WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the January/February 2013 issue of *CERN Courier* – the first digital edition of this magazine.

CERN Courier dates back to August 1959, when the first issue appeared, consisting of eight black-and-white pages. Since then it has seen many changes in design and layout, leading to the current full-colour editions of more than 50 pages on average. It went on the web for the first time in October 1998, when IOP Publishing took over the production work. Now, we have taken another step forward with this digital edition, which provides yet another means to access the content beyond the web and print editions, which continue as before.

Back in 1959, the first issue reported on progress towards the start of CERN's first proton synchrotron. This current issue includes a report from the physics frontier as seen by the ATLAS experiment at the laboratory's current flagship, the LHC, as well as a look at work that is under way to get the most from this remarkable machine in future. Particle physics has changed a great deal since 1959 and this is reflected in the article on the emergence of QCD, the theory of the strong interaction, in the early 1970s.

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CERN COURIER

VOLUME 53 NUMBER 1 JANUARY/FEBRUARY 2013

High luminosity: the heat is on

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

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CERNCOURIER

VOLUME 53 NUMBER 1 JANUARY/FEBRUARY 2013

On the cover: Work towards high-power superconducting links for the HL-LHC project is underway at CERN with tests of cables based on magnesium diboride (p28).

News

LHC NEWS

Marking the end of the first proton run

At 6 a.m. on 17 December, operators ended the LHC's first three-year-long run for proton physics with a new performance milestone. In the preceding days, the space between proton bunches had been successfully halved to the design specification of 25 ns rather than the 50 ns used so far.

Halving the bunch spacing allowed the number of bunches in the machine to be doubled, resulting in a record number of 2748 bunches in each beam; previously the LHC had been running with around 1380 bunches per beam. This gave a record beam intensity of 2.7×10^{14} protons in both beams at the injection energy of 450 GeV.

The LHC operations team then performed a number of ramps taking 25 ns beams from 450 GeV to 4 TeV, increased the total number of bunches at each step to a maximum of 804 per beam. The stepwise approach is needed to monitor the effects of additional electron cloud produced when synchrotron radiation emitted by the protons strikes the vacuum chamber – the synchrotron-radiation photon flux increases significantly as the energy of the protons is increased.

Electron cloud is strongly enhanced by the reduced spacing between bunches and is one of the main limitations for 25 ns operation. It has negative effects on the beam (increasing beam size and losses), the cryogenics (in the heat load on the beam pipe) and the vacuum (pressure rise). As a result, a period of beam-pipe conditioning known as "scrubbing" was needed before ramping the beams. During this period, the machine was operated in a controlled way with beams of increasingly high intensity. This helps to improve the surface characteristics of the beam pipe and reduces the density of the electron cloud. Once each beam had been

Proton physics ends for 2012 with the message "So long and thanks for all the fish" – a phrase from the pages of Douglas Adams' Hitchhiker's Guide to the Galaxy.

ramped to 4 TeV, a pilot physics run of several hours took place with up to 396 bunches, spaced at 25 ns, in each beam. Although the tests were successful, significantly more scrubbing will be required before the full 25 ns beam can be used operationally.

While these tests were taking place, on 13 December representatives of the LHC and five of its experiments delivered a round-up report to CERN Council. All of the collaborations congratulated the LHC team on the machine's exemplary performance over the first three full years of running. In 2012, not only did the collision energy increase from 7 TeV to 8 TeV but the instantaneous luminosity reached 7.7×10^{33} cm^{-2} s^{-1}, more than twice the maximum value obtained in 2011 (3.5×10^{33} cm^{-2} s^{-1}). News from the experiments included LHCb's measurement of the decay of the B_s meson into two muons (p8), ALICE's detailed studies of the quark–gluon plasma and TOTEM's insights on the structure of the proton.

ATLAS and CMS gave updates on the Higgs-like particle first announced in July, with each experiment now observing the new particle with a significance close to 7σ, well beyond the 5σ required for a discovery. So far, the particle's properties seem consistent with those of a Standard Model Higgs boson. The two collaborations are, however, careful to say that further analysis of the data – and a probable combination of both experiments' data next year – will be required before some key properties of the new particle, such as its spin, can be determined conclusively. The focus of the analysis has now moved from discovery to measurement of the new particle in its individual decay channels.

With December 2012 marking the end of the first LHC proton physics running period, 2013 sees a four-week run from mid-January to mid-February for proton–lead collisions before going into a long shut-down for consolidation and maintenance until the end of 2014. Running will resume in 2015 at an increased collision energy of 13 TeV.

