WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the May 2015 issue of *CERN Courier*.

After the first long shutdown, proton beams are back in the LHC, CERN's flagship accelerator. This follows two years of intense maintenance and consolidation work to prepare the machine for operation at 6.5 TeV per beam. During the shutdown, the experiments were also hives of activity. This issue looks at the many challenging tasks undertaken on CMS and ALICE in preparation for Run 2, which will see not only higher energies but also higher intensities. Celebration of the International Year of Light continues with a report on the new, brighter light source at the Brookhaven National Laboratory.

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CERNCOURIER

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A newer, brighter light source for Brookhaven
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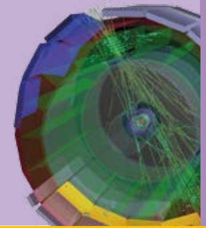

CHRONICLES OF CMS

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

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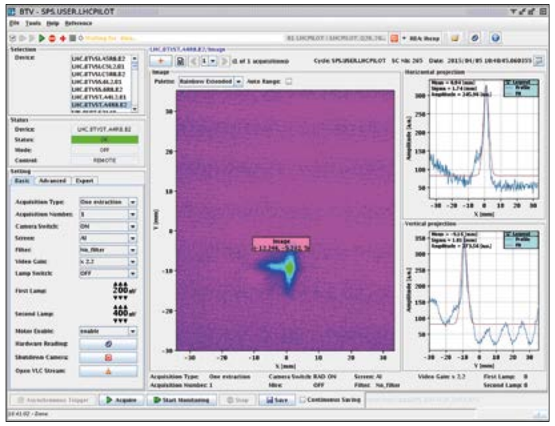
FEATURES

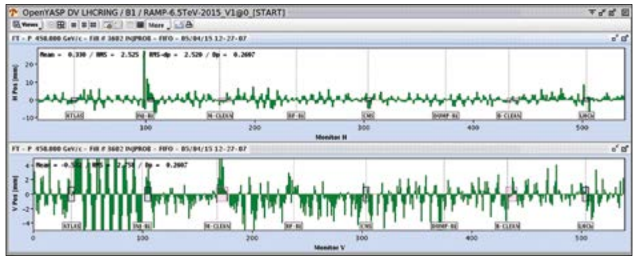
On the cover: Happiness in the CERN Control Centre as the LHC successfully restarts after two years of intense maintenance and consolidation, and several months of preparation (p 5 and p 54).
(Image credit: CERN-PHOTO-201504-063-24.)

News

CERN

Proton beams are back in the LHC





Left: 10.40 a.m.: Beam 2 has completed its first orbit around the ring. Above: 12.27 a.m.: Beam 1's first circuit.

After two years of intense maintenance and consolidation, and several months of preparation for the restart, the LHC is back in operation. At 10.41 a.m. on 5 April, for the first time in more than two years, proton Beam 1 completed an anti-clockwise circuit of the 27-km ring at the injection energy of 450 GeV. Injected at point 8 on the LHC, Beam 1 was allowed round the ring one step at a time, as collimators were opened at each point in turn, once the operators had checked that all was working well. On the way, the protons provided the first "beam-splash" events for the ATLAS and CMS experiments, at points 1 and 5, respectively (see Inside story, p54). Beam 2 then followed a similar procedure. Injected at point 2, it completed its first orbit in the clockwise direction at 12.27 p.m.

The sight of first beam has set the LHC on course for Run 2 – but not without the kind of challenge to be expected when restarting such a complex system after the work undertaken during the long shutdown. The Herculean task to prepare the machine for operation at 6.5 TeV per beam – almost double the energy of Run 1 – involved the consolidation of some 10,000 electrical interconnections between the magnets, the addition of further magnet-protection systems, and the improvement and strengthening of cryogenic, vacuum and electronic systems.

Following the successful injection tests on 7–8 March (*CERN Courier* April 2015 p5), the final training of the superconducting magnets to the current levels required for a beam energy of 6.5 TeV continued in parallel with the many steps required for the machine check-out. During this final phase before beam, the various LHC systems are put through their operational paces from the CERN Control Centre. These include important tests of the beam-dump beam-interlock systems. All of the magnetic circuits are driven through the ramp, squeeze, ramp-down, and pre-cycle steps, together with the collimators and RF. Instrumentation, feedbacks, and the control system are also stress-tested.

By mid-March, the powering tests had left all but two of the 1700 or so magnetic circuits fully qualified for 6.5 TeV – the result of a six-month-long programme of rigorous tests involving the quench-protection system, power converters, energy extraction, uninterruptible power supplies, interlocks, electrical quality assurance and magnet behaviour. The dipoles of sector 4-5 proved a little stubborn but reached the target value of 11,080 A – the value for 6.5 TeV with a margin of an additional 100 A – after some 50 training quenches. Sector 3-4 was also nearly fully trained to the same value, when an earth fault occurred in the early morning of 21 March.

Investigations eventually pinned down the fault to a metal fragment lodged in a box housing a high-current bypass diode. After intensive discussions and simulations, the accelerator team decided to melt the fragment, and on 30 March injected a current of almost 400 A into the diode circuit for just a few milliseconds. Measurements made the following day confirmed that the short-circuit had indeed disappeared. Teams then had to re-qualify the sector, testing all of the circuits, particularly the dipole circuit that carries current up to 11 kA, before training could begin again. By 2 April, sector 3-4 had finally reached the target for operation at 6.5 TeV, and preparations to close the LHC for beam were fully under way again, for the successful restart three days later.

● To find out more, see the LHC reports in CERN Bulletin: bulletin.cern.ch.

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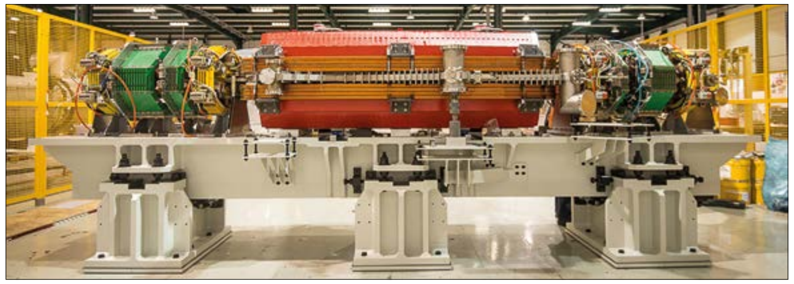
FACILITIES

SESAME passes an important milestone at CERN



Top: The first cell for SESAME, assembled and tested at CERN, with one bending magnet (red), two sets of focusing and defocusing quadrupoles (green) and four sets of correcting sextupoles (yellow). (Image credit: CERN-PHOTO-201503-059-57.) Above: Experts from CERN and SESAME with part of a sextupole assembly. (Image credit: CERN-PHOTO-201503-059-9.)

The SESAME project – the Synchrotron-light for Experimental Science and Applications in the Middle East – passed an important milestone at the beginning of April, with the complete assembly and successful testing at CERN of the first of 16 magnetic cells for the electron storage ring (*CERN Courier* November 2014 p5).

Under construction in Jordan, SESAME is a unique joint venture that brings together scientists from its members: Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey (*CERN Courier* September 2014 p46). The light source consists of an injector, comprised of a 20-MeV microtron and an 800-MeV booster synchrotron, which feeds a 2.5-GeV electron storage ring. CERN is responsible for the magnets of the storage ring and their powering scheme under CESSAMag – a project funded largely by the European Commission. Within the project, CERN has been collaborating with SESAME and the ALBA Synchrotron to design, test and characterize the components of the magnetic system.

The SESAME storage ring is built up from 16 magnetic cells, which make up the periodic structure of the machine, together with insertion regions where special synchrotron radiation can be produced. Each of the periodic cells consists of one bending magnet (a combined function dipole–quadrupole), two focusing and two defocusing magnets (quadrupoles) and four combined sextupole corrector magnets (including orbit and coupling correction). Orders were placed in the UK for the dipoles, in Spain and Turkey for the quadrupoles, and in France, Cyprus and Pakistan for the sextupoles. Italy, Israel and Switzerland are providing the power-supply components, and Iran, Pakistan and Turkey are providing additional in-kind support to CERN in the form of material and personnel.

The integration tests at CERN, which were carried out together with colleagues from SESAME, aimed at assembling a full periodic cell of the machine. Besides the magnets themselves, this involved the girder support structure as well as the vacuum chamber through which the electron beam will pass. The success of the tests demonstrates that these subsystems work together as foreseen.

Production of the magnets and their powering scheme is now in full swing. After acceptance tests and integration for the powering, the components will be shipped in batches to Jordan, where installation and commissioning of the storage ring is planned for 2016, followed by start-up the same year. The SESAME injector, which includes a booster synchrotron, is already operational.

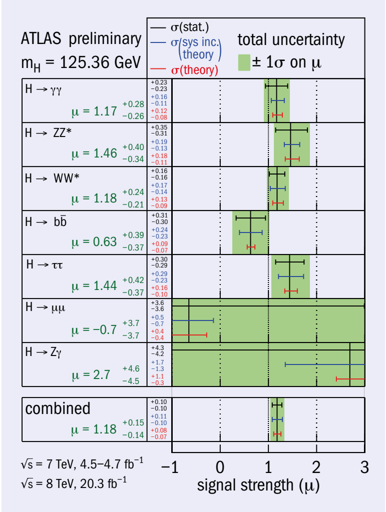
LHC EXPERIMENTS

Latest ATLAS results on the Higgs boson

ATLAS physicists are making increasingly precise measurements of the properties of the observed Higgs boson, including production and decay rates, as well as the spin. Comparisons of the results with theoretical predictions could indicate whether new particles or phenomena beyond the Higgs field of the Standard Model are required for electroweak-symmetry breaking.

Recently published studies concern the decays of the Higgs boson into vector bosons ($\gamma\gamma$, ZZ, WW, $Z\gamma$) and fermions ($\tau\tau$, bb, $\mu\mu$) in various production modes (ATLAS Collaboration 2015a). Measurements of the signal strength, $\mu=\sigma/\sigma_{SM}$, allow the measured cross-sections, σ, of each decay channel to be compared to that predicted by the Standard Model, σ_{SM}. The figure shows that the results are compatible with the Standard Model's prediction, that is, $\mu=1$. The new combination of all of the production and decay channels gives the most precise value from ATLAS to date: $\mu=1.18+0.15-0.14$.

Other new results include studies of the rare process of Higgs-boson production in association with two top quarks – a channel that allows physicists to probe directly the mysteriously large top–Higgs Yukawa coupling (ATLAS Collaboration 2015b). The analyses looked at a number of different decay modes of the Higgs boson, including decays into fermions (bb, $\tau\tau$), and into bosons (WW, ZZ), the latter mode being measured for the first time by ATLAS in association with top quarks. Gathering all of the decay channels together, the data show a small excess of events over background with a strength $\mu(ttH)=1.8\pm0.8$. This gives a significance of 2.4σ with respect to a "no ttH" hypothesis. Observation of the Higgs boson in this production mode will require the new data expected in the LHC's Run 2.



The observed signal strengths (μ) and uncertainties for different Higgs-boson decay channels and their combination for m_H = 125.36 GeV. Higgs-boson signals corresponding to the same decay channel are combined together for all analyses. The best-fit values are shown by the solid vertical lines. The total ±1σ uncertainties are indicated by green shaded bands, with the individual contributions from the statistical uncertainty (top), the total (experimental and theoretical) systematic uncertainty (middle), and the theory systematic uncertainty (bottom) on the signal strength shown as horizontal error bars.

ATLAS has also improved its studies of the spin and parity of the Higgs boson (ATLAS Collaboration 2015c). The Standard Model hypothesis of a spin-0 particle with positive parity is favoured at more than 99% confidence level.

In addition, the ATLAS and CMS collaborations have joined forces to combine their precision measurements of the mass of the Higgs boson, and recently presented a new combined value of $m_H=125.09\pm0.24$ (0.21 stat.±0.11 syst.) GeV, with an uncertainty reduced to two parts in a thousand (0.2%).

The LHC will soon restart running with a proton–proton collision energy of 13 TeV, more than 60% higher than that of Run 1. The production rate of the Standard Model Higgs boson will increase by more than a factor of two, and that of the rare ttH process by almost a factor of four. ATLAS is ready to exploit the full potential of Run 2 to study the Higgs boson and to look beyond for new phenomena.

● Further reading

ATLAS Collaboration 2015a ATLAS-CONF-2015-007.
ATLAS Collaboration 2015b ATLAS-CONF-2015-006, arXiv:1503.05066 [hep-ex].
ATLAS Collaboration 2015c ATLAS-CONF-2015-008.

CMS digs deeply into lepton-pair production

Lepton pairs produced in proton–proton collisions at the LHC provide a clear signal that is easy to identify in the detector. The production is dominated by the Drell–Yan process, in which an intermediate Z/γ^* boson is produced by the incoming partons. The measurements of the Drell–Yan production cross-section as a function of the mass of the intermediate boson, its rapidity (corresponding to the scattering angle) and its transverse momentum allow sensitive tests of QCD, the theory of the strong interaction. Recently, the CMS collaboration published two new measurements that provide a comprehensive view of the production of dimuons, a pair of oppositely charged muons, via the decay of Z bosons at a collision energy of 8 TeV at the LHC.

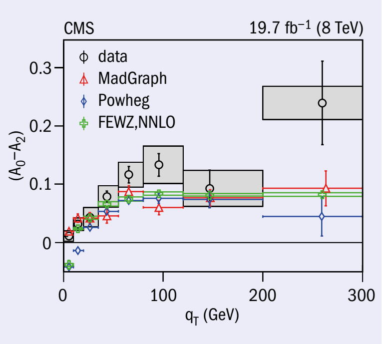
The parton structure of the proton and its evolution, governed by the dynamics of the strong interaction, can be scrutinized over a large range of phase space. By comparing the measurements to calculations that employ different parton distribution functions (PDFs) and different theoretical models for the dynamics, the PDFs and their uncertainty can be improved. These studies are also important for investigating other physics processes, for example searches for new resonances decaying into dileptons in models beyond the Standard Model.

In the CMS analysis, dimuon production in the vicinity of the Z-boson peak was parameterized doubly differentially as functions of the transverse momentum (q_T) and the rapidity (y) of the Z boson. The analysis used the data sample of proton–proton collisions at a centre-of-mass energy of 8 TeV, amounting to an integrated luminosity of 19.7 fb^{-1}. The measurement probes the production of Z bosons up to high transverse momenta of $q_T > 100$ GeV, a kinematic regime in which the production is dominated by gluon–quark fusion. Therefore, the measurement is sensitive to the gluon PDF in a kinematic regime that is important for Higgs-boson production via gluon fusion. In the future, Z-boson production can also be used to constrain

▷

the gluon PDF and provide information complementary to other processes employed, such as direct photon production. The data are well reproduced within uncertainties by the next-to-next-to-leading-order predictions computed with the FEWZ simulation code. The MADGRAPH and POWHEG predictions deviate from data up to 20% at high-z transverse momentum.

The angular distribution of the final-state leptons in Drell–Yan production is determined by the vector and axial-vector coupling structure of the Standard Model Lagrangian, and by the relative contributions of the quark–antiquark annihilation and quark–gluon Compton processes. In the presence of higher-order QCD corrections, the general structure of the lepton angular distribution in the boson rest-frame is given by a formula that contains a set of angular coefficients.



The measured difference of the angular coefficients, A0–A2, as a function of the transverse momentum, q_T, confirms the anticipated deviation from the Lam–Tung relation (A0 = A2).

Using the 8 TeV data, CMS has measured the five major angular coefficients A0 to A4 as a function of q_T and y. None of the theoretical models tested describe all of the coefficients satisfactorily. The coefficients A0 and A2 measured by CMS in proton–proton collisions at the LHC are larger than those measured in proton–antiproton collisions at Fermilab's Tevatron at a lower centre-of-mass energy. This is expected, owing to the significant contribution of the quark–gluon process in proton–proton collisions at the LHC. In addition, as the figure shows, the analysis confirmed for the first time the anticipated deviation from the Lam–Tung relation, A0 = A2 (Lam and Tung 1979). This deviation is expected in QCD calculations beyond the leading order. The measurement by CMS shows that A0 > A2, especially for high q_T. Nonzero values were also measured for A1 and A3.

The comprehensive study of the Z-boson production mechanism presented in these two recently published CMS papers lays the foundation for future high-precision measurements, such as the measurement of the mass of the W boson and the electroweak mixing angle.

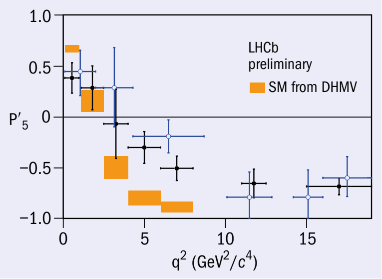
● Further reading

CMS Collaboration 2015a CMS PAS SMP-13-013.
CMS Collaboration 2015b CMS PAS SMP-13-010.
C S Lam and Wu-Ki Tung 1979 *Physics Letters* **B80** 228.

LHCb's new analysis confirms an old puzzle

At the recent Moriond Electroweak (EW) conference at La Thuile, the LHCb collaboration presented an updated angular analysis of the decay $B \to K^{*0}\mu^+\mu^-$ using the experiment's full data set from the LHC's Run 1 (LHCb Collaboration 2015). This is an update of an earlier measurement based on the 2011 data alone, which showed a significant discrepancy in one angular observable (referred to as P'_5) compared with predictions from the Standard Model (LHCb Collaboration 2013 and *CERN Courier* December 2013 p7). Because the discrepancy could be interpreted as a sign of physics beyond the Standard Model, it provoked considerable discussion within the particle-physics community, and the update with the full Run 1 sample has been eagerly awaited.

The decay of a B meson (containing a b quark and a d quark) into a K^{*0} meson (s and d) and a pair of muons is quite a rare process, occurring around once for every million B meson decays. At quark level, the decay involves a change of the quark flavour, $b \to s$, without any change in charge. Such flavour-changing neutral processes are forbidden at the lowest perturbative order in the Standard Model, and come from higher-order loop processes involving virtual W bosons (*CERN Courier* June 2013 p15). In many extensions of the Standard Model, new particles can also contribute to the decay, leading to an enhancement or (through interference) a suppression in the rate of the decay. The contributions from new particles beyond the Standard Model can also change the angular distributions of the kaon and pion from the K^{*0} decay, and of the muons.



The distribution of the P'_5 observable as a function of the dimuon-mass squared, q^2. The black data points correspond to the LHCb result presented for the first time at Moriond EW (LHCb Collaboration 2015). The open blue points show the 2011 result from LHCb (LHCb Collaboration 2013). The orange boxes correspond to a Standard Model calculation from Descotes-Genon et al. *2014, with no prediction shown for $q^2 > 8$ GeV^2/c^4.*

The analysis shown at Moriond, which is the first by any experiment to explore the full angular distribution of the decay, confirms the discrepancy seen in the 2011 data. At low dimuon masses, there is poor agreement between the current Standard Model predictions and the data for the P'_5 observable. The two measurements in the range $4 < q^2 < 8$ GeV^2/c^4 are both 2.9σ from the Standard Model calculation (see figure).

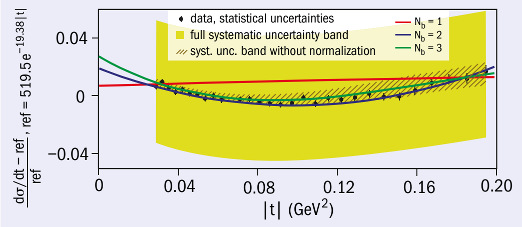
Two invited theory talks followed LHCb's presentation at Moriond. Both speakers were able to give an initial interpretation of the results, and found a consistent picture (see, for example, Straub and Altmannshofer 2015). A model-independent analysis favours a best-fit point that is about 4σ from the current Standard Model predictions.

It is, however, still too soon to claim evidence of new particles. The major challenge in interpreting the results lies in separating the interesting physics from poorly known QCD effects, which could be larger than first expected and hence responsible for the discrepancy. No matter the cause of the anomaly, there will need to be some rethinking of the current understanding of the $B \to K^{*0}\mu^+\mu^-$ decay.

