WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the April 2013 issue of *CERN Courier*.

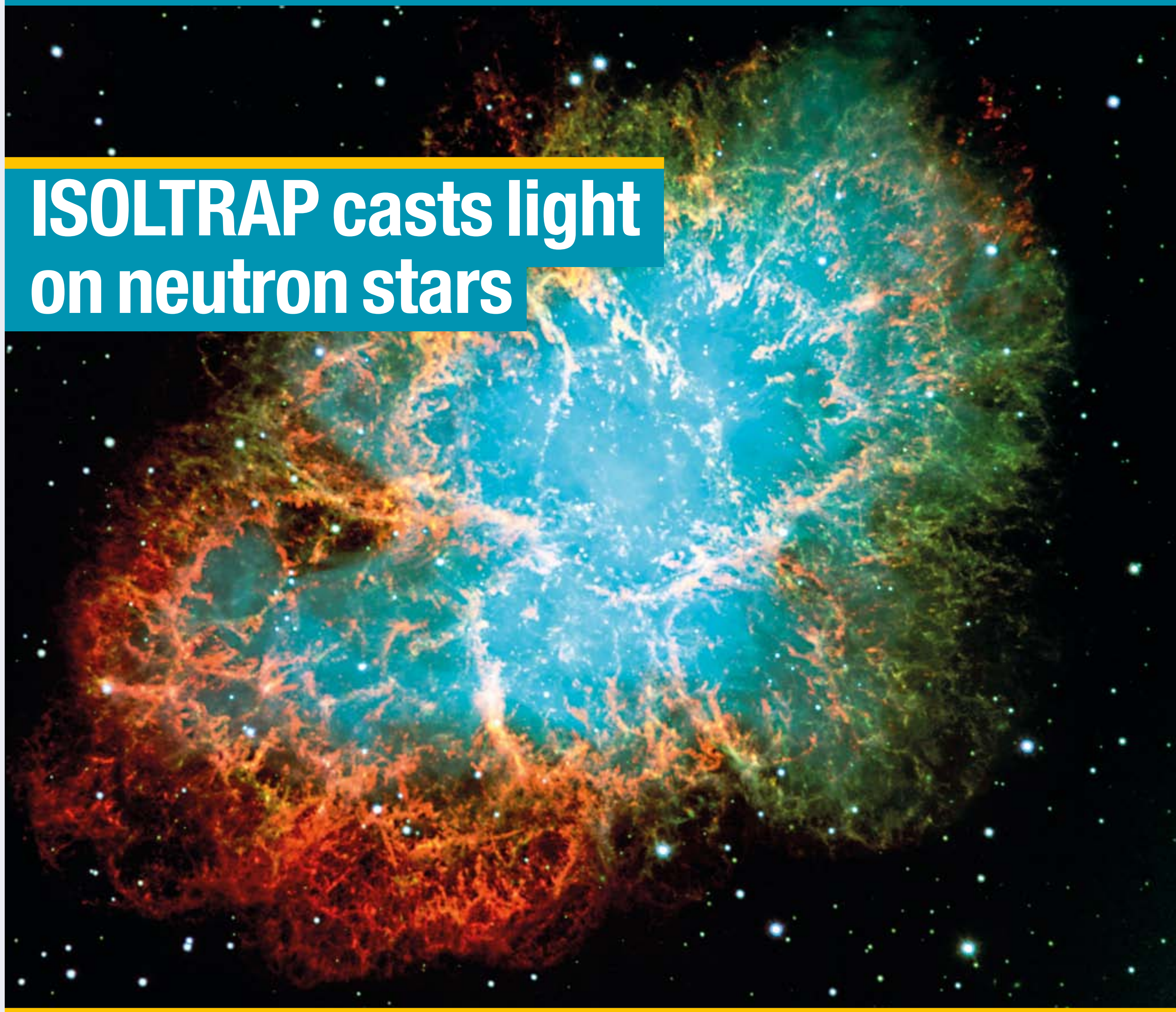
Supernova explosions provide a natural laboratory for some interesting nuclear and particle physics, not least when they leave behind neutron stars, the densest known objects in the cosmos. Conversely, experiments in physics laboratories can cast light on the nature of neutron stars, just as the ISOLTRAP collaboration is doing at CERN's ISOLDE facility, as this month's cover feature describes. Elsewhere at CERN, the long shutdown of the accelerators has begun and a big effort on maintenance and consolidation has started, not only on the LHC but also at the experiments. At Point 5, work is underway to prepare the CMS detector for the expected improvements to the collider. Meanwhile, the Worldwide LHC Computing Grid continues to provide high-performance computing for the experiments 24 hours a day, while it too undergoes a continual process of improvement.

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: CHRISTINE SUTTON, CERN
DIGITAL EDITION CREATED BY JESSE KARJALAINEN/IOP PUBLISHING, UK

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS
CERNCOURIER
VOLUME 53 NUMBER 3 APRIL 2013



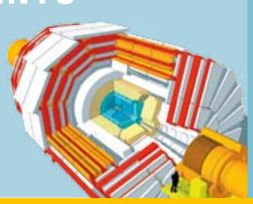
ISOLTRAP casts light on neutron stars

SN BOSE

Kolkata honours a great Indian physicist **p35**

EXPERIMENTS

How CMS is preparing for the future **p16**



COMPUTING AT THE LHC

Work never stops for the WLCG **p21**

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 Christine Sutton
News editor Kate Kahle
Editorial assistant Carolyn Lee
CERN, 1211 Geneva 23, Switzerland
E-mail cern.courier@cern.ch
Fax +41 (0) 22 785 0247
Web cerncourier.com

Advisory board Luis Álvarez-Gaumé, James Gillies, Horst Wenninger

Laboratory correspondents:
Argonne National Laboratory (US) Cosmas Zachos
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) Romeo Bassoli
Jefferson Laboratory (US) Steven Corneliussen
JINR Dubna (Russia) B Starchenko
KEK National Laboratory (Japan) Nobukazu Toge
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) Julia Maddock
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 Jesse Karjalainen
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 Keqing Ma, Library, Institute of High Energy Physics,
PO Box 918, Beijing 100049, People's Republic of China
E-mail: keqingma@mail.ihep.ac.cn
Germany Veronika Werschner, DESY, Notkestr. 85, 22607 Hamburg, Germany
E-mail: desypr@desy.de
Italy Loredana Rum or Anna Pennacchietti, INFN, Casella Postale 56, 00044 Frascati, Rome, Italy
E-mail: loredana.rum@lnf.infn.it
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

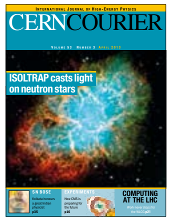
Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

 ISSN 0304-288X

IOP Publishing

CERNCOURIER

VOLUME 53 NUMBER 3 APRIL 2013



On the cover: A three-colour composite image of the Crab Nebula from the FORS2 instrument at the Very Large Telescope of the European Southern Observatory (ESO). This remnant of a supernova explosion observed in 1054 contains a neutron star near its centre. Measurements with the ISOLTRAP instrument at CERN's ISOLDE facility are now casting light on the structure of neutron stars (p24). (Image credit: ESO.)

News

FACILITIES

Colliders unite in the Linear Collider Collaboration

The Compact Linear Collider (CLIC) and the International Linear Collider (ILC) – two studies for next-generation projects to complement the LHC – now belong to the same organization. The Linear Collider Collaboration (LCC) was officially launched on 21 February at TRIUMF, Canada's national laboratory for particle and nuclear physics.

The ILC and CLIC have similar physics goals but use different technologies and are at different stages of readiness. The teams working on them have now united in the new organization to make the best use of the synergies between the two projects and to co-ordinate and advance the global development work for a future linear collider. Lyn Evans, former project leader of the LHC, heads the LCC, while Hitoshi Murayama, director of the Kavli Institute for the Physics and Mathematics of the Universe, is deputy-director.

The LCC has three main sections, reflecting the three areas of research that will continue to be conducted. Mike Harrison of Brookhaven National Laboratory leads the ILC section, Steinar Stapnes of CERN leads the CLIC section and Hitoshi Yamamoto of Tohoku University leads the section for physics and detectors. The Linear Collider Board (LCB), with the University of Tokyo's Sachio Komamiya at the head, is a new oversight committee for the LCC. Appointed by the International Committee for Future Accelerators, the LCC met for the first time at TRIUMF in February. The ILC's Global Design Effort and its supervisory organization, the ILC Steering committee, officially handed over their duties to the LCC and LCB in February but they will continue to work together until the official completion of the *Technical Design Report* for the ILC.

Both the ILC and CLIC will continue to exist and carry on their R&D activities – but with even more synergy between common areas. These include the detectors and the planning of infrastructure, as well as civil-engineering and accelerator aspects. The projects are at different stages of maturity. The CLIC collaboration published its *Conceptual Design Report* in 2012 and is scheduled to complete the *Technical Design Report*, which demonstrates feasibility for construction, in a couple of years.

For the ILC collaboration, which will publish its *Technical Design Report* in June this year, the main focus is on preparing for possible construction while at the same time further advancing acceleration technologies, industrialization and design optimization. The final version of the report will include a new figure for the projected cost. The current estimate is 7.8 thousand million ILC Units (1 ILC unit is equivalent to US$1 of January 2012), plus an explicit estimate for labour costs averaged over the three regional sites, amounting to 23 million person-hours. With the finalization of the *Technical Design Report*, the ILC's Global Design Effort, led by Barry Barish, will formally complete its mandate.

With the discovery of the Higgs-like boson at the LHC, the case for a next-generation collider in the near future has received a boost and researchers are thinking of ways to build the linear collider in stages: first as a so-called Higgs factory for the precision studies of the new particle; second at an energy of 500 GeV; and third, at double this energy, to open further possibilities for as yet undiscovered physics phenomena. Japan is signalling interest to host the ILC.

"Now that the LHC has delivered its first and exciting discovery, I am eager to help the next project on its way," says Evans. "With the strong support the ILC receives from Japan, the LCC may be getting the tunnelling machines out soon for a Higgs factory in Japan while at the same time pushing frontiers in CLIC technology."

Hitoshi Murayama, deputy-director of the Linear Collider Collaboration (LCC), speaks at the press conference in TRIUMF at the launch of the new organization. On the right are Lyn Evans, who heads the LCC, and far right, Sachio Komamiya, head of the Linear Collider Board that will oversee the LCC. On the left is Jonathan Bagger, chair of the ILC Steering Committee. (Image credit: Marcello Pavan/TRIUMF.)

Sommaire en français

CERNCOURIER
Volume 53 Number 3 April 2013
IOP Publishing

CERN

LHC: access required, time estimate about two years

When the LHC and injector beams stopped on 16 February, the following words appeared on LHC Page 1: "No beam for a while. Access required: Time estimate ~2 years". This message marked the start of the first long shutdown (LS1). Over the coming years, major maintenance work will be carried out across the whole of CERN's accelerator chain. Among the many tasks foreseen, more than 10,000 LHC magnet interconnections will be consolidated and the entire ventilation system for the 628-m-circumference Proton Synchrotron will be replaced, as will more than 100 km of cables on the Super Proton Synchrotron. The LHC is scheduled to start up again in 2015, operating at its design energy of 7 TeV per beam, with the rest of the CERN complex restarting in the second half of 2014.

The LHC's first dedicated proton–lead run came to an end on 10 February, having delivered an integrated luminosity of more than 30 nb^{-1} to ALICE, ATLAS and CMS and 2.1 nb^{-1} to LHCb, with the TOTEM, ALFA and LHCf experiments also taking data. This run had ended later than planned because of challenges that had arisen in switching the directions of the two beams (*CERN Courier* March 2013 p5); as a result the 2013 operations were extended slightly to allow four days of proton–proton collisions at 1.38 TeV. To save time, these collisions were performed un-squeezed. After set up, four fills with around 1300 bunches and a peak luminosity of $1.5 \times 10^{32}\ cm^{-2} s^{-1}$ delivered around 5 pb^{-1} of data to ATLAS and CMS. The requisite luminosity scans were somewhat hampered by technical issues but succeeded in the end, leaving just enough time for a fast turnaround and a short final run at 1.38 TeV for ALFA and TOTEM.

A technician practices opening a spare LHC magnet casing in CERN's magnet-testing facility. During the long shutdown, 10,170 such casings will be opened to consolidate interconnections inside.

On 14 February, the shift crew dumped the beams from the LHC to bring to an end the machine's first three-year physics run. Two days of quench tests followed immediately to establish the beam loss required to quench the magnets. Thanks to these tests, it will be possible to set optimum thresholds on the beam-loss monitors when beams circulate again in 2015.

Despite no beam from 16 February onwards, the LHC stayed cold until 4 March so that powering tests could verify the proper functioning of the LHC's main magnet (dipole and quadrupole) circuits. At the same time, teams in the CERN Control Centre performed extensive tests of all of the other circuits, up to current levels corresponding to operation with 7 TeV beams. By powering the entire machine and then going sector by sector, the operators managed to perform more than a thousand tests on 540 circuits in just 10 days. Small issues were resolved by immediate interventions and the operators identified a number of circuits that need a more detailed analysis and possibly intervention during LS1.

With powering tests complete, the Electrical Quality Assurance team could test the electrical insulation of each magnet, sector by sector, before the helium was removed and stored. Beginning with sector 5–6, the magnets are now being warmed up carefully and the entire machine should be at room temperature by the end of May.

COMPUTING

CERN data centre passes 100 petabytes

On the same day that the LHC's first three-year physics run ended, CERN announced that its data centre had recorded more than 100 petabytes (PB) – 100 million gigabytes – of physics data.

Amassed over the past 20 years, the storing of this 100 PB – the equivalent of 700 years of full HD-quality video – has been a challenge. At CERN, the bulk of the data (about 88 PB) is archived on tape using the CERN Advanced Storage (CASTOR) system. The rest (13 PB) is stored on the EOS-disk pool system, which is optimized for fast analysis access by many concurrent users.

For the CASTOR system, eight robotic tape libraries are distributed across two buildings, with each tape library capable of containing up to 14,000 tape cartridges. CERN currently has around 52,000 tape cartridges with a capacity ranging from 1 terabyte (TB) to 5.5 TB each. For the EOS system, the data are stored on more than 17,000 disks attached to 800 disk servers.

Not all of the data are generated by LHC experiments. CERN's IT Department hosts data from many other high-energy physics experiments at CERN, past and present, and is also a data centre for the Alpha Magnetic Spectrometer (*CERN Courier* September 2011 p49).

For both tape and disk, efficient data storage and access must be provided, and this involves identifying performance bottlenecks and understanding how users want to access the data. Tapes are checked regularly to make sure that they stay in good condition and are accessible to users. To optimize storage space, the complete archive is regularly migrated to the newest high-capacity tapes. Disk-based systems are replicated automatically after hard-disk failures and a scalable namespace enables fast concurrent access to millions of individual files.

The data centre will keep busy during the long shutdown of the whole accelerator complex, analysing data taken during the LHC's first three-year run and preparing for the higher expected data flow when the accelerators and experiments start up again. An extension of the centre and the use of a remote data centre in Hungary will further increase the data centre's capacity (*CERN Courier* June 2012 p9).

LHC PHYSICS

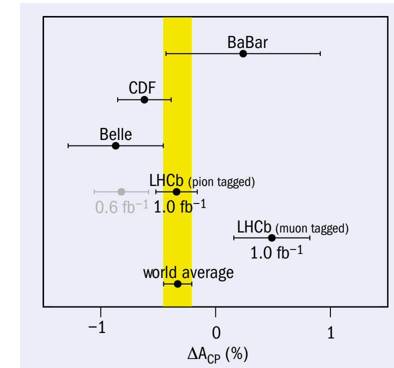
CP violation proves elusive in the charm sector

Using two independent analyses, the LHCb collaboration has updated its measurement of ΔA_{CP}, the difference in CP violation in the decays $D^0 \rightarrow K^+K^-$ and $D^0 \rightarrow \pi^+\pi^-$. This helps to cast light on the whether – and to what extent – CP violation occurs in interactions involving particles, such as the D^0, that contain a charm quark.

The new results represent a significant improvement in the measurement of ΔA_{CP}, which has emerged as an important means to probe the charm sector. A previous measurement from LHCb was 3.5σ from zero and constituted the first evidence for CP violation in the charm sector (LHCb 2012). Subsequent results from the CDF and Belle collaborations, at Fermilab and KEK, respectively, further strengthened the evidence but not to the 5σ gold standard. Because the size of the effect was larger than expected, the result provoked a flurry of theoretical activity, including new physics models that could enhance such asymmetries and ideas for measurements that could elucidate the origin of the effect.

Both of the new measurements by LHCb use the full 2011 data set, corresponding to an integrated luminosity of 1.0 fb^{-1} of proton–proton collisions at 7 TeV in the centre of mass. The first uses the same "tagging" technique as all previous measurements, in which the initial flavour of the D meson (D^0 or $\bar{D}^0$) is inferred from the charge of the pion in the decay $D^{*+} \rightarrow D^0\pi^+$. The second uses D mesons produced in semimuonic B decays, where the charge of the associated muon provides the tag. The two methods allow for useful cross-checks, in particular for biases that have different origins in the two analyses.

Compared with LHCb's previous publication on ΔA_{CP}, the new pion-tagged analysis uses more data, fully reprocessed with improved alignment and calibration constants (LHCb 2013a). The most important change in the analysis procedure is that a vertex constraint has been applied to achieve a factor 2.5 better in background suppression. The result, $\Delta A_{CP} = (-0.34 \pm 0.15\ (stat.) \pm 0.10\ (syst.))\%$, is closer to zero than the previous measurement, which it supersedes. Detailed investigations reveal that the shift caused by each change in the analysis is consistent with a statistical fluctuation.



Comparison of different measurements of ΔA_{CP}. The previous LHCb result is shown as the shaded grey point. The yellow band indicates a naive world.

To add to the picture, the muon-tagged analysis also measures a value that is consistent with zero: $\Delta A_{CP} = (+0.49 \pm 0.30\ (stat.) \pm 0.14\ (syst.))\%$ (LHCb 2013b). In both analyses, the control of systematic uncertainties around the per mille level is substantiated by numerous cross-checks. As the figure shows, the two new results are consistent with each other and with other results at the 2σ level but do not confirm the previous evidence of CP violation in the charm sector.

Theoretical work has shown that several well motivated models could induce large CP-violation effects in the charm sector. These new results constrain the parameter space of such models. Further updates to this and to related measurements will be needed to discover if – and at what level – nature distinguishes between charm and anticharm. The full data sample recorded by LHCb until the start of the long shutdown contains more than three times the number of charm decays analysed in these new results, so progress can be anticipated during the LHC long shutdown.

Further reading

LHCb collaboration 2012 *Phys. Rev. Lett.* **108** 111602.
LHCb collaboration 2013a LHCb-CONF-2013-003.
LHCb collaboration 2013b LHCb-PAPER-2013-003, arXiv:1303.2614 [hep-ex].