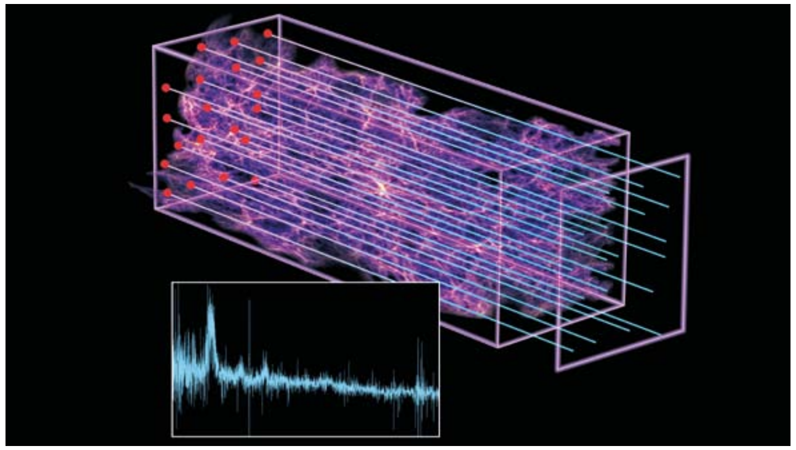
CERN becomes UN observer

On 14 December, the UN General Assembly adopted a resolution to allow CERN to participate in the work of the General Assembly and to attend its sessions as an observer. With this new status, the laboratory can promote the essential role of basic science in development.

In a meeting with UN secretary-general, Ban Ki-moon, on 17 December, CERN's director-general, Rolf Heuer, pledged that CERN was willing to contribute actively to the UN's efforts to promote science, in particular UNESCO's initiative "Science for sustainable development". Ban Ki-moon, left, with Rolf Heuer. (Image credit: Evan Schneider/UN.)

Sommaire en français

ASTROPARTICLE PHYSICS



Light from distant quasars (red dots at left) is partially absorbed as it passes through clouds of hydrogen gas. A "forest" of hydrogen absorption lines in an individual quasar's spectrum (inset) pinpoints denser clumps of gas along the line of sight. The spectra are collected by the telescope's spectrograph (square at right). (Image credit: Zosia Rostomian, LBNL; Nic Ross, BOSS Lyman-alpha team, Berkeley Lab; and Springel et al, Virgo Consortium and Max Planck Institute for Astrophysics.)

BOSS gives clearer view of baryon oscillations

In November the Baryon Oscillation Spectroscopic Survey (BOSS) released its second major result of 2012, using 48,000 quasars with redshifts (z) up to 3.5 as backlights to map intergalactic hydrogen gas in the early universe for the first time, as far back as 11,500 million years ago.

As the light from each quasar passes through clouds of gas on its way to Earth, its spectrum accumulates a thicket of hydrogen absorption lines, the "Lyman-alpha forest", whose redshifts and prominence reveal the varying density of the gas along the line of sight. BOSS collected enough close-together quasars to map the distribution of the gas in 3D over a wide expanse of sky.

The largest component of the third Sloan Digital Sky Survey, BOSS measures baryon acoustic oscillations (BAO) – recurring peaks of matter density that are most evident in net-like strands of galaxies. Initially imprinted in the cosmic microwave background radiation, BAO provide a ruler for measuring the universe's expansion history and probing the nature of dark energy.

In March 2012, BOSS released its first results on more than 350,000 galaxies up to z = 0.7, or 7000 million years ago. However, only quasars are bright enough to probe the gravity-dominated early universe when expansion was slowing, well before the transition to the present, where dark energy dominates and expansion is accelerating. When complete, BOSS will have surveyed 1.5 million galaxies and 160,000 quasars.

To resolve the nature of dark energy will need even greater precision. The BigBOSS collaboration, which, like BOSS, is led by scientists at Lawrence Berkeley National Laboratory (LBNL), proposes to modify the 4-m Mayall Telescope to survey 24 million galaxies to z = 1.7, plus two million quasars to z = 3.5. The Gordon and Betty Moore Foundation recently awarded a grant of $2.1 million to help fund the spectrograph and corrector optics, two key BigBOSS technologies.

● **Further reading**

Busca *et al.* 2012 arXiv:1211.2616v1 [astro-ph.CO] submitted to *Astronomy & Astrophysics*.

Europe launches consortium for astroparticle physics

At the end of November, European funding agencies for astroparticle physics launched a new sustainable entity, the Astroparticle Physics European Consortium (APPEC). This will build on the successful work of the European-funded network, the AStroParticle European Research Area (ASPERA).

Over the past six years, ASPERA has brought together funding agencies and the physics community to set up European co-ordination for astroparticle physics. It has developed common R&D calls and created closer relationships to industry and other research fields. Above all, ASPERA has developed a European strategy for astroparticle physics to prioritize the large infrastructures needed to solve universal mysteries in concerning, for example, neutrinos, gravitational waves, dark matter and dark energy.