● Further reading

S Descotes-Genon *et al.* 2014 arXiv:1407.8526 [hep-ph].
LHCb Collaboration 2013 *Phys. Rev. Lett.* **111** 191801.
LHCb Collaboration 2015, LHCb-CONF-2015-002.
D Straub and W Altmannshofer 2015 arXiv:1503.06199 [hep-ph].

TOTEM finds evidence for non-exponential elastic pp scattering



Fits of the measured differential cross-section with different numbers of parameters in the exponent, N_b.

Measurements of the differential cross-section in proton–proton (pp) or proton–antiproton ($p\bar{p}$) scattering have generally proved consistent with a pure exponential dependence at low values of the square of the four-momentum transfer, $|t|$. However, slight deviations have been observed, notably in elastic pp and $p\bar{p}$ scattering at the Intersecting Storage Rings at CERN. Now, the TOTEM experiment has made a precision measurement of elastic pp scattering at the LHC, and finds that the data exclude a purely exponential behaviour of the cross-section at low $|t|$ at a total energy of 8 TeV in the centre of mass.

The TOTEM experiment, which co-inhabits point 5 on the LHC with CMS, includes a system of Roman Pots, which allow detectors to be brought close to the beam so as to intercept particles scattered at very small angles to the beam. The Roman Pots are in two stations on opposite sides of interaction point 5, and each station is equipped with detectors at both 214 m and 220 m from the interaction point. The detectors consist of stacks of silicon-strip sensors, specially designed to have a narrow insensitive region, of a few tens of micrometres, along the edge that faces the beam (*CERN Courier* September 2009 p19).

TOTEM collected the data during a special run at the LHC in July 2012, in which the Roman Pots were brought in to a distance of only 9.5 times the transverse beam size of the beam. During 11 hours of data taking, the experiment amassed 7.2-million tagged elastic events at a collision energy of 8 TeV. The large data set has allowed a precise measurement of the elastic pp cross-section, with both statistical and systematic uncertainties below 1%, except for overall normalization. As a result of this precision, TOTEM is able to exclude a purely exponential differential cross-section in the range $0.027 < |t| < 0.2$ GeV^2, with a significance greater than 7σ. In contrast, parameterizations with either quadratic or cubic polynomials in the exponent are compatible with the data.

● Further reading

TOTEM Collaboration 2015 arXiv:1503.08111 [hep-ex], submitted to *Nucl. Phys. B*.

NEUTRINOS

New possibilities for particle physics with IceCube

The IceCube Neutrino Observatory has measured neutrino oscillations via atmospheric muon-neutrino disappearance. This opens up new possibilities for particle physics with the experiment at the South Pole that was originally designed to detect neutrinos from distant cosmic sources (*CERN Courier* December 2014 p30).

IceCube records more than 100,000 atmospheric neutrinos a year, most of them muon neutrinos, and its sub-detector DeepCore allows the detection of neutrinos with energies from 100 GeV down to 10 GeV. These lower-energy neutrinos are key to IceCube's oscillation studies. Based on current best-fit oscillation parameters, IceCube should see fewer muon neutrinos at energies around 25 GeV reaching the detector after passing through the Earth. Using data taken between May 2011 and April 2014, the analysis selected muon-neutrino candidates in DeepCore with energies in the region of 6–56 GeV. The detector surrounding DeepCore was used as a veto to suppress the atmospheric muon background. Nearly 5200 neutrino candidates were found, compared with the 6800 or so expected in the non-oscillation scenario. The reconstructed energy and arrival time for these events were used to obtain values for the neutrino-oscillation parameters, $\Delta m_{32}{}^2 = 2.72^{+0.19}_{-0.20} \times 10^{-3}\,\mathrm{ev}^2$ and $\sin^2\theta_{23} = 0.53^{+0.09}_{-0.12}$. These results are compatible and comparable in precision to those of dedicated oscillation experiments.

The collaboration is currently planning the Precision IceCube Next Generation Upgrade (PINGU), in which a much higher density of optical modules in the whole central region will reduce the energy threshold to a few giga-electron-volts. By carefully measuring coherent neutrino interactions with electrons in the Earth (the Mikheyev–Smirnov–Wolfenstein effect), this should allow determination of the neutrino-mass hierarchy, and which neutrino flavour is heaviest.

● **Further reading**

IceCube Collaboration 2014 arXiv:1410.7227 [hep-ex], accepted by *Phys. Rev. D*.

The experiment now known as DUNE

The long-baseline neutrino experiment formerly known as LBNE has a new name: Deep Underground Neutrino Experiment (DUNE). Served by an intense neutrino beam from Fermilab's Long Baseline Neutrino Facility, DUNE will have near detectors at Fermilab and four 10-kt far detectors at the Sanford Underground Research Facility in South Dakota (*CERN Courier* April 2015 p20). In April, the DUNE collaboration – now with more than 700 scientists from 148 institutions in 23 countries – elected two new spokespersons: André Rubbia from ETH Zurich, and Mark Thomson from the University of Cambridge. One will serve as spokesperson for two years, the other for three years, to provide continuity in leadership.

DESIGN STUDIES

Collaboration meets for the first FCC week

As many as 340 physicists, engineers, science managers and journalists gathered in Washington DC for the first annual meeting of the global Future Circular Collider (FCC) study (*CERN Courier* April 2014 p16). The FCC week covered all aspects of the study – designs of 100-km hadron and lepton colliders, infrastructures, technology R&D, experiments and physics.

The meeting began with an exciting presentation by US congressman Bill Foster, who recalled the history of the LHC as well as the former design studies for a Very Large Hadron Collider (*CERN Courier* April 1999 p18). A special session on Thursday was devoted to the experience with the US LHC Accelerator Research Program (LARP), to the US particle-physics strategy, and US R&D activities in high-field magnets and superconducting RF. A well-attended industrial exhibition and a complementary "industry fast-track" session were focused on Nb_3Sn and high-temperature superconductor development.

James Siegrist from the US Department of Energy (DOE) pointed the way for aligning the high-field magnet R&D efforts at the four leading US magnet laboratories (Brookhaven, Fermilab, Berkeley Lab and the National High Magnetic Field Laboratory) with the goals of the FCC study. An implementation plan for joint magnet R&D will be composed in the near future. Discussions with further US institutes and universities are ongoing, and within the coming months several other DOE laboratories should join the FCC collaboration. A first US demonstrator magnet could be ready as early as 2016.

Congressman Bill Foster told the audience: "never be shy in standing up for the unique nature of your field and never be afraid of big numbers". (Image credit: Bob Palmer, BNL.)

A total of 51 institutes have joined the FCC collaboration since February 2014, and the FCC study has been recognized by the European Commission (EC). Through the EuroCirCol project within the HORIZON2020 programme, the EC will fund R&D by 16 beneficiaries – including KEK in Japan – on the core components of the hadron collider. The four key themes addressed by EuroCirCol are the FCC-hh arc design (led by CEA Saclay), the interaction-region design (John Adams Institute), the cryo-beam-vacuum system (CELLS consortium), and the high-field magnet design (CERN). On the last day of the FCC week, the first meeting of the FCC International Collaboration was held. Leonid Rivkin was confirmed as chair of the board, with a mandate consistent with the production of the Conceptual Design Report, that is, to the end of 2018.

The next FCC Week will be held in Rome on 11–15 April 2016.

● The FCC Week in Washington was jointly organized by CERN and the US DOE, with support from the IEEE Council of Superconductivity. More than a third of the participants (120) came from the US. CERN (93), Germany (20), China (16), UK (16), Italy (12), France (11), Russia (11), Japan (10), Switzerland (10) and Spain (6) were also strongly represented. For further information, visit cern.ch/fccw2015.

NUCLEAR PHYSICS

First measurement of ionization potential casts light on 'last' actinide

The quest for new heavy chemical elements is the subject of intense research, as the synthesis and identification of these new elements fill up empty boxes in the familiar Periodic Table. The measurement of their properties for a proper classification in the table has proved challenging, because the isotopes of these elements are short-lived and new methods must be devised to cope with synthesis rates that yield only one atom at a time. Now, an international team led by researchers from the Japanese Atomic Energy Agency (JAEA) in Tokai has developed an elegant experimental strategy to measure the first ionization potential of the heaviest actinide, lawrencium (atomic number, $Z = 103$).

Using a new surface ion source (figure 1) and a mass-separated beam, the team's measurement of 4.96±0.08 eV – published recently in *Nature* (Sato *et al*. 2015) – agrees perfectly with state-of-the-art quantum chemical calculations that include relativistic effects, which play an increasingly important role in this region of the Periodic Table. The result confirms the extremely low binding energy of the outermost valence electron in this element, therefore confirming its position as the last element in the actinide series. This is in line with the concept of heavier homologues of the lanthanide rare earths, which was introduced by Glenn Seaborg in the 1940s.

In the investigations at JAEA the researchers have exploited the isotope-separation online (ISOL) technique, which has been used for nuclear-physics studies at CERN's ISOLDE facility since the 1960s (*CERN Courier* December 2004 p16). The technique has now been adapted to perform ionization studies with the one-atom-at-a-time rates that are accessible for studies of lawrencium. A new surface-ion source was developed and calibrated with a series of lanthanide isotopes of known ionization potentials. The ionization probability of the mass-separated

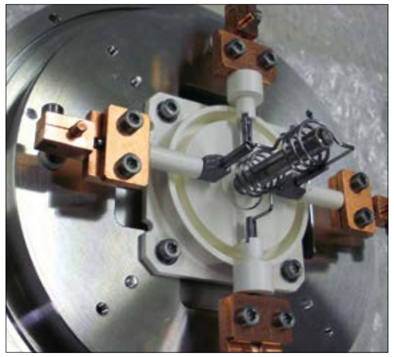


Fig. 1. The newly developed surface ion source (the grey tantalum tube in the centre of the photo surrounded by two heating filaments) installed in the JAEA-ISOL system at the JAEA Tandem accelerator. (Image credit: JAEA.)

▷

lawrencium could then be exploited to determine its ionization potential using the calibration master curve.

The special position of lawrencium in the Periodic Table has placed the element at the focus of questions on the influence of relativistic effects, and the determination of properties to confirm its position as the last actinide. The two aspects most frequently addressed have concerned its ground-state electronic configuration and the value of its first ionization potential.

Relativistic effects strongly affect the electron configurations of the heaviest elements. In the actinides, the relativistic expansion of the 5f orbital contributes to the actinide contraction – the regular decrease in the ionic radii with increasing Z. Together with direct relativistic effects on the 7s and $7p_{1/2}$ orbitals, this influences the binding energies of valence electrons and the energetic ordering of the electron configurations. However, it is difficult to measure the energy levels of the heaviest actinides with $Z > 100$ by a spectroscopic method because these elements are not available in a weighable amount.

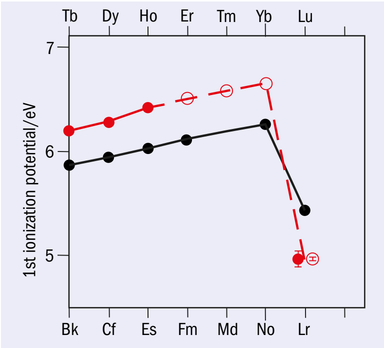
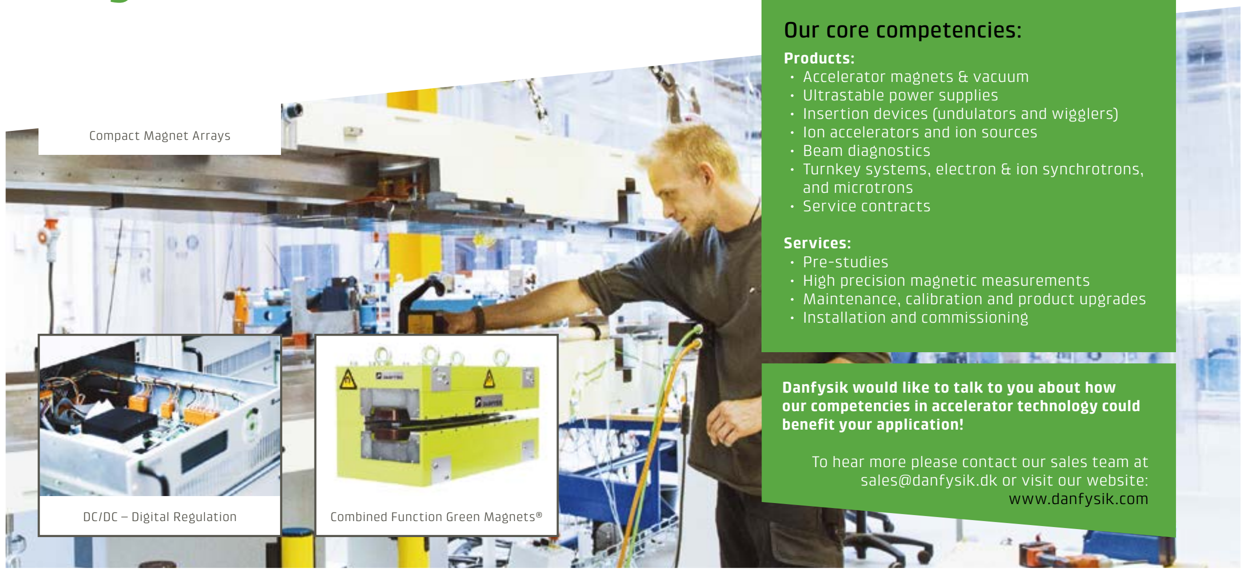


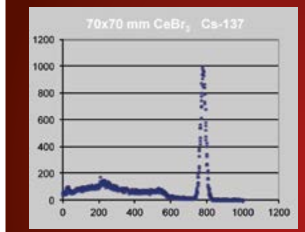
Fig. 2. The ionization potential of heavy lanthanides (black symbols) and actinides (red symbols), including the new results for lawrencium (Lr). Closed and open symbols indicate experimental and estimated values, respectively. The experimental and theoretical values for lawrencium are in excellent agreement.

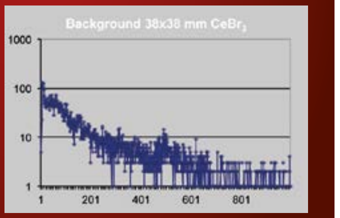
The ground-state electronic configuration of lawrencium (Lr) is expected to be $[Rn]5f^{14}7s^27p_{1/2}$. This is different from that of its homologue in the lanthanide series, lutetium, which is $[Xe]4f^{14}6s^25d$. The reason for this change is the stabilization by strong relativistic effects of the $7p_{1/2}$ orbital of Lr below the 6d orbital. Lr, therefore, is anticipated to be the first element with a $7p_{1/2}$ orbital in its electronic ground state. As the measurement of the ionization potential directly reflects the binding energy of a valence electron under the influence of relativistic effects, its experimental determination provides direct information on the energetics of the electronic orbitals of Lr, including relativistic effects, and a test for modern theories. However, this measurement cannot answer questions about the electronic configuration itself. Nevertheless, as figure 2 shows, the experimental result is in excellent agreement with a new theoretical calculation that includes these effects and favours the $[Rn]5f^{14}7s^27p_{1/2}$ ground-state configuration.

● Further reading

T K Sato *et al.* 2015 *Nature* **520** 166.







Sciencewatch

Compiled by John Swain, Northeastern University

Ethiopian fossil pushes back the origin of Homo genus

Happy news for scientists, but a bad time for opponents of evolution. A 2.8-million-year-old jawbone found in Ethiopia pushes back the origins of the human species and fills a gap in the fossil record. Brian Villmoare of the University of Nevada, Las Vegas, and colleagues report in the journal *Science* on a fossil from the Afar region in Ethiopia. The fossil was found by graduate student Chalachew Seyoum, sticking out of sand and mudstone at the remote site of Ledi-Geraru.


This partial lower jaw from Ethiopia is the oldest example of the genus Homo. *(Image credit: Kaye Reed.)*

The fossil not only has key features of the genus *Homo*, but also has primitive traits seen in *Australopithecus afarensis*, a human ancestor that lived 3–4 million years ago. This is the oldest bone from the *Homo* genus and pushes human origins back 400,000 years.

● **Further reading**
A Gibbons 2015 *Science* **347** 1056.
B Villmoare *et al.* 2015 *Science* **347** 1352.

Record entanglement

For a new record in entanglement, Robert McCornell of Massachusetts Institute of Technology and colleagues put a cloud of 3100 laser-cooled and polarized ^{87}Rb atoms between two weakly transmitting mirrors and sent in polarized photons. These bounced back and forth around 5000 times before passing through one of the mirrors, allowing the polarization of one of the photons to be measured. If it had rotated, this indicated that the atoms could have become entangled.

Most photons came out with their polarizations unrotated, but when they were rotated, the group could rotate the overall atomic polarization and confirm that the atoms had indeed been entangled. More precisely, the researchers reconstructed a negative-valued Wigner function, clearly indicating non-classicality, and verified an entanglement depth (the minimum number of mutually entangled atoms) of 2910±190 out of 3100 atoms. Remarkably, this entanglement was produced by a single photon.

● **Further reading**
R McConnell *et al.* 2015 *Nature* **519** 439.

Eyelash length explained

The reason for eyelashes now has a good explanation, which even accounts for why they are as long as they are. David Hu and colleagues of the Georgia Institute of Technology found that 22 species of mammals have eyelashes that are one third the width of the eye. Eyelashes create a protective stagnation zone that reduces the air blowing onto the eye, an effect that increases with length until the eyelashes start to channel air flow towards the eye. Scaling theory, numerical simulations and wind-tunnel experiments confirm the ratio of one third as optimal, blocking airborne particles from blowing into the eye and slowing the evaporation of tear film by a factor of two.

● **Further reading**
G J Amador *et al.* 2015 *J. R. Soc. Interface* **12** 20141294.

Origin of life

Researchers may have found the key to the origin of life on Earth. Three critical types of biomolecules seem to be needed to get things started: nucleic acids, amino acids and lipids. John Sutherland and colleagues at the MRC Laboratory of Molecular Biology, Cambridge, have now identified a common chemistry that could lead to these ingredients.

Hydrogen cyanide (HCN) and hydrogen sulphide (H$_2$S) should have been present on the young Earth, the latter having been common and the former being abundant in comets that could bring it in, or produce it from hydrogen, carbon and nitrogen during their frequent collisions with the young planet. In the presence of ultraviolet light and metal catalysts that could be provided by minerals, these two simple molecules form precursors to all three types of molecule needed. So the recipe for primordial soup may have needed only two ingredients, both of which could have been present in abundance when the Earth was young.

● **Further reading**
B H Patel *et al.* 2015 *Nature Chemistry* **7** 301.

Dragonfly colour vision


One of the 12 species: Indolestes peregrinus. *(Image credit: Alpsdake.)*

Humans have three distinct colour receptors – opsins – in their eyes, covering red, green, and blue. Most animals are di-, tri- or tetra-chromatic, but Ryo Futahashi of the National Institute of Advanced Industrial Science and Technology in Tsukuba and colleagues have found that dragonflies go far beyond this. Among 12 dragonfly species, none had fewer than 11 opsin genes and some, amazingly, as many as 30, covering the human visual spectrum and extending into the ultraviolet.

● **Further reading**
R Futahashi *et al.* 2015 *Proc. Nat. Acad. Sci.*, 10.1073/pnas.1424670112.

Cousins closer than daughters

The usual laws of inheritance would suggest that mothers and daughters would be more similar then cousins, but, surprisingly, this is not the case – even under tightly controlled conditions with single cells undergoing repeated divisions.

Oded Sandler and colleagues at the Hebrew University in Jerusalem studied mammalian lymphoblast cells, and used time-lapse microscopy to look at the time they took between divisions. As expected, strong correlations were found between sister cells, but negligible ones between mothers and daughters, and weak correlations between grandmothers and granddaughters. However, they found surprisingly strong correlations between cousins. Detailed analysis of the data suggests that an unidentified cellular oscillator, which controls doubling times, effectively "skips a generation". Whether anything similar extends to multicellular organisms is still an open question.

● **Further reading**
O Sandler *et al.* 2015 *Nature* **519** 468.

