were extremely versatile. He was president of the Council on Electromagnetic Interactions and a member of the Bureau of the Nuclear Physics Department of the Russian Academy of Sciences, editor-in-chief of the journals *Physics of Elementary Particles and Atomic Nuclei* and *Physics of Particles and Nuclei Letters*, as well as a member of the editorial boards of many scientific publications. Baldin was also very much appreciated for the effort he put into training younger scientists, giving lectures and organising international schools of physics.

The achievements of this outstanding scientist have been awarded with the Lenin Prize, the State Prize, and the V I Veksler Prize, as well as with several governmental awards. He has also been awarded orders and medals of the JINR member states. Baldin was also given the title of honorary citizen of the town of Dubna. The street that leads to the main gates of the laboratory is named after him.

OUTREACH

CERN exhibition reopens to the public

After a major revamp last year, "Microcosm", one of CERN's two on-site exhibitions, is once again open to visitors. The new exhibition takes visitors on a journey through CERN's key installations, following the path of particles from the bottle of hydrogen, through the network of accelerators and on to collisions inside vast experiments. Objects, life-sized audiovisuals and high-definition photographs are used to recreate real CERN spaces, while live data feeds bring news of the LHC direct to the exhibitions. Throughout, the focus is on the people who design and use this extraordinary technology to further our understanding of the universe. Screen content continues to evolve, and more games will be introduced into the exhibition during 2016. The exhibition is free and open to all.

CERN

Role models for students – 1:1 scale audiovisual in "Microcosm" allows visitors to meet the people who make CERN tick.

All image credits: CERN

Networking

CERN signs agreements with Lebanon, Palestine, the US, ESO and IRENA

December was a good month for global collaboration in particle physics because it saw the signature of several agreements that will contribute to cementing CERN's partnerships and create frameworks for fruitful co-operation.

On 3 December last year, CERN signed an International Co-operation Agreement (ICA) with the Lebanese National Council for Scientific Research, CNRSL, paving the way for future collaboration with Lebanese academia. Soon after, on 18 December, a second ICA was signed with Palestine, allowing CERN to forge stronger links with Palestinian universities.

Lebanese researchers have long had links with CERN's theory group, and have recently expressed an interest in joining the LHC experiments. Three Lebanese doctoral students active on LHC experiments gave talks at the signing ceremony, held at the Lebanese University in Beirut, where Lebanon also expressed immediate interest in the heavy-ion programme at the LHC and in hardware upgrades on CMS. Links between CERN and Palestine have so far been more limited, with a number of individuals working on CERN programmes and Palestinian participation in CERN summer student programmes. However, this new agreement confirms the increasing interest in the LHC and opens the way for Palestinian researchers to join the ATLAS collaboration.

CERN has a high level of engagement in the Middle East and North Africa region, with ICAs already signed with Iran, Jordan, Saudi Arabia and the United Arab Emirates, and well-established contacts with Oman and Qatar. Moreover, CERN plays an important role in SESAME, the region's first intergovernmental research organisation (*CERN Courier* July/August 2015 p19).

Also in December, CERN signed ICAs with the European Southern Observatory (ESO) and with the International Renewable Energy Agency (IRENA). The agreements address many areas, including scientific research, technology development and sharing, and big-data solutions, as well as education and public-outreach activities.

Collaboration between CERN and the US is nothing new: the US is a valued partner in the LHC, contributing to investment in the facility, to the running of LHC experiments and to the globally distributed computing infrastructure necessary to process the vast data volumes produced by the experiments. The most recent co-operation agreement was signed between CERN, the US Department of Energy and the US National Science Foundation at the White House on 7 May last year, marking both a renewal of a long-standing friendship and a commitment to take the partnership further.

The new protocols signed in December confirm the US's commitment to the LHC project and its upgrade programme, the High-Luminosity LHC. For the first time, they set down in black and white European participation through CERN in pioneering neutrino research in the US. They are a significant step towards a fully connected trans-Atlantic research programme.

In this framework, CERN, which is no longer running its own neutrino beamlines, will serve as a platform for worldwide scientists engaged in neutrino-detector R&D, who will go on to work at neutrino experiments in the US and elsewhere.