TOTEM's luminosity-independent cross-sections

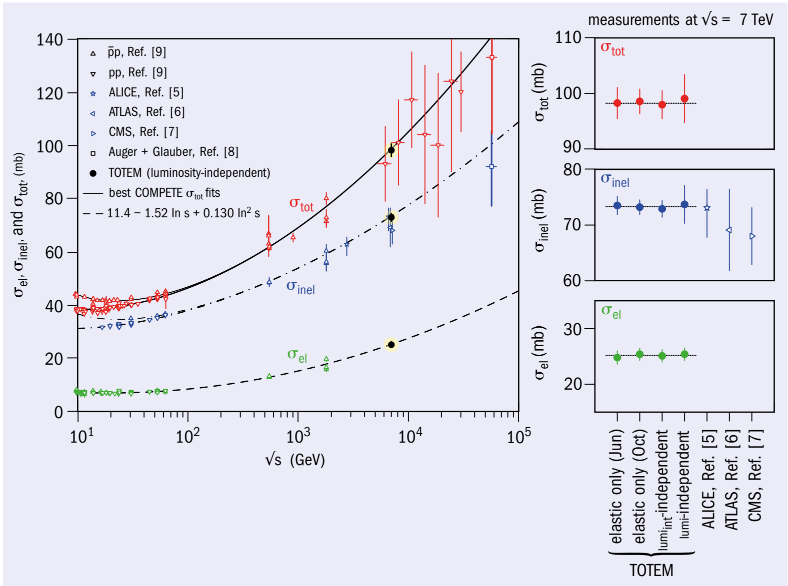
The TOTEM collaboration has published the first luminosity-independent measurement of the total proton–proton cross-section at a centre-of-mass energy of 7 TeV. This is based on the experiment's simultaneous studies of both inelastic and elastic scattering in proton collisions at the LHC.

The TOTEM (TOTal cross-section, Elastic scattering and diffraction dissociation Measurement) experiment, which co-habits the intersection region at Point 5 (IP5) with the CMS experiment, is optimized for making precise measurements of particles that emerge from collisions close to the non-interacting beam particles. To study elastic proton–proton (pp) collisions, in which the interacting protons simply change direction slightly, the experiment uses silicon detectors in Roman Pots, which can bring the detectors close to the beam line (*CERN Courier* September 2009 p19). For inelastic collisions, where new particles are created, two charged-particle telescopes, T1 and T2, come into play. T1 is based on cathode-strip chambers in two "arms" at about 9 m from IP5; T2 employs gas electron-multiplier (GEM) chambers, in this case in two arms at around 13.5 m from IP5.

The measurements at 7 TeV in the centre of mass are based on data recorded in October 2011 with a special setting of the LHC in which the beams were not squeezed for high luminosity but were left relatively wide and straight. With the Roman Pot detectors moved close to the beam, the TOTEM collaboration measured the differential elastic cross-section, $d\sigma/dt$, down to values of the four-momentum transfer squared, $|t| < 0.005\ GeV^2$. Using the luminosity at IP5 as measured by CMS then gave a value for the elastic pp cross-section, $\sigma_{el} = 25.4 \pm 1.1$ mb (*CERN Courier* November 2012 p7, TOTEM collaboration 2013a). Using the optical theorem, which relates $d\sigma/dt$ at $t=0$ to σ_{tot}, the measurement of $d\sigma/dt$ also provided a value of the total cross-section, σ_{tot}, and indirectly, for the inelastic cross-section, as $\sigma_{inel} = \sigma_{tot} - \sigma_{el}$. This yielded $\sigma_{inel} = 73.2 \pm 1.4$ mb.

To measure σ_{inel} more directly, the collaboration has analysed events that have at least one charged particle in the T2 telescope. After applying several corrections and, again, the luminosity from CMS, they arrive at a final result of $\sigma_{inel} = 73.7 \pm 3.4$ mb (TOTEM collaboration 2013b).

The excellent agreement between this value for σ_{inel} and the one determined from $d\sigma/dt$ confirms that the collaboration understands well the systematic uncertainties and corrections used in the analysis and allows them to extract still more information from the data. In particular, as the elastic and inelastic data were collected simultaneously, the optical theorem allows the rates to be combined without the need to know the luminosity. This gives luminosity-independent values of $\sigma_{el} = 25.1 \pm 1.1$ mb, $\sigma_{inel} = 72.9 \pm 1.5$ mb and $\sigma_{tot} = 98.0 \pm 2.5$ mb (TOTEM collaboration 2013c). Using the optical theorem in a complementary way also allows TOTEM to determine the luminosity and in this case the collaboration finds values that are in excellent agreement with those measured by CMS.



Left, the dependence of the cross-sections σ_{tot}, σ_{inel} and σ_{el} on the centre-of-mass energy. The continuous lines are best fits to σ_{tot} by the COMPETE collaboration, the dashed line is a fit to elastic-scattering data and the dash-dotted line σ_{inel} is obtained from the difference between the continuous and dashed fits. On the right are the measurements by TOTEM and the other LHC experiments. (TOTEM collaboration 2013c.)

An arm of the T2 telescope, which uses gas electron-multiplier (GEM) chambers, under construction.

Further reading

TOTEM collaboration 2013a *Europhys. Lett.* **101** 21002.
TOTEM collaboration 2013b *Europhys. Lett.* **101** 21003.
TOTEM collaboration 2013c *Europhys. Lett.* **101** 21004.

ATLAS completes precision luminosity measurement

The ATLAS collaboration achieved a milestone in February when it applied the finishing touches to the measurement of the luminosity for proton–proton (pp) data recorded in 2011 at 7 TeV in the centre of mass. With a relative uncertainty of ±1.8%, the understanding of the luminosity delivered to ATLAS exceeds the accuracy expected before running at the LHC began and opens up exciting possibilities for precision measurements.

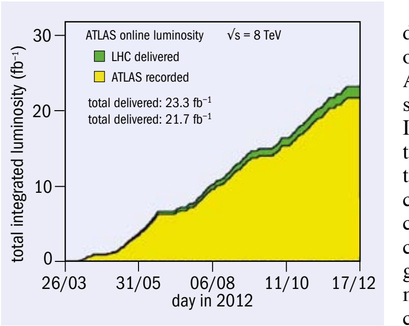
The absolute scale for luminosity – a measure of how many particles pass through a given area in a given time – is calibrated by combining simultaneous precision measurements of the bunch currents in the LHC and of the convolved transverse size of the colliding bunches. Using a technique pioneered by Simon van der Meer nearly 50 years ago at CERN's Intersecting Storage Rings, the inelastic pp collision rate is monitored as the beams are separated first in the horizontal and then in the vertical direction. This "vdM scan" provides a measurement of the beam-overlap area, which when combined with the numbers of protons in each bunch, determines the absolute luminosity produced in head-on collisions.

The success of the procedure for vdM scans at the LHC resulted from close co-operation between the LHC accelerator team and the four large experimental collaborations. The scans are performed in special fills with carefully tailored beam conditions. These fills are optimized for the accuracy of the luminosity measurement while remaining within acceptable operational parameters for the accelerator complex. One key input, the understanding of the number of protons per bunch in the LHC, is determined from several different beam instrumentation measurements, as well as from additional supporting measurements by each of the four LHC collaborations. This effort, led by the LHC Bunch Current Normalization Working Group, has reduced the uncertainty on this key component of the luminosity calibration from around 10% in early 2010 to 0.5% for the final 2011 result.

ATLAS uses two main detectors to monitor the luminosity delivered during physics collisions. LUCID is a segmented Cherenkov detector wrapped around the forward beam pipe; it has been designed specifically for luminosity measurements. The beam conditions monitor (BCM) is a set of small sensors made from synthetic (CVD) diamonds, which also provide fast-abort signals to protect the inner tracking-detectors from radiation damage. LUCID and the BCM both deliver individual luminosity measurements for each of the 3564 possible colliding-bunch slots in the LHC's fill pattern.

The vdM scans provide a direct calibration of these detectors at a single point in time. The accuracy of that calibration in 2011 was determined to be ±1.5%. The dominant uncertainties in this calibration are linked to the reproducibility of the result from one scan to the next and among different colliding bunches in the same scan, as well as to the understanding of the numbers of protons mentioned above.

Assembling LUCID. (Image credit: LUCID/ATLAS.)



ATLAS integrated luminosity in 2012.

To verify that the luminosity calibration determined during vdM scans is stable over an entire year of LHC operation, ATLAS relies on the consistency between several different detectors and algorithms. In addition to LUCID and the BCM, the electrical current flowing through the liquid argon gaps of the forward calorimeter, as well as the photomultiplier currents in selected cells of the hadronic calorimeter, have proved to be remarkably good luminosity monitors. Additional measurements, such as the rate of primary collision vertices reconstructed by the ATLAS tracking system, provide additional cross-checks. Altogether, the agreement among the different luminosity methods has limited any possible variation of the luminosity scale to less than ±1% over the entire year.

The story of the 2011 luminosity measurement has come to a close with the submission of an ATLAS paper on the topic. However, each year brings new challenges and past performance does not guarantee future returns. Considerable machine time was devoted to vdM scans in 2012 to provide the data necessary for a successful luminosity calibration, this time at 8 TeV. This analysis is ongoing, but the accuracy established in 2011 has set a high standard for future luminosity measurements at the LHC.

Further reading

ATLAS collaboration 2013 arXiv:1302.4393, submitted to *EPJC*.

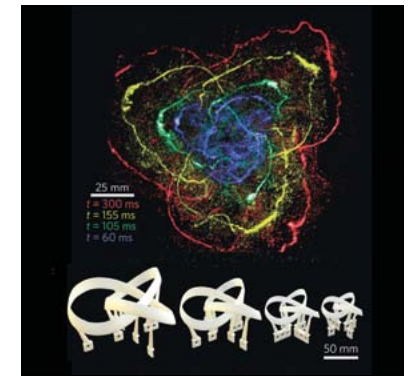
Sciencewatch

Compiled by John Swain, Northeastern University

Vortices tie water into knots

Rings in fluids, such as smoke rings, are easy to form by pushing the fluid quickly through an orifice. But what about knotted rings? Such knots are expected theoretically in many branches of physics and they have now been made in the laboratory. Dustin Kleckner and William T M Irvine of the University of Chicago used a 3D printer to make a tiny, knotted aeroplane wing that, when suddenly accelerated, throws off a trefoil-shaped knotted vortex.

The researchers even managed to make the rings visible by injecting tiny gas bubbles into the fluid, which were pulled into the knotted vortex. The work finally shows that these knotted vortices do, indeed, exist and opens hopes for a whole new field in fluid mechanics.



Top: An overlay of vortex knots taken at the same rescaled time. The vortex r.m.s radii are 60, 45, 30 and 22.5 mm for red, yellow, green and blue colouring, respectively. The generating wing speed is 3.10 m s^{-1} for all except the largest vortex knot, for which it is 2.15 m s^{-1}. Bottom: A photograph of the four knot-generating wings.

● **Further reading**
D Kleckner and W T M Irvine 2013 *Nature Physics* doi:10.1038/NPHYA2560, published online 3 March.

Spin–spin interactions and the Earth's Core

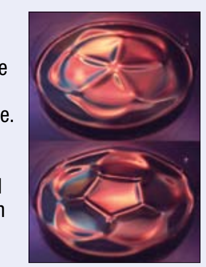
Many theories suggest weak, but long-range interactions between spins but now new and better limits have been obtained using the Earth's core as a huge source of polarized electrons. Larry Hunter of Amherst College and colleagues argue as follows. The Earth's mainly iron core has about 10^{49} unpaired electrons, of which about 1 in 10^{7} will be polarized. That makes for 10^{42} polarized fermions, which is more than 10^{17} times larger than in any laboratory experiments.

The researchers reanalysed previous laboratory experiments, taking into account the Earth's core. They found that for a power law that falls sufficiently slowly, the new analysis leads to limits thousands of times better, even though laboratory-polarized sources are only tens of centimetres away from detecting devices while the Earth's core is a few thousand kilometres away – a nice example of thinking "outside the box".

● **Further reading**
L Hunter *et al.* 2013 *Science* **339** 928.

Star-shaped waves

Vibrating a thin layer of silicon oil in a flat container can produce standing waves of a kind never seen before. Jean Rajchenbach and colleagues of the University of Nice find that for strong enough vertical vibrations, patterns emerge that alternate between a star and a polygon, with n-fold symmetry determined by the frequency and intensity of the vibrations but not by the shape of the container. The team tracks these brand-new forms of standing waves down to a nonlinear resonance-coupling between waves.



An example of a new type of standing wave that alternates between a five-pointed star and a pentagon.

● **Further reading**
J Rajchenbach *et al.* 2013 *Phys. Rev. Letts.* **110** 094502.

Smelling in stereo

While stereo sensing for sound and light is common, there has been no clear evidence of an olfactory analogue. Now, Kenneth Catania of Vanderbilt University has made studies of the blind eastern American (or common) mole. Not only blind but with poor hearing and a bad sense of touch, the animal can head straight to food after a quick sniff. Plugging either nostril makes the animal veer in the direction of the open one and putting tubes in their nostrils and crossing them makes the moles go left when they should go right and vice versa – something that would not happen if they were just moving towards a stronger scent with no left-right discrimination.

Because the moles dig for their food, they may need this faculty to avoid wasting large amounts of energy in moving soil unnecessarily. It remains to be seen if other animals share this skill and to what degree.

● **Further reading**
K C Catania 2013 *Nature Communications* **4** 1441.

Psychiatric drug makes fish bolder

While it is known that pharmaceuticals enter aquatic ecosystems as pollution, little has been known about their effects on wildlife. Now, there is some disturbing news from studies of fish. Tomas Brodin and colleagues at the University of Umeå in Sweden subjected wild European perch (*Perca fluviatilis*) to oxazepam – a benzodiazepine anxiolytic drug used to treat anxiety – at levels of 1.7 μg/l. Fish from the Fyris river had been found in the wild to have six times the concentration as the surrounding water (0.58 μg/l), indicating that the drug concentrates in the fish, so the dose seemed a fair one for a quick test.

After seven days, the fish had levels similar to what they received in the wild. The perch, which are normally shy and hunt together, showed increased activity, reduced sociability and higher feeding rates. This is just one drug of a vast cocktail that is now found in natural water sources, so there is clear cause for concern.

● **Further reading**
T Brodin *et al.* 2013 *Science* **339** 814.

Astrowatch

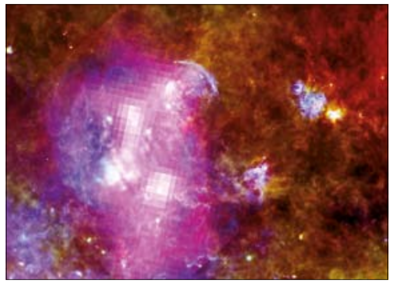
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

Supernova remnants accelerate cosmic rays

A century after the discovery of cosmic rays, NASA's Fermi Gamma-ray Space Telescope has gathered strong evidence that protons are, indeed, accelerated to high-energies by supernova remnants (SNRs). The "smoking gun" is the production of neutral pions in proton–proton collisions and their subsequent decay, revealed by the shape of the gamma-ray spectrum measured in two SNRs.

Cosmic rays are high-energy charged particles (mostly protons) interacting in the Earth's atmosphere. Except for the low-energy component in the solar wind, they hit the Earth from all directions because the interstellar magnetic field deflects them randomly. This means that cosmic rays cannot be traced to their sources – so their origin has remained a mystery since their discovery by Victor Hess in 1912 (*CERN Courier* July/August 2012 p14).

Based on the pioneering work of Enrico Fermi in 1949, researchers have suspected that SNRs are capable of accelerating particles to cosmic-ray energies according to the following scenario. A massive star exploding as a supernova will produce an expanding shock wave in the interstellar medium. A particle crossing the shock front gains an increase in speed of about 1%. This is not much but it can become important for multiple crossings that can be induced when a turbulent magnetic field deflects a charged particle in a random walk process. A particle that crosses the shock discontinuity many times can gain enough energy to break free and escape into the Galaxy – becoming a cosmic ray.



This image combines data from ESA's Herschel Space Observatory with Fermi's gamma-ray observations (magenta) of supernova remnant W44. (Image credit: NASA/DOE/Fermi LAT collaboration and ESA/Herschel.)

The detection of high-energy gamma rays emitted by SNRs provided the first observational evidence for such a mechanism (*CERN Courier* January/February 2005 p30). This was corroborated by the detection with Cherenkov telescope arrays of the nearby starburst galaxies M82 and NGC 253 (*CERN Courier* December 2009 p11). However, it was still possible that the gamma-ray radiation could be induced by bremsstrahlung or inverse-Compton radiation from electrons, rather than by cosmic-ray protons.

An opportunity to disentangle the two processes by studying lower-energy gamma-rays at energies of MeV to GeV came with the launch of the Fermi satellite in 2008 (*CERN Courier* November 2008 p13).

To prove that SNRs produce cosmic rays, the Fermi collaboration has focused on two particular objects, known as IC 443 and W44. Not too distant in the Galaxy, these have the advantage that they are expanding into cold, dense clouds of interstellar gas. These clouds emit gamma rays when struck by high-speed particles escaping the remnants. If these particles are protons, then they can produce neutral pions when colliding with ambient nuclei in the gas clouds. The pions then instantly decay into pairs of gamma rays with an energy of half of the pion rest mass, 135 MeV, in the rest frame of the particle. While the photon number spectrum is thus centred at 67.5 MeV, the usual representation of the gamma-ray spectrum – the photon number spectrum multiplied by the square of the photon energy – rises steeply below around 200 MeV.

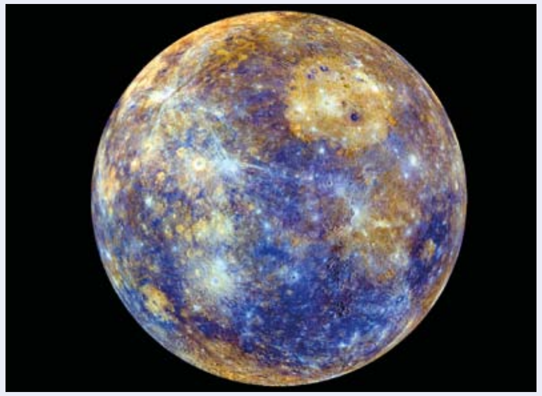
Thanks to improved calibrations at low energies, the Fermi spectra of IC 443 and W44 can now show the presence of the low-energy spectral cut-off expected from pion decay. The study published in *Science* by the Fermi collaboration shows that the gamma-ray spectra of both sources are better reproduced by pion decay rather than by bremsstrahlung radiation from electrons. This observational proof of proton acceleration in SNRs was one of the key objectives of the Fermi mission and confirms the basic principle of particle acceleration suggested by Enrico Fermi some 60 years ago.

Further reading

M Ackermann *et al.* 2013 *Science* **339** 807.

Picture of the month

This colourful view of Mercury was produced by assembling thousands of images of its surface taken by NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft, which has been in orbit round the planet for two years (*CERN Courier* April 2012 p15). Before MESSENGER, more than half of the planet was a complete mystery. This image (and the one of the opposite side) completes the 100% coverage of the planet. The colours are not what Mercury would look like to the human eye but enhance the chemical, mineralogical and physical differences between the rocks that make up its surface. The giant Caloris basin is the large circular, tan-coloured feature to the upper right. Created by the impact of a comet or asteroid during the Solar System's early years, it was subsequently flooded with lava from volcanic activity. Younger impact craters are surrounded by rays of ejected material appearing light blue or white. (Image credit: NASA /JHU Applied Physics Lab/Carnegie Inst. Washington.)



CERN Courier Archive: 1970

A look back to CERN Courier vol. 8, April 1970, compiled by Peggie Rimmer

SACLAY

Mirabelle is ready to move

Mirabelle, the large hydrogen bubble chamber built by the Elementary Particle Physics Department of the CEA, the French Atomic Energy Commission, is being dismantled for removal to Serpukhov's 76 GeV accelerator, where experiments with the chamber are due to start from the middle of 1971.