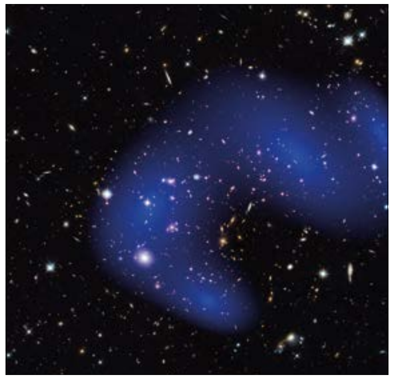
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva, and CHIPP, University of Zurich

Dark-matter self-interactions are weak

Astronomers using observations from the NASA/ESA Hubble Space Telescope and NASA's Chandra X-ray Observatory have studied how dark matter in clusters of galaxies behaves when the clusters collide. The results confirm the distinct existence of dark matter with high significance, and show that dark matter interacts with itself even less than thought previously.

Although there is more dark matter than visible matter in the universe, dark matter remains extremely elusive and is, most likely, in a form outside of the Standard Model of particle physics. Dark matter does not reflect, absorb or emit light, making it transparent. The presence of a massive clump of dark matter can be probed only by its gravitational distortion of space–time, which bends the light path in its vicinity. This weak gravitational-lensing effect distorts the shape of background galaxies, making it possible to infer the spatial distribution of dark matter (*CERN Courier* January/February 2007 p11).

Collisions between clusters of galaxies provide a way to estimate the interaction of dark matter with itself. The "bullet cluster" is a prime example of such a collision, showing that while the hot gas is slowed down by ram pressure, the motion of both the dark matter and galaxies seems to be unaltered by the event (*CERN Courier* October 2006 p9). It constraints the self-interaction cross-section of dark matter by unit mass to $\sigma_{DM}/m < 1.25\,cm^2/g$ (68% CL). To tighten this constraint further, a group of astronomers led by David Harvey – affiliated to both the École Polytechnique Fédérale de Lausanne (EPFL) and the University of Edinburgh – studied a sample of 72 mergers identified in 30 colliding systems, with archival observations by Hubble in the visible range and by Chandra in X-rays.



This Hubble image shows the complex distribution of galaxies and dark matter (overlaid in blue) in the colliding galaxy cluster MACS J0717.5+3745. (Image credit: NASA, ESA, D Harvey (EPFL), R Massey (Durham University), Harald Ebeling (University of Hawaii at Manoa) and Jean-Paul Kneib (LAM).)

The team determined the central position of the hot gas glowing in X-rays, the galaxies and dark matter in each of the 72 collisions. The researchers assume that the direction of motion is given by the line connecting the location of the gas and of the galaxies, and then measure the position of the dark-matter component, both parallel and perpendicular to this direction. The latter serves as a check, and is found to be consistent with zero on average, as expected. Along the line of motion, the distribution of the offsets between dark matter and gas is found to be inconsistent (at 7.6σ) with the hypothesis that dark matter does not exist, i.e. that all of the cluster's mass – except only about 3% in the form of stars in galaxies – is co-spatial with the hot gas. This rules out dark-matter alternatives such as modified Newtonian dynamics (MOND).

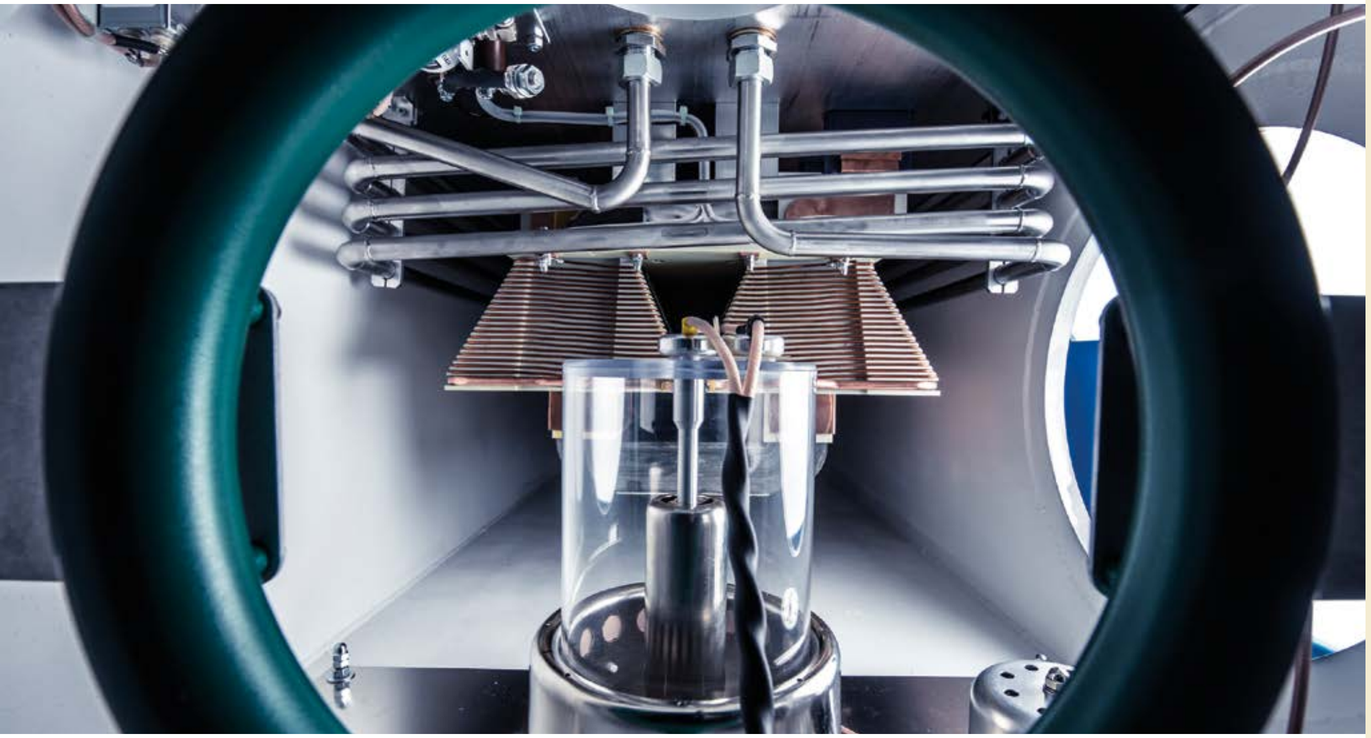
More interestingly, the ratio of dark matter and gas offsets from galaxies is a dimensionless measure of the drag force acting on dark matter. The authors of the study measured an average value of -0.04 ± 0.07 (68% CL), which they translate to an upper limit of $\sigma_{DM}/m < 0.47\,cm^2/g$ (95% CL) on the momentum transfer cross-section of dark matter. They note that this result rules out parts of the hidden-sector dark-matter models that predict $\sigma_{DM}/m = 1$ barn/GeV $= 0.6\,cm^2/g$, which is similar to nuclear cross-sections in the Standard Model. Such a high coupling in the dark sector would not have been in conflict with the orders-of-magnitude lower coupling between dark matter and Standard Model particles, which is at most in the order of picobarns.

● Further reading

D Harvey *et al.* 2015 *Science* **347** 1462.

Picture of the month

This amazing view of the Sun's corona was taken during the total solar eclipse of 20 March 2015. While clouds prevented the view of the partial eclipse in many European countries, beautiful but freezing weather rewarded intrepid eclipse chasers, who made the trip to the Arctic archipelago of Svalbard, Norway. Miloslav Druckmüller and colleagues were among them to take this unusual view, which is actually a composite of 29 images taken with different exposure times to balance the contrast over four orders of magnitude in brightness. The resulting image renders in detail the loops and streams of solar wind emanating from the outer solar atmosphere. It also shows solar prominences in pink, and even structures on the dark side of the Moon faintly illuminated by sunlight reflected from the Earth. (Image credit: Miloslav Druckmüller, Shadia Habbal, Peter Aniol, Pavel Starha.)



CERN Courier Archive: 1972

A look back to CERN Courier vol. 12, May 1972, compiled by Peggie Rimmer

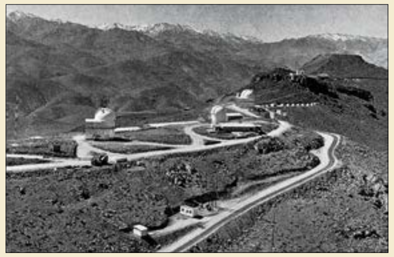
ESO

Progress of telescope project

The European Southern Observatory (ESO) is a joint enterprise of European astronomers to establish facilities beyond the reach of individual research centres. The aim is to study the sky in the southern hemisphere, which has not yet been subjected to such close scrutiny as the northern sky.

An observatory has been in action since 1967 on La Silla mountain, 600 km north of Santiago in Chile, with viewing conditions among the best in the world. The astronomers have been using a battery of small telescopes, and await the arrival of a large optical telescope with a mirror diameter of 3.6 m. This project is on a scale considerably larger than the small ESO organization is used to, and in 1970 ESO entered into an agreement with CERN to design and construct the telescope.

The major task of the past two years has been to complete the detailed design of the telescope and its building. The present schedule calls for assembly of the telescope in Europe early in 1975 and, if all goes well, it should move to La Silla at the end of that year and come into use in 1976.



The ESO observatory in the Atacama desert, Chile. Near the top right-hand corner is the flattened summit where the 3.6 m telescope will be erected.

- Compiled from texts on pp159–160.

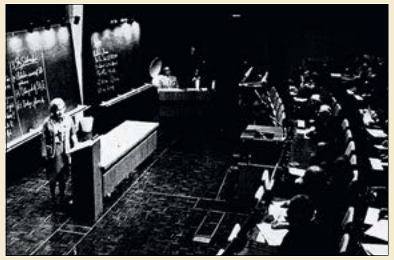
CERN NEWS

Telescope conference

From 2 to 5 May, about 180 scientists, predominantly astronomers, came to CERN for the ESO/CERN Conference on Auxiliary Instrumentation for Large Telescopes.

Many of the telescope projects in the 3 to 4 m range have matured to the point where attention needs to turn to instrumentation, to foresee the likely requirements of research programmes in a few years' time and the technical developments needed to meet them.

Most of the conference concentrated on spectrographic methods, but to make good observations on many astronomical features currently of interest, detectors with much higher efficiencies than photographic plates will be needed. Already, devices are under development in Europe and the US, such as image tubes (with the phosphor scanned in less than the decay time of the effect of the incoming light, and integration over long times) and tiny diode arrays (with light input converted directly to electronic information). It seems inevitable, although in many ways sad, that astronomers will soon be observing the universe via computer output.



Professor Margaret Burbidge, director of the Royal Greenwich Observatory, giving the introductory lecture at the conference on auxiliary instrumentation for large telescopes. (Image credit: CERN 149.5.72.)

- Compiled from texts on p165.

BROOKHAVEN

Mystery of the missing neutrinos

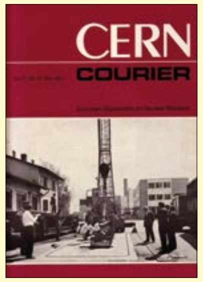
Started in 1968, the Brookhaven solar-neutrino experiment involves an imaginative alliance of physics and chemistry to catch neutrinos coming from the Sun. A measure of the neutrino rate indicates whether our ideas about fusion interactions going on in the heart of the Sun are correct. The latest results, reported at the Washington meeting of the American Physical Society on 26 April, suggest that so far our ideas are wrong.

The neutrino detector is a huge tank of perchloroethylene (a common dry-cleaning solvent, 80% chlorine) about 1.5 km down the Homestake Gold Mine in South Dakota, where only neutrinos can be expected to penetrate. Neutrinos interacting with chlorine produce argon-37, $Cl^{37} + \nu \rightarrow A^{37} + e$, which is radioactive with a half-life of 35 days. After collecting neutrinos for about 100 days, the liquid is purged with helium gas to pick up the argon atoms whose decays are counted with a small proportional counter.

The detection sensitivity has been improved since the early days, but the measured neutrino flux is still a factor of 10 below theoretical expectations. If our ideas on the source of solar neutrinos are correct, two neutrinos per day should be captured – the measured rate is less than 0.2. No convincing explanation for this observation has yet been put forward.

- Compiled from texts on pp173–174.

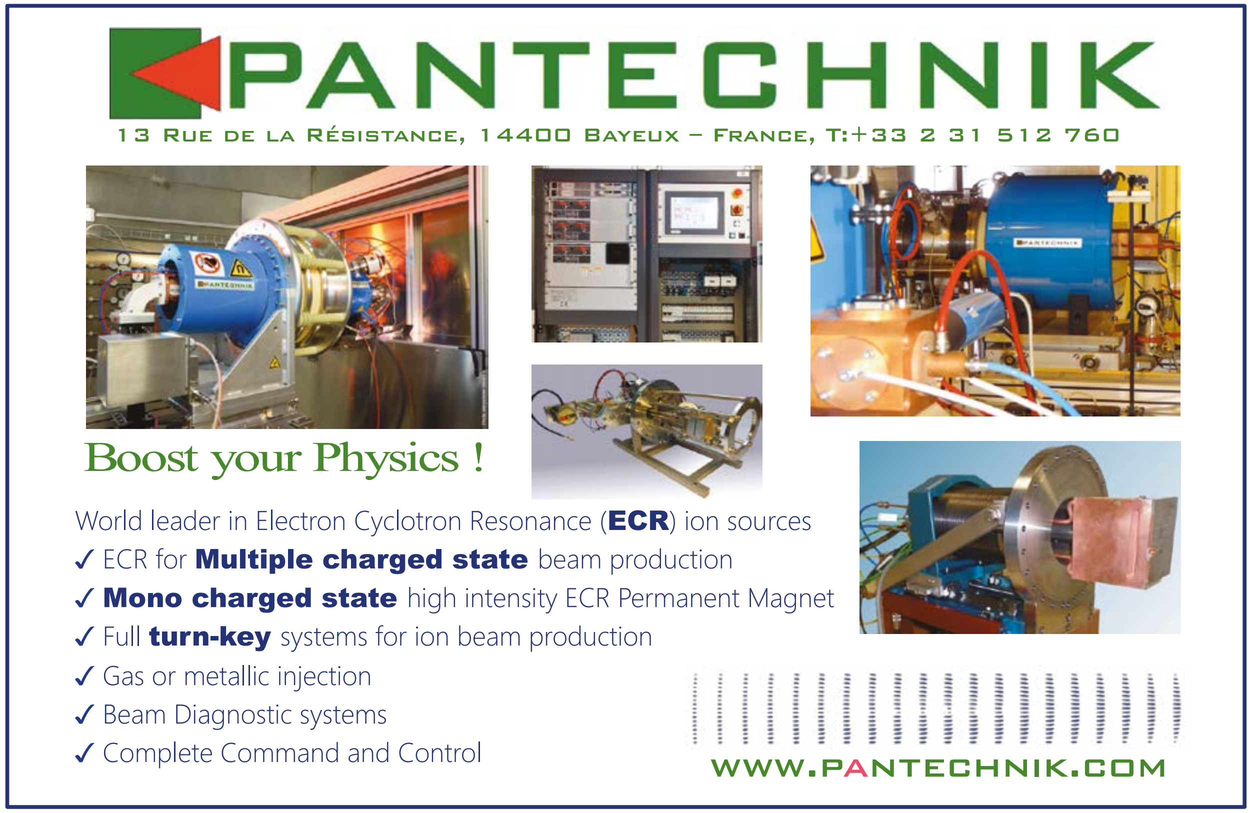
Compiler's Note



Margaret Burbidge was the first female director of the Royal Greenwich Observatory. Next year, CERN will have its first female director-general, Fabiola Gianotti.

We now know that those missing solar neutrinos had made a flavour-changing journey to Earth, but particle astrophysicists still face many mysteries.

The latest and largest telescope installed in the high and dry Chilean desert is the Atacama Large Millimeter/submillimeter Array, inaugurated in March 2013. ALMA, built by ESO in collaboration with US and Japanese partners, consists of 66 high-precision antennas, spread across distances of up to 16 km, at an altitude of 5000 m (*CERN Courier* October 2007 p23). It is already providing stunning images of unprecedented resolution (*CERN Courier* January/February 2015 p15).



Aerial view of the NSLS-II synchrotron radiation facility. (All image credits: Brookhaven National Laboratory.)

Brookhaven ushers in a new bright era

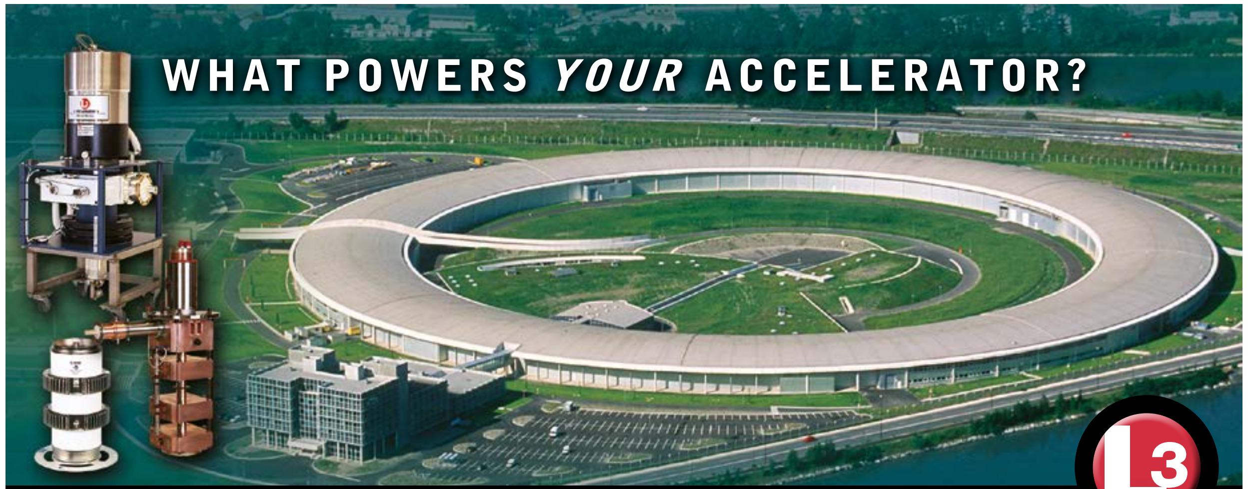
The National Synchrotron Light Source II will offer up to 10,000 times the brightness of its predecessor and host more than 60 beamlines.

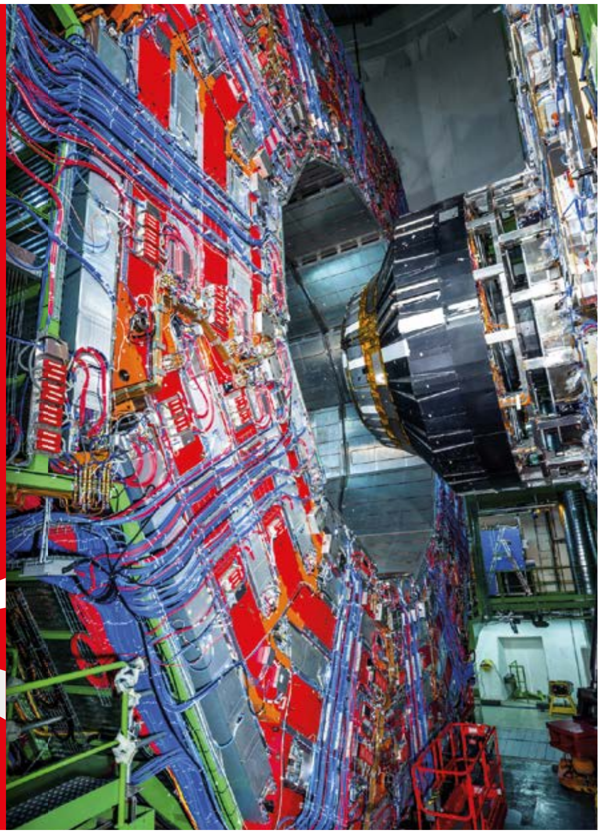
INTERNATIONAL YEAR OF LIGHT 2015

An era came to an end on 30 September 2014, when the National Synchrotron Light Source (NSLS) ended its last run and dumped its last beam after more than 30 years of operation at Brookhaven National Laboratory. NSLS was the first of the modern synchrotron light sources, and had an enormous impact on synchrotron-light-based science during the past decades. It contributed a wealth of pioneering scientific results, including work that resulted in two Nobel prizes. The following day, 1 October, a new era began for Brookhaven, with the start-up of the new facility, NSLS-II, which is designed to provide the brightest beams ever produced by a synchrotron light source.