APPEC now plans to develop a European common action plan to fund the upcoming large astroparticle-physics infrastructures as defined in ASPERA's road map. Ten countries have already joined the new APPEC consortium, with nine others following the accession process. APPEC's activities will be organized through three functional centres, located at DESY, the Astronomy, Particle Physics and Cosmology laboratory of the French CNRS/CEA, and the INFN's Gran Sasso National Laboratory. Stavros Katsanevas of CNRS has been elected as chair of APPEC and Thomas Berghoefer of DESY as general secretary.

● APPEC is the Astroparticle Physics European Consortium. It currently comprises 10 countries represented by their Ministries, funding agencies or their designated institution: Belgium (FWO), Croatia (HRZZ), France (CEA, CNRS), Germany (DESY), Ireland (RIA), Italy (INFN), The Netherlands (FOM), Poland (NCN), Romania (IFIN) and the UK (STFC).

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

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

LHC PHYSICS

ATLAS enlists monojets in search for new physics

Events with a single jet of particles in the final state have traditionally been studied in the context of searches for supersymmetry, for large extra spatial dimensions and for candidates for dark matter. Having searched for new phenomena in monojet final states in the 2011 data, the ATLAS collaboration turned its attention to data collected in 2012, with the first results presented at the Hadron Collider Physics (HCP) symposium in Kyoto in November.

Models with large extra spatial dimensions aim to provide a solution to the mass-hierarchy problem (related to the large difference between the electroweak unification scale at around 10^2 GeV and the Planck scale around 10^{19} GeV) by postulating the presence of n extra dimensions, such that the Planck scale in 4+n dimensions becomes naturally close to the electroweak scale. In these models, gravitons (the particles hypothesized as mediators of the gravitational interaction) are produced in association with a jet of hadrons; the extremely weakly interacting gravitons would escape detection, leading to a monojet signature in the final state.

Dark-matter particles could also give rise to monojet events. According to the current understanding of cosmology, non-baryonic non-luminous matter contributes about 23% of the total mass-energy budget of the universe but the exact nature of this dark matter remains unknown. A commonly accepted hypothesis is that it consists of weakly interacting massive particles (WIMPs) acting through gravitational or weak interactions. At the LHC, WIMPs could be produced in pairs that would pass through the experimental devices undetected. Such events could be identified by the presence of an energetic jet from initial-state radiation, leading again to a monojet signature. The LHC experiments have a unique sensitivity for dark-matter candidates with masses below 4 GeV and are therefore complementary to other searches for dark matter.

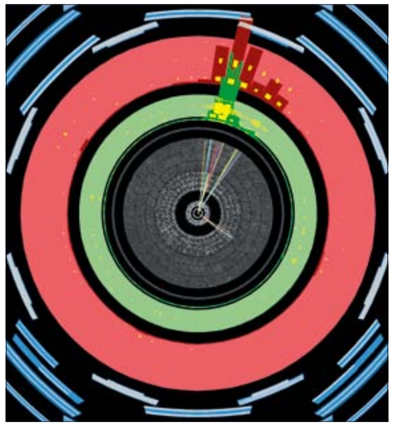


Fig. 1. Event display for a monojet event.

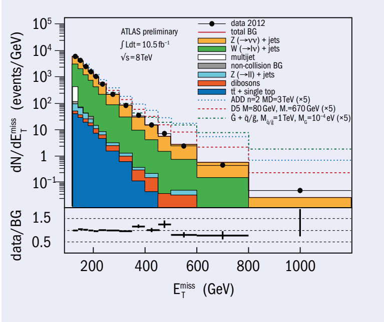


Fig. 2. Measured missing transverse momentum distribution for the monojet events collected by the ATLAS experiment.

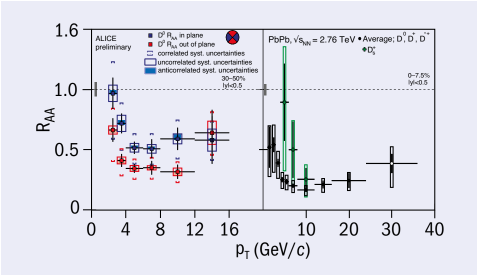
The study presented at HCP uses 10 fb^{-1} of proton–proton data collected during 2012, at a centre-of-mass energy of 8 TeV. As with the earlier analysis, the results are still in good agreement with the predictions of the Standard Model (figure 2). The new results have been translated into updated exclusion limits on the presence of large extra spatial dimensions and the production of WIMPs, as well as new limits on the production of gravitinos (the supersymmetric partners of gravitons) that result in the best lower bound to date on the mass of the gravitino.

● **Further reading**

ATLAS collaboration, ATLAS-CONF-2012-147 (and references therein).