In 1966, a Franco–Soviet agreement was signed specifying that a large bubble chamber would be built at Saclay and installed at Serpukhov for collaborative experiments. It gave French physicists the possibility of working with the highest energy accelerator in the world while allowing Soviet scientists to profit from Saclay's considerable experience in the field of bubble chamber construction, shown in the table.

First op.	Useful volume	Operated at
1957	1 litre (a model known as ME3 in which tracks were first photographed)	Saclay
1959	3 litre (20 cm long)	Saclay
1959	25 litre (35 cm long)	Saclay
1960	70 litre (50 cm long)	Saclay
1961	70 litre (81 cm long)	CERN
1962	300 cm^3 (Model ME5, installed as a target inside a heavy liquid chamb.)	Saclay
1964	130 litre (81 cm long)	DESY
1964	180 litre (81 cm long)	Rutherford
1966	7000 litre (The Mirabelle prototype known as ME6)	Saclay
1969	7000 litre (Mirabelle)	Saclay/Serpukhov

The agreement laid down that the chamber, which costs 37 million French francs, would be operated at Serpukhov for at least five years by French staff, while, in return, teams of French physicists would take part in the experiments in mixed teams.

Mirabelle weighs 2000 tonnes, and the total weight, including all the auxiliary equipment, is 3600 tonnes. Dismantling, transporting and reassembling such a huge assembly is a labour of Herculean proportions and will take a year to complete. The equipment will be taken from Paris to Le Havre by road, from there to Leningrad by boat, and then by train to the experimental hall at Serpukhov.

Once Mirabelle is operating, a small colony of fifty families from Saclay will be housed in the village of Protvino, near Serpukhov. Together with the families of scientists taking part in joint experiments, there will be a total of almost 250 French people. Saclay has given particular attention to this problem of "transplantation".

The families will be distributed in blocks of flats in which local people also live. An infants' school has been set up, integrated into a local Russian school, with its operating costs shared between the French Ministry of Education and the CEA. Two French teachers are to be employed initially. To make it easier for the children to become adapted to their new surroundings, they will receive lessons in Russian from a Russian teacher.

● Compiled from texts on pp118–119.

CONFERENCE

European Molecular Biology Conference

A very successful session of the European Molecular Biology Conference was held at CERN on 6–8 April. For the first time the Conference was meeting "formally", as sufficient European governments had ratified the agreement setting up the Conference for it to move from provisional to formal status.

Before the creation of the Conference, the European Molecular Biology Organization (EMBO) and individual scientists had been urging that a European Laboratory for Molecular Biology should be established to bring together the many disciplines involved in the pursuit of molecular biology. Similar to the way in which CERN operates, the Laboratory is seen as a research centre with limited "permanent" scientific staff, to which visiting scientists would come to carry out experiments in a multi-disciplinary environment with first-class equipment and then return to their home countries.

A new detailed proposal concerning the establishment of such a Laboratory was presented to the Conference and was warmly welcomed. It has not yet been examined by the governments but there is a strong conviction in the scientific community that such a Laboratory is of vital importance for the future of molecular biology in Europe. The Conference set up a Working Group to pursue the study of the proposed Laboratory and to make recommendations at its session on 26–27 November 1970.

● Compiled from texts on p117.

Compiler's Note

The EMBO was founded in 1964, with 140 nominated scientists, to set the highest standards for European research and training in the life sciences. Today the 1500 or so members, elected annually on scientific merit, include 57 Nobel laureates.

In 1969, EMBO formed its conference as the organization's intergovernmental funding body and fulfilled its second founding mandate in 1974 when the European Molecular Biology Laboratory (EMBL) was established in Heidelberg, Germany. At present, the laboratory is supported by 20 European countries, plus Australia as an associate member. It now operates from five sites: the main laboratory in Heidelberg and outstations for bioinformatics in Hinxton (UK), structural biology in Grenoble (France) and Hamburg (Germany), and mouse biology in Monterotondo (Italy).

While the Saclay/Serpukhov collaboration was getting underway, a second CERN/Serpukhov experiment was being prepared at the 76 GeV proton synchrotron. The Antonov 22 cargo plane (see cover thumbnail) that transported some of the equipment to Moscow attracted a great deal of attention at Geneva airport in early April.

CMS prepares for the future

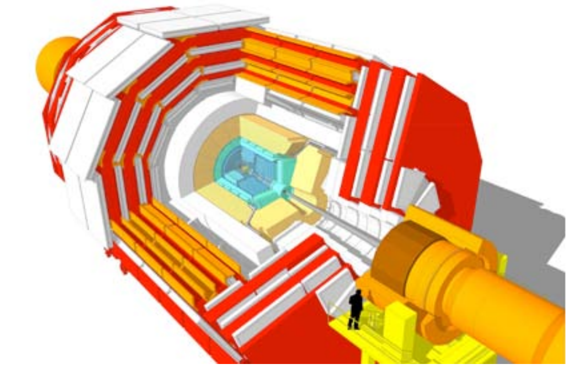
There will be no rest at Point 5, site of the CMS detector, during the long shutdown.

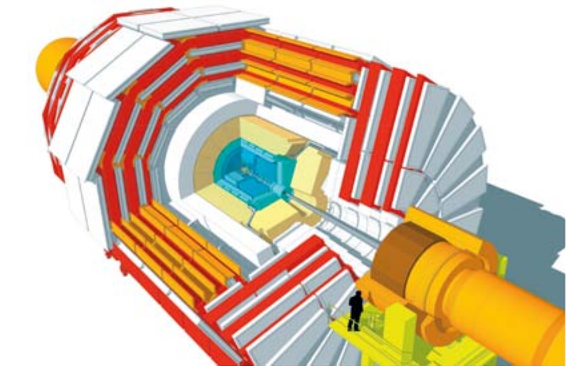
Three years after resuming operation at a centre-of-mass energy of 7 TeV in 2010 and ramping up to 8 TeV last year, the LHC is now taking a break for its first long shutdown, LS1 (*CERN Courier* March 2012 p26). During the long period of highly successful running, the CMS collaboration took advantage of the accelerator's superb performance to produce high-quality results in a variety of physics analyses, the most significant of which being the joint discovery with ATLAS of a new, Higgs-boson-like particle in July 2012 (*CERN Courier* September 2012 p49).

Now, as the LHC teams prepare the machine for running from 2015 onwards at a higher centre-of-mass energy (13–14 TeV) and with increasing luminosity, the collaboration will continue to be busy maintaining and consolidating the CMS subdetectors and making sure that they can handle the collider's improved performance. For several systems, this will involve making provision for upgrades to be implemented later in the detector's lifetime. Point 5, the home of the CMS detector and control room, will see a busy LS1.

Tracker climate control

Perhaps the biggest priority for CMS is to reduce the effects of radiation damage on the performance of the Tracker. The CMS tracking system forms the innermost subdetector and fits snugly round the LHC beampipe. It must withstand an onslaught of some 10^{10} particles a second and the aggressive field of mixed radiation that this produces. The only way to mitigate against the progressive effects of this irradiation is to operate the Tracker at a lower temperature than the present few degrees Celsius – perhaps as much as 30° C lower. It is crucial that the Tracker will run under these conditions over the next decade, during which a replacement will be designed and built. The issue here is two-fold: on the one hand, the Tracker coolant must run at a lower temperature; on the other, there can be no condensation on the cooling circuits and detectors, which will be much colder than before, and that is a matter of controlling humidity.





Before (top) and after: A fourth layer of muon chambers (light grey) will be mounted on the third shielding disc (red) in the endcap muon system at both ends of the CMS detector.

Because the Tracker will not be in an hermetically sealed environment, despite an intensive programme of improvement, the humidity inside it will have to be controlled by blowing in dry gas to force out all of the water vapour. In addition to the Tracker itself, the nearby coolant pipes – which will also be at low temperature because of the coolant – are not well insulated. The collaboration will have to make sure that the detector and nearby pipework are dry, to avoid condensation and the growth of ice, which can inflict major damage. ▷

Left: Disc three, equipped with the muon chambers for the third muon station, could be preassembled on the surface; it was lowered by heavy-lifting crane in November 2006. The fourth muon station, to be mounted on the opposite side of disc three, and the fourth (shielding) disc will have to be assembled in situ.

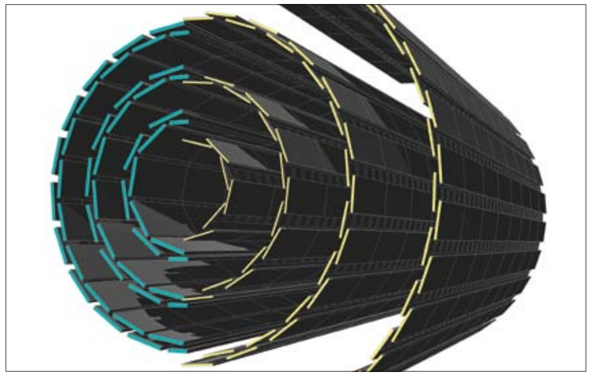
CMS will require substantially more dry gas (nitrogen during operation, air during maintenance) than previously (up to a few hundred normal cubic metres per hour are envisaged) making it no longer cost-effective to purchase liquefied nitrogen. The collaboration has therefore procured an on-site plant that extracts the water vapour and, optionally, the oxygen from air, outputting a dry atmosphere with (optionally) 95% nitrogen. This plant is a relatively large piece of equipment that requires integration, installation and commissioning. It will be deployed in a few months' time, after the detector is opened up, to confirm that the improved sealing system works well enough to allow the Tracker to run at a much reduced temperature after LS1 and beyond. This is the number one priority for CMS for the shutdown.

During the normal year-end technical stop of 2016–2017, the collaboration will install the Phase 1 upgrade of the CMS pixel tracker, which is the closest physics detector to the collision point. This will feature an additional, fourth layer, among other improvements. To get the first layer as close to the collision point as possible, a smaller-diameter beampipe will be installed during LS1, with an outer diameter of 45 mm – compared with the current 59.6 mm. The additional pixel layer will improve the CMS experiment's ability to tell where a track comes from, which vertex it comes from or if, indeed, it comes from a primary vertex at all. Running under conditions of high pile-up, resolving which tracks and clusters belong to which vertices is absolutely crucial for the physics analyses.

Although replacing the pixel tracker will require a shutdown of only three to four months, installing a new beampipe will take significantly longer – more than a year – so this has to take place during LS1. It is a delicate operation that requires the detector to be in its most open condition with the pixels removed. Once the new beampipe is in place, the collaboration will conduct a dry run by installing a "3D print" of the new pixel detector: a shell that represents the volume of the detector. This is to make sure that the operation can be performed rapidly with the real object, that it does not jam anywhere and that the adjustment systems all work.

More for muons

Another major element of the CMS plans for LS1 features work to improve the muon detectors. The original design for the endcap part of this system had four triggering and measurement stations for muons but the fourth layer was not considered essential for initial operation. However, to function effectively in the future, the fourth layer is now needed to provide more discriminatory power between interesting muons and fake signatures from mismeasurement or background. Hundreds of detector components have to be built and installed. The biggest assembly site is in Building 904 on CERN's Prévessin site, where teams from CERN and around the world, including the US, China, Russia, Korea, Pakistan and



The geometry of the existing three-layer pixel tracker barrel (left) compared with the upgraded four-layer detector.

Italy, are halfway through the detector-construction project. Meanwhile, preparations are well advanced for a consolidation of the barrel part of the muon system; some key on-board electronics will be moved from the underground experimental cavern to the neighbouring service cavern, thus taking advantage of the accessibility of this latter cavern for maintenance activities even during LHC operation.

Associated with the installation of the fourth endcap layer is the refurbishment of chambers in the first layer. The inner wires of these chambers were read out in groups in the initial version of CMS. This was fine for lower collision rates but in future the full granularity of this detector layer will be required. In addition, the electronics are not optimal for the expected higher collision rates, so the collaboration is going to replace all of the on-board electronics. The electronics from the first layer will be reused to provide electronics for the outer layer, where it is easier to cope with the collision rate. A special operational support centre has been built at Point 5 specifically for this refurbishment task and for other detector activities, including cold-storage of the pixel tracker while the new beampipe is fitted. Because some elements to be stored or modified may have been activated by radiation, the centre includes a controlled workshop area.

New shielding discs, 10 cm deep, are to be installed outside the new fourth muon stations on the endcap yoke on either end of the detector. Each shielding disc is made of 12 iron sector-casings filled with a special concrete. Following manufacture and preassembly tests in Pakistan, these discs, whose preparation has taken five years, with the design finished only two years ago, are now being re-assembled and filled at CERN. The first has just been finished. The concrete, developed for this specific application by CERN's civil engineers, is almost 50% denser than normal

Work in 2007 on installing muon chambers in the CMS barrel.

concrete – it is made using haematite (or ferric oxide) instead of the usual sand – and it is loaded with boron to absorb low-energy neutrons that would otherwise give rise to unwanted hits in the detector. The overall density of neutrons flying round the cavern will be decreased by having these massive 14-m-diameter shielding discs installed.

The new 100-tonne shielding discs represent the first large mechanical elements of CMS to be constructed entirely underground in the experimental cavern, because the heavy-duty cranes – used to lower each of the existing elements of CMS in their entirety – are no longer installed at Point 5. (The CMS experiment was unique in being constructed in massive "slices" above ground, see *CERN Courier* October 2008 p45 and April 2007 p6.) Each disc will have to be taken apart into its 12 component sectors for lowering and then be rebuilt in a vertical position underground. The shielding discs will have an installed clearance to the new detector layer of around 10–20 mm, so it will be a delicate operation and the logical course of action is to install the discs before the detectors.

The magnet and other systems

The consolidation and upgrade programme aims to equip CMS for running well into the 2030s, and a key element of operating for another two decades will be the CMS magnet – a unique object that is impossible to envisage replacing. Changes are being made to ensure that the experiment is not vulnerable to a major breakdown of the supporting cryogenic system, which could prevent CMS from running for a long time, or to avoid unnecessary on–off cycles, which could prematurely age the magnet.

It is important to remember that the detector was designed for 10 years of operation, with a cycle of 7 months for operation and 5 months of shutdown, and a technical stop every three weeks. In practice, there has been three years of continuous operation with only short winter stops – not long enough to open the detector up for thorough servicing – and a technical stop every 6, 8 or 10 weeks. This is a radically different scenario from the one for which CMS was built. Although, the detector has performed well, there is a pressing need to consolidate it for the new regime. For the magnet consolidation, the obvious change is to install a duplicate compressor plant, to mitigate against the failure of the existing plant at Point 5, which has compressors that have run well beyond the recommended service intervals of 40,000 hours without maintenance.

The electrical system is going to be completely revised so that the two levels of the underground service cavern will be supplied through the UPS (uninterruptible power supply), system to give better protection against power glitches. There will also be cooling modifications, not only to make the magnet more robust but also to accommodate the new detectors of the fourth muon layer, the new operating conditions for the Tracker and the future pixel tracker. Many of these modifications have to be put in place during LS1 because there will not be adequate time to do so later.

All of the photo-transducers of the Hadron Calorimeter (HCAL) are to be replaced. Although the work will only be finished during subsequent shutdowns, it is important to begin now while the CMS teams have access to detector components that will not be accessible later. For example, it might not be possible to access the outer HCAL (HO) on the central yoke wheel during LS2, whereas this can be done in the current shutdown.

To be sure that all systems are running well, the collaboration will repeat the Cosmic Run At Four Tesla (CRAFT) (actually 3.8 T) exercise in late summer of 2014, after closing the yoke and testing the magnet (*CERN Courier* January/February 2009 p8.). Although there will be no collisions, the detector will record valuable calibration and commissioning data from cosmic rays. If there is a problem with the new cooling systems or with the humidity control of the Tracker, for example, this should be detected promptly and should give the teams just enough time to open up the detector, do whatever needs to be done to fix it and close it again, before the designated end of the shutdown.

The schedule for 2013 is planned in fine detail with a list of hundreds of tasks that are currently being translated into day-to-day planning schematics, and with work packages that have to be understood, approved, checked for co-activity, possible radiological factors and so forth. In addition, amid all this important technical work, the CMS collaboration will attempt to welcome around 20,000 visitors to the site at Point 5 over the course of the year. The coming two years might be described as a shutdown period for the LHC and its experiments but life at Point 5 will be as busy as it has ever been.

Résumé

CMS prépare le futur

Il n'y aura pas de répit au point 5, site du détecteur CMS, au cours du premier long arrêt du LHC. Pendant que l'on prépare l'accélérateur à fonctionner, à partir de 2015, à une énergie plus élevée, et avec une luminosité plus forte, la collaboration CMS aura elle aussi du pain sur la planche. Des équipes procéderont à des travaux de maintenance et de consolidation sur les sous-détecteurs de CMS, afin de leur permettre de faire face à la performance améliorée du collisionneur. Il y aura notamment des opérations importantes sur le système de refroidissement pour le trajectographe et sur les détecteurs de muons des bouchons.

Austin Ball and **Achintya Rao**, CERN.

The LHC's worldwide computer

Behind the excellent results from the LHC lies the Worldwide LHC Computing Grid – a giant that never sleeps.

Mid-February marked the end of the first three-year run of the LHC. While the machine exceeded all expectations, delivering significantly more data to the experiments than initially foreseen, high-performance distributed computing also enabled physicists to announce on 4 July the discovery of a new particle (*CERN Courier* September 2012 p46). With the first run now over, it is a good time to look back at the Worldwide LHC Computing Grid to see what was initially planned, how it performed and what is foreseen for the future.

Back in the late 1990s, it was already clear that the expected amount of LHC data would far exceed the computing capacity at CERN alone. Distributed computing was the sensible choice. The first model proposed was MONARC (Models of Networked Analysis at Regional Centres for LHC Experiments), on which the experiments originally based their computing models (*CERN Courier* June 2000 p17). In September 2001, CERN Council approved the first phase of the LHC Computing Grid project, led by Les Robertson of CERN's IT department (*CERN Courier* November 2001 p5). From 2002 to 2005, staff at CERN and collaborating institutes around the world developed prototype equipment and techniques. From 2006, the LHC Computing Grid became the Worldwide LHC Computing Grid (WLCG) as global computing centres became connected to CERN to help store data and provide computing power.

WLCG uses a tier structure with the CERN data centre as Tier-0 (figure 1). CERN sends out data to each of the 11 major data centres around the world that form the first level, or Tier-1, via optical-fibre links working at multiples of 10 Gbit/s. Each Tier-1 site is then linked to a number of Tier-2 sites, usually located in the same geographical region. Computing resources are supported by the national funding agencies of the countries where each tier is located.

Worldwide LHC Computing Grid in numbers

- About 10,000 physicists use it
- On average well in excess of 250,000 jobs run concurrently on the Grid
- 30 million jobs ran in January 2013
- 260,000 available processing cores
- 180 PB disk storage available worldwide
- 15% of the computing resources are at CERN
- 10 Gbit/s optical-fibre links connect CERN to each of the 11 Tier-1 institutes
- There are now more than 70 PB of stored data at CERN from the LHC

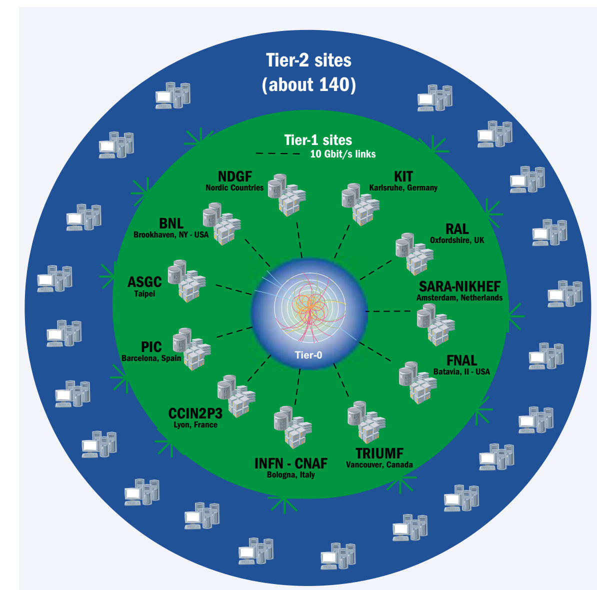


Fig. 1. Diagram showing the tier system of WLCG, with CERN's Tier-0 site sending data to the 11 Tier-1 sites and their corresponding Tier-2 sites. More Tier-1 and Tier-2 sites are foreseen.