The mission for a follow-up to NSLS was to provide a factor of 10 more flux and up to four orders of magnitude more brightness relative to the earlier machine (where brightness is defined as the number of photons per second divided by the beam cross-section and the divergence at the emission points, integrated over a narrow bandwidth of 1%). It was to be capable of achieving energy resolution of a fraction of a milli-electron-volt and spatial resolution on the nanometre scale. This ambition was acknowledged in 2005, when NSLS-II received CD-0, the first of five "critical decisions" for the construction of any new science facility funded by the US Department of Energy (DOE). The new light source was to enable novel science opportunities in all fields of synchrotron-radiation-based science, and would allow experiments that were not possible at any of the other facilities at that time. The project went swiftly through the design and R&D phase with critical decisions CD-1 and CD-2, and in June 2009 CD-3 was approved, allowing construction of the facility to begin.

The NSLS-II electron storage ring consists of 30 double-bend achromates (DBA) separated by 15 long (9.3 m) and 15 short (6.6 m) straight sections for insertion devices, which are the source of ultra-bright synchrotron radiation. The ring is designed for a beam energy of 3 GeV. To achieve the desired high brightness based on a horizontal beam emittance of $\varepsilon_x = 0.8\,\pi$ nrad m, it has a large circumference of 792 m. The bending magnets are fairly long (2.69 m) and weak (0.4 T). These design choices have two ▷






View of a double-bend achromate cell in the accelerator tunnel.


One of six damping wigglers, used to reduce beam emittance.

advantages. They allow the design of a stable lattice with a beam emittance close to the DBA minimum emittance, and at the same time, the synchrotron-radiation power of photons emitted in the bending magnets is fairly moderate (283 keV per turn per electron). This allows an efficient doubling of the radiation-damping rate, and therefore a reduction of the beam emittance by a factor of two, by the use of six 3.4-m-long damping wigglers with a peak field of 1.85 T.

NSLS-II has a conventional system of electromagnets for bending, focusing and nonlinear corrections. However, the field quality of these magnets is pushed beyond what has been achieved previously ($\Delta B/B = 10^{-5} - 10^{-4}$ at $r = 25$ mm). Further, the alignment of the magnetic centres with respect to each other is held to unprecedentedly small tolerances with rms values of less than 10 μm.

The other critical parameter for high-brightness performance is the beam current of 500 mA. High beam current is obtained with an accelerating structure based on two single-cell 500-MHz superconducting cavities of the type known as CESR-B. This RF system offers advantages for beam stability because the structures exhibit weak parasitic RF modes and are superior for suppressing beam-loading effects.

In addition, beyond-state-of-the-art instrumentation is required to control the orbital stability of the beam with its small beam sizes ($\sigma_y = 3$ μm at the insertion devices). Therefore, both a novel beam-position monitor system with a resolution and stability of less than 200 nm and a fast orbit-feedback system have been designed and implemented. These will limit the motion of the beam orbit to within 10% of the (vertical) beam size for frequencies up to 1 kHz.

The vacuum system is made of extruded, keyhole-shaped aluminium. The antechamber houses two non-evaporable getter strips for distributed pumping. The girder system is designed for high thermal stability and to avoid amplification of mechanical vibrations below 30 Hz.

All of the electronics and power supplies are located on the tunnel roof and are housed in sealed air-cooled racks, protecting the sensitive equipment from dust, temperature fluctuations, humidity and leaking cooling water. This protection is a major element of the strategy to achieve high operational reliability for the more than 1000 magnet power supplies, the beam-position monitors, controls and vacuum-control equipment. The facility aims for a reliability greater than 95% once its operation is matured fully.

The NSLS-II injector consists of a 200-MeV S-band linac, which feeds the 3-GeV combined-function booster synchrotron for on-energy injection in "top-off" mode, where frequent injection maintains the beam current. The booster synchrotron was designed and built by the Budker Institute of Nuclear Physics in Novosibirsk, and installed in collaboration with NSLS-II staff (*CERN Courier* October 2014 p10).

The civil construction with the accelerator tunnels and the ring-shaped experimental floor was completed in 2012. Installation of the accelerator components, which started in 2011, was completed in 2013.

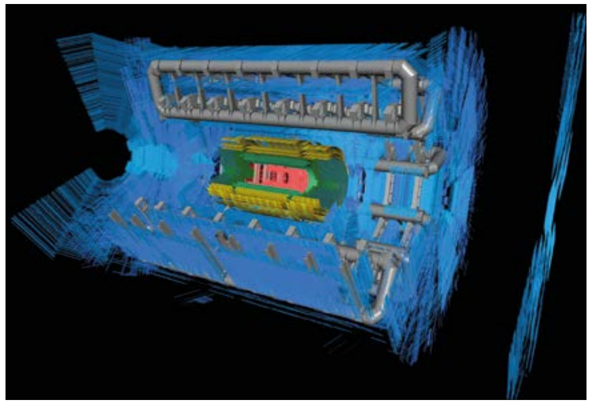
The commissioning of the linac was already possible in April 2012 and the commissioning of the booster synchrotron followed in December 2013. Storage-ring commissioning took place soon after, in April 2014. The commissioning time for the entire complex was remarkably short, the superb robustness and reproducibility of the machine being demonstrated by the fact that restarts are possible only a few hours after shutdowns.

The summer of 2014 saw the installation of the first NSLS-II insertion devices. Three pairs of 3.4-m-long damping wigglers with peak fields of 1.85 T not only provide a factor of two in emittance reduction by enhanced radiation damping, they are also powerful sources (195 kW at a beam current of 500 mA) of photons up to energies of 100 keV. The workhorses of NSLS-II are in-vacuum undulators with a period of 20–23 mm and an extremely small gap height of 5 mm. Four such devices up to 3 m in length are part of the initial installation. There is also a pair of 2-m-long elliptical polarizing undulators (EPUs). The insertion devices were commissioned with their corresponding front-end systems during autumn 2014.

The construction of NSLS-II within budget and to schedule is the result of excellent teamwork.

An initial suite of six beamlines is also part of the scope of the NSLS-II project. These beamlines are based ▷

One of the four in-vacuum undulators – the workhorses of NSLS-II.



First light seen at the CSX beamline.

on state-of-the-art – or beyond – beamline technology. They cover a range of synchrotron-light experimental techniques, including powder diffraction (XPD), coherent hard X-ray scattering (CHX), nano-focus imaging (HNX), inelastic X-ray scattering with extreme energy resolution < 1 meV (IXS), X-ray spectroscopy (SRX) and coherent soft X-ray scattering (CSX). All of these beamlines have started technical commissioning. The first light emitted by the NSLS-II EPU was observed on 23 October in the CSX beamline, followed by similar events for the other beamlines.

At the same time that the science commissioning of the existing beamlines at NSLSI-II is taking place, nine further insertion-device beamlines are under construction. The first three, known as the ABBIX beamlines, are scheduled to start up in the spring of 2016. They are specialized for biological research. The other six insertion-device beamlines – the so-called "NEXT" beamlines – are planned to start up the following autumn. Finally, there is an ongoing programme that consists of reusing NSLS equipment and integrating it into five new beamlines (NxtGen) that will receive bending-magnet radiation. As the field of the NSLS-II dipole magnets is weak, some of the source points are equipped with a wavelength-shifter consisting of a three-pole wiggler with 1.2 T peak field.

A number of non-Brookhaven institutions have responded positively to the opportunity to work with NSLS-II, and they will develop five additional beamlines in collaboration with NSLS-II staff. Therefore by 2018, NSLS-II will run with 27 beamlines and will have recovered from the reduction in the scientific programme between the shutdown of NSLS and the development period of the NSLS-II user facility. In its final configuration, the NSLS-II facility will host more than 60 beamlines.

The construction of NSLS-II within budget ($912 million) and to schedule is the result of excellent teamwork between scientists, engineers and technicians. In a ceremony on 6 February, the US secretary of energy, Ernest Moniz, dedicated the new facility (*CERN Courier* April 2015 p31). The first science results from NSLS-II were reported as early as March (Wang *et al.* 2015), and the science programme will start for most beamlines in the summer. The bright future of the NSLS-II era has begun.

● NSLS-II was constructed under DOE contract No. DE-AC02-98CH10886. For further information, visit www.bnl.gov/ps/nsls2/about-NSLS-II.php.

● Further reading

K Wang *et al.* 2015 *Applied Physics Letters – Materials* **3** 041513.

Résumé

Un avenir brillant à Brookhaven

*Une page s'est tournée, le 30 septembre 2014, quand la source nationale de lumière synchrotron (*National Synchrotron Light Source, *NSLS) est arrivée à la fin de sa dernière exploitation et que son dernier faisceau a été arrêté, après plus de 30 ans d'exploitation de l'accélérateur, au Laboratoire national de Brookhaven (États-Unis). Le lendemain, 1er octobre, Brookhaven est entré dans une nouvelle ère avec le démarrage de sa nouvelle installation, la NSLS-II. Conçue pour fournir les faisceaux les plus brillants jamais produits par une source de lumière synchrotron – jusqu'à 10 000 fois plus brillants que dans l'installation précédente – elle accueillera plus de 60 lignes de faisceaux, et pourra fournir une résolution spatiale de l'ordre du nanomètre.*

Ferdinand Willeke, Brookhaven National Laboratory.

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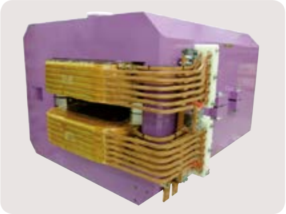

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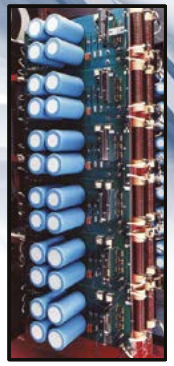

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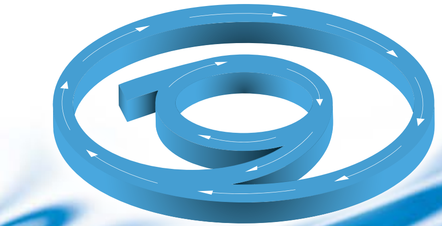

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Chronicles of CMS: the saga of LS1

As the CMS experiment gets going again, **Austin Ball** looks back at the vast amount of work done during LS1 and some of the challenges that arose along the way.

For the past two years, teams from the CMS collaboration, many from distant countries, have been hard at work at LHC point 5 at Cessy in France. Their goal – to ensure that the CMS detector will be able to handle the improved performance of the LHC when it starts operations at higher energy and luminosity. More than 60,000 visitors to the CMS underground experimental cavern during the first long shutdown (LS1) witnessed scenes of intense and spectacular activity – from movements of the 1500-tonne endcap modules to the installation of the delicate pixel tracker, only the size of a portable toolbox but containing almost 70-million active sensors.

This endeavour involved planning for a huge programme of work (*CERN Courier* April 2013 p17). Since LS1 began, more than 1000 separate work packages have been carried out, ranging from the repairs and maintenance required after three years of operation during the LHC's Run 1, through consolidation work for a long-term future, to the installation of completely new detector systems as well as the extension of existing ones. In addition to the many CMS teams involved, the programme relied on the strong general support and substantial direct contributions from physics and technical departments at CERN. This article, by no means exhaustive, aims to provide some insight into LS1 as it happened at point 5.

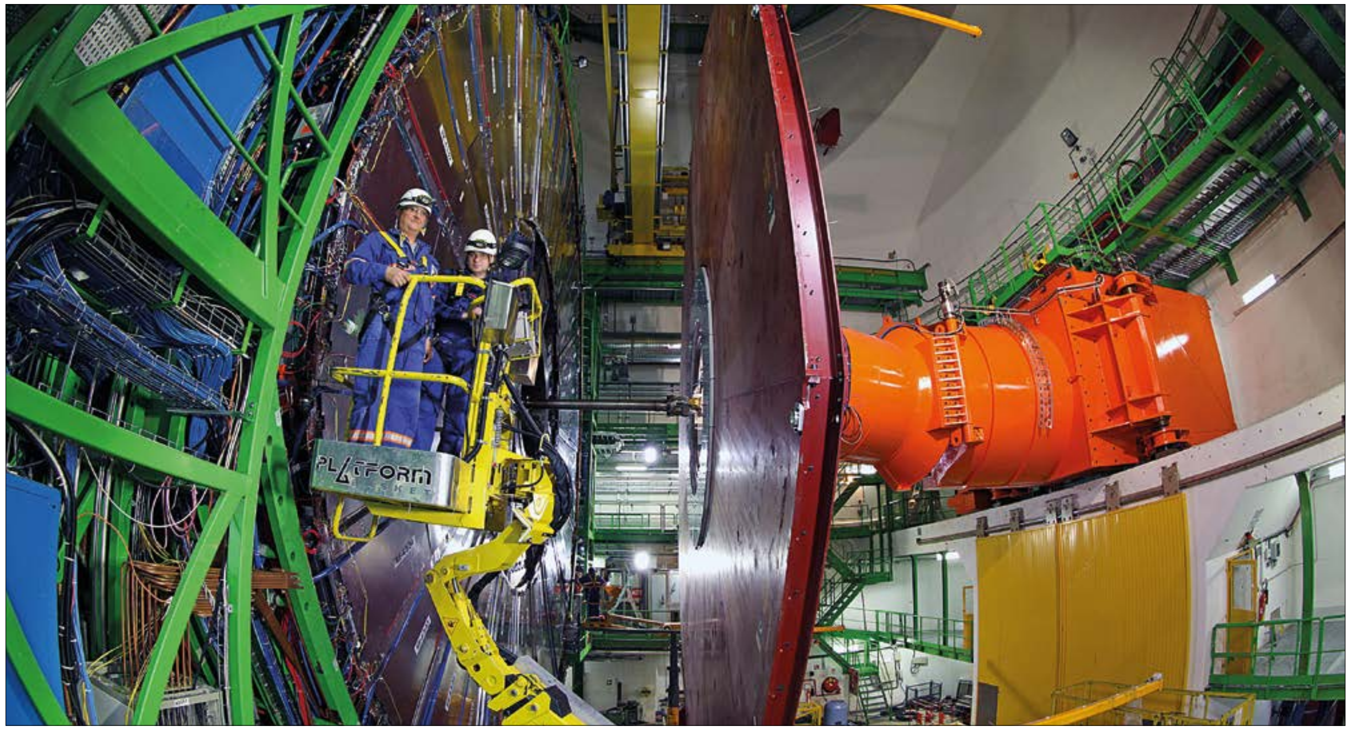


Fig. 1. The new YE4 disc, pushed back from the parent YE3, showing parts of the new fourth endcap muon station. (Image credits: Michael Hoch.)

An early start

Vital contributions started as early as 2009, well before LS1 began. One example is the refurbishment by CERN's General Services and Physics Departments of building 904 on the Prévessin site, to provide 2000 m^2 of detector-assembly laboratories, which were used for the new parts of the muon detector. Another is the creation by CMS (mainly through contracts managed by CERN's Engineering Department) of the Operational Support Centre in the surface-assembly building at point 5. This centre incorporates work areas for all of the CMS systems that had to be brought to the surface during LS1, and includes a cold-storage, cold-maintenance facility where the pixel tracker was kept until the new beampipe was fitted. There is also a workshop area suitable for modifying elements activated by collision products, which, as the LS1 story progressed, provided useful flexibility for dealing with unexpected work.

The highest-priority objective for CMS during LS1 was to operate the tracker cold. The silicon sensors of this innermost subdetector, which surrounds the LHC beampipe, must endure more than 10^9 particles a second passing through it, and cannot be completely replaced until about a decade from now. The damaging effects of this particle flux, sustained over many years of operation, can be mitigated by operating the sensor system at a temperature that is 20–30 °C lower than the few degrees above zero used so far. Alongside modifications to allow delivery of the coolant at much lower temperatures, a new system of humidity control had to be introduced to prevent condensation and icing. This involved sealing the tracker envelope, while making provision for a flow of up to 400 m^3/h of dry gas. The system installed by CMS is a novel one at CERN: it dries air and then optionally removes oxygen via filtering membranes. The first full-scale tests took place at the end of 2013, and there was great satisfaction when an operating temperature of –20 °C was achieved stably.

However, as one challenge faded, a new one emerged immediately. On warming up, tell-tale drips of water were visible coming from the insulated bundles of pipework carrying the coolant into the detector – indication that air at room temperature and humidity had been reaching the cold pipes inside the system and forming ice. Fortunately, tests soon showed that an additional flow of dry air, injected separately into the pipework bundles, would suppress this problem. Responding to CMS's request for help, the Engineering Department recently delivered a new dry-air plant that will make humidity suppression in the cooling distribution feasible on a routine basis, with a comfortable margin in capacity.

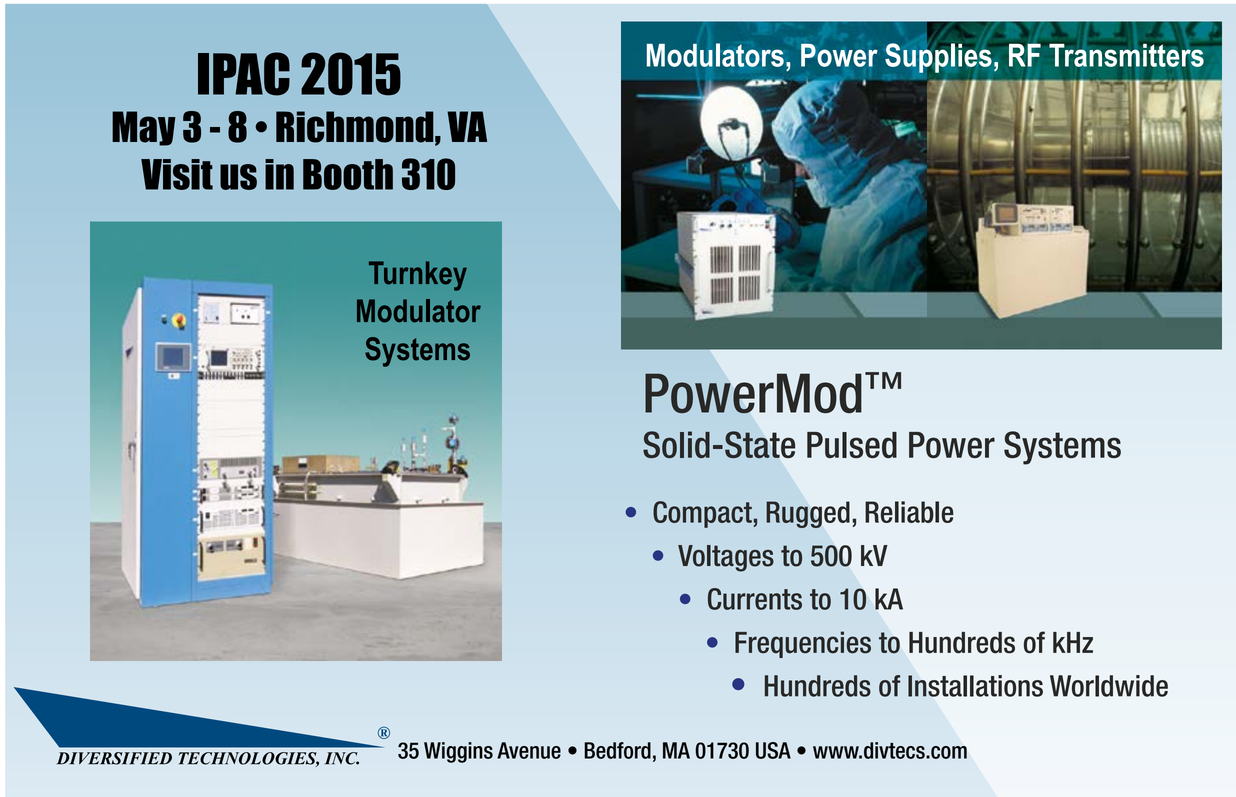
Another high-priority project for LS1 involved the muon detectors. A fourth triggering and measurement station in each of the endcaps was incorporated into the original CMS design, but it was not considered essential for initial operation. These stations are now needed to increase the power to discriminate between interesting low-momentum muons originating from the collision (e.g. potentially from a Higgs-boson decay) and fake muon signatures caused by backgrounds. Seventy-two new cathode-strip chambers (CSCs) and 144 new resistive-plate chambers (RPCs) were assembled across a three-year period by a typical CMS multinational team from institutes in Belgium, Bulgaria, China, Colombia, Egypt, Georgia, India, Italy, Korea, Mexico, Pakistan, Russia and the US, as well as from CERN. They were then installed as superposed layers of CSCs and RPCs on the two existing discs at the ends of the steel yoke that forms the structural backbone of CMS. Teams worked on the installation and commissioning in two major bursts of activity, matching the periods when the required detector configuration was available, and completing the job in late spring 2014.