From left to right: Ambassador Pamela Hamamoto of the US (left) and CERN Director-General (2009–2015) Rolf Heuer; Ibrahim Khraishi (right) Palestinian ambassador to the international organisations in Geneva with Rolf Heuer, after signing the Co-operation Agreement between Palestine and CERN; and Mouïn Hamzé (left), secretary general of the Lebanese National Council for Scientific research, CNRSL, and CERN's Rüdiger Voss, after signing the International Collaboration Agreement.

Visits

Image credits: CERN

On 20 January, Her Excellency Dr Dalia Grybauskait, President of the Republic of Lithuania, visited CERN. Three days later, on 23 January, CMS welcomed His Excellency Mr Muhammad Nawaz Sharif, Prime Minister of the Islamic Republic of Pakistan. The Lithuanian delegation had a busy morning, visiting several CERN facilities. The tour of the laboratory started at Point 5 (the CMS experiment), where the President and her delegation were welcomed by Director-General Fabiola Gianotti. In the afternoon, the delegation stopped off at the Computing Centre, where they heard a presentation on the worldwide LHC Computing Grid. At the end of the visit, the President took a moment to shake hands with members of the Lithuanian community at CERN, and also participated in a virtual visit by a high-school class connected remotely from Lithuania as part of the S'Cool LAB project. CMS also received a visit by His Excellency Mr Muhammad Nawaz Sharif from Pakistan. The delegation was welcomed by the representative of France, Stéphane Donnot, sous-Préfet de Gex, CERN's Director-General, and other members of the CERN directorate. It was the first visit by a head of government of Pakistan since the country became CERN's latest associate member state in July 2015. The Prime Minister then had the opportunity to visit the CMS underground experimental area accompanied by the CMS Spokesperson, Tiziano Camporesi, and the CMS collaboration's national contact physicist for Pakistan, Hafeez Hoorani. At the end of his visit, the Prime Minister took the time to sign CERN's guestbook and to meet with a number of Pakistanis collaborating with CERN. Picture on the left: **The President of Lithuania, Dalia Grybauskait**, observing a cloud-chamber experiment at the S'Cool LAB. Picture on the right: From left to right: **Minister of Finance Mr Mohammad Ishaq Dar, Prime Minister of the Islamic Republic of Pakistan Muhammad Nawaz Sharif, CERN Director-General Fabiola Gianotti** and CMS national contact physicist **Hafeez Hoorani**.

Obituary

Michael K Craddock 1936–2015

Michael Craddock.

Michael K Craddock, UBC emeritus professor and retired TRIUMF research scientist, passed away in Vancouver, Canada, on 11 November, following a brief battle with cancer. One of TRIUMF's founding fathers, he worked tirelessly on the cyclotron and other key projects for 50 years, including 33 years as TRIUMF's head accelerator physicist, until his retirement in 2001.

Mike Craddock was born on 15 April 1936 in the UK. He received his Bachelor's and Master's degrees in mathematics and physics at Oxford University in 1957 and 1961, respectively. He was a scientific officer at Rutherford Appleton Laboratory while pursuing a D.Phil in nuclear physics at Oxford, which he was awarded in 1964. Upon graduation, Mike joined the Physics Department at the University of British Columbia (UBC), where he remained throughout his career.

Originally hoping simply to conduct experiments at UBC's Van de Graaf accelerator, he was thrust almost immediately into the department's campaign to build a new accelerator on campus. Tasked with investigating options for a new machine, he recommended a modified version of the H^- cyclotron design of Reg Richardson at UCLA. Mike managed the overall specification, which settled on a scaled-down 500 MeV, $20\,\mu A$ machine. In 1968, the TRIUMF proposal was approved by the Canadian government, and for the next 10 years, Mike was the beam-dynamics group leader. His most memorable challenge in that time was responsibility for determining the position and number of the magnetic shims installed during the massive cyclotron field-shaping campaign. Mike's reward came when he was present at Reg Richardson's shoulder as the first beam emerged on 15 December 1974.

Mike was TRIUMF's leading beam physicist throughout his career, from joint head of the Beam Development Group from 1978 to 1981, then as Accelerator Research Division head from 1982 to 1988 and head of the Accelerator Division from 1989 to 1994, to group leader for accelerator physics from 1995 until his retirement in 2001. He was a chief architect of the KAON Factory Project, where as deputy to project-leader Alan Astbury, he led a multidisciplinary team in the engineering design of a suite of synchrotron-type proton accelerators. KAON was unable to attract federal funding, and so Mike set to work on projects related to the Large Hadron Collider (LHC) accelerator injector chain at CERN, the success of which raised the lab's profile worldwide. Remarkably, during all this time he supervised more than 14 graduate students, regularly taught undergraduate and graduate physics courses, and acted as TRIUMF's correspondent for the *CERN Courier* for 29 years, until August 2004.