Exceeding expectations

Before the LHC run began, the experiment collaborations had high expectations for the Grid. Distributed computing was the only way that they could store, process and analyse the data – both simulated and real. But, equally, there was some hesitation: the scale of the data processing was unprecedented and it was the first time that analysis had been distributed in this way, dependent on work done at so many different places and funded by so many sources.

There was caution on the computing side too; concerns about network reliability led to built-in complexities such as database ▷

replication. As it turned out, the network performed much better than expected. Networking in general saw a big improvement, with connections of 10 Gbit/s being more or less standard to the many university departments where the tiers are housed. Greater reliability, greater bandwidth and greater performance led to increased confidence. The initial complexities and the need for replication of databases reduced, and over time the Grid saw increased simplicity, with a greater reliance on central services run at CERN.

A wealth of data

Network improvements, coupled with the reduced costs of computing hardware meant that more resources could be provided. Improved performance allowed the physics to evolve as the LHC experiments increased their trigger rates to explore more regions than initially foreseen, thus increasing the instantaneous data. LHCb now writes as much data as had been initially estimated for ATLAS and CMS. In 2010, the LHC produced its nominal 15 petabytes (PB) of data a year. Since then, it has increased to 23 PB in 2011 and 27 PB in 2012. LHC data contributed about 70 PB to the recent milestone of 100 PB of CERN data storage (see p6).

In ATLAS and CMS, at least one collision took place every 50 ns i.e. with a frequency of 20 MHz. The ATLAS trigger output-rate increased over the years to up to 400 Hz of output into the main physics streams in 2012, giving more than 5.5×10^9 recorded physics collisions. CMS collected more than 10^{10} collision events after the start of the run and reconstructed more than 2×10^{10} simulated crossings.

For ALICE, the most important periods of data-taking were the heavy-ion (PbPb) periods – about 40 days in 2010 and 2011. The collaboration collected some 200 million PbPb events with various trigger set-ups. These periods produced the bulk of the data volume in ALICE and their reconstruction and analysis required the biggest amount of CPU resources. In addition, the ALICE detector operated during the proton–proton periods and collected reference data for comparison with the heavy-ion data. In 2013, just before the long shutdown, ALICE collected asymmetrical proton–lead collisions with an interaction versus trigger rate of 10%. In total, from 2010, ALICE accumulated about 8 PB of raw data. Add to that the reconstruction, Monte Carlo simulations and analysis results, and the total data volume grows to 20 PB.

In LHCb, the trigger reduces 20 million collisions a second to 5000 events written to tape each second. The experiment produces about 350 MB of raw data per second of LHC running, with the total raw data recorded since the start of LHC at about 3 PB. The total amount of data stored by LHCb is 20 PB, of which about 8 PB are on disk. Simulated data accounts for about 20% of the total. On average, about one tenth of the jobs running concurrently on the WLCG come from LHCb.

The WLCG gives access to vast distributed resources across the globe in Tier-1 and Tier-2 sites, as well as to additional voluntary resources from interested institutions, ensuring built-in resilience because the analysis is not performed in a single data centre and hence is not dependent on that centre. It also makes the LHC data available worldwide at the same time.

As time has gone on, the Tier-2 sites have been used far more than foreseen (figure 2). Originally thought to be just for analysis and Monte Carlo simulations, the sites can now do much more with more resources and networking than anticipated. They currently contribute to data reprocessing, normally run at Tier-1 sites, and have enabled the Grid to absorb peak loads that have arisen when processing real data as a result of the extension of the LHC run and the higher-than-expected data collection rates. Because the capacity available at Tier-0 and Tier-1 was insufficient to process new data and reprocess earlier data simultaneously, the reprocessing activity was largely done on Tier-2s. Without them it would not have been possible to have the complete 2012 data set reprocessed in time for analyses targeting the winter conferences in early 2013.

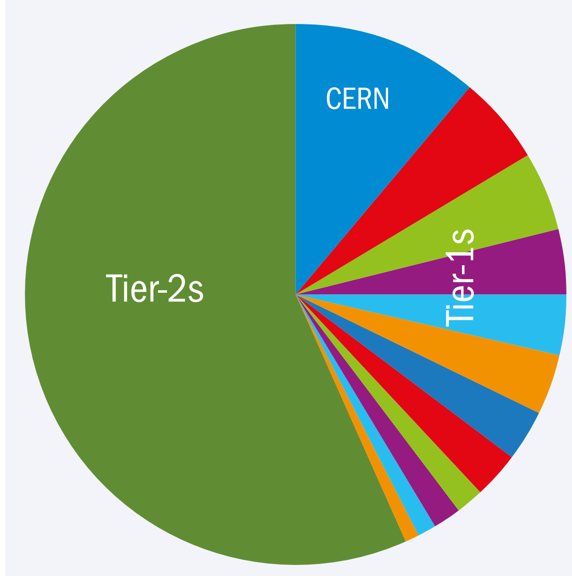


Fig. 2. The Tier-2 sites of the Worldwide LHC Computing Grid now regularly deliver more than 50% of total resources. They were initially foreseen to deliver 40%.

Improved performance allowed the physics to evolve as experiments increased trigger rates to explore new regions.

Fig. 3. The Grid never sleeps: this image shows the activity on 1 January 2013, just after midnight, with almost 250,000 jobs running. (Image credit: Data SIO, NOAA, US Navy, NGA, GEBCO, Google, US Dept. of State Geographer, GeoBasis, DE/BKG.)

The challenges for the Grid were three-fold. The main one was to understand how best to manage the LHC data and use the Grid's heterogeneous environment in a way that physicists could concern themselves with analysis without needing to know where their data were. A distributed system is more complex and demanding to master than the usual batch-processing farms, so the physicists required continuous education on how to use the system. The Grid needs to be fully operational at all times (24/7, 365 days/year) and should "never sleep" (figure 3), meaning that important upgrades of the Grid middleware in all data centres must be done on a regular basis. For the latter, the success can be attributed in part to the excellent quality of the middleware itself (supplied by various common projects, such as WLCG/EGEE in Europe and OSG in the US, see box) and to the administrators of the computing centres, who keep the computing fabric running continuously.

Requirements for the future

With CERN now entering its first long shutdown (LS1), the physicists previously on shift in the control rooms are turning to analysis of the data. Hence LS1 will not be a period of "pause" for the Grid. In addition to analysis, the computing infrastructure will undergo a continual process of upgrades and improvements.

The computing requirements of ALICE, ATLAS, CMS and LHCb are expected to evolve and increase in conjunction with the experiments' physics programmes and the improved precision of the detectors' measurements. The ALICE collaboration will re-calibrate, re-process and re-analyse the data collected from 2010 until 2013 during LS1. After the shutdown, the Grid capacity (CPU and storage) will be about 30% more than that currently installed, which will allow the experiment to resume data-taking and immediate data processing at the higher LHC energy. The ATLAS collaboration has an ambitious plan to improve its software and computing performance further during LS1 to moderate the increase in hardware needs. They nonetheless expect a substantial increase in their computing needs compared with what was pledged for 2012. The CMS collaboration expects the trigger rate – and subsequently the processing and analysis challenges – to continue to grow with the higher energy and luminosity after LS1. LHCb's broader scope to include charm physics may increase the experiment's data rate by a factor of about two after LS1, which would require more storage on the Grid and more CPU power. The collaboration also plans to make much more use of Tier-2 sites for data processing than was the case up until now.

For the Grid itself, the aim is to make it simpler and more integrated, with work now underway to extend CERN's Tier-0 data centre, using resources at CERN and the Wigner Research Centre in Budapest (*CERN Courier* June 2012 p9). Equipment is already being installed and should be fully operational in 2013.

Future challenges and requirements are the result of great successes. Grid performance has been excellent and all of the experiments have not only been good at recording data, but have also found that their detectors could even do more. This has led to the experiment collaborations wanting to capitalize on this potential. With a wealth of data, they can be thankful for the worldwide computer, showing global collaboration at its best.

Beyond particle physics

Throughout its lifetime, WLCG has worked closely with Grid projects co-funded by the European Commission, such as EGEE (Enabling Grids for E-sciencE) and EGI (European Grid Infrastructure), or funded by the US National Science Foundation and Department of Energy, such as OSG (Open Science Grid). These projects have provided operational and developmental support and enabled wider scientific communities to use Grid computing, from biologists who simulate millions of molecular drug candidates to find out how they interact with specific proteins, to Earth-scientists who model the future of the planet's climate.

Résumé

Le calculateur mondial du LHC

Si le LHC, au cours de sa première période d'exploitation, a dépassé toutes les attentes, le calcul distribué à haute performance a aussi joué son rôle pour permettre aux physiciens d'annoncer l'année dernière la découverte d'un nouveau boson. Cette prouesse, et beaucoup d'autres résultats remarquables, n'auraient pas été possibles sans la Grille de calcul mondiale du LHC, qu'on peut comparer à un géant qui ne dort jamais. L'article fait le point sur ce projet de grille mondiale : ce qui était prévu à l'origine, ce qui a été obtenu, et ce qui est prévu pour le futur. Grâce à l'excellente performance de la grille, les expériences ont pu recueillir un nombre impressionnant de données, démontrant que les détecteurs pouvaient produire des résultats au-delà de toutes les attentes.

Kate Kahle and **Mélissa Gaillard**, CERN, with thanks to Frédéric Hemmer and Ian Bird (CERN), Borut Kerševan (ATLAS), Ian Fisk (CMS), Latchezar Betev (ALICE), Marco Cattaneo and Peter Clarke (LHCb).

Plumbing the depths of neutron stars

New techniques developed by the ISOLTRAP collaboration are allowing investigations of a possible birthplace of the heavy elements.

Imagine the mass of the entire Sun squeezed into a radius of just 10 km. This is about the density of a neutron star – the highest density known in the cosmos. These extremely dense objects are the residues of core-collapse supernova explosions, so a significant fraction of the stars in the universe finish their lives this way. They are often present as binary systems that eventually merge, in principle radiating detectable gravity waves. Another tantalizing possibility is that the ejecta from these events might enrich the interstellar medium with heavy elements, created by a rapid neutron-capture process (the r process). The composition of neutron stars is therefore important yet the description of these ultracompact objects remains one of the biggest challenges facing nuclear and particle physics today.

As the name implies, neutron stars are essentially – but not wholly – composed of neutrons. As figure 1 shows, neutron stars are thought to consist of three layers: a homogeneous core and two concentric shells (Lattimer and Prakash 2004). The surface of the star contains only nuclei that are stable under natural terrestrial conditions. Below this "outer crust", however, the rapidly increasing internal densities form nuclei that are increasingly neutron-rich, eventually reaching the "drip line", or the brink of nuclear stability. This marks the transition to the "inner crust", which is an inhomogeneous assembly of neutron–proton clusters and unbound neutrons that is neutralized by a quasi-uniform electron gas. Deeper into the star, the clusters start to smooth out, giving way to the inner core whose structure is the source of much debate.

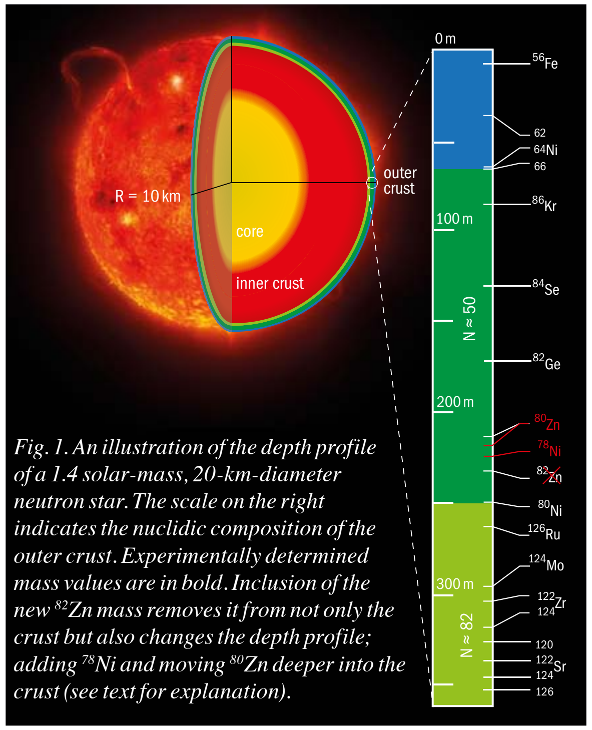


Fig. 1. An illustration of the depth profile of a 1.4 solar-mass, 20-km-diameter neutron star. The scale on the right indicates the nuclidic composition of the outer crust. Experimentally determined mass values are in bold. Inclusion of the new ^{82}Zn mass removes it from not only the crust but also changes the depth profile; adding ^{78}Ni and moving ^{80}Zn deeper into the crust (see text for explanation).

Magic numbers

A landmark paper in 1971 presented a model for neutron stars that assumed cold, catalysed matter in which increasingly heavy and neutron-rich nuclides (resulting from electron capture) exist in a state of equilibrium for beta-decay processes (Baym, Pethick and Sutherland, 1971). The effects of the shell structure of nuclei mean that the nuclides residing in neutron-star crusts will cluster around the "magic" neutron numbers, N = 50 and 82, which correspond to closed shells (see figure 2). Indeed, one of the outstanding questions in nuclear physics is whether these magic numbers retain their "supernatural" characteristics in nuclides far from stability. The most exotic N = 50 and N = 82 species are therefore the priority for many experiments in nuclear physics.

Neutron-star crusts present a situation in which solid-state physics is combined with nuclear physics and relativistic gravitation. Although it will remain impossible to create such conditions in the laboratory, recent developments in nuclear theory are now providing consistent and accurate knowledge of nuclear binding energies and a nuclear equation of state that can help to place the composition of the outer crust on firm ground. In analogy with ice cores, scientists can "drill" into the neutron star to determine the most abundant species in each layer. Using known masses, the composition of the outer crust has been well determined to a depth of about 215 m (for the star shown in figure 1) but deeper knowledge relies on theoretical models of nuclear masses. However, different state-of-the-art mass models do not predict the same composition and they can be tested only by high-precision mass measurements on further exotic species.

Unlike many scenarios in nucleosynthesis, where astrophysical uncertainties dominate those resulting from nuclear physics, those of the neutron-star crust are relatively robust. This is because of its likeness to a crystalline semiconductor in a sea of charge-carriers, except that the crust is a lattice of neutron-rich nuclides surrounded by neutrons. The lattice and thermodynamic conditions are therefore well defined, so the crustal composition will depend mainly on the nuclear binding energies.

The ISOLTRAP Penning-trap mass spectrometer at CERN's ISOLDE radioactive-beam facility has pioneered the art of online precision mass measurements (*CERN Courier* March 2004 p5 and December 2004 p9, April 2009 p7 and April 2012 p8). It uses

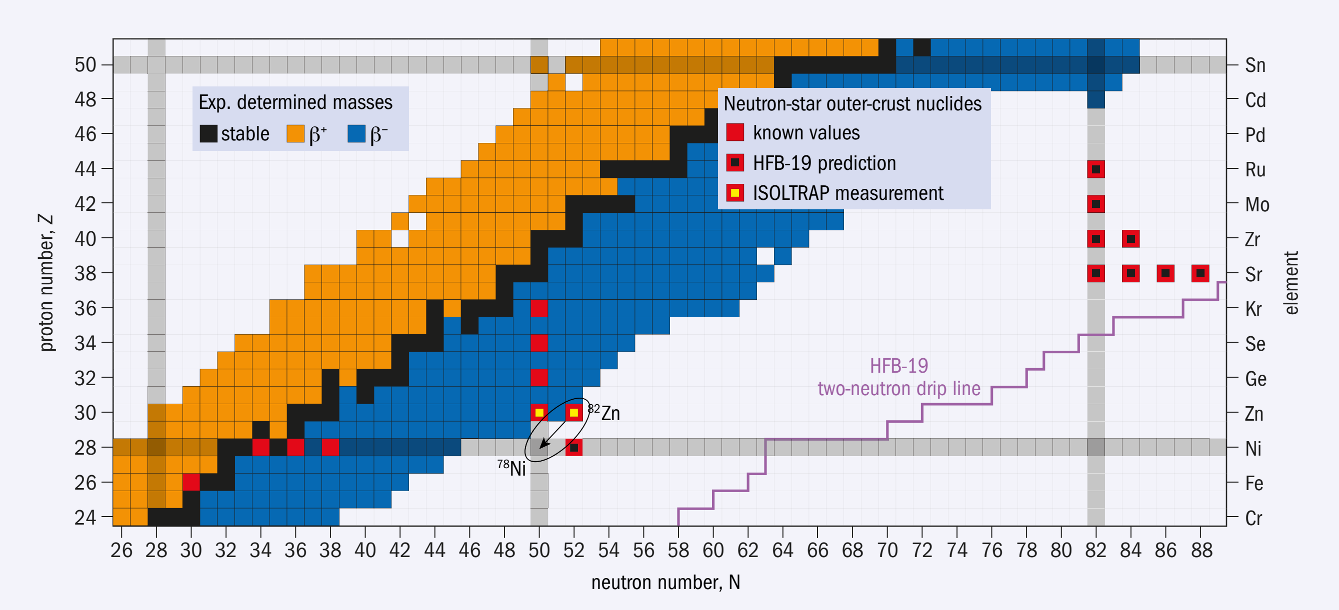


Fig. 2. A chart of nuclides showing the neutron-rich regions near the magic numbers N=50 and N=82. Nuclides shown in red are predicted to be present in the outer crust of neutron stars, according to the classic model of Baym et al. *based on experimentally measured masses. The red and black squares correspond to nuclides whose masses are predicted by the mean-field model HFB-19 (Pearson* et al. *2011). The red and yellow squares result from the new ISOLTRAP mass measurement of ^{82}Zn.*

static electric and magnetic fields to confine ions in an unperturbed environment to weigh accurately the exotic nuclides produced by ISOLDE. Recently, an advance in mass spectrometry with the ISOLTRAP experiment combined with the state-of-the-art purification techniques at ISOLDE, have enabled a first measurement of the mass of ^{82}Zn, an exotic nuclide predicted to reside in neutron-star crusts (Wolf *et al.* 2013).

The ISOLDE facility produces exotic zinc isotopes by fission in a uranium-carbide target bombarded by the 1.4 GeV proton beams from CERN's PS-Booster (PSB). Because protons also induce transmutation through the process of spallation, other neutron-deficient elements having the same mass number (isobars) are also produced. Isobaric contamination is the worst enemy of exotic nuclides because their intensity can be up to a million times higher than that of the isobar being sought.

The composition of neutron stars remains one of the biggest challenges facing nuclear and particle physics.