A further improvement of the endcap muon system was achieved by installing new on-chamber electronics boards in the first, innermost layer of the CSCs to withstand the higher luminosity, while reusing the older electronics in one of the new fourth layers, where it is easier to cope with the collision rate. Here again, the unexpected had to be dealt with. One of the two layers had just been re-installed after months of re-fitting work, when tests revealed a potential instability caused by the accidental omission of a tiny passive electronic component. It was considered significantly risky to leave this uncorrected, so the installation teams had to go into full reverse. Working late into the evenings and at weekends to avoid interfering with previously scheduled activities, they partially extracted all 36 chambers, corrected the fault, put them back in place and re-commissioned them.

No part of the detector escaped the attention of the upgrade and maintenance teams. The modular structure of CMS, which can be separated into 13 major slices, was fully exploited to allow simultaneous activity, with as many as eight mobile work platforms frequently in use to give access to different slices and different parts of their 14 m diameter. Multiple maintenance interventions on the five barrel-yoke wheels restored the number of working channels to 99.7% – a figure not seen since 2009, just after installation. Similar interventions on the CSC and RPC stations on the endcap disks were also successful, with the few per cent that had degraded over the past few years restored completely. In addition, to improve maintainability, some key on-board electronics from the barrel part of the muon system was moved from the underground experimental cavern to the neighbouring service cavern, where it will now remain accessible during LHC operation. All of the photo-transducers and much of the on-detector electronics of the hadron calorimeter (HCAL) are to be replaced over the next few years, and a substantial part of this work was completed during LS1. In particular, photo-transducers of a new type were installed in the outer barrel and forward parts of the sytem, which will lead to an immediate improvement in performance.

The need for some work streams was completely unforeseen until revealed by routine inspection. The most notable example was the discovery of a charred feed-through connector serving the environmental-screen heaters of one of the two preshower systems for the electromagnetic calorimeter (ECAL). Full diagnosis (under-rated capacitors) and subsequent repair of both preshower systems required their removal to the surface, where a semi-clean lab was created at short notice within the Operational Support Centre. The repairs and re-installation were a complete success, and the preshower system has been re-commissioned recently at its planned operating temperature of –8 °C.

The CMS consolidation programme had also to prepare the infrastructure of the experiment – originally designed for a 10-year operating lifetime – for running well into the 2030s. LHC operating periods lasting around three years will be interleaved ▷



with substantial shutdowns of one to two years in length. Moreover, the rate of proton–proton collisions will be five times higher, and the integrated number of collisions (ultimately) 10 times higher, than the original design goal.

Key adaptations were made during LS1 to address redundancy in the power and cryogenics systems, to extend the predicted lifetime of the one-of-a-kind CMS magnet. Further measures for protection against power glitches were implemented through an extension of the detector's short-term uninterruptible power supply. Changes to the detector cooling included modifications for greater capacity and redundancy, as well as the addition of a new system in preparation for the upcoming upgrade of the pixel tracker, based on two-phase (evaporating liquid) carbon dioxide. This technology, new for CMS, involved the installation of precision-built concentric vacuum-insulated feed and return lines – difficult-to-modify structures that have to be made extremely accurately to ensure proper integration with the constricted channels that feed services into the apparatus. These changes presented challenges for the CMS Integration Office, where the "compact" in CMS was defended vigorously every day in computer models and then in the caverns.

New detectors were not the only large-scale additions to CMS. The most massive change to the structure of the experiment was the addition of the new 125-tonne shielding discs – yoke endcap disc four (YE4) – installed outside of the fourth endcap muon station at either end of the detector. Each shielding disc, 14 m in diameter but only 125 mm thick, was made of 12 iron sector casings. Following manufacture and pre-assembly tests in Pakistan, these discs, whose design and preparation took five years, were disassembled for shipping to CERN and then re-assembled on the Meyrin site, where they were filled with a special dense (haemetite) shielding concrete, mixed for this specific application by CERN's civil engineers. Loaded with a small percentage of boron, this concoction will act as a "sponge" to soak up many of the low-energy neutrons that give unwanted hits in the detector, and whose numbers will increase as the LHC beam intensities get higher.

The YE4 discs, transported in sectors to point 5, were the first slices of CMS to be assembled underground – all of the existing major elements had been pre-assembled on the surface and lowered into the underground cavern in sequence (*CERN Courier* July/August 2006 p28). In the original concept, the YE4 discs could be separated from the supporting YE3 only by driving the whole endcap system back to the cavern headwall, where YE4 could be unhooked and supported. Because all of the other slices of the CMS "swiss roll" can be displaced from one another to give access to the detectors sandwiched in between, it was decided late in the project – in fact, after assembly had already started – to equip each YE4 shielding disc with air pads and a system of electric screw-jacks. This would allow the YE4 disc to separate from the supporting neighbour disc (YE3) by up to 3.7 m without the necessity to move it to the headwall – a major operation. In fact, one so-called "push-back system" was used immediately after assembly of the YE4 disc, to permit installation of RPCs with the endcaps partially closed. This maintained the rapid-access modularity that was a core feature of the CMS design (*CERN Courier* October 2008 p48).

Mobile phones began to buzz with reports of the first indications of a severe fault.


Fig. 2. CMS ready to close, showing the beampipe and the extensive new environmental seal.

The final change was at the heart of CMS, in preparation for the installation during the LHC's year-end technical stop of 2016–2017 of an upgraded pixel tracker – the closest physics detector to the collision point. The 0.8-mm-thick central beampipe used during Run 1, with an outer diameter of 59.6 mm, was replaced by a similar one of 45-mm outer diameter and, like the first one, made of beryllium, to be as transparent as possible to particles emanating from the LHC collisions. The narrower beampipe will allow the first layer of the new pixel tracker to be closer to the collision point than before. This geometrical improvement, combined with an additional fourth layer of sensors, will upgrade the tracker's ability to resolve where a charged particle originated. When running under conditions of high pile-up in Run 2 and Run 3 – that is, with many more protons colliding every time counter-rotating bunches meet at the centre of CMS – the disentangling of which tracks belong to which collision vertices will be crucial for most physics analyses.

The delicate operations of removing and replacing the beampipe – requiring the detector to be open fully – are possible only in a long shutdown. The new beampipe, designed jointly with CERN's Technology Department, which procured and prepared it on behalf of CMS, was installed in June 2014. Its installation was followed immediately by vacuum pumping, combined with heating ("bake-out") to more than 200 °C, to expel gas molecules attached to the chamber walls. This ensured that the operating pressure of around 10^{-10} mbar would be possible – and achieved eventually. Following the bake-out of the new central beampipe, several mechanical tests were made to ensure that the upgraded pixel tracker can be installed in the limited time window that will be available in 2016–2017.

It is probable that a proverb exists in every language and culture involved in CMS, warning against relaxing before the job is finished. In mid-August 2014, the end of the LS1 project seemed to be on the horizon. The beampipe bake-out was being completed and preparations for the pixel tracker's re-installation were underway, so many team members took the opportunity for a quick summer holiday. Then, their mobile phones began to buzz with reports of the first indications of a severe fault found in pre-installation tests of the barrel pixel system, which had been removed only to allow the change of beampipe. About 25% (around 50) of the modules in one ▷

quadrant were not responding. By the end of August, the half-shell containing the faulty quadrant had been transported to its makers at the Paul Scherrer Institute (PSI) for detailed investigation.

On 5 September, the diagnostics revealed that the reason for failure was electro-migration-induced shorts between adjacent bond pads of the high-density interconnect – a flexible, complex, multilayer printed circuit used to extract the signals. An investigation showed that the most likely origin was a brief and inadvertent lapse in humidity-control protocols in the course of routine calibration exercises many months earlier, when the pixel system was up in the surface laboratory. By 18 September, a comprehensive strategy of replacement and repair had been worked out by the PSI team. Because this required purchasing new components and restarting the production of detector modules, the revised schedule foresaw the detector being back at CERN by the end of November, with installation planned for around 8 December, almost exactly two months later than intended originally.

A new end game

At this late stage, with insufficient contingency remaining in the baseline schedule to accommodate the delay, it was decided to change radically the end-game sequence of the shutdown. Instead of waiting for the repair of the pixel tracker, CMS was closed immediately to conduct a short magnet-test, to identify any problems that otherwise would not have appeared until the final closure for beam. After finishing the remaining work on the bulkhead seal that allows the tracker to be operated cold, this sequence of closing the detector, testing the magnet and then re-opening CMS became the critical path for two months, with the remaining upgrade activity being postponed or re-arranged around the new schedule. The new sequence implied unexpected tight deadlines for several teams – particularly those working on the magnet and the forward region – and a massive extra workload for the heavy-engineering team. The additional closing and opening sequence required 36 single movements of heavy discs, and 16 insertions and removals of the heavy-raiser platforms that support the forward calorimeters at beam height. A concerted and exceptional effort resulted in the magnet yoke being closed by mid-October, and both forward regions being closed and ready for magnetic field by 6 November.

The following day, the magnet was ramped to 1 T and then discharged. This sequence allowed yoke elements to settle, and also verified that the control and safety systems performed as expected. By 10 November, enough liquid helium had been accumulated for 36 hours of operation at full field, and the test programme resumed. However, at 2.4 T, the main elevator providing underground access stopped working, owing to some field-sensitive floor-level sensors having been installed mistakenly during routine maintenance. After reducing the field temporarily to allow personnel to leave the underground areas, the ramp-up continued, reaching the working value of 3.8 T at around 7.00 p.m., demonstrating that the magnet's upgraded power and cryogenics system worked well. Despite the rapid endcap-yoke closure with only approximate axial alignment, the movements under the magnetic forces of the endcap discs (including the new YE4s) and the forward systems were well within the ranges observed previously, although specific movements occurred at different field values. The new beampipe support system and the new phototransducers of the HCAL and beam-halo monitors were shown to be tolerant to the magnetic field. Most importantly, the environmental seal around the tracker and the new dry-gas injection system functioned well enough in the magnetic field to allow tracker operation at –20 °C. The top-priority task of LS1 could therefore be declared a success.


Fig. 3. The barrel pixel tracker being re-installed around the beampipe, December 2014.

Following this, the opening of the detector was a race against time to meet the target of installing the barrel and forward pixel trackers, and enclosing them in a stable environment before CERN's 2014 end-of-year closure. This was achieved successfully, providing a fortuitous "dry run" of what will have to be done during the year-end stop of 2016–2017, when the new pixel tracker will be installed. Following a thorough check and pre-calibration of the pixel system, the last new elements of CMS in the LS1 project – upgraded beam monitors and the innovative pixel luminosity telescope (*CERN Courier* March 2015 p6) – were installed by the end of the first week of February 2015.

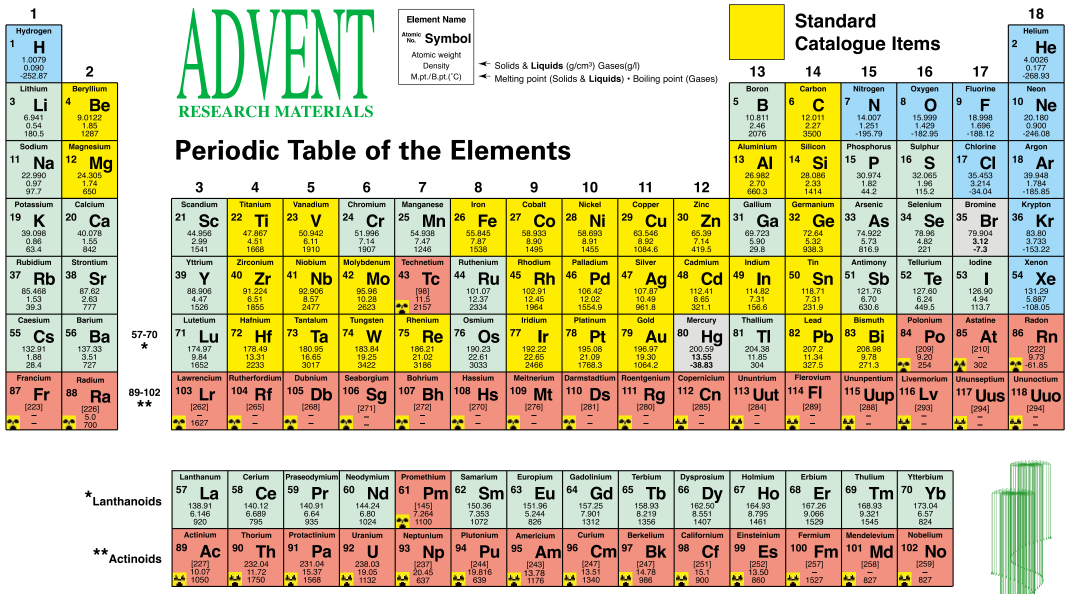
The closing of the experiment, just in time for first beam in 2015, brought the saga of LS1 to a happy ending. It is time to celebrate with the collaboration teams, contractors and CERN technical groups, who have all contributed to the successful outcome. The imminent start of Run 2 now raises the exciting prospect of new physics, but behind the scenes preparations for the next CMS shut-down adventure have already begun.

Résumé

Chroniques de CMS : la saga du LS1

Depuis deux ans, des équipes de la collaboration CMS, dont beaucoup viennent de pays lointains, travaillent avec acharnement au point 5 à Cessy. Leur mission ? Faire en sorte que le détecteur CMS puisse fonctionner avec la performance améliorée du LHC, quand celui-ci redémarrera à une énergie et une luminosité plus élevées. Une activité intense et spectaculaire a été déployée pour y parvenir : notamment déplacement des modules des bouchons de 1 500 tonnes, et installation du fragile trajectographe à pixels. Dans cet article, Austin Ball évoque l'immense volume de travaux réalisés pendant l'arrêt du LHC et certains des défis qui se sont présentés pendant cette aventure.

Austin Ball, for the CMS Technical Co-ordination team.



ALICE: from LS1 to readiness for Run 2

For ALICE, LS1 has been a time of intense installation, consolidation and upgrade work, with interventions that touched almost all of the sub-detectors and online systems.

It is nearly two years since the beams in the LHC were switched off and Long Shutdown 1 (LS1) began. Since then, a myriad of scientists and engineers have been repairing and consolidating the accelerator and the experiments for running at the unprecedented energy of 13 TeV (or 6.5 TeV/beam) – almost twice that of 2012.

In terms of installation work, ALICE is now complete. The remaining five super modules of the transition radiation detector (TRD), which were missing in Run 1, have been produced and installed. At the same time, the low-voltage distribution system for the TRD was re-worked to eliminate intermittent overheating problems that were experienced during the previous operational phase. On the read-out side, the data transmission over the optical links was upgraded to double the throughput to 4 GB/s. The TRD pre-trigger system used in Run 1 – a separate, minimum-bias trigger derived from the ALICE veto (V0) and start-counter (T0) detectors – was replaced by a new, ultrafast (425 ns) level-0 trigger featuring a complete veto and "busy" logic within the ALICE central trigger processor (CTP). This implementation required the relocation of racks hosting the V0 and T0 front-end cards to reduce cable delays to the CTP, together with optimization of the V0 front-end firmware for faster generation of time hits in minimum-bias triggers.

The ALICE electromagnetic calorimeter system was augmented with the installation of eight (six full-size and two one-third-size) super modules of the brand new dijet calorimeter (DCal). This now sits back-to-back with the existing electromagnetic calorimeter (EMCal), and brings the total azimuthal calorimeter coverage to 174° – that is, 107° (EMCal) plus 67° (DCal). One module of the photon spectrometer calorimeter (PHOS) was added to the pre-existing three modules and equipped with one charged-particle veto (CPV) detector module. The CPV is based on multiwire proportional chambers with pad read-out, and is designed to suppress the detection of charged hadrons in the PHOS calorimeter.

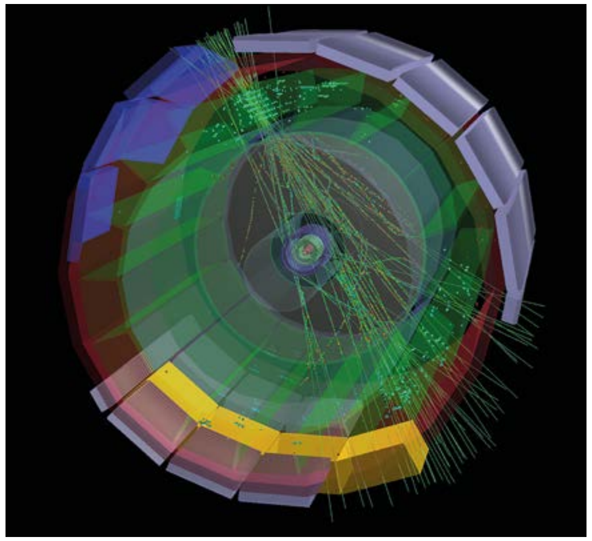
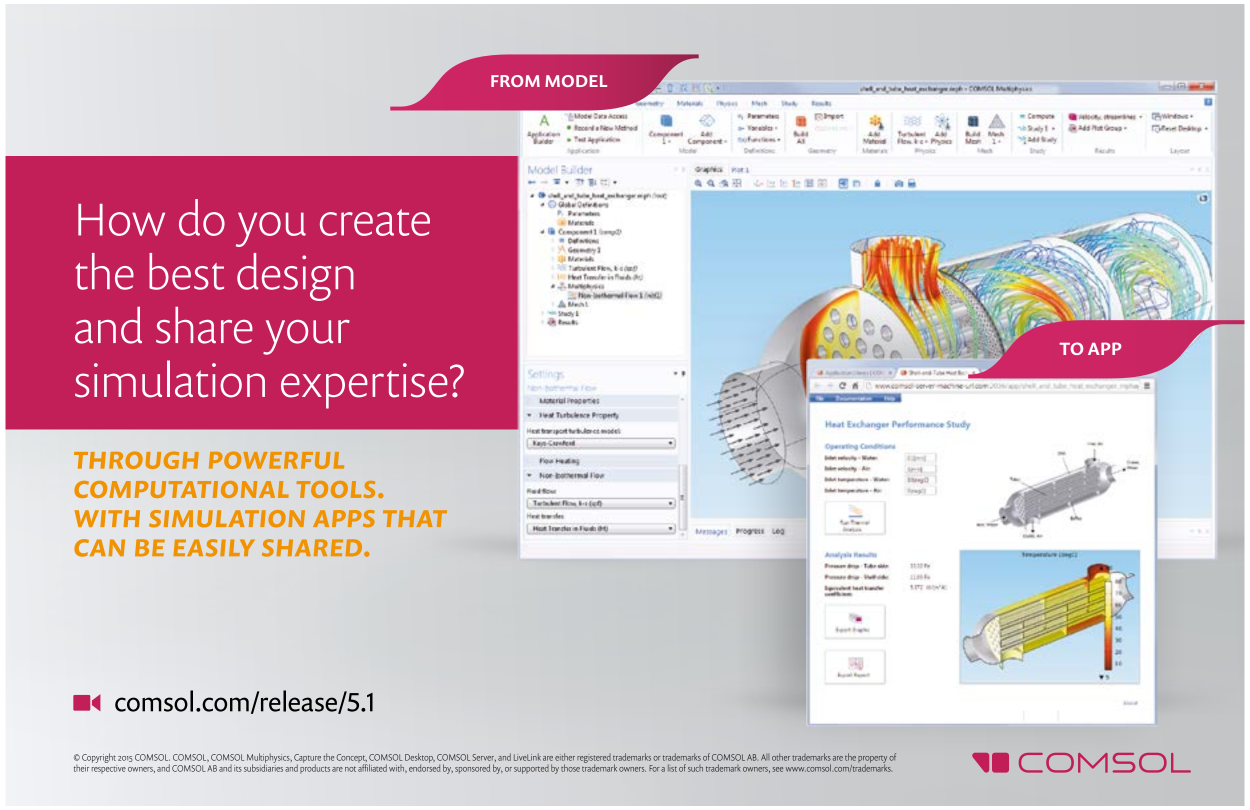


Fig. 1. An event display from the completed ALICE detector with full TRD azimuthal coverage, one extra PHOS module and the EMCal/Dcal electromagnetic calorimeter system. The event shows a high-energy cosmic muon developing a particle shower within the TRD and TPC volumes. The event was reconstructed online during the re-commissioning campaign this year. (Image credit: Jeremi Niedziela.)