ALICE takes new directions in charm-suppression studies

Using data from the second high-statistics lead–lead (PbPb) run of the LHC, which took place in 2011, the ALICE experiment is taking new directions in studying the interaction of charm quarks within strongly interacting matter at the high energy-density and temperature produced in these heavy-ion collisions. Following the observation of a large suppression of the production of charmed hadrons at high momentum (*CERN Courier* June 2012 p15), the collaboration is seeking further insight by quantifying the strength of this effect in different directions relative to the reaction plane, as well as by measuring the production of the charm-strange meson, D_s.



(Left) D^0 R_{AA} for the two regions of the event plane as a function of transverse momentum. A larger suppression is measured in the out-of-plane region (red points) with respect to the in-plane one (blue points). (Right) D_s^+ R_{AA} (green points) as a function of p_T compared with the average R_{AA} of non-strange D mesons.

After production in initial hard partonic collisions, c and b quarks propagate across the expanding dense matter that has been formed in the PbPb collisions. Interactions with this medium's constituents can lead to energy loss that results in the suppression of high-momentum hadrons, as observed for D mesons via the nuclear-modification factor R_{AA} – the ratio of the yield measured in nucleus–nucleus collisions to that expected from a superposition of proton–proton collisions. It is an open question as to whether heavy quarks can be slowed down to the point of being affected by the collective expansion of the system or if they form hadrons by recombining with light quarks from the medium.

Because the overlap area of the two nuclei is almond-shaped, elongated in a direction perpendicular to the reaction plane (defined by the beamline and the impact parameter of the collision), non-central collisions exhibit an initial azimuthal anisotropy. ALICE measured R_{AA} for charmed mesons by reconstructing secondary vertices from $D^0 \rightarrow K^-\pi^+$ decays in two 90°-wide regions of azimuthal angle centred on the in-plane and out-of-plane directions. As the left panel of the figure shows, the observed suppression is larger in the out-of-plane region than in the in-plane region. This suggests that charm quarks lose more energy when having a longer path length in the medium, in the out-of-plane direction. In the low-momentum range, collective expansion under anisotropic pressure gradients could also contribute to the observed azimuthal asymmetry (*CERN Courier* April 2011 p7).

By exploiting the high statistics available with the 2011 PbPb run, as well as the vertexing and hadron identification capabilities of the detector, the ALICE collaboration has for the first time been able to reconstruct $D_s^+ \rightarrow K^+K^-\pi^+$ decays in heavy-ion collisions. D_s mesons are formed by a charm and a strange quark and are thus sensitive to the mechanism of c-quark hadronization – the process in which the quarks become bound in hadrons. In particular, if low-momentum c quarks hadronize by recombination, the D_s yield is expected to be enhanced with respect to that of non-strange D mesons, because of the high strangeness-content of the medium (*CERN Courier* December 2011 p20).

The right panel of the figure shows the values of R_{AA} measured for D_s mesons in central collisions and reveals, at high momentum, an equally strong suppression as for non-strange D mesons. The suppression is reduced at lower momenta, although it remains consistent within uncertainties with that for non-strange D mesons. This is just a first measurement but it shows that with larger-statistics data samples from future LHC runs, ALICE should be able to draw firm conclusions on a possible enhancement of D_s production in PbPb collisions.

● Further reading

D Caffarri (ALICE collaboration) 2012 arXiv:1212.0786.

G M Innocenti (ALICE collaboration) 2012 arXiv:1210.6388.

$B_s \rightarrow \mu\mu$ seen after being sought for decades

It has taken decades of hunting but finally the first evidence for one of the rarest particle decays ever seen in nature, the decay of a B_s (composed of a beauty antiquark and a strange quark) into two muons, has been uncovered by the LHCb collaboration.

In the Standard Model, the decay $B_s \rightarrow \mu\mu$ is calculated to occur only three times in every 1000 million B_s decays. While the Standard Model has been incredibly successful, it leaves many unanswered questions concerning, for example, the origin of the matter–antimatter asymmetry and the essence of dark matter. Extended theories, such as supersymmetry, may resolve some of these issues. These theories allow for new particles and phenomena that can affect measurable quantities. The branching fraction $B(B_s \rightarrow \mu\mu)$, for example, can be enhanced or reduced with respect to the Standard Model prediction, so the measurement has the potential to reveal hints of new physics. The LHCb experiment is particularly suited for such an indirect search for the effects of new physics, complementary to direct searches for new particles.

The LHCb collaboration performed the search for $B_s \rightarrow \mu\mu$ (and $B^0 \rightarrow \mu\mu$) by analysing 1.0 fb^{-1} of proton–proton collisions at 7 TeV in the centre of mass (from 2011) and 1.1 fb^{-1} at 8 TeV (2012). The signal selection starts with the search for pairs of oppositely charged muons that make a vertex that is displaced from the proton–proton interaction vertex (see figure 1). The signal and background are then separated using simultaneously the invariant mass of the two muons as well as kinematic and topological information combined in a multivariate analysis classifier. The particular classifier used is a boosted decision-tree (BDT) algorithm, which is calibrated with data for both signal and background events. The latter are dominated by random combinations of two muons from two different B mesons; this contribution is carefully determined from data.