The first line of defence against this is a special version of an ISOLDE target that includes a tungsten convertor unit. Instead of aiming for the target itself, the PSB operators bear left, to hit the converter. The result is an effusion of slow neutrons that induce fission in the nearby target material but without producing the isobaric contamination that would result from direct spallation reactions. Having produced only neutron-rich isobars, the next line of defence is a highly selective, three-step laser excitation tuned to ionize only zinc isotopes. Yet another trick is then pulled from ISOLDE's sleeve to eliminate residual surface-ionized isobars: a temperature-controlled quartz transfer-line between the target and the ion source. Nevertheless, despite these state-of-the-art precautions, more than 6000 ions per second of ^{82}Rb were still present in the beam delivered to ISOLTRAP in comparison to just a few ions of zinc, making this one of the most challenging measurements of exotic nuclides to date.

To measure ^{82}Zn, yet another type of ion trap was integrated into the suite of Paul and Penning traps comprising ISOLTRAP's mass spectrometer. The multi-reflection time-of-flight mass separator (MR-ToF MS), shown in figure 3 (overleaf), allowed residual $^{82}Rb^{+}$ contaminants to be separated in time after multiple reflections between electrostatic mirrors. The advantage over purification in Penning traps is a mass-resolving power in excess of 100,000, obtained in about only 15 ms. From the MR-ToF MS, ▷

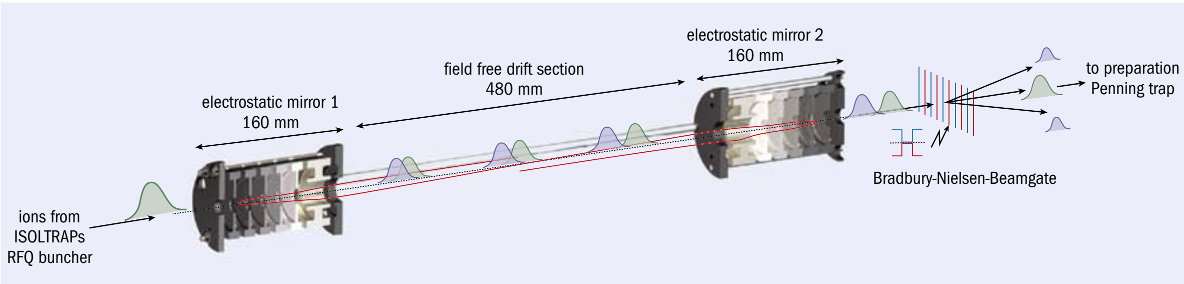


Fig. 3. The new multi-reflection time-of-flight mass separator (MR-ToF MS), developed at the University of Greifswald and integrated into the ISOLTRAP set-up at ISOLDE (Wolf et al. *2013). The injected ^{82}Zn ions are reflected back and forth approximately 100 times, covering a distance of around 100 m in 2.5 ms, and separating themselves from their isobaric neighbours in the process. The fast beam-gate is timed to let only the ions of interest through to the next trap.*

the short-lived $^{82}Zn^{+}$ ions were sent through an electronic beam gate, opened quickly for ^{82}Zn but otherwise closed to block the contaminants. The purified sample was transferred to the first of two Penning traps situated in individual superconducting solenoids, where the ions were cooled in a helium buffer-gas in preparation for the final mass measurement in the second, hyperbolic high-precision Penning trap. There, the standard time-of-flight ion cyclotron-resonance technique was used to determine the mass. This successful implementation of the MR-ToF MS represents a pioneering advance in mass spectrometry.

Drilling deeper

Probing neutron-star composition requires solving relativistic equations, known as the Tolman-Oppenheimer-Volkov (TOV) equations, that govern hydrostatic equilibrium in neutron-degenerate matter. The TOV equations relate pressure and mass-energy to the neutron-star radius and therefore require an equation of state. Stable- and radioactive-beam facilities have provided substantial information about the equations of state of finite nuclei but even the most exotic systems studied have proton fractions of 25–30%, which is far larger than the few per cent found in neutron stars. With this in mind, a Brussels-Montréal collaboration has developed a model for predicting nuclear binding energies based on the Skyrme force – an effective interaction between nucleons that also provides an equation of state – within the same theoretical framework (Pearson *et al.* 2011).

With the new ^{82}Zn mass, calculations were performed to "drill" deeper into the neutron-star crust. This was done by minimizing the Gibb's free energy per nucleon, where the total pressure at a given depth can be determined by the electron pressure and the lattice pressure. The abundances of all neighbouring nuclides were calculated for an array of nucleon densities and pressures. Last, the depths of the crust at which the nuclides are formed can be found using the TOV equations. Figures 1 and 2 illustrate the results. Because the new mass is considerably less bound than the predictions of the mean-field model HFB-19, ^{82}Zn is no longer present in the neutron-star crust. The nuclide ^{80}Zn remains but its presence is now constrained experimentally – deeper in the core than predicted by HFB-19. This result has extended knowledge of the crust composition of neutron stars to new depths.

This composition may have relevance for the nucleosynthesis of heavy elements by the r process, named for the series of rapid neutron captures that are involved (Arnould *et al.* 2007). The decompression of a neutron star's matter brought about by tidal effects from a merger with a black hole or another neutron star, allows an r process to occur as the ejected clump vaporizes into the interstellar medium. While the total ejected mass per event is relatively low, it can still explain the total enrichment of r nuclei in the Galaxy; moreover, the calculated abundance distribution is tantalizingly close to that observed in the Solar System. The robustness of these predictions to the variation of input parameters makes the composition of neutron stars one of the most promising situations for addressing the important question of the origin of the elements.

Further reading

R N Wolf *et al.* 2013 *Phys. Rev. Letts.* **110** 041101.
M Lattimer and M Prakash 2004 *Science* **304** 536.
M Arnould, S Goriely and K Takahashi 2007 *Phys. Reports* **450** 97.
G Baym, C Pethick and P Sutherland 1971 *Ap. J.* **170** 299.
J M Pearson, S Goriely and N Chamel 2011 *Phys. Rev.* **C83** 065810.

Résumé

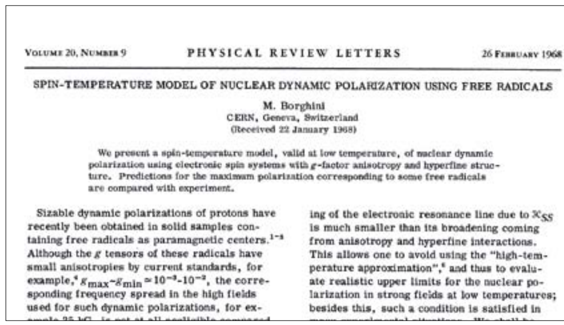
Sonder les profondeurs des étoiles à neutrons

L'expérience ISOLTRAP, à l'installation à faisceaux radioactifs ISOLDE du CERN, a été à l'avant-garde des mesures de masse de précision en ligne. Récemment, une amélioration de la spectrométrie de masse, avec ISOLTRAP, associée aux techniques de purification de pointe d'ISOLDE, a permis de réaliser une première mesure de la masse du zinc-82. D'après les prédictions, ce nucléide exotique devrait résider dans les zones extérieures – les « croûtes » – des étoiles à neutrons, c'est-à-dire les restes ultra-denses d'explosions de supernovas. Le nouveau résultat d'ISOLTRAP permet de mieux comprendre la composition de ces croûtes et pourrait jeter une lumière nouvelle sur la nucléosynthèse des éléments les plus lourds.

David Lunney, CSNSM/CNRS Université de Paris Sud, **Stéphane Goriely**, IAA/FNRS Université Libre de Bruxelles, **Susanne Kreim**, CERN, and **Robert Wolf**, Ernst-Moritz-Arndt Universität Greifswald.

Michel Borghini and the rise of polarized targets

Colleagues and friends recall the work of a pioneer of a key technique in high-energy particle physics.


Volume 20, Number 9 PHYSICAL REVIEW LETTERS 26 February 1968

SPIN-TEMPERATURE MODEL OF NUCLEAR DYNAMIC POLARIZATION USING FREE RADICALS

M. Borghini
CERN, Geneva, Switzerland
(Received 22 January 1968)

We present a spin-temperature model, valid at low temperature, of nuclear dynamic polarization using electronic spin systems with g-factor anisotropy and hyperfine structure. Predictions for the maximum polarization corresponding to some free radicals are compared with experiment.

Sizable dynamic polarizations of protons have recently been obtained in solid samples containing free radicals as paramagnetic centers.[1-3] Although the g tensors of these radicals have small anisotropies by current standards, for example,[4] $g_{max}-g_{min} \simeq 10^{-3}-10^{-2}$, the corresponding frequency spread in the high fields used for such dynamic polarizations, for ex- ing of the electronic resonance line due to $\mathcal{H}_{SS}$ is much smaller than its broadening coming from anisotropy and hyperfine interactions. This allows one to avoid using the "high-temperature approximation",[5] and thus to evaluate realistic upper limits for the nuclear polarization in strong fields at low temperatures; besides this, such a condition is satisfied in

Michel's 1968 paper on his "spin-temperature model".

Michel Borghini, who passed away unexpectedly on 15 December 2012, was at CERN for more than 30 years. Born in 1934, Michel was a citizen of Monaco. He graduated from Ecole Polytechnique in 1955 and went on to obtain a degree in electrical engineering from Ecole Supérieure d'Electricité, Paris, in 1957. He then joined the group of Anatole Abragam at what was the Centre d'Etudes Nucléaires, Saclay, where he took part in the study of dynamic nuclear polarization that led to the development of the first polarized proton targets for use in high-energy physics experiments. It was here that he gained the experience that he was to develop at CERN, to the great benefit of experimental particle physics.

The basic aim with a polarized target is to line up the spins of the protons, say, in a given direction. In principle, this can be done by aligning the spins with a magnetic field but the magnitude of the proton's magnetic moment is such that it takes little energy to knock them out of alignment; thermal vibrations are sufficient. Even at low temperatures and reasonably high magnetic fields, the polarization achieved by this "brute force" method is small: only 0.1% at a temperature of 1 K and in an applied magnetic field of 1 T. To overcome this limitation, dynamic polarization exploits the much larger magnetic moment of electrons by harnessing the coupling of free proton spins in a material with nearby free electron spins. At temperatures of about 1 K, the electron spins are almost fully polarized in an external magnetic field of 1 T and the application of microwaves of around 70 GHz induces resonant transitions between the spin levels of coupled electron–proton pairs. The effect is to increase the natural, small proton polarization by more than two orders of magnitude. The polarization can be reversed with a slight change of the microwave frequency, with no need to reverse the external magnetic field.

First experiments

In 1962, Abragam's group, including Michel, reported on what was the first experiment to measure the scattering of polarized protons – in this case a 20 MeV beam derived from the cyclotron at Saclay – off a polarized proton target (Abragam *et al.* 1962). The target was a single crystal of lanthanum magnesium nitrate ($La_2Mg_3(NO_3)_{12}.24H_2O$ or LMN), with 0.2% of the La^{3+} replaced with Ce^{3+}, yielding a proton polarization of 20%.

Michel moved to CERN three years later, where he and others from Saclay and CERN had just tested a polarized target in an experiment on proton–proton scattering at 600 MeV at the Synchrocyclotron (SC) (*CERN Courier* December 2007 p12). Developed by the Saclay group for the higher energy beams of the Proton Synchrotron (PS), the target consisted of a crystal of LMN 4.5 cm long with transverse dimensions 1.2 cm × 1.2 cm and doped with 1% neodymium. It was cooled to around 1 K in a ^{4}He cryostat built in Saclay by Pierre Roubeau, in the field of a 1.8 T magnet designed by CERN's Guido Petrucci and built in the SC workshop. This target, with an average polarization of around 70%, was used in several experiments at the PS between 1965 and 1968, in both pion and proton beams with momenta of several GeV/*c*. These experiments measured the polarization parameter for $\pi^{\pm}$ elastic scattering and for the charge-exchange reaction $\pi^-p \rightarrow \pi^0 n$ at small values of t, the square of the four-momentum transfer, typically, $|t| < 1\ GeV^2$.

In LMN crystals, the fraction of free, polarized protons is only around 1/16 of the total number of target protons. As a consequence, the unpolarized protons bound in the La, Mg, N and O nuclei formed a serious background in these early experiments. This background was reduced by imposing on the final-state particles the strict kinematic constraints expected from the collisions off protons at rest; the residual background was then subtracted by taking special data with a "dummy" target containing no free protons.

Michel's group at CERN thus began investigating the possibility of developing polarized targets with a higher content of free protons. In this context, in 1968 Michel published two important ▷

papers in which he proposed a new phenomenological model of dynamic nuclear polarization: the "spin-temperature model" (Borghini 1968a and 1968b). The model suggested that sizable proton polarizations could be reached in frozen organic liquids doped with paramagnetic radicals. Despite some initial scepticism, in 1969 Michel's team succeeded in measuring a polarization of around 40% in a 5 cm^3 sample consisting of tiny beads made from a frozen mixture of 95% butanol (C_4H_9OH) and 5% water saturated with the free-radical porphyrexide. The beads were cooled to 1 K in an external magnetic field of 2.5 T and the fraction of free, polarized protons in the sample was around 1/4 – some four times higher than in LMN (Mango, Runólfsson and Borghini 1969).

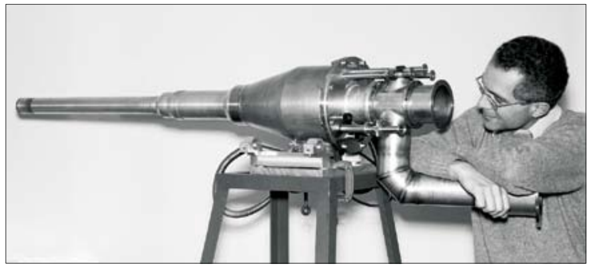
The group at CERN went on to study a large number of organic materials doped with free-paramagnetic radicals, searching for the optimum combination for polarized targets. In this activity, where cryostats based on ^{3}He–^{4}He dilution capable of reaching temperatures below 0.1 K were developed, Michel guided two PhD students: Wim de Boer of the University of Delft (now professor at the Karlsruhe Institute of Technology) and Tapio Niinikoski of the University of Helsinki, who went on to join CERN in 1974. They finally obtained polarizations of almost 100% in samples of propanediol ($C_3H_8O_2$) doped with chromium (V) complexes and cooled to 0.1 K, in a field of 2.5 T, with 19% free, polarized protons.

In this work, the concept of spin temperature that Michel had proposed was verified by polarizing several nuclei simultaneously in a special sample containing ^{13}C and deuterons. The nuclei had different polarizations but their values corresponded to a single spin temperature in the Boltzmann formula giving the populations of the various spin states.

These targets were used in a number of experiments at CERN, at both the PS and the Super Proton Synchrotron (SPS). They measured polarization parameters in the elastic scattering of pions, kaons and protons on protons in the forward diffraction region and at backward scattering angles; in the charge-exchange reactions $K^-p \rightarrow \bar{K}^0n$ and $\bar{p}p \rightarrow \bar{n}n$; in the reaction $\pi^-p \rightarrow K^0\Lambda^0$; and in proton–deuteron scattering. In all of these experiments, Jean-Michel Rieubland of CERN provided invaluable help to ensure a smooth operation of the targets.

In the early 1970s, Michel also initiated the development of "frozen spin" targets. In these targets, the proton spins were first dynamically polarized in a high, uniform magnetic field, and then cooled to a low enough temperature so that the spin-relaxation rate of the protons would be slow even in lower magnetic fields. The targets could then be moved to the detector, thus providing more freedom in the choice of magnetic spectrometers and orientations of the polarization vector. The first frozen spin target was successfully operated at CERN in 1974.

In 1969, Michel took leave from CERN to join the Berkeley group led by Owen Chamberlain working at SLAC, where he took part in a test of T-invariance in inelastic $e^{\pm}$ scattering from polarized protons in collaboration with the SLAC group led by Richard Taylor. The target, built at Berkeley, was made of butanol and the SLAC 20 GeV spectrometer served as the electron (and positron) analyser. The experiment measured the up–down asymmetry for transverse target spin for both electrons and positrons. No time-reversal violations were seen at the few per cent level.



Michel with a frozen-spin target at CERN in 1976.

The target's internal structure.

Michel during his time with the CERN Staff Association.

Michel took leave to work at SLAC again in 1977, this time on a search for parity violation in deep-inelastic scattering of polarized electrons off an unpolarized deuterium target. Here, he worked on the polarized electron source and its associated laser, as well as on the electron spectrometer. The small parity-violation effects expected from the interference of the photon and Z exchanges were, indeed, observed and published in 1978. Michel then moved to the University of Michigan at Ann Arbor, where he joined the group led by Alan Krisch and took part in an experiment to measure proton–proton elastic scattering using both a polarized target and a 6 GeV polarized beam from the 12 GeV Zero Gradient Synchrotron at Argonne National Laboratory.

Michel left CERN's polarized target group in 1978, succeeded by Niinikoski. Writing in 1985 on major contributions to spin physics, Chamberlain listed the people that he felt to be "the heroes – the people who have given [this] work a special push" (Chamberlain 1985). Michel is the only one that he cites twice: with Abragam and colleagues for the first polarized target and the first experiment to use such a target; and with Niinikoski, for their introduction of the frozen spin target and showing the advantages of powerful (dilution) refrigerators. Today, polarized targets with volumes of several litres and large ^{3}He–^{4}He dilution cryostats are still in operation, for example in the NA58 (COMPASS) experiment at the SPS, where the spin structure of the proton has been studied using deep-inelastic scattering of high-energy muons (*CERN Courier* July/August 2006 p15 and September 2010 p34). Dynamic nuclear polarization has also found applications in medical magnetic-resonance imaging and Michel's spin-temperature model is still widely used.

In the 1980s, Michel took part in the UA2 experiment at CERN's SPS proton–antiproton collider, where he contributed to the calibration of the 1444 analogue-to-digital converters (ADCs) that were used to measure the energy deposited in the central calorimeter. He wrote all of the software to drive the large number of precision pulse-generators that monitored the ADC stability during data-taking.

From 1983 to 1996, he was a member of the Executive Committee of the CERN Staff Association, being its vice-president until 1990 and then its president until June 1996. After retiring from CERN in January 1999, he returned to Monaco where in 2003 he was nominated Permanent Representative of Monaco to the United Nations (New York), a post that he kept until 2005.

Michel was an outstanding physicist, equally at ease with theory and being in the laboratory. He had broad professional competences, a sharp, analytical mind, imagination and organizational skills. He is well remembered by his collaborators for his wisdom and advice, and also for his quiet demeanour and his keen but often subtle, sense of humour. His culture and interests extended well beyond science. He was also a talented tennis player. He will be sorely missed by those who had the privilege of working with him, or of being among his friends. Much sympathy goes to his two daughters, Anne and Isabelle, and to their families.

• Further reading

A Abragam *et al.* 1962 *Phys. Lett.* **2** 310.
M Borghini 1968a *Phys. Lett.* **26A** 242.
M Borghini 1968b *Phys. Rev. Lett.* **20** 419.
O Chamberlain 1985 *J. Phys. Colloques* **46 C2** 743.
S Mango, Ö Runólfsson and M Borghini 1969 *Nucl. Instr. Meth.* **72** 45.