The overall PHOS/DCal set-up is located in the bottom part of the ALICE detector, and is now held in place by a completely new support structure. During LS1, the read-out electronics of the three calorimeters was fully upgraded from serial to parallel links, to allow operation at a 48 kHz lead–lead interaction rate with a minimum-bias trigger. The PHOS level-0 and level-1 trigger electronics was also upgraded, the latter being interfaced with the neighbouring DCal modules. This will allow the DCal/PHOS system to be used as a single calorimeter able to produce both shower and jet triggers from its full acceptance. ▷

The remaining five super modules of the transition radiation detector have been produced and installed.



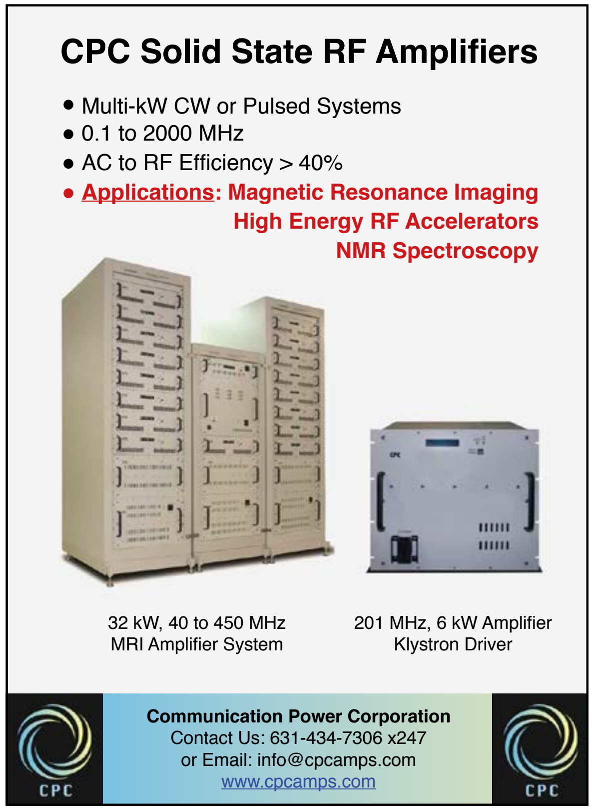



Fig. 2. The new ALICE Run Control Centre at point 2. (Image credit: Federico Ronchetti.)

The gas mixture of the ALICE time-projection chamber (TPC) was changed from Ne(90):CO_2(10) to Ar(90):CO_2(10), to allow for a more stable response to the high particle fluxes generated during proton–lead and lead–lead running without significant degradation of momentum resolution at the lowest transverse momenta. The read-out electronics for the TPC chambers was fully redesigned, doubling the data lines and introducing more field-programmable gate-array (FPGA) capacity for faster processing and online noise removal. One of the 18 TPC sectors (on one side) is already instrumented with a pre-production series of the new read-out cards, to allow for commissioning before operation with the first proton beams in Run 2. The remaining boards are being produced and will be installed on the TPC during the first LHC Technical Stop (TS1). The increased read-out speed will be exploited fully during the four weeks of lead collisions foreseen for mid November 2015. For lead running, ALICE will operate mainly with minimum-bias triggers at a collision rate of 8 kHz or higher, which will produce a track load in the TPC equivalent to operation at 700 kHz in proton running.

LS1 has also seen the design and installation of a new subsystem – the ALICE diffractive (AD) detector. This consists of two double layers of scintillation counters placed far from the interaction region on both sides, one in the ALICE cavern (at z = 16 m) and one in the LHC tunnel (at z = –19 m). The AD photomultiplier tubes are all accessible from the ALICE cavern, and the collected light is transported via clear optical fibres.

The ALICE muon chambers (MCH) underwent a major hardware consolidation of the low-voltage system in which the bus bars were fully re-soldered to minimize the effects of spurious chamber occupancies. The muon trigger (MTR) gas-distribution system was switched to closed-loop operation, and the gas inlet and outlet "beaks" were replaced with flexible material to avoid cracking from mechanical stress. One of the MTR resistive-plate chambers was instrumented with a pre-production front-end card being developed for the upgrade programme in LS2.

The increased read-out rates of the TPC and TRD have been matched by a complete upgrade (replacement) of both the data-acquisition (DAQ) and high-level trigger (HLT) computer clusters. In addition, the DAQ and HLT read-out/receiver cards have been redesigned, and now feature higher-density parallel optical connectivity on a PCIe-bus interface and a common FPGA design. The ALICE CTP board was also fully redesigned to double the number of trigger classes (logic combinations of primary inputs from trigger detectors) from 50 to 100, and to handle the new, faster level-0 trigger architecture developed to increase the efficiency of the TRD minimum-bias inspection.

Regarding data-taking operations, a full optimization of the DAQ and HLT sequences was performed with the aim of maximizing the running efficiency. All of the detector-initialization procedures were analysed to identify and eliminate bottlenecks, to speed up the start- and end-of-run phases. In addition, an in-run recovery protocol was implemented on both the DAQ/HLT/CTP and the detector sides to allow, in case of hiccups, on-the-fly front-end resets and reconfiguration without the need to stop the ongoing run. The ALICE HLT software framework was in turn modified to discard any possible incomplete events originating during online detector recovery. At the detector level, the leakage of "busy time" between the central barrel and muon-arm read-out detectors has been minimized by implementing multievent buffers on the shared trigger detectors. In addition, the central barrel and the muon-arm triggers can now be paused independently to allow for the execution of the in-run recovery.

Towards routine running

The ALICE control room was renovated completely during LS1, with the removal of the internal walls to create an ergonomic open space with 29 universal workstations. Desks in the front rows face 11 extra-large-format LED screens displaying the LHC and ALICE controls and status. They are reserved for the shift crew and the run-co-ordination team. Four concentric lateral rows of desks are reserved for the work of detector experts. The new ALICE Run Control Centre also includes an access ramp for personnel with reduced mobility. In addition, there are three large windows – one of which can be transformed into a semi-transparent, back-lit touchscreen – for the best visitor experience with minimal disturbance to the ALICE operators.

The increased read-out speed will be exploited fully during the lead collisions foreseen in mid November.

Following the detector installations and interventions on almost all of the components of the hardware, electronics, and supporting systems, the ALICE teams began an early integration campaign at the end of 2014, allowing the ▷

ALICE detector to start routine cosmic running with most of the central-barrel detectors by the end of December. The first weeks of 2015 have seen intensive work on performing track alignment of the central-barrel detectors using cosmic muons under different magnetic-field settings. Hence, ALICE's solenoid magnet has also been extensively tested – together with the dipole magnet in the muon arm – after almost two years of inactivity. Various special runs, such as TPC and TRD krypton calibrations, have been performed, producing a spectacular 5 PB of raw data in a single week, and providing a challenging stress test for the online systems.

The ALICE detector is located at point 2 of the LHC, and the end of the TI2 transfer line – which injects beam 1 (the clockwise beam) into the LHC from the Super Proton Synchrotron (SPS) – is 300 m from the interaction region. This set-up implies additional vacuum equipment and protection collimators close (80 m) to the ALICE cavern, which are a potential source of background interactions. The LHC teams have refurbished most of these components during LS1 to improve the background conditions during proton operations in Run 2.

ALICE took data during the injection tests in early March when beam from the SPS was injected into the LHC and dumped half way along the ring (*CERN Courier* April 2015 p5). The tests also produced so-called beam-splash events on the SPS beam dump and the TI2 collimator, which were used by ALICE to perform the time alignment for the trigger detectors and to calibrate the beam-monitoring system. The splash events were recorded using all of the ALICE detectors that could be operated safely in such conditions, including the muon arm.

The LHC sector tests mark the beginning of Run 2. The ALICE collaboration plans to exploit fully the first weeks of LHC running with proton collisions at a luminosity of about 10^{31} Hz/cm^2. The aim will be to collect rare triggers and switch to a different trigger strategy (an optimized balance of minimum bias and rare triggers) when the LHC finally moves to operation with a proton bunch separation of 25 ns.

Control of ALICE's operating luminosity during the 25 ns phase will be challenging, because the experiment has to operate with very intense beam currents but relatively low luminosity in the interaction region. This requires using online systems to monitor the luminous beam region continuously, to control its transverse size and ensure proper feedback to the LHC operators. At the same time, optimized trigger algorithms will be employed to reduce the fraction of pile-up events in the detector.

The higher energy of proton collisions of Run 2 will result in a significant increase in the cross-sections for hard probes, and the long-awaited first lead–lead run after LS1 will see ALICE operating at a luminosity of 10^{27} Hz/cm^2. However, the ALICE collaboration is already looking into the future with its upgrade plans for LS2, focusing on physics channels that do not exhibit hardware trigger signatures in a high-multiplicity environment like that in lead–lead collisions. At the current event storage rate of 0.5 kHz, the foreseen boost of luminosity from the present 10^{27} Hz/cm^2 to more than 6×10^{27} Hz/cm^2 will increase the collected statistics by a factor of 100. This will require free-running data acquisition and storage of the full data stream to tape for offline analysis.

In this way, the LS2 upgrades will allow ALICE to exploit the full potential of the LHC for a complete characterization of quark–gluon plasma through measurements of unprecedented precision.

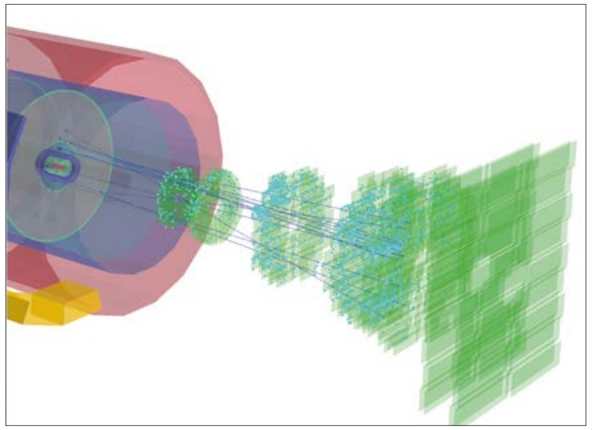


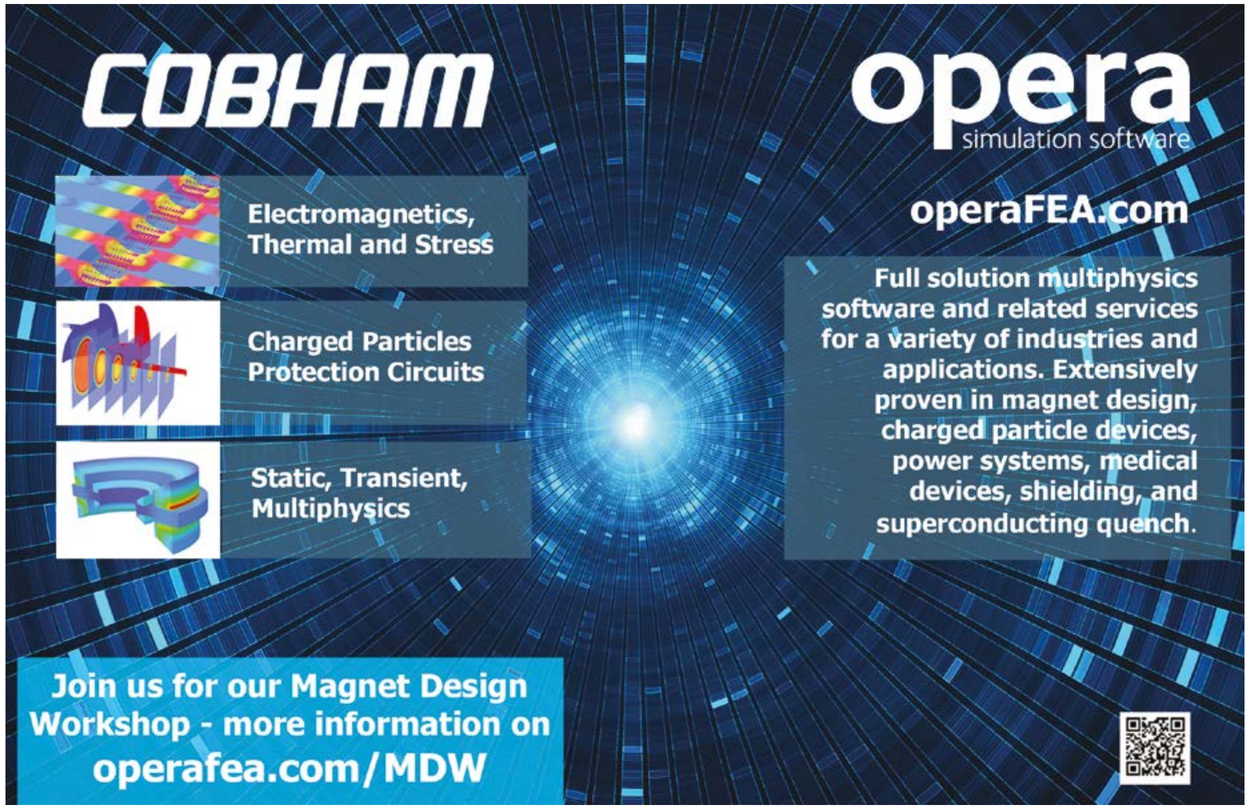
Fig. 3. A "splash" event (triggered by the T0 detector) as seen from the ALICE muon chambers. (Image credit: Philippe Pillot.)

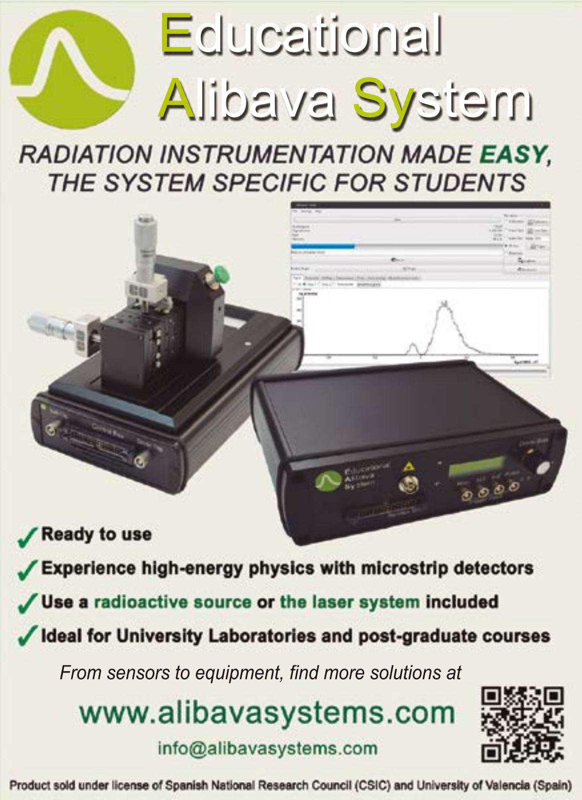
Résumé

ALICE : du LS1 à la deuxième période d'exploitation

Pour la collaboration ALICE, le LS1 a été marqué par d'importants travaux d'installation, de consolidation et d'amélioration, avec des interventions qui ont concerné pratiquement tous les sous-détecteurs et systèmes en ligne. Les travaux ont consisté notamment à installer de nouveaux sous-détecteurs et à compléter les sous-détecteurs existants, ainsi qu'à rénover entièrement la salle de contrôle. L'achèvement concluant du programme de travail a permis aux expériences de commencer fin 2014 l'acquisition de données avec des rayons cosmiques, puis avec des « éclaboussures de faisceaux » pendant les tests d'injection du LHC, en vue de la reprise de l'exploitation avec des collisions de plomb prévues pour plus tard, à mi-novembre.

Federico Ronchetti, INFN (Laboratori Nazionali di Frascati) and CERN, for the ALICE collaboration.





Faces & Places

CERN

Building 774: open for business

Left: The foundation stone for Building 774 was laid in a ceremony on 28 February 2013, attended by Stéphane Donnot, sub-prefect of Gex, Octavio Mestre and Francesco Soppelsa, the building's architects, and Sigurd Lettow, CERN's director of administration and general infrastructure. (Image credit: CERN-GE-1302044-01.) Right: Almost exactly two years later, the building was handed over to the Beams Department, to house the large Control group together for the first time. (Image credit: Francesco Soppelsa.)

In July 2012, the demolition of Building 936 on CERN's Prévessin site marked the start of the Building 774 project. Less than three years later, on 23 February, the new 3900-m² building was handed over to the Beams Department. The 120 occupants of the building have just moved into their new home, bringing all of the members of the department's Controls group into the same building for the first time. The location near to the CERN Control Centre (CCC) is a huge advantage for the members of the Controls group, who interact with the accelerator operators several times a day.

Building 774 contains offices, laboratories and meeting rooms, and a huge public area consisting of a 104-seat auditorium, a changing room/shower in the basement, and a cafeteria. Thanks to its public areas and reserved parking for buses and coaches, the building will become a pivotal location for welcoming visitors and dignitaries to the Prévessin site. The inauguration, planned for mid-May, will bring the project to a close.

AWARDS

ATLAS physicist wins L'Oréal–UNESCO Women in Science award

Award-winning woman in science: Rajaâ Cherkaoui El Moursli. (Image credit: Brigitte Lacombe.)

Rajaâ Cherkaoui El Moursli, vice-president of the Mohammed V University, Rabat, is one of the five laureates of the 2015 L'Oréal–UNESCO For Women in Science Awards. She has received the award "for her key contribution to one of the greatest discoveries in physics: proof of the existence of the Higgs boson, the particle responsible for the creation of mass in the universe".

El Moursli, who contributed to the simulation and construction of the electromagnetic calorimeter of the ATLAS experiment at the LHC, leads a group in Rabat working on the consolidation of a distributed-analysis support team (DAST) for ATLAS. DAST is a team of shifters forming the front line for all help requests on distributed data analysis. The focus of her team's analysis is on top-quark and Higgs-boson physics.

The award winners, selected from five different regions of the world, were recognized for their contributions to groundbreaking discoveries in the physical sciences, in a ceremony at the Sorbonne University in Paris on 18 March. El Moursli won the prize for Africa and the Arab States; inorganic chemist Yi Xie for Asia/Pacific; physical chemist Carol Robinson for Europe; astronomer Thaisa Storchi Bergmann for Latin America; and polymer chemist Molly Shoichet for North America.

● For an interview with El Moursli, visit atlas.ch/news/2015/atlas-physicist-wins-loreal-unesco-women-in-science-award.html.

At the 117th session of the JINR Scientific Council, held on 19–20 February, the prestigious international Bruno Pontecorvo Prize for 2014 was awarded to Grigory Domogatsky, right, of the Russian Academy of Sciences Institute for Nuclear Research, Moscow, for his outstanding contributions to high-energy neutrino astrophysics and neutrino astronomy, in particular, for pioneering the development of a method for detecting high-energy neutrinos using an underwater detector, and the construction of the experiment at Lake Baikal. The Bruno Pontecorvo prize was established at JINR in 1995 to commemorate the name of this important physicist. It is awarded annually by the international jury to scientists who have made a significant contribution to the field of elementary-particle physics. The award was presented by Victor Matveev, the director of JINR. (Image credit: JINR.)

Chalmers University honours Maria Borge

Maria José García Borge, spokesperson and leader of the ISOLDE physics group at CERN, is to receive an honorary doctorate from Chalmers University of Technology in Gothenburg, in a ceremony on 9 May. The award recognizes her "exceptionally strong merits within nuclear and atomic physics, in particular concerning experimental studies of exotic light subatomic systems, mainly her expertise within the field of β-delayed particle emission is world leading". Leader of the ISOLDE physics group at CERN since 2012, she is also research professor at the Consejo Superior de Investigaciones Cientificas, Madrid, and has collaborated closely with the researchers at Chalmers for decades.