Retirement did little to tamper with Mike's relentless energy. He joined the Accelerator Development Group and worked on several projects before settling on fixed-field alternating-gradient accelerators (FFAGs) from 2004 to 2012, where he participated in an international project to build a 20 MeV electron model (EMMA) at Daresbury, UK. He was a constant presence at the lab, organising conferences, and presenting introductory accelerator-physics lectures to students at TRIUMF, UBC, and the University of Victoria, all the while acting as TRIUMF's unofficial historian.

During a career that spanned five indefatigable decades, Mike demonstrated exceptional leadership in the field of high-energy subatomic-particle physics, notably in particle-accelerator design and construction, and he was instrumental in fostering new generations of accelerator physicists in Canada and abroad. A testament to his outstanding character, before he passed away, Mike made a very generous gift to TRIUMF, establishing the Michael Craddock Fund for Accelerator students.

His passing has been felt worldwide and has left a gaping hole in the TRIUMF family. He will be sorely missed by all who knew him.

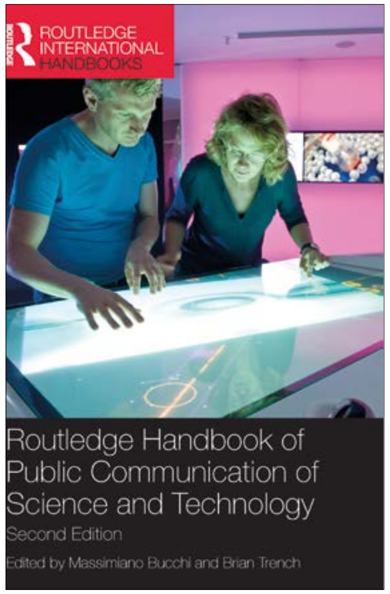
● *His friends and colleagues.*

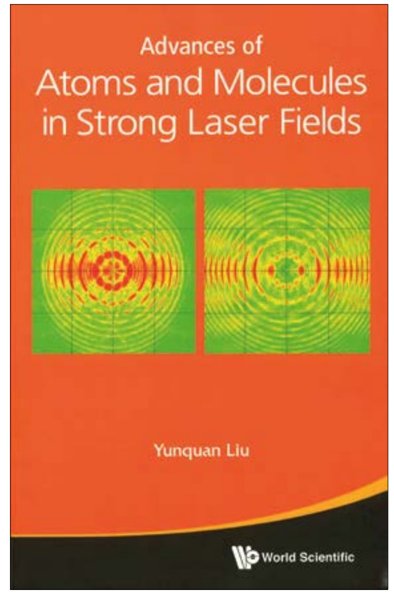
Recruitment

For advertising enquiries, contact CERN Courier recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
Tel +44 (0)117 930 1264 Fax +44 (0)117 930 1178 E-mail sales@cerncourier.com
Please contact us for information about rates, colour options, publication dates and deadlines.

Bookshelf

Compiled by Virginia Greco, CERN





Routledge Handbook of Public Communication of Science and Technology (2nd edition)
By M Bucchi and B Trench (eds)
Routledge

With scientists increasingly asked to engage the public and society-at-large with their research, and include outreach plans as part of grant applications, it helps to have a guide to various involvement possibilities and the research behind them. The second edition of the *Routledge Handbook of Public Communication of Science and Technology* (henceforth referred to as "the *Handbook*") provides a thorough introduction to public engagement – or outreach, as it is sometimes called – through a varied collection of articles on the subject. In particular, it brings to attention the underlying issues associated with the old "deficit model of science communication", which presupposes a knowledge deficit about science among the general public that must be filled by scientists providing facts, and facts alone. Although primarily targeting science-communication practitioners and academics researching the field, the *Handbook* can also help scientists to reflect on their outreach efforts and to appreciate the interplay between science and society.