Résumé

Michel Borghini et l'avènement des cibles polarisées

Michel Borghini, qui nous a quittés en décembre 2012, a été le pionnier d'une technique essentielle de la physique des particules. Il a commencé sa carrière au Centre d'études nucléaires de Saclay, où il a travaillé avec Anatole Abragam sur les études de polarisation nucléaire dynamique qui ont abouti aux premières cibles de protons polarisés pour la physique des hautes énergies. Au CERN, le groupe de Borghini a réalisé des avancées importantes dans le développement de cibles à base de liquides organiques gelés, pouvant permettre des polarisations de protons élevées. Dans cet article, ses collègues et amis rappellent différents aspects de ses contributions aux expériences, au CERN et ailleurs.

His colleagues and friends, at CERN and elsewhere.

Technology transfer

Accelerating innovation

A workshop on the technology of particle accelerators and detectors marked the revival of an EPS group focusing on innovative areas and potential spin-offs.

Some 25 experts gave presentations and joined in discussions on topics including accelerators, detectors, electronics, informatics, R&D and spin-offs, with a particular emphasis on medical applications. (Image credit: EMFCSC.)

Last year, the Executive Committee of the European Physical Society (EPS) decided to revive the EPS Technology and Innovation Group (TIG) by launching a workshop to take stock of projected R&D and technological innovations in research in accelerator and particle physics and their potential spin-offs to society. The three-day workshop took place on 22–24 October at the Ettore Majorana Foundation and Centre for Scientific Culture, in Erice, with some 25 participants. While it could not cover all ongoing technology and innovation activities, the workshop nevertheless provided the opportunity to review important developments based on international, interdisciplinary collaboration between research laboratories and university groups, supported by technology-transfer professionals as well as small and medium-size companies (SMEs).

The workshop opened with a talk by Phil Bryant, formerly of CERN, on "Accelerators: a history of innovation and spin-off". His review of the repeated reincarnation of accelerators during the 20th century illustrated the importance of these machines – which were developed for nuclear and particle physics – as a major spin-off from basic research to medical applications. In the following presentation, Ken Peach of Oxford University stressed the importance of close collaboration between accelerator scientists, oncologists, radiobiologists and biophysicists. In his overview of radio- and proton-therapy he explained the underlying physics of radiation and its effects on tumour cells and normal tissue, the evolution of instruments and techniques, as well as the clinical aspects and the challenges. He gave many examples and statistics together with a list of improvements required after the transfer of instruments from accelerator laboratories to hospitals. His instructive overview of industrial solutions, new ideas and novel techniques showed the importance of this technology's spin-off from research to society. Last, he outlined the potential of radionuclide production for medical tracers and described a proposal for a new biomedical facility at the Low-Energy Ion Ring (LEIR) at CERN. Several other speakers also discussed this latter topic, highlighting the need for more research in radiation biophysics and presenting details of the proposal.

Complementary to the accelerators are the detectors, sensors, and sophisticated electronic read-out chips that are now available for medical imaging. Jean-Marie Le Goff of CERN made the case for a low-energy cyclotron to produce isotopes for positron-emission tomography (PET). He covered the use in medicine of PET and computerized tomography technologies, presenting an overview of cyclotron manufacturers, as well as applications in industry and in the production of radiopharmaceuticals. He also described the joint project by CERN and the Spanish research centre, CIEMAT, to develop an ultracompact cyclotron for single-dose production in collaboration with an industrial consortium.

Another highlight was the talk by Michael Campbell of CERN on the incredible success story of the Medipix chip, which started in the days of the LAA project at CERN, driven by requirements for the LHC experiments for a hybrid-pixel detector. Hybrid-pixel vertex detectors are now installed in the ALICE, ATLAS and CMS experiments at the LHC and the same technology is being used in the photon detectors in LHCb's ring-imaging Cherenkov detectors. All four of these systems are making a significant contribution to the output of LHC physics.

Meanwhile, the Medipix2 and Medipix3 collaborations have applied the hybrid approach to all kinds of applications in particle imaging. While some were foreseen, in many cases the applications (such as low-energy electron microscopy, or space-based dosimetry) were unimaginable at the start of the work. Background radiation can be seen with the Timepix chip, which has also become a powerful pedagogical tool for inspiring the next generation of scientists and engineers (see, for example, *CERN Courier* May 2010 p22). Moreover, and thanks to the application of a novel read-out-architecture in deep sub-micron CMOS technology by the Medipix3 collaboration, high-resolution colour X-ray imaging is coming within reach.

To conclude on the topic of medical applications, Viviana ▷

Vitolo of the Italian National Centre for Oncological Treatment (CNAO) presented a clinical perspective on hadron therapy. She gave a complete overview of particle facilities in Europe and showed the preliminary clinical results from CNAO. Although based on a small number of patients and a limited time-scale, the results are encouraging because none of the patients present progressive disease and all present stable disease at first follow-up. She proposes that the particle-therapy community should over the coming years produce evidence on the need for hadron therapy, define clinical indications and convince the decision-makers.

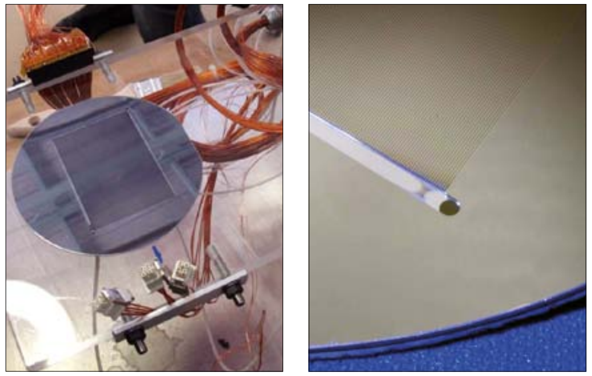
Advanced technologies

A second major topic of the workshop concerned the R&D initiatives for the LHC upgrade and future research programmes at the collider. International collaboration in an innovative domain is exemplified in the latest studies and tests on crab cavities and superconducting-RF technology. In linear accelerators there is an R&D effort to improve efficiency and energy recovery, with a scheme to recycle the otherwise lost beam power in light sources and colliders to produce the RF power that is needed to accelerate. There is ongoing development and transfer to industry of superconducting-magnet technology, all of which is related to the proposed luminosity and energy increase of the LHC and its injectors.

European initiatives in detector R&D include the European Radiation Detection and Imaging Technology Platform (ERDIT). This activity is truly multidisciplinary. It involves scientists from microelectronics, semiconductor materials, computing science and various application areas. There is a general understanding that the lack of advanced detectors is the limiting factor in many applications, although the multidisciplinary character of the work makes it hard to find funding. The ERDIT proposal is an initiative to make detector scientists and users from different application fields join forces to put these issues onto the agenda of European funding agencies and industry. Even if the application requirements differ a great deal, several generic technologies are required to make an advanced detector. These include sensor materials, analogue-signal processing, digital processing, storage and communication, hybridization, mounting, packaging and information processing. By pushing the technology limits in these fields it should be possible to develop high-quality devices that can be combined in different configurations to create new and advanced radiation detectors in an efficient way. ERDIT would then be a forum to discuss the priorities and road maps for the research and to promote initiatives in this field.

Another interesting initiative is the ATLAS Technology Lab (ATLAB), which is an organized effort to support detector R&D in the ATLAS experiment. Using many examples from ATLAS today and the future goals for the detector's performance, Marzio Nessi of CERN explained how the detector community could organize itself – in partnership with industry – to foster effective and necessary detector R&D. He also outlined ATTRACT, which is an initiative outside ATLAS that serves the radiation-sensor and imaging R&D community at large. As with ERDIT, this would work in close collaboration with industry – notably SMEs – to define a work programme for radiation detectors and their infrastructures and then distribute and manage related EU funding.

Talks on microelectronics and successful microchip projects



Left: A test set-up with a prototype of the microchannel cooling wafer that will be used in NA62's Gigatracker. Right: A close-up of the test device showing a corner of the manifold with its single inlet/outlet. (Image credits: M Fiorini, G Nuessle, A Kluge, F Marchetto/NA62.)

complemented those on detector challenges. Microfabrication, for example, could lead to the integration of services – such as cooling in silicon. At CERN, several projects have been launched in the Physics Department (PH) in collaboration with experimental groups. Microchannel cooling has been adopted by the NA62 experiment for the Gigatracker and results have been published on prototypes; the technology is also being studied for the upgrade of the Vertex Locator in the LHCb experiment. Microfluidic scintillation detectors are under consideration for single-particle tracking and calorimeters in the ATLAS and ALICE experiments and in the Compact Linear Collider design study, as well as for beam monitors for hadron therapy. In the long term, the formation of a competence centre in microfabrication within PH, with synergies with the existing excellence in microelectronics design and wire-bonding module integration, could crucially advance the development of novel detectors for the LHC and future projects, providing exciting spin-offs to other fields.

New user facilities such as the European Spallation Source (ESS) are a trigger for innovation and collaboration with industry. Steve Peggs reported on this green-field construction project, a multilab collaboration with in-kind contributions from partners. He reviewed different types of spallation accelerators and the road map based on accelerator-driven systems (ADS). Neutron physics, which allows the observation of magnetic atoms and atoms moving inside materials, has seen a steady evolution of performance from research reactors and pulsed sources. The ESS will increase the research potential through its projected high flux and high average-availability time. Peggs also addressed the technical options, challenges and final design of the multimegawatt ESS, for which energy efficiency and recovery are design goals. Starting up in 2019 with 1.5 MW and aiming at 5 MW by 2025, this project is a "wonderful challenge".

Other new user facilities include MYRRHA in Belgium, which is a high-power research reactor based on ADS to produce intense beams of secondary particles relevant for fundamental and applied science, and the International Facility for Anti-Proton and Ion

Research (FAIR), currently under construction at the GSI laboratory in Darmstadt.

Transferring technology

The workshop went on to review technology-transfer techniques and success stories. One notable success story is that of Cristoforo Benvenuti, formerly of CERN. Using the non-evaporable getter pumping that he introduced in the dipole chambers for the Large Electron–Positron (LEP) collider and the sputtering techniques that he developed for the LEP superconducting RF cavities, a one-to-one transfer of accelerator technologies to the domain of solar thermal panels has occurred. Panel efficiency has been improved using evacuation to decrease thermal losses, which together with an intelligent process applied to solder the front glass to the metal frame, yields a competitive advantage. The resulting collector is highly efficient even when exposed to diffused light, which may comprise more than 50% of the total daylight in central Europe. Fully automatic production of these collectors, using intelligent robots designed by the company SRB Energy that Benvenuti created with the Spanish Grupo Segura, has resulted in the first orders.

Two presentations at the workshop were devoted to technology-transfer mechanisms. With proactive support for innovation and by improving the commercialization of research, the UK's Science and Technology Facilities Council (STFC) has already obtained measurable progress, including open access for companies to labs, new jobs being created, new products taken to market, patent applications made and licensing agreements signed. In a new initiative, the STFC and CERN are jointly announcing a first call for a hi-tech start-up or SME looking to take high-energy physics technologies to commercial applications as part of the programme for a new business-incubation centre. This is just one example of a large number of activities that come under CERN's Knowledge and Transfer group, which is keen to find help with promoting the many initiatives.

Computing infrastructure, networking and high-performance data-handling are all important topics in terms of technology transfer. Whereas the world wide web provides seamless access to information stored in many millions of different geographical locations, the Grid is an infrastructure that provides seamless access to computing power and data-storage capacity distributed throughout the globe. Bob Jones of CERN described the Worldwide LHC Computing Grid, which is vital in analysing the huge amount of data from the LHC. Such Grids are important for not only particle physics but also other research communities and business; in future, moves from Grids to clouds are foreseen. Jones also presented the successful CERN openlab project, which is a public–private partnership between the research community and industry. Volker Lindenstruth of the University of Frankfurt then described an innovative cooling-system architecture, the Green Cube, for the FAIR project's high-performance computing backbone. He proposed investing in modern parallel programming to gain efficiency for the future computing needs of the Condensed Baryon Matter experiment at FAIR or of ALICE at CERN, as well as for lattice QCD physics analysis.

A video conference with Neville Reeve and Jean-Emmanuel Faure of the European Commission provided details about the

Cristoforo Benvenuti invented more efficient solar panels based on a technology that he developed at CERN.

Horizon 2020 programme. It was stressed during the workshop that transnational collaborations between research and industry are required and, indeed favoured, within this forthcoming programme. Projects similar to the model of CERN openlab or the ATTRACT/ERDIT initiative of the ATLAS collaboration are clearly in line with these requirements, allowing the distribution and management of related Horizon 2020 funding on behalf of the EU as part of its efforts to externalize funding. The intention is for the community to suggest more such proposals for co-innovation and collaborative frameworks between industry and research infrastructures that leverage the innovation potential and know-how gained by working together in areas of common interest and offering at the same time new benefits for industry.

• Further reading

For the names of all of the workshop speakers and for their presentations, see https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=215087. See also www.epsnews.eu/2012/eps-tig-workshop/.

Résumé

Accélérer l'innovation

L'année dernière, la Société européenne de physique décidait de relancer le groupe Technologie et innovation, dont la mission est de s'intéresser aux innovations et à leurs retombées éventuelles. C'est ainsi qu'a été organisé un atelier sur les avancées technologiques et les innovations dans le domaine de la physique des accélérateurs et de la physique des particules, et leurs retombées éventuelles pour la société. Cette manifestation, d'une durée de trois jours, a eu lieu en octobre à la Fondation Ettore Majorana et Centre de culture scientifique, à Erice. L'atelier a été l'occasion de passer en revue des avancées technologiques résultant de la collaboration internationale et interdisciplinaire entre des groupes de recherche appuyés par des professionnels du transfert de technologie, et des petites et moyennes entreprises.

Manjit Dosanjh and **Horst Wenninger**, CERN.

Faces & Places

Awards

Karlsruhe honours Cronin, Jenni and Della Negra

The awards of the Julius Wess Award and an honorary doctorate were two of the highlights of the inaugural symposium of the Karlsruhe School of Elementary Particle and Astroparticle Physics – Science and Technology (KSETA), which took place on 1 February. The school has been founded thanks to a successful application within the context of the 2012 German Excellence Initiative.

Nobel laureate James Cronin was made an honorary doctor of the Karlsruher Institut für Technologie (KIT) for his outstanding achievements in cosmic-ray research, which culminated in the successful construction and operation of the Auger Observatory in Argentina. A research group from KIT has been working closely with Cronin since the beginning of the project.

Peter Jenni and Michel Della Negra of CERN were presented with KIT's 2013 Julius Wess Award for their outstanding contributions to hadron-collider physics, which led to the discovery of the W and Z bosons in 1983 and of what could well prove to be the Higgs boson in 2012. As long-term spokespersons, they are often dubbed the "founding fathers" of the ATLAS and CMS experiments at the LHC, respectively, and they created the present-day culture of competition between friends. KIT has been deeply involved in CMS for almost 18 years.

Above: Winners of the Julius Wess Award, Peter Jenni, centre left, and Michel Della Negra, together with Johannes Blümer, far left, Detlef Löhe and Thomas Müller, right.

Right: New honorary doctor Jim Cronin speaks to an attentive audience. (Image credits: KIT.)

International

UN secretary-general Ban Ki-moon visits CERN

On 1 March, Ban Ki-moon, secretary-general of the United Nations, visited CERN for the first time since the organization was granted observer status at the United Nations General Assembly last December (*CERN Courier* Jan/Feb 2013 p5).

Ban visited underground areas at the LHC, as well as UNOSAT, the UN technology-intensive programme hosted by CERN to deliver imagery analysis and satellite solutions to relief and development organizations (*CERN Courier* October 2009 p17).

The visit offered the opportunity to discuss CERN's contribution to science-related UN activities, such as ECOSOC, the United Nations platform on economic and social issues. CERN contributed on the theme of young women in science to ECOSOC's youth forum on 27 March and will be taking part in ECOSOC meetings in Geneva in July. Ban and CERN's director-general also discussed the role of the secretary-general's recently established science advisory board.

Above: The new spokesperson for ATLAS, Dave Charlton, left, discusses the experiment with Ban Ki-moon during a tour of the underground cavern.

Left: The UN secretary-general, left, meets representatives from UNOSAT.

India

Kolkata pays tribute to the memory of Bose

A bust of Satyendra Nath Bose, the Indian scientist best known for his work on Bose-Einstein statistics, was unveiled on 6 October on the corner of a prominent thoroughfare in the northern region of Kolkata. Bikash Sinha, the Homi Bhabha chair professor at the Indian Department of Atomic Energy, performed the unveiling in a ceremony attended by many distinguished people, including scientists, ministers and eminent academics.

Bose's ancestral home is located nearby, next to the Scottish Church Collegiate School. Sinha had his early education in the same school and came to know Bose closely, visiting him after school hours. Bose himself explained to the young Sinha about the beauty and the elegance of his famous statistics and how spin-0 and spin-1 elementary particles obey Bose-Einstein statistics.

Since the announcement of the discovery of a Higgs-like boson on 4 July 2012, a keen interest has gripped this area of Kolkata. Intense intellectual discussion is the order of the day, with no end to the discussion of the relevance of the Higgs boson and its capacity for creating mass. The general public is extremely curious about the newly found boson and its connection to God because it has often been referred to as the "God particle". The hysteria, Sinha notes, seems to have gone so far that Bose – a Bengali – is now viewed by some as a favoured son of God.

Bikash Sinha unveiled the new bust of Satyendra Nath Bose in northern Kolkata. (Image credit: Sutanati Book Fair Committee/Suman Bhowmick.)

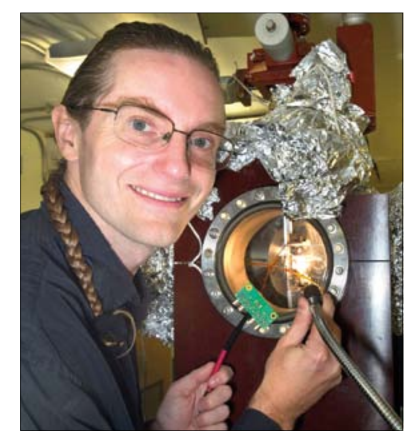
Prizes

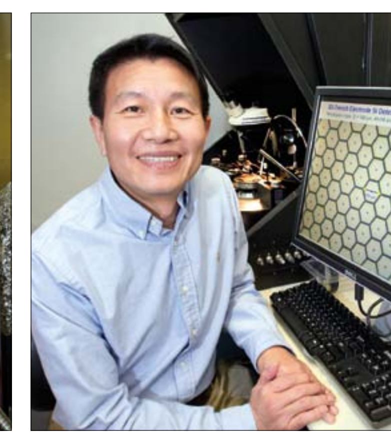
Brookhaven physicists win IEEE awards for innovation

Two physicists at Brookhaven National Laboratory (BNL) are to receive awards from the Institute of Electrical and Electronics Engineers (IEEE) at a ceremony on Long Island, NY, on 21 March.

John Smedley is the 2013 recipient of the Charles Hirsch Award in recognition of his "contributions to the advancement of photocathode technology". The award, made by the Long Island section of the IEEE, recognizes innovative and significant technical accomplishments. Smedley has been researching and designing novel accelerator photocathodes at Brookhaven for almost 20 years. Most recently, he has been involved in the development of a diamond-amplified photocathode that could revolutionize fourth-generation light-source technology, with amplifiers capable of increasing an electron beam's current by a factor of more than 300.

Zheng Li is the 2012 recipient of the IEEE Region 1 Technological Innovation Award for his groundbreaking work in "the development of novel silicon detectors in photon science and particle physics research". To increase detection efficiency and lower the signal-to-noise ratio, in 2004 Li developed a novel "stripixel" detector – a single-sided silicon strip detector that significantly increased the accuracy and output of data of the PHENIX experiment at the Brookhaven's Relativistic Heavy-Ion Collider. More recently, he developed a "3D-trench electrode detector" based on his stripixel research that has potential applications beyond high-energy and nuclear physics. Already, one company based in New York has expressed interest.