Chalmers awards its honorary doctorates to people who have a strong relationship with the university, in recognition of a prominent professional performance associated with the university's areas of expertise. The awards for 2015 go also to Ludvig Strigeus and Martin Lorentzon for their work with the music service Spotify, computer-scientist Benjamin Pierce, and biotechnologist Jay D Keasling.

Maria José García Borge. (Image credit: CERN-PHOTO-201503-045-1.)

MEETING

The **13th International Conference on Heavy Ion Accelerator Technology** (HIAT2015) will be held at Yokohama, Japan, on 7–11 September. HIAT is an international conference dedicated to the design, construction, development and operation of heavy-ion accelerators and their components. It focuses on the operational experience of existing facilities, achievements in heavy-ion accelerator physics and technology, progress on the implementation of new projects and infrastructure upgrades, and trends in the proposal and design of heavy-ion accelerators as well as their main systems and components. For further information, visit www.nishina.riken.jp/hiat2015/.

SCHOOL

CLASHEP goes to Ecuador

The eighth CERN–Latin-American School of High-Energy Physics (CLASHEP) took place in the Hacienda Chorlavi, near Ibarra in Ecuador, on 4–17 March. A total of 69 students, of 19 different nationalities, followed an intense programme of lectures and discussion sessions. The teachers, from 11 different countries, also reflected the global nature of high-energy physics.

In addition to courses on numerous aspects of particle-physics theory, there were classes addressing experimental facilities and statistical techniques. By popular demand, some additional lectures were scheduled in optional after-dinner sessions. The students also presented and discussed their own research in an informal evening poster session, and worked on group projects.

Organizing the school was an important event for the host country, Ecuador, where discussions are going on with two universities, Escuela Politecnica Nacional (EPN), Quito, and Universidad San Francisco de Quito (USFQ), as well as with the national funding agency Secretaría de Educación Superior, Ciencia, Tecnología e Innovación (SENESCYT), towards a possible formal national and institutional involvement in the CMS experiment at CERN. This builds on the already existing effort at the level of individual Ecuadorian physicists.

The strong interest in particle physics was exemplified by high-level representation at the opening of the school, including Rina Pazos, general sub-secretary of SENESCYT, Jaime Calderon, rector of EPN, and Carlos Montufar, president of USFQ. Also present were Fernando Albericio, rector of Yachay Tech University, and Daniel Larson, chancellor of Yachay Tech University. This interest was also reflected in the visit to CERN of Ecuadorian president Rafael Correa Delgado in October 2014 (*CERN Courier* January/February 2015 p36).

Having a large number of eminent scientists as teachers at the school was an opportunity for the local organizers, led by Edgar Carrera from USFQ, to arrange associated outreach activities. These included four public lectures in Quito, with audiences of up to about 400, and one at Yachay. The school and associated activities were also covered in local, regional and national newspapers.

An important objective of the school, in addition to teaching the participants about particle physics and related disciplines, is to foster cultural exchange and networking between young researchers from different countries. With this end in mind, an effort was made to mix students from different countries in the discussion and project groups, and also in shared sleeping quarters.

In addition to the academic activities, the participants had the occasion to experience the natural beauty of Ecuador. Excursions included the spectacular volcanic Cuicocha lake, the tropical forest in the Seven Waterfalls reserve and the thermal springs at Chachimbiro, as well as the towns of Cotacachi, Ibarra and Otavalo.

● CERN is involved in organizing two off-site, residential schools of high-energy physics each year. The Latin-American events have been held in odd-numbered years since 2001, alternating with Asia-Europe-Pacific Schools in even-numbered years since 2012 (*CERN Courier* January/February 2015 p35). Schools have been organized annually in Europe since the early 1960s (*CERN Courier* June 2013 p27). For more information on the schools of physics, visit cern.ch/PhysicSchool/.

Left: Students participating in a discussion session at the school. (Image credit: EPN.) Right: John Iliopoulos discussing with students in an ad-hoc after-dinner session at the school. (Image credit: USFQ.)

CERN has received the award of Best Swiss Twitter Page 2015. Nicholas Muldoon, Agile coach at Twitter, selected CERN from a shortlist of 10 Twitter accounts, ranging from tourism to luxury brands to sports personalities. He says that he chose the @CERN account for a number of reasons, the most significant for him being "that @CERN is bringing people around the world into one of the greatest explorations of our universe, and doing it in a very social-media-savvy way". Muldoon presented the award to Kate Kahle, CERN's social-media manager, and James Gillies, CERN's head of communications, at the worldwebforum conference in Zurich on 10 March. (Image credit: CERN-PHOTO-201503-060-4.)

VISITS

As the LHC underground areas closed for the start of Run 2, CMS provided one place still available for visits. On 26 February, the Polish minister of foreign affairs, **Grzegorz Schetyna**, right, came to CERN. Before touring CMS, he met briefly with the president of CERN Council, Polish physicist **Agnieszka Zalewska**. (Image credit: CERN-PHOTO-201502-040-34.)

On the morning of 5 March, it was the turn of **Abul Hassan Mahmood Ali**, left, foreign minister, People's Republic of Bangladesh, to come to CERN. After meeting the director-general, **Rolf Heuer**, he went on to see CMS together with Emanuel Tsesmelis, CERN's adviser for the People's Republic of Bangladesh. (Image credit: CERN-PHOTO-201503-044-3.)

In the afternoon of 5 March, **Manuel González Sanz**, right, minister of foreign affairs and worship for the Republic of Costa Rica, visited CERN. During his time at the laboratory he also toured the CMS underground cavern together with the spokesperson, **Tiziano Camporesi**. (Image credit: CERN-PHOTO-201503-046-26.)

On 3 March, **Eladio Loizaga**, Paraguay's minister of external relations, visited CERN to sign a statement of intent between the government of the Republic of Paraguay and CERN. Following the signature, he visited the CMS experimental area at point 5 on the LHC. (Image credit: CERN-PHOTO-201503-043-4.)

One of the highest-ranking Buddhist masters, **His Holiness the XIIth Gyalwang Drukpa**, came to CERN on 17 March for the event "Science meets Buddhism: Great minds, great matters", at which he discussed the intersection of science, philosophy and spirituality with some of the laboratory's leading scientists. (Image credit: CERN-PHOTO-201503-054-1.)

OBITUARIES

Klaus Winter 1930–2015

Distinguished CERN physicist Klaus Winter passed away on 9 February, after a long illness.

Winter graduated from the university of his native Hamburg, before moving to Paris where, in 1958, he obtained his PhD in nuclear physics from the Collège de France under the supervision of Francis Perrin. It was then that he learnt to master his immaculate French, and also developed a deep interest in modern art, which would accompany him for the rest of his life.

In 1958, Winter joined the staff of CERN, where he remained for his entire career. His first experiment – a measurement of the lifetime of π^0 mesons at the Proton Synchrotron (PS) in the group of Guy von Dardel – became the subject of his "habilitation" in Hamburg in 1963. He was soon promoted to senior physicist and leader of a CERN research group. Shortly after the discovery of CP violation in 1964, he began measurements of the interference of the decays of K^0_L and K^0_S into two charged pions, and was one of the first to determine the phase of the CP asymmetry parameter, η_{+-}. Together with Marcel Vivargent, he subsequently led a precision experiment to test the $\Delta Q = \Delta S$ rule in semileptonic K^0 decays.

Soon after the Intersecting Storage Rings were commissioned in 1971, Winter's research shifted to the study of proton–proton collisions at the highest energies then attainable. Leading the CERN–Hamburg–Orsay–Vienna (CHOV) collaboration, his investigations focused on the study of elastic proton–proton scattering, diffraction dissociation and double pomeron exchange with the Split-Field Magnet facility.

When the Super Proton Synchrotron (SPS) came into operation in the late 1970s, Winter returned to weak-interaction physics and began to devote his career to the investigation of neutrinos – the least understood elementary particles at that time. First in a long series of measurements with the SPS neutrino beam was the experiment of the CERN–Hamburg–Amsterdam–Rome–Moscow (CHARM) collaboration, which he set up jointly with Ugo Amaldi. The experiment was designed to study in detail the neutrino neutral-current interactions, discovered in 1973 with the Gargamelle bubble chamber at the PS. A unique feature of the CHARM detector was the target calorimeter, which used large plates of Carrara marble as absorber material. This experiment was followed by CHARM II, optimized for the measurement of neutral-current neutrino-electron interactions and based on a 700-t target calorimeter built from glass plates and streamer tubes. Through deep-inelastic neutrino scattering, these experiments allowed, *inter alia*, measurements of the electroweak mixing angle, θ_W, and of nucleon structure functions, thereby making seminal contributions to establishing the Standard Model of particle physics.

Klaus Winter and the CHARM detector in 1978. (Image credit: CERN-PHOTO-7812581-1.)

The last experiment under Winter's leadership, from 1991 until his retirement, was CHORUS. This used a hybrid emulsion–electronic detector designed primarily to search for ν_μ–ν_τ oscillations in the then-favoured region of large mass-squared differences and small mixing angle.

In recognition of these fundamental results, obtained with innovative and original experimental techniques, in 1993, Winter was awarded the Stern–Gerlach Medal, the highest distinction of the German Physical Society, for exceptional achievements in experimental physics. In 1997, he was awarded the Bruno Pontecorvo Prize for his major contributions to neutrino physics by the JINR in Dubna.

Winter was a visionary and uncompromising scientist who applied the highest standards to his own work, as well as to that of his many students and collaborators. He paid particular attention to the quality of his publications and to the publications of others: as a long-term editor, he helped to establish *Physics Letters B* as one of the leading high-energy physics journals. He was also the editor of two renowned books, *Neutrino Physics* (1991 and 2000) and *Neutrino Mass* with Guido Altarelli (2003), and served for many years on the advisory committee of the prestigious International Conference on Neutrino Physics and Astrophysics.

In 1973, he became honorary professor at the University of Hamburg. Later, soon after the reunification of Germany, he became a guest professor at the Humboldt University of Berlin, where he taught particle physics for many years. Under his impact, Humboldt University established one of the first chairs of experimental high-energy physics in former East Germany.

Only a few years after his retirement from CERN, Winter suffered a bicycle accident from which he never recovered fully. With his passing, the particle-physics community has lost an outstanding scientist and recognized leader. We will remember him with sympathy and gratitude.

● *His friends and colleagues.*

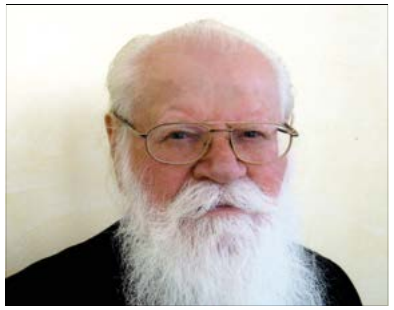
Anatoly Alekseevich Logunov 1926–2015

Anatoly Alekseevich Logunov, an outstanding Russian theorist in the field of quantum theory and gravitation, and a founder of large-scale high-energy physics research in Russia, passed away on 1 March in Moscow.

Born on 30 December 1926, Logunov studied physics at Moscow State University (MSU), where he received his Candidate of Sciences degree (equivalent to a PhD) in ▷

astrophysics. Soon afterwards, he joined the theoretical group led by Nicolai Bogoliubov, and concentrated on what was then a new and promising problem of renormalization in quantum field theory. In 1956, Logunov generalized the renormalization group in gauge theories (QED), introducing the "running" gauge parameter. Three years later he showed, with Bogoliubov and Dmitry Shirkov, that the causality principle enables the elimination of the "ghost" (Landau) pole from the effective QED coupling. During the 1950s, Logunov also proved many dispersion relations on the basis of the "majorization" of relevant Feynman diagrams.

Working with Albert Tavkhelidze, in 1963 Logunov developed a covariant generalization of the potential interaction on the basis of the "quasi-potential" equation, which allowed a probabilistic treatment of the wave function to be extended in a relativistic context. Then in 1967, together with Lev Soloviev, Logunov and Tavkhelidze derived the famous finite-energy sum rules that related the resonance and Regge energy regions, leading to the notion of "duality". At the same time, the growing role of particle production in higher-energy collisions prompted Logunov to search for a new approach to multiparticle processes. In 1967, he introduced a new class of cross-sections (later referred to as "inclusive") to deal with reactions producing many particles, and obtained general bounds on their high-energy behaviour. Two years later, the experimental study of inclusive processes at the Serpukhov accelerator revealed the effect of "scaling" in hadron production.



Anatoly Alekseevich Logunov. (Image credit: IHEP.)

In 1963, at the age of only 36, Logunov was appointed director of the newly established Institute for High Energy Physics (IHEP) near Serpukhov. The 70-GeV proton synchrotron (U-70) was constructed under his leadership and commissioned in 1967. For five years the U-70 held the world record for proton-beam energy, and saw the launch of unprecedented international co-operation in experimental research. The most active participation was by groups from CERN (under an agreement of 1967) and the French Commissariat à l'énergie atomique (an agreement of 1966). Logunov played a key role in establishing this first large-scale collaboration between what was then the Soviet Union and the West. His deep personal conviction about the international nature of fundamental science helped him to obtain the necessary support from the national government and the academic community. He remained director of IHEP until 1974, and was appointed to the post again in the years 1993–2003.

A full member of the Russian Academy of Sciences from 1972, Logunov was vice-president in the years 1974–1991. In this role, he managed to consolidate the high-energy particle-physics community in Russia, in particular, under the State Programme for High-Energy Physics (1987–1992), which provided the funding and support for new research projects in Protvino, Troitsk, Baksan and Novosibirsk. He was also rector of MSU from 1977 until 1992, and managed to bring autonomy to the university and to do much for its future development. He established new faculties of materials science (1991), sociology (1989), foreign languages and area studies (1988).

At the age of 50, Logunov switched unexpectedly to problems of gravitation, a subject quite far from his previous research interests. Starting from a critical review of Albert Einstein's general-relativity theory, Logunov finally came to his own theory based on a rigorous implementation of the energy–momentum and angular-momentum conservation laws. His theory of gravitation – the relativistic theory of gravitation – keeps pseudo-Euclidean geometry as a basis, allowing the gravitational field to be treated as a conventional physical field in the sense of Faraday and Maxwell. A peculiar feature of the theory is that the gravitational field is massive. Moreover, there are no black holes, and the spatially infinite universe evolves cyclically there. All known observational data comply with the theory. Logunov considered his research on gravitation to be his life's aim, and worked on it enthusiastically until his last days.

In recognition of his achievements in research and in the development of science, he received the highest awards of the Soviet Union and the Russian Federation, as well as honorary titles and prizes, and awards from many foreign universities.

Anatoly Alekseevich Logunov will be remembered by all of his colleagues and future generations of researchers.

● *His colleagues at IHEP, Protvino.*

New Products

Hiden Analytical has developed the TMS series of mass-spectrometer-based gas analysers to address the requirement for monitoring fast-evolving and pulsing gases. Standard options enable measurement of gas and vapour species with molecular weights up to 200 amu or 300 amu, with higher mass-range options also available. Systems are compact and bench-top mounting, with cart-mounted options available for system mobility. For further information, e-mail info@hiden.co.uk, or visit www.HidenAnalytical.com.

Murata Power Solutions' OKDx-T/20-W12 and OKDx-T/25-W12 series point-of-load (PoL) DC/DC converters offer high-power-density, high-efficiency, PMBus-compatible digital power solutions for space-constrained embedded applications. The digitally controlled converters are capable of delivering 20 A/66 W and 25 A/82.5 W, respectively, yet measure only 25.65 × 13.8 × 8.2 mm, and are available in through-hole, single-in-line or surface-mount packages. Murata has also launched the 1600-W rated D1U86P Series of ultra-high-density power converters, with AC- and DC-input models. Designed to fit 1U enclosures, they are 86 mm wide and 197.7 mm deep. For more details, contact Donia Kamil, tel +31 23 5698456, e-mail dkamil@murata.com, or visit www.murata .com.

VadaTech has announced two new high-performance AMC boards that use Xilinx all-programmable FPGAs. The AMC523 is a dual 16-bit 250-MSPS digital-to-analogue converter featuring a XC7K410T Kintex-7 FPGA from Xilinx. The FPGA has an interface to the DDR3 memory, allowing for storage of large buffer sizes during processing, as well as for queuing the data to the host. The MicroTCA.4-compliant AMC523 allows for flexible external clocking as well as internal clocking. It also has a corresponding RTM with 10 ADCs. VadaTech has also announced the AMC525 – a dual FPGA mezzanine card carrier as per the VITA 57 specification. This card features a Xilinx 690T Virtex-7 FPGA and an on-board QorIQ P2040 quadcore processor. For more information, e-mail info@vadatech.com.

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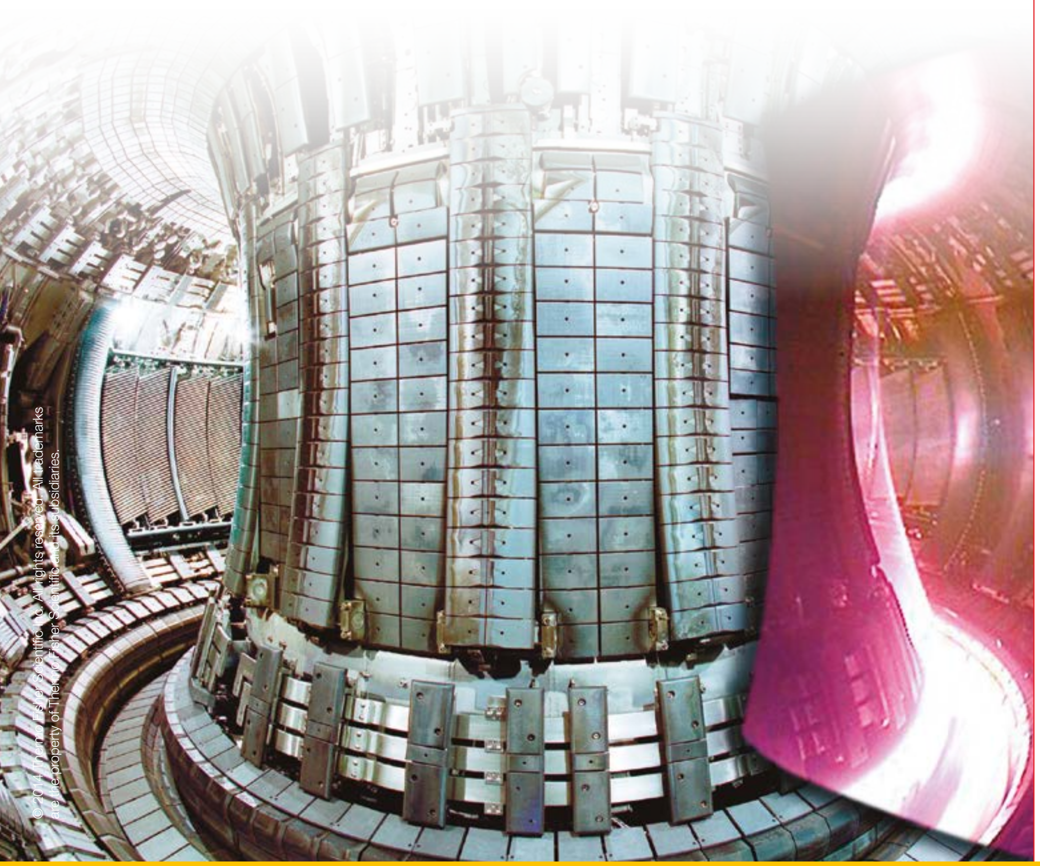

Recruitment

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Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

PARTICLE PHYSICS.

DESY, Hamburg location, is seeking:
Scientist (m/f)

DESY

DESY is one of the world's leading research centres for photon science, particle and astroparticle physics as well as accelerator physics.

The particle physics programme of DESY consists of strong contributions to the LHC experiments ATLAS and CMS and to the preparation of a future linear collider. The experimental programme is enhanced by collaboration with a strong theory group. DESY is searching an experienced high energy experimental physicist, who will take a leading role in the reconstruction of charged particles in ATLAS and contribute actively to physics data analysis.