The number of $B^0 \rightarrow \mu\mu$ candidates that LHCb observes is consistent with the background expectation, giving an upper limit of $B(B^0 \rightarrow \mu\mu) < 9.4 \times 10^{-10}$ at 95% confidence level. This is the world's most stringent upper limit from a single experiment on this branching fraction. However, for $B_s \rightarrow \mu\mu$, LHCb sees an

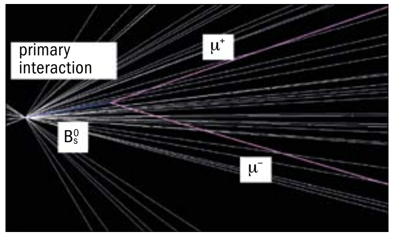


Fig. 1. Illustration of one of the cleanest candidates for the $B_s \rightarrow \mu\mu$ decay, as reconstructed in LHCb vertex locator. The B_s decay length is 30 mm.

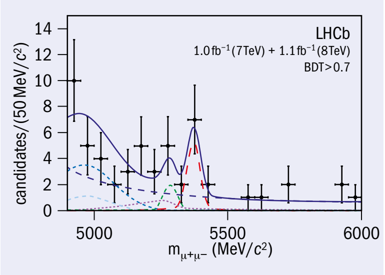


Fig. 2. Invariant mass distribution of observed signal candidates (points) for a region of BDT favouring signal over background. The components in red and green correspond to the signals of the B_s and the B^0 modes, while the other components are different background sources.

excess of candidates with respect to the background expectation (figure 2). A maximum-likelihood fit gives a branching fraction of $B(B_s \rightarrow \mu\mu) = 3.2^{+1.5}_{-1.2} \times 10^{-9}$. The probability that the background could produce an excess of this size or larger is 5.3×10^{-4}, corresponding to a signal significance of 3.5σ.

The measurement of $B_s \rightarrow \mu\mu$ is close to the Standard Model prediction, albeit with a large uncertainty. This eagerly awaited result was presented at the Hadron Collider Physics Symposium in Kyoto and at a CERN seminar, and is now published. While it does not provide evidence for supersymmetry, it does constrain the parameter space for this and other models of new physics, and is a step further in understanding the universe.

● Further reading

LHCb collaboration 2013 *Phys. Rev. Lett.* **110** 021801.

Mysterious long-range correlations seen in pPb collisions

The CMS collaboration has published its first result on proton–lead (pPb) collisions (CMS collaboration 2012), related to the observation of a phenomenon that was seen first in nucleus–nucleus collisions but also detected by CMS in 2010 in the first LHC proton–proton (pp) collisions at a centre-of-mass energy of 7 TeV (V Khachatryan *et al.* CMS collaboration 2010). The effect is a correlation between pairs of particles formed in high-multiplicity collisions – that is, collisions producing a high number of particles – which manifests as a ridge-like structure.

About once in every 100,000 pp collisions with the highest produced particle multiplicity, CMS observed an enhancement of particle pairs with small relative azimuthal angle Δφ (figure 1a). Such correlations had not been observed before in pp collisions but they were reminiscent of effects seen in nucleus–nucleus collisions first at Brookhaven's Relativistic Heavy-Ion Collider (RHIC) and later in collisions of lead–lead nuclei (PbPb) at the LHC (figure 1b shows peripheral PbPb collisions from CMS).

Nucleus–nucleus collisions produce a hot, dense medium similar to the quark–gluon plasma (QGP) thought to have existed in the first microseconds after the Big Bang. The long-range correlations in PbPb collisions are interpreted as a result of a hydrodynamic expansion of this medium and are used to determine its fluid properties. Remarkably, this matter is found to have low frictional resistance (shear viscosity/entropy density ratio), behaving as a (nearly) perfect liquid. Because a QGP medium was not expected in the small pp system, the CMS results led to a large variety of theoretical models, which attempted to explain the origin of these ridge-like correlations (Wei Li 2012).

In September 2012, the LHC provided a short pilot run of pPb collisions at a centre-of-mass energy of 5 TeV per nucleus, for just a few hours. CMS collected two million pPb collisions (figure 2) – and now the first correlation analysis of these data has revealed strong long-range correlations, most easily visible as the ridge-like structure highlighted in figure 1c. As was the case for the pp data, the most common simulations of pPb collisions do not show ridge-like correlations, thus indicating a new, still unexplained phenomenon. Surprisingly, the effect in pPb collisions is much stronger than in pp collisions. In fact, it is similar to that seen in PbPb collisions.

The 2013 pPb run should yield at least a 30,000-fold increase in the pPb data sample at the same collision energy. Combined with the surprisingly large magnitude of the observed correlations, this will enable detailed studies and open a new testing ground for basic questions in the physics of strongly interacting systems and the nature of the initial state of nuclear collisions.