John Smedley, left, and Zheng Li, winners of IEEE innovation awards. (Image credits: BNL.)

COLLABORATION

ALICE matters around the world

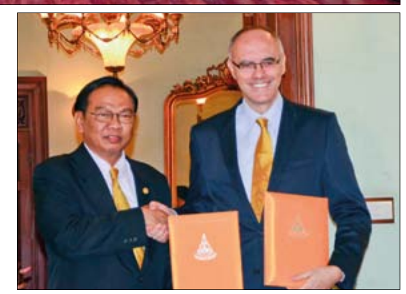
The latest ALICE Physics Week – a tradition that began in Erice in 2005 – took place outside Europe for the first time when it was held at the Benemérita Universidad Autónoma de Puebla (BUAP), Mexico, on 27 November – 1 December. Participants were welcomed by Enrique Agüera Ibáñez, rector of BUAP, and Arturo Fernandez Tellez also of BUAP, who chaired the meeting, as well as by representatives from the Centro de Investigación y Estudios Avanzados, the Universidad Autónoma de Sinaloa and the Universidad Nacional Autónoma de México.

During the week, some 110 ALICE members discussed the top issues in the ALICE physics programme, with a special emphasis on results from the pilot proton–lead run that took place in September, as well as on the detector upgrade. As part of the effort to open the physics week to the city of Puebla, the organizers arranged for a public lecture on "the perfect fluid" to be given by the ALICE spokesperson, Paolo Giubellino. His talk was followed by a lively discussion with the audience, including many students in attendance.

The collaboration also celebrated Guy Paić's 75th birthday with a symposium on 1–2 December on "open issues in heavy-ion physics", with talks by Paić's colleagues from ALICE and CMS at CERN, as well as from the experiments at the Relativistic Heavy-Ion Collider at Brookhaven. In particular, Gerardo Herrera Corral of the Centre for Research and Advanced Studies of the National Polytechnic Institute described Guy's career in Mexico, which started more than 10 years ago.

Recognizing the importance of the physics week, the Mayor of Puebla awarded Giubellino, together with leading ALICE members Federico Antinori, Jean-Pierre Revol and Jürgen Schukraft, a diploma as distinguished visitors of Puebla.

Above: ALICE members at the meeting in Puebla. (Image credit: Domenico Collela.)



Right: Paolo Giubellino, spokesperson of ALICE, and Prasart Suebka, rector of SUT, hold two copies of the MoU signed between CERN, ALICE and SUT. (Image credit: SUT Press Office.)

In December, Suranaree University of Technology (SUT) signed a memorandum of understanding (MoU) with CERN and the ALICE collaboration. This followed the ALICE collaboration board's acceptance of SUT as a member of the collaboration in October. Princess Maha Chakri Sirindhorn graciously presided over the signing ceremony.

The agreement will further strengthen the capacity and capability of Thailand's research programme. The MoU refers to the building of a Tier-2 computing centre, which is a part of the National e-Science Infrastructure Consortium of Thailand. SUT will provide computer equipment for the system on which large amounts of data from ALICE will be stored and processed. Researchers in a variety of other disciplines in SUT will also benefit from the high-performance system. In addition, SUT will participate in the upgrade of the ALICE inner tracking system.

LETTER

In memory of Gordon Fraser

I was saddened to learn that Gordon Fraser, long-time editor of *CERN Courier*, had died earlier this year (*CERN Courier* March 2013 p36). I will remember Gordon first and foremost as my editor and collaborator in trying to communicate high-energy physics beyond the strict confines of the discipline. Every month or so, I'd send him a draft news item or longer article about goings-on at SLAC. He'd gently nudge my awkward copy into something more readable by the audience that *CERN Courier* was aiming to reach. I learnt a lot from him. Although we may have met only a handful of times, at an international conference or during one of my CERN visits, we became good friends and trusted colleagues via e-mail and the occasional phone call, despite well known interlab rivalries.

I last saw Gordon while at CERN to cover the impending "Higgs boson discovery" for *Physics World* and *Scientific American*. We shared a memorable Sunday visiting the Einstein Museum and home (closed for repairs, unfortunately) in Bern. On the train there, we discussed Gordon's suggestion to rename this new particle the "higgson", which I immediately thought a marvellous idea. So we quickly wrote an opinion piece together that *Physics World* published in its August 2012 issue, which announced the discovery of the new particle. This time Gordon served as the writer, dashing off 1000 words in a few hours, and me the editor. Our last joint effort will always remain my fondest memory of him, and of all our many attempts to explain physics to wider audiences. I'm glad that I had this final opportunity.

● *Michael Riordan, former SLAC correspondent, Eastsound, WA.*

OBITUARIES

Aldo Menzione 1943–2012

Aldo Menzione, a pioneer in the development and use of silicon vertex detectors, passed away quietly and unexpectedly in Pisa on 23 December 2012.

Aldo graduated in physics in 1967 with a thesis on "Production of Neutral Mesons Decaying into All-neutral secondaries" at the CERN Proton Synchrotron and in 1969 joined the Pisa-Stony Brook collaboration at the Intersecting Storage Rings (ISR). This experiment discovered that the total proton–proton cross-section starts increasing at ISR energies, a departure from what had previously appeared to be a flat "asymptotic" behaviour. Aldo made important contributions in setting up the experiment and in the study of short-range correlations among particles produced in inelastic collisions, which were observed by the same experiment for the first time as an early manifestation of hadron jets.

In 1978, as a member of the Pisa team, Aldo designed and built the small-angle spectrometer of the NA1 (later NA7) experiment. This spectrometer obtained the most precise measurements of the pion and kaon charge-radius, as well as a number of new results in charm physics. The tracking system of NA1, to which Aldo devoted much of his effort, used one of the first active targets of silicon detectors and later an innovative germanium-strip detector to identify the decay of long-lived charmed hadrons, allowing measurement of their lifetimes. From this, Aldo understood that a silicon-strip vertex detector could be used to signal the decays of charmed and beauty hadrons close to the vacuum pipe at a hadron collider, thereby tagging jets containing heavy flavour.

Aldo Menzione. (Image credit: Courtesy Bichina Menzione.)

Starting in 1980, he began work on the detailed design of the CDF detector at Fermilab's Tevatron with his characteristic vigour, originality and vision. Aldo was leader of the Silicon Vertex Detector construction project, which played an essential role in the discovery of the top quark in 1995 by identifying the b quarks from top decays. For Run 2 of CDF, an upgraded vertex detector was implemented with fast front-end trigger electronics, which allowed operation of a displaced vertex trigger, the Silicon Vertex Trigger (SVT). Aldo and the prime designer of the SVT, Luciano Ristori, were awarded the 2009 Panofsky Prize in Experimental Particle Physics of the American Physical Society in 2009 for "their leading role in the establishment and use of precision silicon tracking detectors at hadron colliders, enabling broad advances in knowledge of the top quark, b hadrons, and charm hadrons" (*CERN Courier* December 2008 p34).

Besides being an extremely skilled experimentalist, Aldo was warm, direct and a wonderful colleague and friend. He participated actively in physics discussions with crisply thought-out, bluntly expressed and often deeply original contributions. Aldo created a special atmosphere in which the best decisions were made and everybody, including the junior members, felt included.

● *Adapted with permission from material that originally appeared in* Physics Today's Daily Edition, *www.physicstoday.org/1.2902567.*

Ger van Middelkoop 1937–2013

Ger van Middelkoop, an experimental nuclear and particle physicist with a talent for scientific leadership, passed away on 4 February after unexpected heart failure.

Ger studied and worked at Utrecht University, obtaining his PhD in 1966 with Pieter Endt for work on neutron capture, research performed at the Reactor Research Facility in Petten (now known as Energy Centre Netherlands). He also worked as a postdoc at Chalk River Nuclear Laboratories in Canada.

In 1979 he was appointed as professor in experimental physics at the Vrije Universiteit in Amsterdam. In the following years he played a key role in the merger of the separate Nuclear Physics and High-Energy Physics sections into what is now the National Institute for Subatomic Physics (Nikhef). He was scientific director of the Nuclear Physics section for several years (1983–1988) and later the first scientific director of the combined Nikhef institute (1996–2001). He managed to bridge the cultural differences between the sections with his direct but also amiable style.

Ger van Middelkoop. (Image credit: Nikhef.)

Ger was the driving force in the participation of Nikhef in the New Muon collaboration (NA37) at CERN and was spokesperson from 1990 until 1995. Besides his managerial work, he always kept close contact with the ongoing work of PhD students and colleagues at the laboratory – often walking in and discussing physics even when they were working late. Many colleagues remember him as someone who carefully read and corrected publications and thesis manuscripts, and who was always stimulating staff and students to attend weekly colloquia at the institute, where he himself enlivened the discussion with sharp questions.

Later in his career and after his retirement,

he stayed active in the field. He led the organization of the 2002 International Conference on High-Energy Physics in Amsterdam, was active in scientific advisory boards as well as organized and participated in various physics outreach activities in the Netherlands. After a difficult period in his personal life, in which he lost his wife, he organized and enjoyed with his new partner various cultural activities in their second home in France.
● *His friends and colleagues.*

David Olive 1937–2012

David Olive, a pioneer of string theory who made seminal contributions to S-matrix theory, superstrings and gauge theories, died on 7 November 2012. Among many honours, he was awarded the 1997 ICTP Dirac Medal, shared with Peter Goddard.

Born in 1937, David was educated in Edinburgh and then Cambridge, where he obtained his PhD in 1963. After a postdoctoral appointment at the Carnegie Institute in Pittsburgh, he became lecturer in the department of applied mathematics and theoretical physics in Cambridge in 1965. A year later, with Richard Eden, Peter Landshoff and John Polkinghorne, he published *The Analytic S-matrix*, the definitive text on S-matrix theory.

In 1971, David joined the CERN Theory Division, keen to work in the stimulating group of theorists around Sergio Fubini and Daniele Amati on the dual-resonance model, later recognized as string theory. It was an enormously fruitful time, highlighted in his memoir "From dual fermion to superstring" in *The Birth of String Theory* (Cappelli *et al*. eds, CUP 2012). His work at CERN, in collaboration with Lars Brink and others, initially focused on the consistent formulation of dual fermion amplitudes and resulted in several major contributions to string theory, including the "Gliozzi-Scherk-Olive (GSO) projection" which was an essential step in establishing 10-dimensional superstring theory. His vision of string theory as a unified theory of all particle interactions, including gravity, informed his highly influential plenary talk at the 1974 "Rochester" conference in London.

David's collaboration with Peter Goddard led to seminal papers on the mathematical

David Olive, right, receiving the 1997 ICTP Dirac Medal from Miguel Angel Virasoro, at a ceremony in Trieste. (Image credit: ICTP Photo Archives.)

foundations of string theory, notably on Virasoro and Kac-Moody algebras, their representations and relationships with vertex operators. Their work on algebras and lattices identified the special role played by the two Lie groups SO(32) and E8 × E8, which were shown by Michael Green and John Schwarz to exhibit the anomaly cancellation that led to the renaissance of string theory in 1984.

Another major interest concerned duality symmetries in gauge field theories, which played a key role in later developments of string/M theory. In 1977, while still at CERN, he and Claus Montonen conjectured that there should exist an electromagnetic dual theory in which the roles of monopoles and gauge bosons are interchanged. Subsequent work with Ed Witten showed that this duality is fulfilled in some supersymmetric theories. The Olive-Montonen duality emerged later from a deeper web of dualities underlying string/M theory, ushering in the second superstring revolution of the mid-1990s.

David moved to Imperial College in 1977, becoming professor in 1984 and head of theoretical physics in 1988. He left in 1992 for Swansea University, where he and Ian Halliday built the theoretical particle physics group, now one of the UK's leading theory groups. At Swansea he explored the deep symmetries underlying integrable quantum field theories, especially affine Toda theory.

The mathematics of symmetry was a lifelong enthusiasm, suiting the predilection for clarity, precision and depth that characterized all of David's work in theoretical physics and made him a worthy recipient of the medal named after Dirac, whom he admired deeply. David was a generous supervisor and teacher, guiding many PhD students who have gone on to accomplished careers around the world. His wide circle of friends, colleagues and collaborators remember him with respect and affection as a brilliant but unassuming theorist whose insights have become part of the fabric of modern theoretical physics.

David was a devoted family man. He married Jenny in 1963 while at Cambridge and they have daughters Katie and Rosalind. As well as his continuing battles with the game of golf, reflecting his Scottish upbringing, his days at CERN led to enthusiasms for hiking and skiing. He had a lifelong love of classical music, and amassed a fine collection of recordings.
● *Ed Corrigan, Ian Drummond, Graham Shore and Tony Sudbury.*

Hamlet Vartapetyan 1927–2013

Hamlet Vartapetyan, professor of physics and mathematics, and member of the Armenian National Academy of Sciences, passed away on 22 January 2013. A well known Armenian scientist, he had a decisive role in the establishment and development of theoretical and experimental research in particle and nuclear physics in the Republic of Armenia.

Vartapetyan was born on 26 May 1927 in Yerevan, Armenia. He graduated from the Ecole Supérieure de Physique et Chimie Industrielles in Paris in 1952 and from the Sorbonne University in 1953. From 1952 until 1957 he worked with Irène and Frédéric Joliot-Curie in the Radium Institute in Paris, receiving his PhD degree under Frédéric Joliot-Curie, then moving to the Institut de Physique Nucléaire, Orsay, until 1958.

In 1960 Vartapetyan began research on the electron synchrotron at Yerevan Physics Institute (YPI). In the following decades, thanks to his efforts, the institute acquired state-of-the-art electronic and computer technology, and under his leadership established a powerful experimental infrastructure, where an extensive programme in nuclear and particle physics was successfully accomplished.

His group achieved a series of important results on fundamental properties of elementary particles; the results on photoproduction at the electron synchrotron, in particular, brought recognition to Vartapetyan and his colleagues. He was awarded the Red Flag Medal in 1971, the Badge of Honour in 1976 and, along with his colleagues, received the Republic of Armenia Award in Science and Technology for his fertile scientific work.

Vartapetyan also worked diligently in scientific organizational matters and international collaborations. His involvement in JINR, Dubna, was particularly important; for many years he had the role of liaison representative for the Republic of Armenia.

In addition, he had an important role in the education and development of young Armenian scientists. He lectured at the Yerevan State University's Physics Department from 1968 and in the years 1969–1974 was the chair of nuclear physics. He created the Experimental Physics School in Armenia and more than 20 PhD students received their diplomas under his guidance. In parallel, he worked successfully with secondary schools on science education.

The memory of the highly respected Hamlet Vartapetyan will forever remain in the hearts and minds of those who had the good fortune to know and work with him.
● *Ashot Chilingarian, YPI.*

Hamlet Vartapetyan. (Image credit: YPI.)

Arthur Wightman 1922–2013

Arthur Strong Wightman, a mathematical physicist and one of the founders of axiomatic quantum field theory, passed away on 13 January 2013.

Born in Rochester, NY, Arthur Wightman gained his PhD in 1949 under John Wheeler at Princeton University, where he was to spend the rest of his academic career, becoming professor of mathematical physics in theoretical physics.

The goal of axiomatic quantum field theory was to put on a firm mathematical basis some of the features of local field theory in such a way as to avoid illegal mathematical operations, which produced the well known infinities of QED. Wightman's axioms went one step further in terms of rigour than the preceding formulation of Harry Lehmann, Kurt Symanzik and Wolfhart Zimmermann, opening the way to the more sophisticated construction of Rudolf Haag, Huzihiro Araki and Daniel Kastler. However, it was only with the work of Henri Epstein and Vladimir Glaser that ultraviolet divergences could be avoided on the basis of locality. In the meantime, Wightman launched a programme of "constructive field theories", which was entrusted to Arthur Jaffé and Oscar Landford. This programme exhibited non-trivial relativistic field theories that fulfil the Wightman axioms but, unfortunately, examples remained far from matching current physical models.

Wightman had many other interests. In particular, in 1952 he co-signed with Gian Carlo Wick and Eugene Wigner a paper – the "WWW paper" – in which the symmetry properties of elementary systems are studied and the notion of "superselection rules" is introduced. In this paper they raise, in a footnote, doubts on the exact conservation of parity and charge conjugation. Independently, at the same time, Louis Michel made the observation that there is no proof of conservation of parity in weak interactions. Wightman's interest in weak interactions existed from the beginning of his career. Indeed, he and Michel, together with Val Telegdi and Valentine Bargmann started to write a book on weak interactions that was never finished. Wightman also supported Barry Simon in the study of nonrelativistic quantum mechanics.

Wightman was an enchanting lecturer both in public and in private. He was active at the Erice Ettore Majorana Centre for Scientific Culture, where he founded and directed the International School of Mathematical Physics. He was awarded the Heineman Prize by the American Physical Society, and the Henri Poincaré Prize by the International Association for Mathematical Physics.

We will miss an outstanding physicist and a wonderful person.
● *His friends at CERN.*

Antonino Zichichi listening to a lecture by Arthur Wightman given in the Dirac hall at the Ettore Majorana Centre for Scientific Culture in Erice in 1988. (Image credit: EMCSC.)

Obituary note

Peter Sharp 1937–2011

I would like to thank all of those friends and colleagues working on CMS with Peter and at CERN who wrote and sent me such kind sentiments about him after his death in March 2011 (*CERN Courier* June 2011 p36). My thanks also for the generous contributions, which will go to the Sobell House Hospice in Oxford. Peter's last two difficult years of life were made more bearable by all your encouragement and support, which was so appreciated by both of us.

My sincere apologies to all for the delay in thanking you. He was a very special person and is much missed.
● *Betty Sharp*

Faces & Places

Visits

José Antonio Meade Kuribreña, the Mexican secretary of foreign affairs, visited CERN on 26 February. He met Rolf Heuer, CERN's director-general, and Sergio Bertolucci, director for research and scientific computing, who introduced the laboratory's activities. He also took the opportunity during his visit to tour the LHC tunnel and the underground cavern of the ALICE experiment, before meeting Mexican scientists at CERN.

The Mongolian minister for foreign affairs, **Lusanvandan Bold**, right, signed CERN's guest book when he met the director-general during a visit to the laboratory on 26 February. Rüdiger Voss, adviser for international relations, presented a general introduction to CERN, which was followed by a visit underground to the ALICE experiment's cavern.

Meetings

CEC/ICMC 2013, the 19th joint Cryogenic Engineering Conference and International Cryogenic Materials Conference, will take place in Anchorage, Alaska, on 17–21 June. The programme features the latest research and state-of-the-art developments in all cryogenics areas, including superconductivity, cryocoolers, cryogenic materials and applications. For conference and registration details, see www.cec-icmc.org. Immediately before the conference, the Cryogenic Society of America (CSA) is offering **CSA Short Courses** on 16 June at the Anchorage Marriott Downtown. These are aimed at seasoned professionals and those new to the field. For details and to register, visit http://2csa.us/2013shortcourses.

ICALEPCS 2013, the 14th International Conference on Accelerator and Large Experimental Physics Control Systems will be held on 6–11 October in San Francisco, hosted by the National Ignition Facility at the Lawrence Livermore National Laboratory. At the conference, managers, scientists, engineers and decision makers of pre-eminent world-class science laboratories and facilities will discuss control and information systems for big science. For further details, see www.icalepcs2013.org.