The position

- Active role in the ATLAS experiment
- Leading role in the reconstruction of charged particles and in the analysis of ATLAS data
- Participation in the supervision of students and postdocs

Requirements

- PhD in experimental High Energy Physics
- Extensive knowledge in tracking algorithms
- Experience in HEP data analysis preferentially at hadron colliders
- Outstanding teamwork abilities
- Excellent communication skills and knowledge of English

For further Information please contact Klaus Moenig +49-33762-7-7271, klaus.moenig@desy.de or Ingrid-Maria Gregor +49-40-8998-3032, ingrid.gregor@desy.de.

Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is a bilingual kindergarten on the DESY site.

We are looking forward to your application quoting the reference code preferably via our electronic application System: Online-Application or by email recruitment@desy.de
Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: EM045/2015
Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-3392
Deadline for applications: 15 May 2015
www.desy.de

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ASSOCIATION

Accelerators | Photon Science | Particle Physics
Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

SELF SEEDING.

DESY, Hamburg location, is seeking:
Postdoctoral Scientist (f/m)

DESY

DESY is one of the world's leading research centres for photon science, particle and astroparticle physics as well as accelerator physics.

The accelerator physics group (MPY) at DESY (Hamburg) is pursuing the development, construction and operation of accelerators in Hamburg. For the European XFEL accelerator we are looking for a physicist (f/m) with some experience in FEL physics and accelerator operation.

The position

- Coordinate the development work towards implementation of the self-seeding option, a method to enhance the spectral brightness of the FEL radiation by inserting a crystal monochromator into the FEL radiator, within an international collaboration
- Participate in the commissioning of the European XFEL accelerator
- Pursue accelerator research at FLASH and European XFEL

Requirements

- PhD in accelerator physics or equivalent
- Experience in numerical simulations of FELs physics and preferable operation of accelerators
- Capability to coordinate a small team of engineers and physicists

For further information please contact Winfried Decking, +49 40 8998-3430.

The position is limited until 30th September 2017.
Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is a bilingual kindergarten on the DESY site.

We are looking forward to your application quoting the reference code preferably via our electronic application system:
https://www.desy.de/about_desy/career/online_application/index_eng.html
or by e-mail recruitment@desy.de

Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: EP012/2015
Notkestraße 85 | 22607 Hamburg | Germany
Phone: +49 40 8998-3392
Deadline for applications: 30th April 2015
www.desy.de

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HELMHOLTZ
GEMEINSCHAFT

UNIVERSITY OF
BIRMINGHAM

College of Engineering and Physical Sciences
School of Physics and Astronomy

Lecturer/Senior Lecturer/Reader in Particle Physics Instrumentation – Ref: 52822

Level of appointment will depend on the skills/experience of the candidate

Starting salary of appointment at Lecturer level £38,511 to £51,702. Starting salary at Senior Lecturer or Reader level £47,328 to £71,509

The School of Physics and Astronomy at the University of Birmingham has over 100 academic and research staff covering a broad range of research interests, along with 120 graduate students and 35 technical staff. It takes in around 180 undergraduates per year. As part of a major new strategic investment by the University in semiconductor detector instrumentation, Birmingham has appointed a new professor (Allport) to lead this activity and will make rolling appointments of 3 new academic positions. The first post, having the role to support the ATLAS Upgrade project, in the first instance, is available with immediate effect at a level dependent on the experience and qualifications of the successful candidate.

Applicants are invited to obtain more information and submit their application online to us, via www.hr.bham.ac.uk/jobs. Informal inquiries can be sent to Prof Phil Allport (p.p.allport@bham.ac.uk; tel: +44-1214144717) or Prof Paul Newman (p.r.newman@bham.ac.uk; tel: +44-1214144617).

Closing date: 29 May 2015.

VALUING EXCELLENCE; SUSTAINING INVESTMENT.

Fermilab

Post-Doctoral Opportunity in Accelerator Physics at Fermilab

This position is for an initial period of up to three (3) years with the potential for extension.

Fermi National Accelerator Laboratory seeks a highly qualified candidate for a postdoctoral Research Associate position in its Accelerator Division's IOTA/ASTA Department to work on the theoretical Advanced Accelerator R&D program with the focus on the development of novel concepts for future intensity frontier experiments. The successful candidate will be accepted to participate in a comprehensive feasibility study and investigation of an integrable optics rapid cycling synchrotron as an essential component of a potential future multi-MW facility to advance neutrino science. The range of activities will also include modeling of beam dynamics effects, evaluation of technical aspects, interpretation and scientific publication of results.

Respect, understand, and value individual differences that embody the principles of diversity.

Abide by all environmental, safety, and health regulations.

Qualifications and Essential Job Functions

- Ph.D. or an equivalent degree in Physics, Accelerator Physics or related fields by the time of the appointment
- Strong record of recent accomplishments in physics
- Excellent oral and written communication skills as demonstrated by presentations at conferences and a record of publication(s) in peer-reviewed journals.

Application Instructions

interested candidates should submit: 1) a cover letter including a brief statement of research interests and 2) a curriculum vitae with a list of selected publications.

Online application: https://fermi.hodesiq.com/apply_online_1.asp?jobid=4996444

The application deadline is May 31, 2015.

For general information about this position, please contact Dr. Alexander Valishev at valishev@fnal.gov

There is no legal requirement that Fermilab sponsor an employee for U.S. permanent residence. As a result, Fermilab will make the decision to sponsor an employee on a case-by-case basis. Fermilab will consider the following factors, among others, when determining whether to sponsor an employee for US permanent residence: performance, length of service, long-term need for the position, and cost.

Diverse People, Diverse Jobs

Fermilab is an Equal Opportunity Employer.
Minorities/Women/Disabled/Veterans are encouraged to apply.

RWTH AACHEN UNIVERSITY

Thinking the Future.

RESEARCH ASSISTANT / ASSOCIATE
in Experimental and Theoretical Particle/Astroparticle Physics
RESEARCH TRAINING GROUP (GRADUIERTENKOLLEG) PARTICLE AND ASTROPARTICLE PHYSICS IN THE LIGHT OF LHC

OUR PROFILE
The research goal of the DFG graduate school "Particle and Astroparticle Physics in the Light of LHC" is to explore the limits of the standard model of particle physics in the era of new data from major experiments in particle and astroparticle physics. Our experimental research groups participate in the CMS and LHCb experiments at the LHC, in the AMS experiment on the ISS, in the Pierre Auger Observatory in Argentina, in the IceCube Neutrino Observatory at the South Pole, and in various neutrino physics experiments. Theoretical research focuses on electroweak symmetry breaking, physics beyond the standard model, top quark and flavour physics, dark matter and cosmology.

YOUR PROFILE
You have received an excellent university degree (master or equivalent) in particle physics, astroparticle physics or cosmology. We expect strong commitment to teamwork, excellent communication skills, and high flexibility. Please apply with a curriculum vitae, a one-page summary of your thesis, two letters of reference, and a one-page description of your research interests within the framework of the graduate school. Selection will be based on competitive evaluation. Preference will be given to those candidates whose research interests combine two of the aforementioned scientific areas.

YOUR DUTIES AND RESPONSIBILITIES
You will work in close collaboration with your advisor(s) on the scientific goals of this graduate school. You will participate in the school's training programs (e.g., seminars, special lectures, etc.), and present your work at our annual workshop.

OUR OFFER
The position is of two years with a possible prolongation of 12 months and to be filled as soon as possible. This is a part-time position (75 % of the standard weekly hours for full-time employees). The successful candidate has the opportunity to pursue a doctoral degree. The salary corresponds to level TV-L E13 of the German public service salary scale (TV-L).

RWTH Aachen University is certified as a "Family-Friendly University". We particularly welcome and encourage applications from women, disabled persons and ethnic minority groups, recognizing they are underrepresented across RWTH Aachen University. The principles of fair and open competition apply and appointments will be made on merit.

YOUR CONTACT PERSON
For further details, please contact

Prof. Dr. Stefan Schael
Tel.: +49 (0) 241-80-27159
Fax: +49 (0) 241-80-22661
Email: Stefan.Schael@physik.rwth-aachen.de

For further information, please visit our website at:
www1b.physik.rwth-aachen.de/~kolleg2012/

Please send your application by April 30, 2015 to

Prof. Dr. Stefan Schael
I. Physikalisches Institut B
RWTH Aachen
D-52056 Aachen, Germany

IFIN-HH

eli Nuclear Physics

Senior and Junior Researchers, Postdoctoral research assistants, PhD students, Engineers, Physicists and Technicians at Extreme Light Infrastructure – Nuclear Physics (ELI-NP)

Extreme Light Infrastructure – Nuclear Physics (ELI-NP) will be a new Center for Scientific Research to be built by the National Institute of Physics and Nuclear Engineering (IFIN-HH) in Bucharest-Magurele, Romania.

ELI-NP is a complex facility which will host two state-of-the-art machines of high performances:

- A very high intensity laser beams from two 10 PW lasers;
- A very intense, brilliant γ beam, very low bandwidth, with $E_\gamma > 19$ MeV, which is obtained by incoherent Compton back scattering of a laser light off an intense electron beam ($E_e > 700$ MeV) produced by a warm linac.

IFIN-HH - ELI-NP is organizing competitions for filling the folowing positions:

Senior and Junior Researchers, Postdoctoral research assistants, PhD students, Engineers/Physicists (particle accelerators, mechanics, optics), Engineers (physics, laser, electronic, electrical, electrotechnical, instrumentation and control) and Technicians.

The jobs description, the Candidate's profiles and the Rules of Procedures of Selection can be found at http://www.eli-np.ro/jobs.php.

The applications shall be accompanied by the documents required in the Rules and Procedures of Selection for these positions

The applications shall be sent to the Human Resources Department at human.resources@eli-np.ro.

CERN

CERN, the European Laboratory for Particle Physics, is one of the world's largest and most respected centres for scientific research. Its core mission is the study of the fundamental constituents of matter and other elementary particles using high-energy accelerators; it addresses some of the most exciting outstanding questions in physics. The laboratory, based in Geneva (Switzerland), currently operates the most powerful accelerator in the world, the Large Hadron Collider (LHC).

CERN is an Intergovernmental Organization with 21 Member States. It employs around 2500 staff members (physicists, engineers, technical and administrative personnel). Its research facilities are used by more than 11000 scientists, coming from more than 600 institutes from all over the world and representing nearly 100 different nationalities. For more details, see: http://www.cern.ch/

CERN is seeking to recruit:

A Director for Finance and Human Resources

As a member of the Directorate, reporting to the Director-General, the Director for Finance and Human Resources will play a leading role in ensuring that the Organization's available and expected financial and human resources match its scientific programme and allow operation of the Laboratory's facilities. Full details of this post and how to apply can be found on http://cern.ch/jobs/DirectorFHR.

And

A Director for International Relations

As a member of the Directorate, reporting to the Director-General, the Director for International Relations will play a leading role in shaping and implementing the international relations strategy of the Organization, with the primary aim of securing the highest level of support from governments and funding agencies of Member-State and other countries.

Full details of this post and how to apply can be found on http://cern.ch/jobs/DirectorIR.

Both positions are for a five-year period, from 1 January 2016 until 31 December 2020.

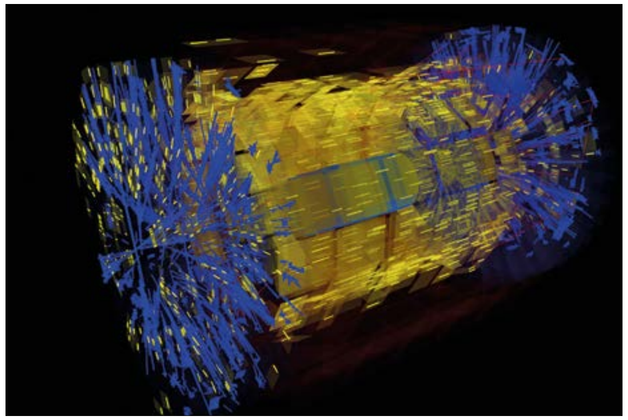
Inside (photo)story

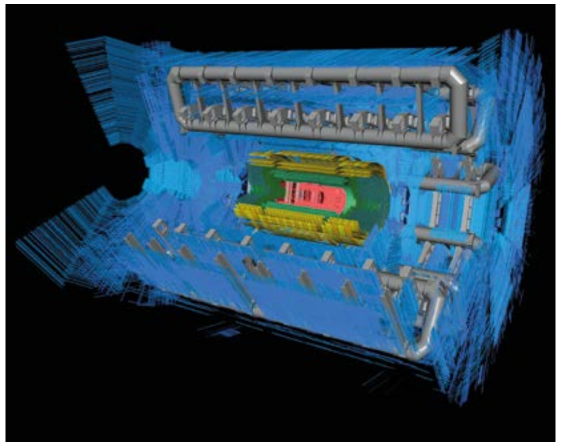
LHC: Season 2

The LHC's second run began with a "splash", as experiments recorded events when the first protons made low-intensity collisions with collimators not far from the detectors.

Above: A host of screens show the operators the state of the machine, as the restart gets underway. (Image credit: CERN-PHOTO-201504-063-35.)

Below: 10.25 a.m. CMS sees its first "beam splashes", this one from a few minutes later. (Image credit: CMS Collaboration CMS-PHO-EVENTS-2015-001-1.)

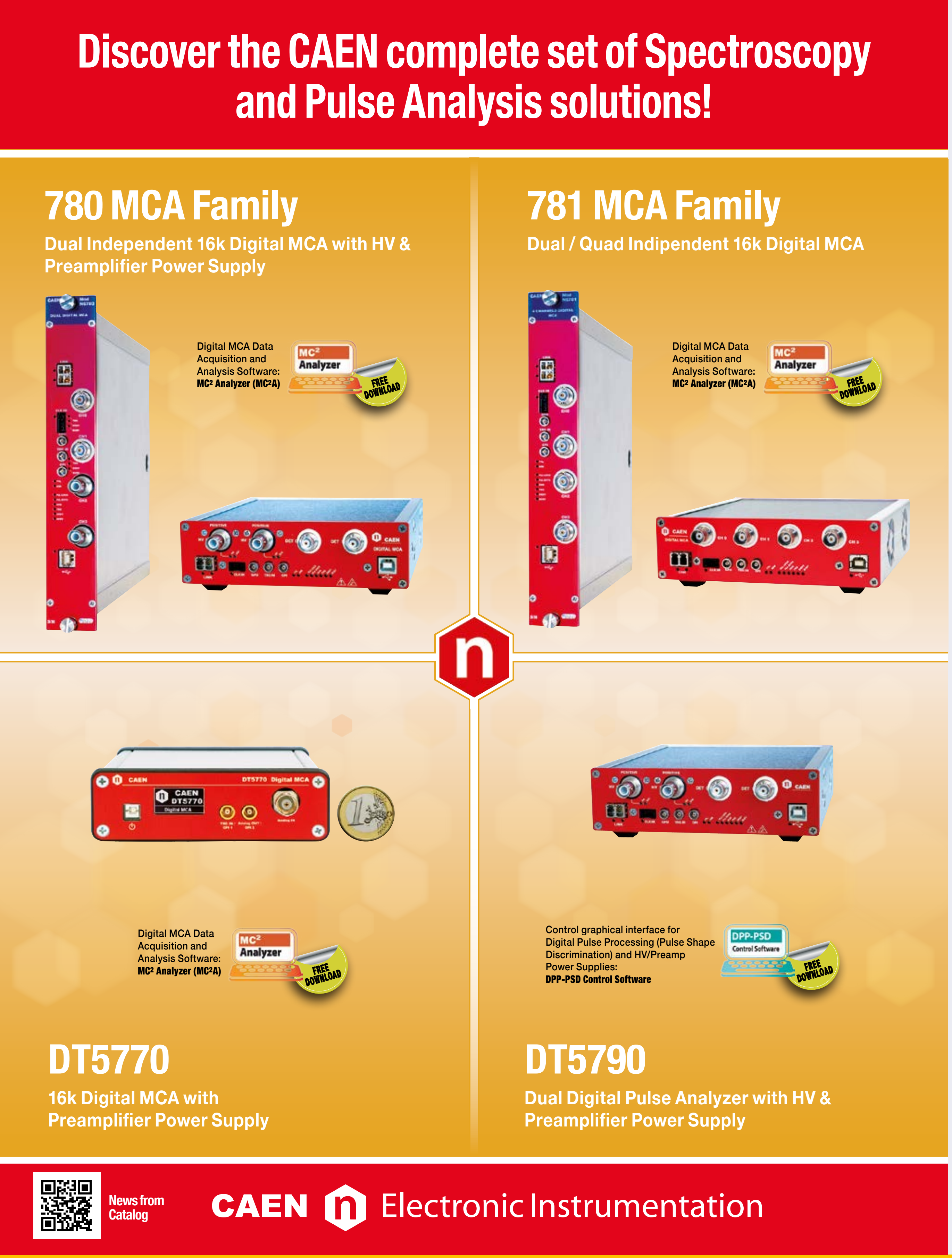




Above: 10.46 a.m. The first "splash event" lights up the ATLAS detector. (Image credit: ATLAS experiment ATLAS-PHO-2015-001-1.)

Left: Dave Charlton (left), spokesperson for the ATLAS collaboration, delivers an Easter egg to the LHC operators on shift, Georges-Henry Hemelsoet and Laurette Ponce. (Image credit: CERN-PHOTO-201504-063-223.)

- For more on the morning's events on 5 April, see the blog at http://run2firstbeam.web.cern.ch/ or watch the afternoon's press briefing at https://cds.cern.ch/record/2006746/.



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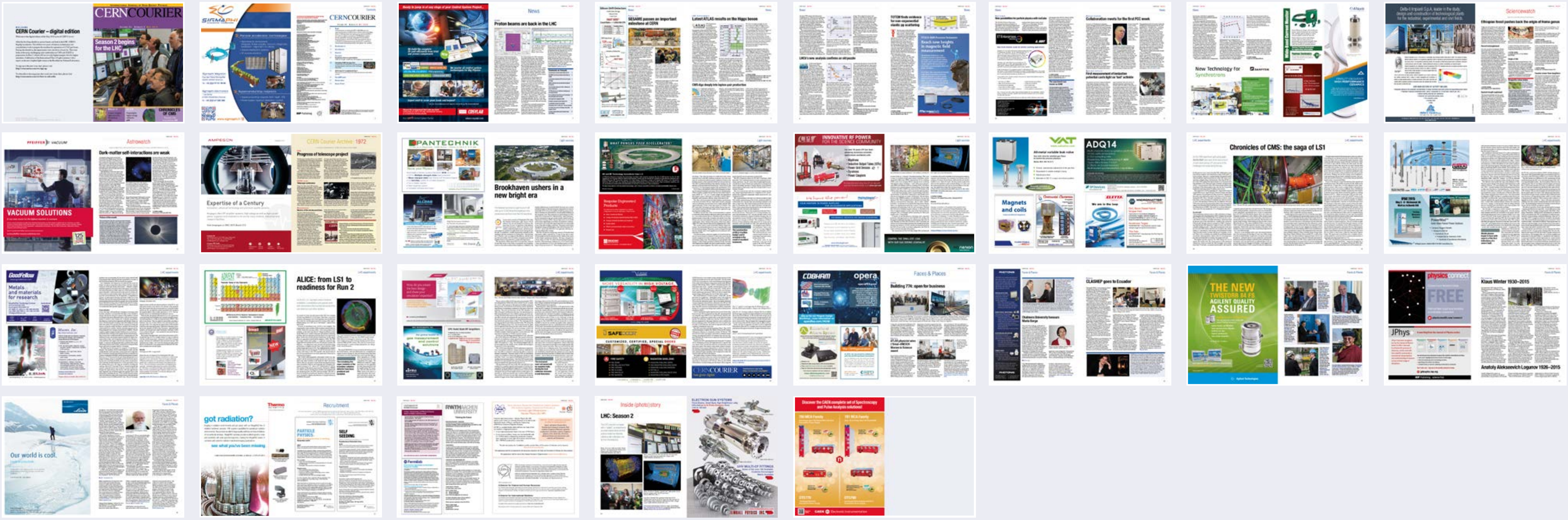

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