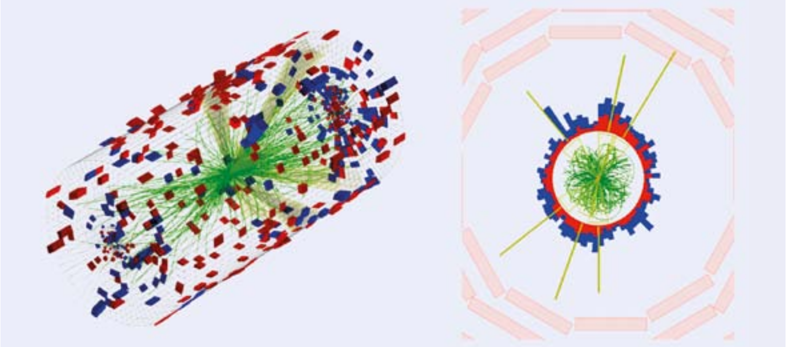


Fig. 2. Event display of a proton–lead collision in CMS, from the pilot run in September.

● Further reading

CMS collaboration 2012 arXiv:1210.5482 *Phys. Lett. B* in press.

V Khachatryan *et al.* CMS collaboration 2010 *JHEP* **09** 091.

Wei Li 2012 *Mod. Phys. Lett.* **A27** 1230018.

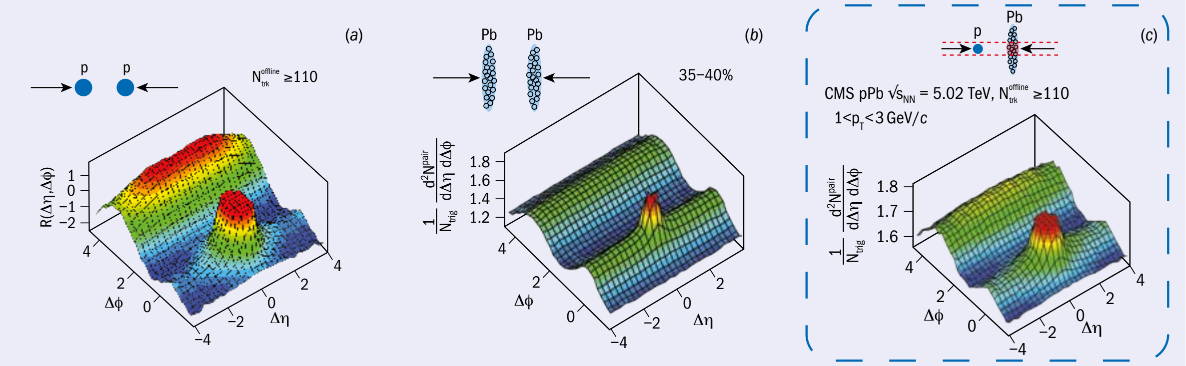


Fig. 1. (a) Correlations between pairs of particles formed in high-multiplicity collisions were first manifest in proton–proton collisions in CMS as a ridge-like enhancement at small relative azimuthal angle Δφ. (b) A similar effect was observed in peripheral lead–lead collisions and (c), most recently, in proton–lead collisions.

New boson's mirror image looks like the Higgs

More than 20 years ago, the CMS and ATLAS experiments at the LHC embarked on a long road into the unknown and, rather like Christopher Columbus, the two collaborations reached a new land last summer. But did they discover what they expected – the long awaited Higgs boson of the Standard Model – or have they found the first hint of a new unknown world? The only way to find out is to measure the characteristics of the new particle to establish if it is compatible with the expectations of the Standard Model.

The decay of the new boson to two Z bosons and subsequently to four leptons (figure 1) is an especially powerful tool. This decay channel produces four well measured tracks of particles in a low-background environment and contains a rich set of information that no other channel can provide. The CMS collaboration has exploited this information first to boost the significance of signal observed last summer and then to go even further. By using the decay kinematics – understanding how the masses and angles of all of the particles in the process are correlated – they have attempted to determine if the new particle is the Standard Model Higgs boson or a gateway to a new world.

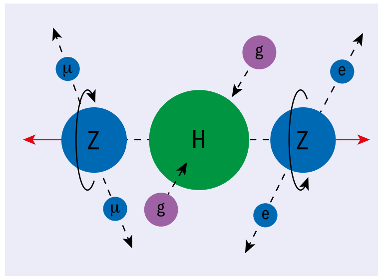


Fig. 1. The new Higgs-like boson, produced in the fusion of two gluons, is observed to decay to two Z bosons and hence to four leptons. Analysing the decay kinematics helps to determine if the new particle is, indeed, the Standard Model Higgs.