New products

The **ORTEC Products Group** of AMETEK Advanced Measurement Technology has introduced the LDM-1, an integrated gamma-ray spectrometer for fixed and mobile counting-room applications. The self-contained Laboratory Detector Module (LDM-1) builds on technologies developed for the ORTEC Detective family of portable nuclide identifiers. Powered from a small 10–17 V DC supply, it has a built-in battery back-up. It also has a built-in a high-stability digital signal processor. For more information, tel +1 865 482 4411, fax +1 865 483 0396 or visit www.ortec-online.com.

Amphenol Aerospace has announced a new high-speed, rugged connector capable of delivering data rates up to 10 Gbps per pair. The high-density Oval Contact System (OCS) features improved signal integrity with reduced cross-talk and enhanced attenuation performance for high-speed applications including, 10/40G Ethernet, HDMI/DVI video, 1/2/4/8G fibre channel and PCI express. For further details, contact Sandra Ford, sford@amphenol-aao.com or see www.amphenol-aerospace.com.

Cobham Technical Services has extended the capabilities of the Opera-3D finite element software for electromagnetic design with a new solver to analyse natural vibration modes. The tool should prove useful for electrical machine developers to investigate and minimize forces that might cause oscillations close to the natural frequencies of the equipment. The new modal solver – STRESS/EV – finds a user-specified number of eigenvalues within a specified frequency range and calculates the eigenvectors of each mode. For more information, contact Julie Shepherd, tel +44 1865 370 151, fax +44 1865 370 277, e-mail vectorfields.info@cobham.com, or visit www.cobham.com/technocalservices.

Hiden Analytical has announced the Hiden HPR-60 mass spectrometer for the direct analysis of ions, radicals and neutral species in reactive processes. The system typically operates in pressure regimes from 5 mbar to 5 bar. Options provide for measurement of neutrals, positive ions, negative ions and ion energies, with a choice of mass range up to 2500 amu. The system samples directly from the process using a sequence of up to three pressure-reduction stages, providing a sampling range of 5 mbar to 100 mbar for the two-stage system and to 5 bar with the third stage. For further details, tel +44 1925 445 225, e-mail info@hiden.co.uk or see www.hidenanalytical.com.

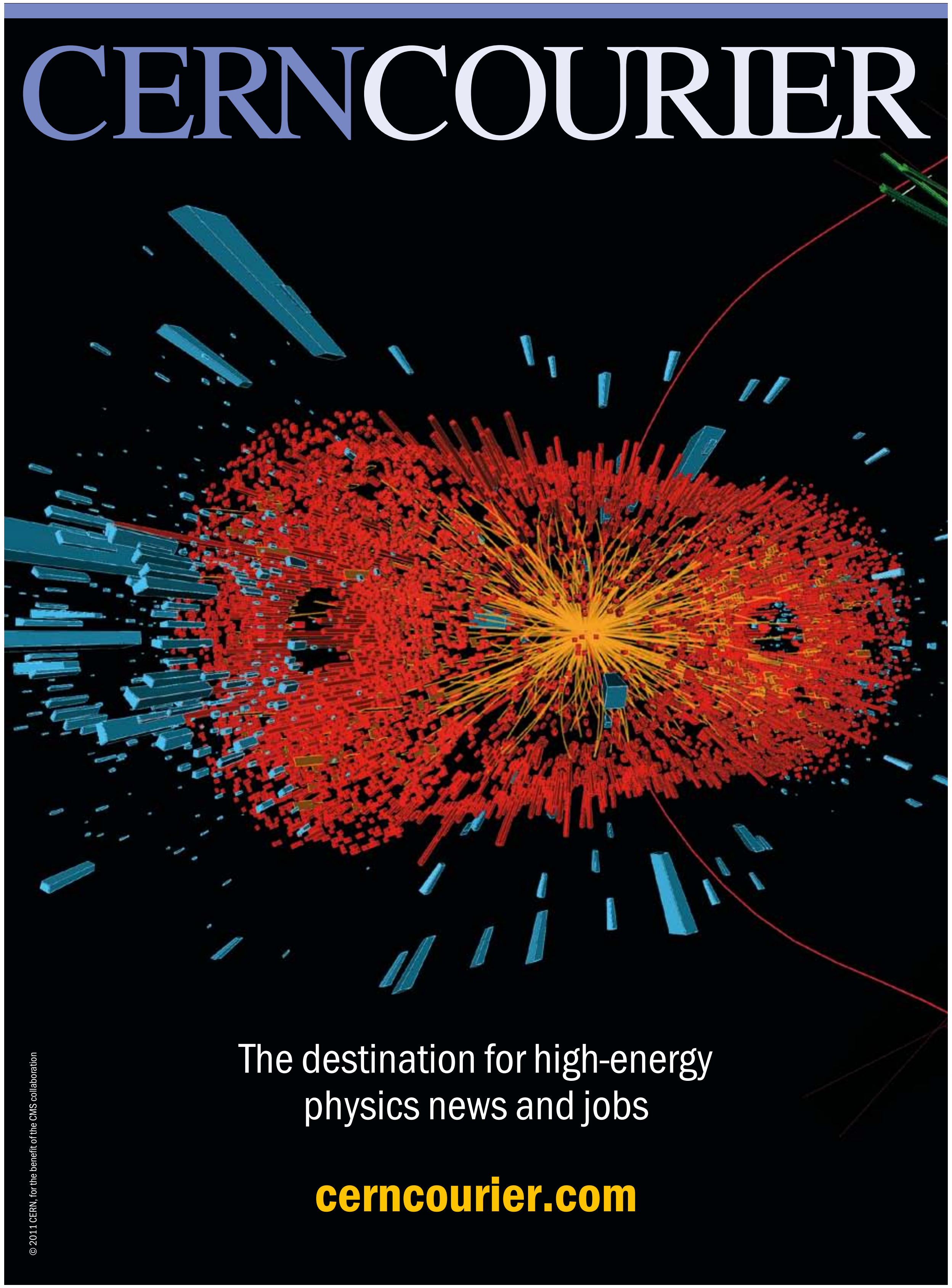
Corrections

Recent articles on the development of QCD have unfortunately reproduced figures without due acknowledgement to the originals. Figure 2 in the article by Harald Fritzsch (*CERN Courier* October 2012 p21) is reproduced from figure 5 in the article by Siegfried Bethke and Peter Zerwas in *Physik Journal* vol. 3 no. 12 pp31–35 (2004). Figure 1 of the article by David Gross and Franck Wilczek is reproduced from figure 3 in Siegfried Bethke "World Summary of α_s (2012)" Oct 2012, MPP-2012-132, arXiv:1210.0325 [hep-ex]. *CERN Courier* apologizes unreservedly for these oversights.

In the news article about the first measurements of electroweak boson fusion by CMS, a zero became lost in the di-muon mass quoted on the event display. This should be 90.2 GeV.

Recruitment

CERN Courier April 2013



Bookshelf

Books received

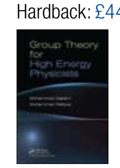
Reviews of Accelerator Science and Technology: Volume 4 – Accelerator Applications in Industry and the Environment

By Alexander W Chao and Weiren Chou (ed.)
World Scientific
Hardback: £111
E-book: £144

Of about 30,000 accelerators at work in the world today, a majority of these are for applications in industry. This volume of *Reviews of Accelerator Science and Technology* contains 14 articles on such applications, all by experts in their respective fields. The first eight articles review various applications, from ion-beam analysis to neutron generation, while the next three discuss accelerator technology that has been developed specifically for industry. The twelfth article tackles the challenging subject of future prospects in this rapidly evolving branch of technology. Last, the volume features an article on the success story of CERN by former director-general, Herwig Schopper, as well as a tribute to Simon van der Meer, "A modest genius of accelerator science".

Group Theory for High-Energy Physicists

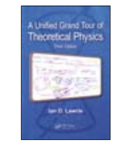
By Mohammad Saleem and Muhammad Rafique
CRC Press/Taylor and Francis
Hardback: £44.99



Although group theory has played a significant role in the development of various disciplines of physics, there are few recent books that start from the beginning and then go on to consider applications from the point of view of high-energy physicists. *Group Theory for High-Energy Physicists* aims to fill that role. The book first introduces the concept of a group and the characteristics that are imperative for developing group theory as applied to high-energy physics. It then describes group representations and, with a focus on continuous groups, analyses the root structure of important groups and obtains the weights of various representations of these groups. It also explains how symmetry principles associated with group theoretical techniques can be used to interpret experimental results and make predictions. This concise introduction should be accessible to undergraduate and graduate students in physics and mathematics, as well as to researchers in high-energy physics.

A Unified Grand Tour of Theoretical Physics, Third Edition

By Ian D Lawrie
CRC Press/Taylor and Francis
Paperback: £44.99



A Unified Grand Tour of Theoretical Physics invites readers on a guided exploration of the theoretical ideas that shape contemporary understanding of the physical world at the fundamental level. Its central themes – which include space–time geometry and the general relativistic account of gravity, quantum field theory and the gauge theories of fundamental forces – are developed in explicit mathematical detail, with an emphasis on conceptual understanding. Straightforward treatments of the Standard Model of particle physics and that of cosmology are supplemented with introductory accounts of more speculative theories, including supersymmetry and string theory. This third edition includes a new chapter on quantum gravity and new sections with extended discussions of topics such as the Higgs boson, massive neutrinos, cosmological perturbations, dark energy and dark matter.

Strings, Gauge Fields, and the Geometry Behind the Legacy of Maximilian Kreuzer

By Anton Rebhan, Ludmil Katzarkov, Johanna Knapp, Radoslav Rashkov and Emanuel Scheidegger (eds.)
World Scientific
Hardback: £104
E-book: £135

This book contains invited contributions from collaborators of Maximilian Kreuzer, a well known string theorist who built a sizeable group at Vienna University of Technology (TU Vienna) but sadly died in November 2010 aged just 50 (*CERN Courier* June 2011 p38). Victor Batyrev, Philip Candelas, Michael Douglas, Alexei Morozov, Joseph Polchinski, Peter van Nieuwenhuizen and Peter Wes are among others giving accounts of Kreuzer's scientific legacy and original articles. Besides reviews of recent progress in the exploration of string-theory vacua and corresponding mathematical developments, Part I reviews in detail Kreuzer's important work with Friedemann Brandt and Norbert Dragon on the classification of anomalies in gauge theories. Similarly, Part III contains a user manual for a new thoroughly revised version of PALP (Package for Analysing Lattice Polytopes with applications to toric geometry), the software developed by Kreuzer and Harald Skarke at TU Vienna.

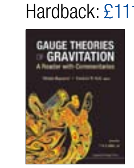
Introduction to Mathematical Physics: Methods and Concepts, Second Edition

By Chun Wa Wong
Oxford University Press
Hardback: £45 $84.95

Introduction to Mathematical Physics explains how and why mathematics is needed in the description of physical events in space. Aimed at physics undergraduates, it is a classroom-tested textbook on vector analysis, linear operators, Fourier series and integrals, differential equations, special functions and functions of a complex variable. Strongly correlated with core undergraduate courses on classical and quantum mechanics and electromagnetism, it helps students master these necessary mathematical skills but also contains advanced topics of interest to graduate students. It includes many tables of mathematical formulae and references to useful materials on the internet, as well as short tutorials on basic mathematical topics to help readers refresh their knowledge. An appendix on Mathematica encourages the reader to use computer-aided algebra to solve problems in mathematical physics. A free *Instructor's Solutions Manual* is available to instructors who order the book.

Gauge Theories of Gravitation: A Reader with Commentaries

By Milutin Blagojevi and Friedrich W Hehl (eds.)
World Scientific
Hardback: £111 $168 S$222



With a foreword by Tom Kibble and commentaries by Milutin Blagojević and Friedrich W Hehl, the aim of this volume is to introduce graduate and advanced undergraduate students of theoretical or mathematical physics – and other interested researchers – to the field of classical gauge theories of gravity. Intended as a guide to the literature in this field, it encourages readers to study the introductory commentaries and become familiar with the basic content of the reprints and the related ideas, before choosing specific reprints and then returning to the text to focus on further topics.

Viewpoint

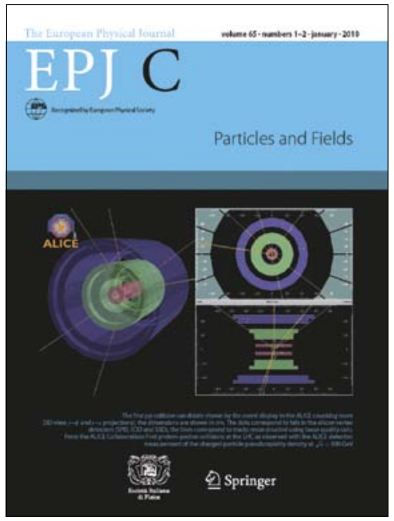
The changing world of *EPJC*

New members of the editorial board look at the role of *EPJC* as a community journal.

As the field of high-energy physics moves inexorably towards full open access, under the SCOAP[3] agreement (*CERN Courier* November 2012 p6), it is worth noting a fact that is often overlooked by the scientific community, namely the concomitant affirmation of the role of scientific journals. Indeed, journals will continue to stand – if not for primary dissemination of information, for the continued, independent and, yes, competitive and occasionally controversial quality assessment. An ecosystem of dedicated journals is precisely what this requires, on top of open pre-"print" archives of equally undisputed role.

Yet, looking at the broader landscape of physics and beyond, open access has quite naturally also brought other changes, namely the emergence of "community journals". By including a variety of kinds of article, these break with the traditional scheme of long established journals, which are typically devoted to single article types, such as letters, regular articles, technical papers or reviews. To promote and foster this development is precisely the aim of *The European Physical Journal C – Particles and Fields* (*EPJC*), where all types of publications relevant to the field of high-energy physics (including astroparticle physics and cosmology) are considered.

EPJC has recently seen a series of significant changes in its editorial board. Since January, Jos Engelen (a former research director at CERN) is the new editor-in-chief of the "Experimental Physics" section. He succeeds Siggi Bethke, who successfully co-ordinated this section of the journal until the end of 2012. A few months earlier, the board of theoretical physics editors of *EPJC* was significantly enlarged. In addition to the traditional board of editors covering the area of "Phenomenology of the Standard Model and Beyond" (now called Theory-I), which Gino Isidori has co-ordinated since



Since 2009, the cover of EPJC *has highlighted a figure from the current monthly issue. In January 2010 this was the famous recording of the first proton–proton collisions at the LHC, as observed by the ALICE experiment in late 2009.*

the end of 2011, Ignatios Antoniadis (the current head of the Theory Unit at CERN) has taken charge of a largely new board of editors covering the areas of gravitation, astroparticle physics and cosmology, general aspects of quantum field theories and alternatives (Theory II).

The latter developments take into account in particular the ongoing rapid "merger" of accelerator-based particle physics with astroparticle physics and cosmology. The next step for our journal will thus be to reach out to experimental non-accelerator physics to provide a first unified platform as a "community journal" in this further extended sense.

Next to letters, regular articles and reviews (tutorial, specialist, technical, topical scientific meeting summaries), *EPJC* is particularly keen to develop its "tools" section. Neither theory nor experiment in the traditional sense, this section is a platform for publishing computational, statistical and engineering physics of immediate and close relevance for understanding technical or interpretational aspects of theoretical and experimental particle physics.

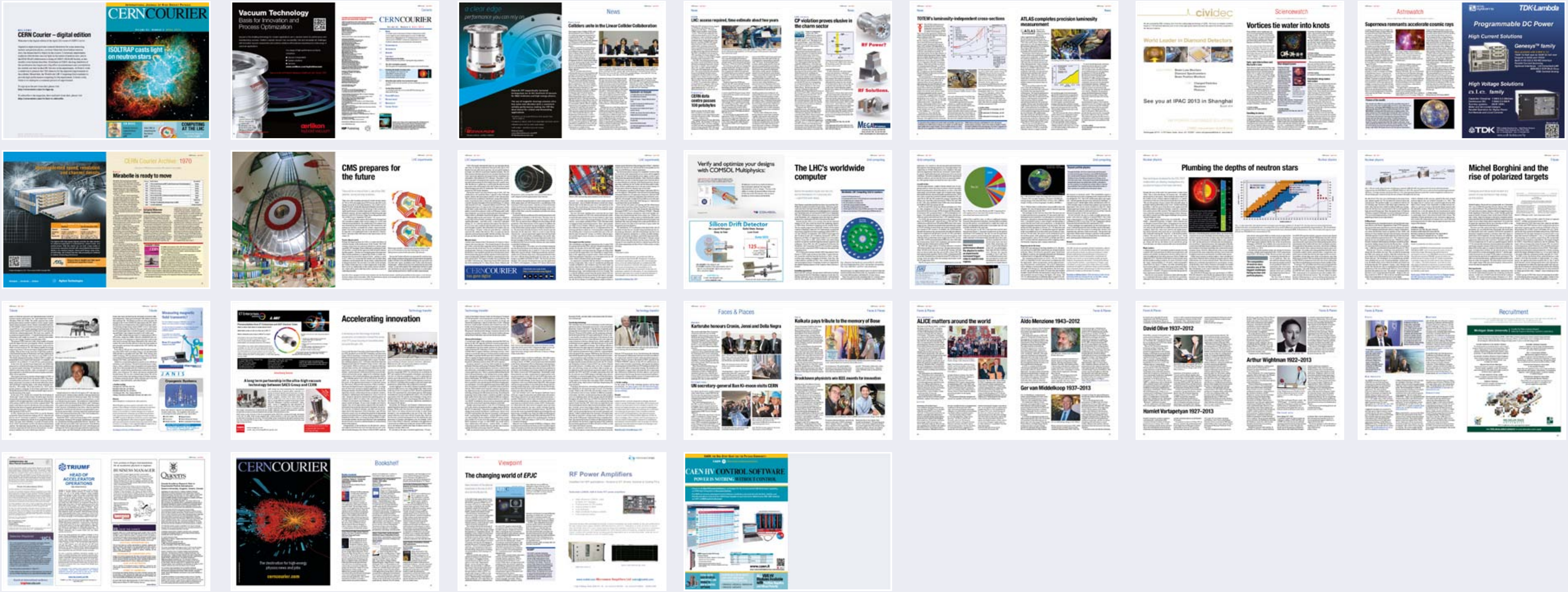
Last but not least, there is another aspect by which *EPJC* wishes to stand out, namely in terms of quality assessment. Taking a lead from Karl Popper, science is a social enterprise and humans react quite differently depending on whether they are solicited personally to comment on quality and relevance or just passively, e.g. as recipients of mailing lists or other automated systems.

At *EPJC*, three independent levels exist to ensure quality control, each mediated by direct communication as peers in the field: the editors-in-chief, the editorial board and the referees. All of them will have been involved in the assessment and decision-making process for every single paper, ensuring a personal, unbiased and fair implementation of the refereeing process, which remains at the core of the activity of any reputable journal.

● *Ignatios Antoniadis, CERN, Jos Engelen, NWO, and Gino Isidori, Frascati/INFN.*

SCOAP[3]

The SCOAP[3] consortium (Sponsoring Consortium for Open Access Publishing in Particle Physics), which aims to convert journals in high-energy physics to open access, has chosen two Springer journals to participate in the initiative. They are the *Journal of High-Energy Physics*, published for the International School for Advanced Studies (SISSA) in Trieste, Italy, and *The European Physical Journal C*, published with Società Italiana di Fisica. The selection is the result of an open and transparent tender process run by CERN for the benefit of SCOAP[3], in which journal quality, price and publishing services were taken into account.



CERNCOURIER

Volume 53 Number 3 April 2013

Contents