Before plunging into the depths of the book, it is important to remember that the study of science communication is the study of evolving terminology. Historically, an effort was made to determine the "scientific literacy" of society, under the assumption that a society knowledgeable in the facts and methods of science would support research endeavours without much opposition. This approach was made obsolete by the introduction of the "public communication of science and technology" paradigm, which itself was superseded by what is today called "public engagement with science and technology", or "public engagement" for short. The first chapter, written by the editors, is the best place to familiarise oneself with the various science-communication models, as well as the terms and phrases used throughout the *Handbook*. That said, those with backgrounds in natural sciences might feel somewhat out of their depth, due to a lack of definitions in the rest of the *Handbook* for words and phrases used on a daily basis by their social-science counterparts. However, this is largely mitigated by each chapter containing a wealth of notes and references at the end, pointing readers in the direction of further reading.

The chapters themselves are stand-alone articles by experts in their respective topics, many written in engaging, conversational styles. They cover everything from policy and participants, to the handling of "hot-button" issues, to research and assessment methodology. Readers of the *Courier* may find the chapters on science journalism, on public relations in science, on the role of scientists as public experts and on risk management particularly illuminating.

What the same readers might find missing from the book is a specific treatment of fundamental research: the *Handbook* focuses on domains of science – such as climate change – that tend to have a direct or immediate impact on society. Scientists from other areas of research might therefore consider shoehorning (perhaps non-existing) societal impact into their science-communication efforts, rather than learning how to adapt the lessons learnt from fields such as climate science to their own work. It is therefore this reviewer's desire that future editions of the *Handbook* address the science-communication challenges of more diverse areas of research, proposing ways in which scientists and practitioners can tackle them.

Overall, the *Handbook* gives readers valuable insight into science-communication research, and merits a place on the library shelves of every university and research institution.

● *Achintya Rao, CERN.*

Advances of Atoms and Molecules in Strong Laser Fields
By Y Liu
World Scientific

The challenge of developing more intense, shorter-pulse lasers has already seen outstanding results and opened up completely new perspectives. In fact, the next generation of very-high-power laser facilities will provide the opportunity to explore even ultrarelativistic and vacuum nonlinearity at unprecedented levels, moving towards a QCD regime. At the same time, during the last few years, attosecond physics has provided a new, intriguing way to visualise both atoms and molecules, and the electromagnetic-field structure of the excitation wave packet itself, because this time domain is comparable with the classical periods of electrons orbiting around the nucleus. This growing research field is so recent that the literature on the subject is not yet adequate: in this sense, this book partially fills the gap. It contains contributions from several Chinese groups, both experimental and theoretical, and reports on recent studies of bound electron and molecular nonlinearities. The content is organised over eight chapters and spans a broad range of topics of this specialist subject.

Strong-field tunnelling is a possible key to the ionisation of neutrals. It offers a sophisticated method to image and probe atomic and molecular quantum processes. In fact, the study of direct and rescattered (by the nucleus) electrons in the ionisation process is able to resolve orbitals; in this context, it becomes important to go beyond strong-field approximation, and to evaluate the contribution of the long-range Coulomb field generated by the ion in the electron dynamical evolution (chapter 1).

Direct and rescattered electrons can be recorded together as a reference wave and a signal wave, respectively: the interferential patterns constitute the analogue of optical holography, reconstructing the illuminated objects. It is possible to integrate the influence of the Coulomb field, either in a numerical solution of the time-dependent Schrödinger equation (TDSE) or in a more intuitive quantum-trajectories Monte Carlo method describing the formation mechanisms of the photoelectron angular distribution of above-threshold ionisation (chapter 2).

Dissociation is a basic process of physical chemistry and, before the advent of new ultrafast tools, seemed completely out of scientists' control, because the typical timescale is below the femtosecond range. For an easier comparison of theoretical predictions and experimental results for a molecule interacting with a strong ultrashort laser pulse, it is necessary to start with the simplest systems – the hydrogen molecular ion H_2^+. In chapter 3, on the basis of a numerical analysis of the related TDSE, the author suggests a pump–probe strategy to understand dissociation.