Using the full event information, the analysis assigns to each event the probability that it is a genuine Higgs boson, a more exotic particle or is just background. From these probabilities, it is possible to say how likely one model is compared with another. Figure 2 shows the expected likelihood for a genuine scalar Higgs boson (blue) and a pseudo-scalar boson (pink). The two hypotheses differ in the parity of the particle; in effect, the pseudo-scalar boson has a reversed mirror image. The green arrow on the plot is the measurement showing that the probability of a pure pseudo-scalar boson is small, indicating that this option is largely disfavoured by the data. This observation makes it possible to rule out a set of possible extensions of the Standard Model. A similar test of the hypothesis of a spin-2 particle has also been performed but it requires more data for a conclusive result. These are just the first steps into this new world. Further studies of the new boson will be possible in future as more data become available.

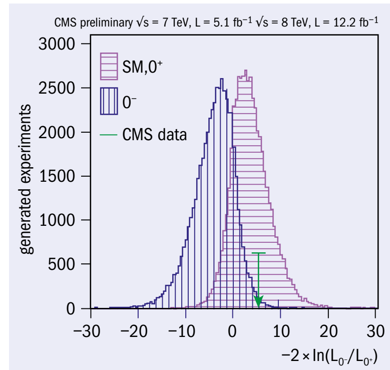
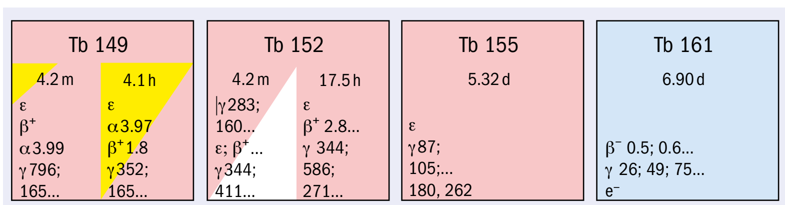


Fig. 2. Expected likelihood for a scalar (0^+) and a pseudo-scalar boson (0^-). The measurement (green arrow) shows that the probability that the new boson is 0^- is very small.

NUCLEAR MEDICINE

Terbium: a new 'Swiss army knife' for nuclear medicine



Terbium which comprises four medically interesting radioisotopes: the "Swiss army knife" for diverse applications in nuclear medicine.

A team of scientists from the Paul Scherrer Institute (PSI), CERN's ISOLDE facility and the Institut Laue-Langevin (ILL) has published results from a preclinical study of new tumour-targeting radiopharmaceuticals based on the element terbium. The results demonstrate the potential of providing a new generation of radioisotopes with excellent properties for the diagnosis and treatment of cancer.

Radiopharmaceuticals in which a radioactive isotope is attached to a carrier that selectively delivers it to tumour cells are used in two main ways, for diagnosis and for treatment. Nuclear imaging for diagnostics involves either β^+-emitting radioisotopes for positron-emission tomography (PET) or γ-emitting radioisotopes for use in single-photon-emission computed tomography (SPECT) and in planar imaging with gamma-cameras. By contrast, targeted radionuclide therapy employs the short-range radiation (α-particles and electrons) emitted by radioisotopes to destroy cancer cells.

So-called "matched pairs" of diagnostic and therapeutic radioisotopes of the same chemical element are particularly useful because they allow the preparation of radiopharmaceuticals that are absorbed and distributed in identical ways in the body. Terbium is the only element in the periodic table to offer not just a pair but four clinically interesting radioisotopes with complementary nuclear-decay characteristics covering all of the options for nuclear medicine: ^{152}Tb for PET, ^{155}Tb for SPECT, ^{149}Tb for α-particle therapy and ^{161}Tb for therapy with electrons (β^-, conversion and Auger electrons).

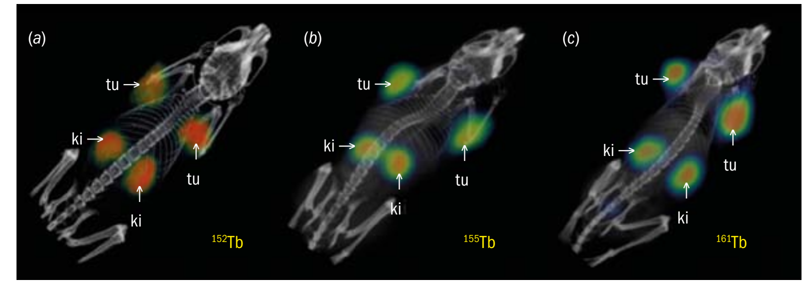


Fig. 2. PET (a) and SPECT images (b, c) of KB tumour-bearing mice 24 hours after injection of (a) ^{152}Tb-cm09, (b) ^{155}Tb-cm09 and (c) ^{161}Tb-cm09.