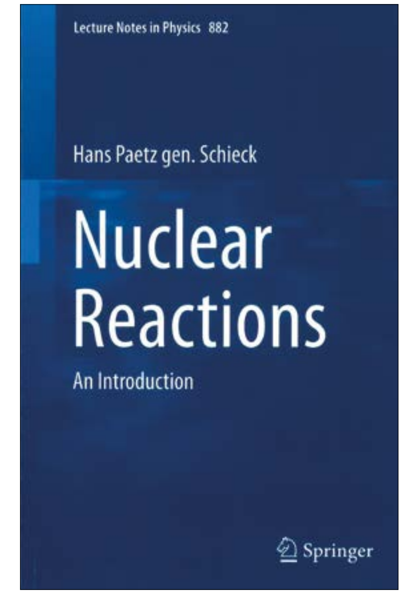
The theoretical discussion of double ionisation in a strong laser field is treated in chapters 4 and 5 for different kinds of atoms. In the case of high Z, the experiments show a different degree of correlation of the two expelled electrons, with respect to the low-Z case: this is due to the major importance of rescattering, as described by a semiclassical model. For the simpler systems H_2 and He, TDSE is a powerful tool for calculating all of the main features of double ionisation (total and differential cross-sections, recoil-ion momentum spectra, two electron angular distributions, and two electron-interference phenomena).

A promising application of strong-field excitation on atoms and molecules is high-order harmonics generation (HHG), usually providing a XUV comb with different harmonics at the same intensities, both in a single attosecond pulse and in a train of attosecond pulses, by a conversion of the light frequency from IR to the X-ray regime. This technique provides a tomographic image of molecular orbitals as an alternative to scanning tunnelling microscopy or angle-resolved photoelectron spectroscopy, as well as a way to study ultrafast electronic structures, electron dynamics and multichannel dynamics (chapters 6 and 7).

Finally, chapter 8 presents an interesting review of the properties of free electron laser radiation, showing how nuclear motion in photo-induced reactions can be monitored in real time, the electronic dynamics in molecular co-ordinates can be extracted, and the site-specific information in the structural dynamics of chemical reactions can be provided. The experiments are based on EUV pump–probe and optical pump-X-ray probe excitation techniques, and are located at FLASH (Hamburg) and LCLS (SLAC), respectively.

As a summary, the book is a useful update for people who are interested in the specialised field of the interaction of atoms and molecules with femtosecond or sub-femtosecond high-intensity fields. The comprehensive bibliography allows the reader to gain a more exhaustive view of the subject.

● *Emilio Mariotti, University of Siena, Italy.*



Nuclear Reactions: An Introduction
By Hans Paetz gen. Schieck
Springer

The study of the structure of complex nuclei has experienced a revival in recent years, thanks to the availability of energetic radioactive beams. New facilities such as HIE-ISOLDE at CERN are coming online. Nuclear reactions are exciting objects of study in their own right and are also indispensable tools to study the structure of nuclei. Therefore, one should expect a reactivation of nuclear-reaction courses in graduate nuclear-physics curricula, and the aim of the present book is to provide the material for such courses.

The author is an experimentalist, and as a consequence, the text contains a refreshing mix of experimental facts and methods with basic theoretical knowledge. The book will convince the reader that nuclear physics is a lively and modern field. As examples of recent progress describe, one can cite the discovery of halo nuclei using high-energy reactions induced by radioactive beams (chapter 2), as well as the treatment of superheavy nuclei (chapter 15). It is, however, also satisfying to see some elegant traditional-physics manifestations, such as Ericson fluctuations (chapter 11), which have disappeared from many recent courses.

The first four chapters contain material commonly taught in undergraduate classes, such as cross-section definition, Rutherford scattering and partial wave expansion, which are a prerequisite for following the more intricate parts of the book that start in chapter 5. I was surprised, however, that the author uses the particle-physics definition of isospin ($t_3 = +\frac{1}{2}$ for the proton), which could create some confusion in a nuclear-physics book. An attractive originality of the book is the detailed description of reactions with nuclei with spin and polarised targets or beams – topics that are too often glossed over. Models for direct and compound nucleus reactions are competently covered. The chapter on heavy-ion reactions is minimal. The last part of the book, which starts at chapter 16, describes the techniques for studying nuclear reactions, accelerators and detectors, and gives some applications in the fields of medicine, energy production and fusion. This part makes for lighter reading, and could bring back on board readers who might have found the heart of the material somewhat arduous. These last chapters should be considered as an enticement for the reader to go on to more detailed descriptions of the subjects that arouse their curiosity. At the end of each chapter, some exercises are proposed so that the reader can test their understanding of the concepts presented. ▷

CERN COURIER
Volume 56 Number 2 March 2016
IOP Publishing

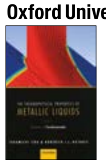
Bookshelf

The book proposes a solid graduate curriculum on nuclear reactions and contains a clear presentation of the basic concepts necessary for undertaking a PhD in nuclear physics, illustrated by examples of modern discoveries and experiments that should motivate the reader. Its aim is not, however, to replace books that are indispensable to the practitioner, such as *Direct Nuclear Reactions* by G R Satchler. Let's hope that this relatively modern and accessible course in nuclear reactions will encourage the teaching of the subject to reappear in many universities where it has been somewhat neglected in recent years. Progress in nuclear structure is, after all, dependent on the understanding of nuclear reactions.

● *Yorick Blumenfeld, IPNO, Orsay, France.*

Books received

The Thermophysical Properties of Metallic Liquids: Fundamentals (volume 1) and Predictive Models (volume 2)
By T Iida and R I L Guthrie
Oxford University Press



Authored by two leading experts in the field, these books provide a complete review of the static and dynamic thermophysical properties of metallic liquids. Divided into two volumes, the first one (*Fundamentals*) is intended as an introductory text in which the basic topics are covered: the structure of metallic liquids, their thermodynamic properties, density, velocity of sound, surface tension, viscosity, diffusion, and electrical and thermal conductivities. Essential concepts about the methods used to measure these experimental data are also presented.

In the second volume (*Predictive Models*), the authors explain how to develop reliable models of liquid metals, starting from the essential conditions for a model to be truly predictive. They use a statistical approach to rate the validity of different models. On the basis of this assessment, the authors have compiled tables of predicted values for the thermophysical properties of metallic liquids, which are included in the book. A large amount of experimental data are also given.

The two books are particularly oriented to students of materials science and engineering, but also to research scientists and engineers engaged in liquid metallic processing. They collect a large amount of information and are written in a clear and readable way, therefore they are bound to become an essential reference for students and researchers involved in the field.

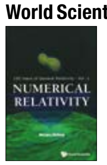
Quantum Confined Laser Devices: Optical Gain and Recombination in Semiconductors
By P Blood
Oxford University Press

This book provides a comprehensive discussion of quantum confined semiconductor lasers, based on the author's long and extensive experience in the field. In a pedagogical fashion, it takes the reader from the physics principles and processes exploited by lasers (giving a consistent treatment of both quantum-dot and quantum-well structures) to operation of the most advanced devices.

The text begins with a short historical account of the birth and development of lasers in general (called "maser" at the very beginning because restricted to microwaves), and the diode laser in particular. Thereafter, the book is organised into five sections. The first, dedicated to the diode laser, provides the framework for the whole volume. The second section describes the fundamental processes involved in the physics of lasers, a subject that is then treated in depth in the third part. The fourth section discusses the operation of laser devices and their characteristics (light-current curves, threshold current, efficiency, etc). Finally, the author tackles the important topics of recombination and optical gain, describing ways in which they can be measured on device structures and compared with theoretical predictions.

Full of detailed explanations, illustrations from model calculations and experimental observations, as well as a comprehensive set of exercises, the book is recommended to final-year undergraduate and PhD students, as well as researchers who are new to the field and need a complete overview of the subject.

Numerical Relativity: 100 Years of General Relativity – Vol. 1
By M Shibata
World Scientific

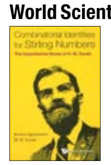


Numerical relativity is a field of theoretical physics in which Einstein's equation and associated matter field equations are solved using computer calculations, because they are nonlinear partial-differential equations and therefore they cannot be solved analytically for general problems.

The purpose of this volume is to describe the techniques of numerical relativity and to report the knowledge obtained from the numerical simulations performed so far. The first chapter offers an overview of the basics of general relativity, gravitational waves and relativistic astrophysics, which are the background of numerical relativity. Then, in the first part of the book (chapters 2 to 7), the author discusses the most used formulations and numerical methods, while in the second part (chapters 8 to 11), he reports on representative numerical-relativity simulations and the knowledge derived from them.

Particular importance is given to the results obtained by applying these simulation techniques to the study of black-hole formation, binary compact objects, and the merger of binary neutron stars and black holes. New frontiers in numerical relativity are also touched on in the last two chapters.

Combinatorial Identities for Stirling Numbers: The Unpublished Notes of H W Gould
By J Quaintance and H W Gould
World Scientific



Written by Henry Gould's assistant Jocelyn Quaintance, this book is the result of the deep work and personal relationship between the great mathematician and the author. They met when Quaintance had recently graduated with a PhD, and was looking for a career in research and an advisor who could guide him. He had the luck to collaborate with Gould, who showed him his manuscripts: several handwritten volumes on combinatorial identities. Quaintance offered to edit a text collecting together all of that material, which led to the publication of this book.

The first eight chapters introduce readers to the special techniques that Gould used in proving his binomial identities. This first part is easily accessible to people who have taken basic courses in calculus and discrete mathematics. The second half of the book applies the techniques from the first part, and is particularly relevant for mathematics researchers. It focuses on the connection between various classes of Stirling numbers, and between them and Bernoulli numbers.

Some of the demonstrations presented in the volume represent the only systematic record of Gould's results. As such, this book is a unique work that could appeal to a wide audience: from graduate students to specialists in enumerative combinatorics, to enthusiasts of Gould's work.

CERN Courier Archive: 1973

A look back to CERN Courier vol. 13, March 1973, compiled by Peggie Rimmer

Laboratory II

Telling the mole in the hole where to go

February 19 was the second anniversary of the authorisation of construction of the Super Proton Synchrotron (SPS). It was celebrated by the start of tunnel boring by the "mole". This conventional Robbins boring machine, built in Seattle, came by sea from the US Pacific Coast, through the Panama Canal to Rotterdam, up the Rhine to Basel, and then by lorry to Geneva. It arrived at the end of last year.

The SPS tunnel will be 4.8 m in diameter with a circumference of 6.9 km. A tunnelling scheme was selected (rather than the "cut-and-fill" method) to avoid changing the character of the countryside in a major way so that agricultural and forestry activities can continue much as previously. A second reason is the variation in altitude over the site. To retain a minimum Earth shield of 20 m for radiation protection, the tunnel will be 65 m below the highest point on the surface at an average depth of 40 m. A final point is that the molasse bedrock is solid enough to allow the tunnel to be bored reasonably easily.

Survey problems at the SPS are different to those encountered in building the PS or the Batavia accelerator in trenches in open flat land. The problems at Laboratory II are:
- installation of the magnet ring in an underground tunnel;
- links with existing installations at Laboratory I, mainly using the PS as injector;
- about 45 m difference in surface altitude around the circumference of the ring;
- wooded land which interferes with the line-of-sight in survey measurements.

To solve these problems, the surveyors had to resort to triangulation (angular measurement) and trilateration (distance measurement). Datum points are located on high buildings (ISR Laboratory, Laboratory 5, SB Building, etc). It was impossible to use the top of the ISR water tower, the highest point at CERN, because it is subject to movements of up to 2 cm. Other points [monuments], some beyond the site, have been set in the ground at a height of about 1.5 m, one at a height of 8 m. The baseline is provided by two PS survey points. The results give an accuracy of 2 mm between all points.

In subterranean surveying, one of the most difficult problems is the dropping of a perpendicular line within a shaft to transfer surface co-ordinates to the tunnel level. Various methods were used for this operation, giving results to better than 0.5 mm for depths of 60 m. It is amusing to note that the curvature of the Earth requires a correction of about 8 mm for the deepest shafts, to ensure that the SPS has the same diameter underground as that calculated at the surface.

The first underground survey consisted in laying out the line of the tunnel between two shafts (PGC and PP1), some 200 m apart. After the tunnel had been pierced, metal brackets with reference sockets containing an automatic centring system were fitted to the walls. Distances were measured with invar wire and directions with a gyro-theodolite. This underground alignment was accurate to a very satisfactory 2.4 mm compared with the surface alignment.

The first survey monument in the tunnel, with its reference socket and support for the laser used to guide the boring machine, is already in place. Monuments will be built every 32 m as the mole progresses. The survey team has considerable confidence that the mole will arrive back where it is starting from.

● Compiled from texts on pp70–72.

CERN

The mole being installed underground at the point where boring is beginning. Its 7 km journey around the ring is expected to be completed by autumn 1974. The machine, 80 m in length, comprises the 4.8 m diameter head, shown here, pressure and supporting pads, an operator's cabin, electrical equipment, conveyor belts, tunnel-lining system, skip changer and spoil-removal train.

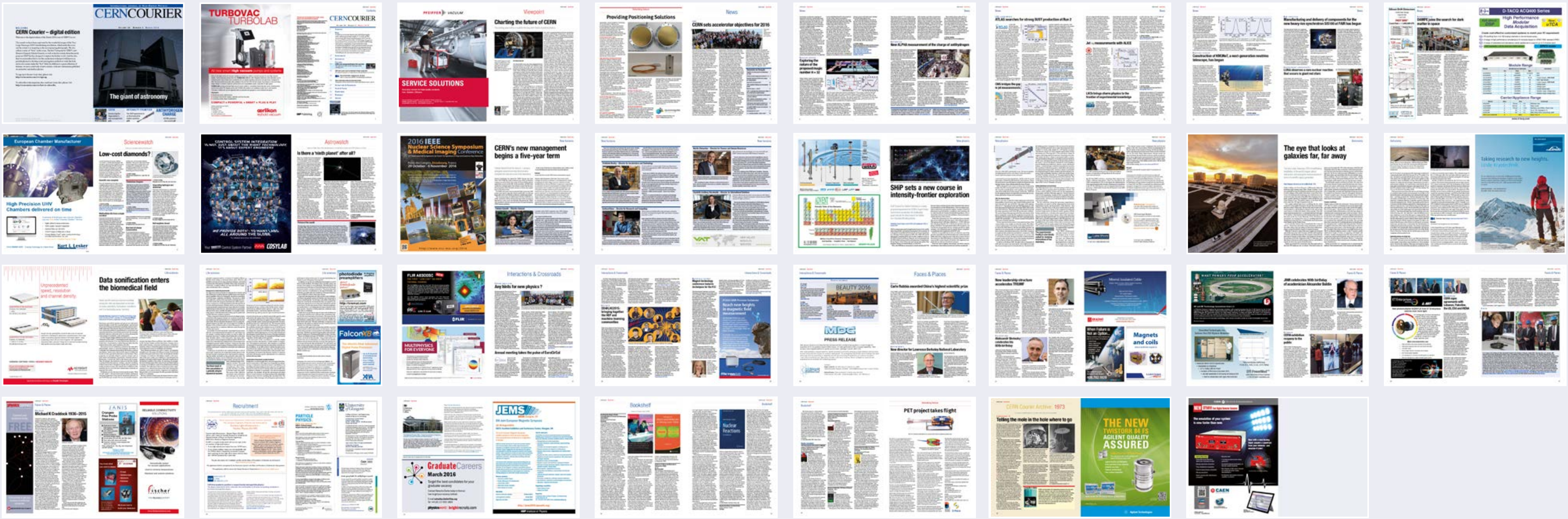
CERN

Geodetic measurements are often taken under an umbrella to shelter the surveyors from the Sun, but here a gyro-theodolite and its operator are being protected from water seeping in at the bottom of the PP1 shaft, some 40 m below the surface.

Compiler's Note

CERN's next impressive civil-engineering programme was even more challenging. Started in 1985, the 27 km underground ring for the Large Electron–Positron Collider (LEP) was Europe's largest tunnelling project, prior to the Channel Tunnel. It was excavated by three moles burrowing for three years. The ring had to link with the SPS as an injector and was given a 1.4% tilt to minimise the depth and cost of the access shafts under the Jura. The depth of the ring varies from 175 m on the Jura side to 50 m on the lake side, with an average of 100 m. Since 2007, it has housed the LHC.


CAEN Electronic Instrumentation
NEW DT5810 Fast Digital Detector Emulator
The emulation of your system is now faster than ever.
CAEN DT5810D Dual Fast Digital Detector Emulator
Now with a new Analog Input: acquire a spectrum from your detector and emulate it later!
• Sub ns Rise Time
• Pulser/Emulator/Function Generator operating modes
• Energy spectrum emulation
• Time distribution emulation
• Custom signal shape emulation
• Pile-up emulation
• Noise and periodic interference emulation
• Baseline drift
• 1 ns/step programmable delay generator
• Correlated signals generation on the two output channels
• Two shapes on the same channel for testing the pulse shape discrimination
• Continuous and pulsed reset pre-amplifier emulation
Local monitor of emulation settings
CHECK THIS OUT!
DDE CAEN
Detector Emulator Control Center
CAEN Tools for Discovery
FREE DOWNLOAD
All Control Software are free downloadable from CAEN web site.
Graphical User Interface for Digital Detector Emulators
www.caen.it
Small details… Great differences



CERNCOURIER

Volume 56 Number 2 March 2016

Contents