The team from the PSI, ILL and CERN has now made the first comprehensive preclinical study of this range of terbium radiopharmaceuticals. The neutron-deficient isotopes ^{149}Tb, ^{152}Tb and ^{155}Tb were produced by 1.4 GeV proton-induced spallation in a tantalum target and separated with the ISOLDE online isotope separator at CERN. ^{161}Tb was produced at the high-flux reactor of ILL and at the spallation neutron source SINQ at PSI. The isotopes were then purified using cation-exchange chromatography at PSI.

For this first *in vivo* proof-of-principle study the team developed a new delivery agent, which targets folate receptors in the body. These receptors are over-expressed in a variety of aggressive tumours, including ovarian and other gynaecological cancers as well as certain breast, renal, lung, colorectal and brain cancers, while their distribution in normal tissues and organs is highly limited. Folate vitamins have a rapid uptake in the body but they are also rapidly eliminated, so they do not remain long enough to reach all cancer cells. Hence, the team designed a new folate delivery agent called "cm09", where folic acid is conjugated with an albumin-binding entity to prolong the circulation time in the blood.

For the study, the terbium radioisotopes were combined with the cm09 and then administered to tumour-bearing mice. Excellent tumour-to-background ratios 24 hours after injection allowed tumour xenografts in mice to be seen using small-animal PET (^{152}Tb-cm09) and small-animal SPECT (^{155}Tb-cm09 and ^{161}Tb-cm09). *In vivo* therapy experiments using ^{149}Tb-cm09 (α-therapy) and ^{161}Tb-cm09 (β-therapy) resulted in a marked delay in tumour growth or even complete remission, as well as a significant increased survival in treated animals compared with untreated controls.

Future progress in these promising diagnostic and treatment options depends crucially on the regular availability of the terbium isotopes, in particular of ^{149}Tb. At present ISOLDE at CERN is the world's only source of this isotope.

Further reading

C Müller *et al.* 2012 *J. Nucl. Med.* **53** 1951.

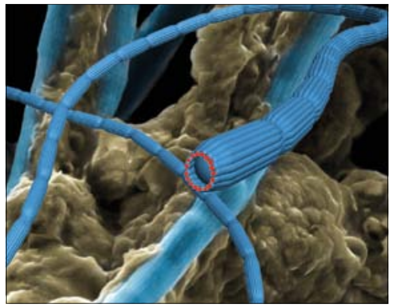
Sciencewatch

Compiled by John Swain, Northeastern University

Bacteria form living cables on the seabed

Bacteria in marine sediments that have no access to oxygen can instead use electro-acceptors such as sulphate but this produces toxic hydrogen sulphide. However, it seems that some bacteria can turn the hydrogen sulphide into sulphur via electrons transported from higher layers that contain oxygen. These electrons are transported – amazingly – along insulated wires.

Christian Pfeffer of Aarhus University in Denmark and colleagues made this discovery in bacteria of the *Desulphobulbaceae* family. Each of these



Cable bacteria in the mud of the sea bottom. (Image credit: Mingdong Dong, Jie Song and Nils Risgaard-Petersen.)

"cable bacteria" contains a bundle of insulated wires up to 1.5 cm long, which lead an electric current from one end to the other. Cutting the "wires" impedes the conversion of hydrogen sulphide and reduces oxygen consumption in the upper layers.

Further reading

C Pfeffer *et al.* 2012 *Nature* **491** 218.

Through a ground glass – clearly

A new technique allows fluorescent objects to be imaged clearly through strongly scattering media. Previous approaches have used ballistic photons (where those that do not scatter get through faster – but this only works for short distances) or phase conjugation (which forms an image behind the scattering medium where it cannot be seen easily).

Jacopo Bertolotti of the University of Twente and the University of Florence in Italy and colleagues illuminate an object behind a scattering layer with a laser at various angles and use the information from the speckle pattern to reconstruct an uncorrupted image. They are able to retrieve detailed images of human-cell sized (50 μm) objects 6 mm away through ground glass, well beyond what can be done with the ballistic technique. The work opens up the possibility of obtaining clear images through biological tissues and blood using only light.

Further reading

J Bertolotti *et al.* 2012 *Nature* **491** 232.

Collisional origin for the Moon

The similarity of the ratios of oxygen isotopes of the Moon and the Earth to 5 parts per million (in contrast to other objects), and other evidence, suggests a common origin for both. Tungsten-isotope dating requires that the Moon formed more than 30 million years after the start of the Solar System, much later than the few hundred thousands of years for other objects of similar size – hence the suggestion that a great collision could have given rise to both.

Previous models have had trouble fitting this great event, but now two are in good agreement, assuming a day on the early Earth of 2.5 hours. Matija Ćuk, now at the SETI Institute in California and Sarah Stewart of Harvard favour a model in which a smaller object hits the Earth, while Robin Canup of Southwest Research Institute in Boulder prefers a young Earth being hit by a small, fast object – so there is still no single model. That the Earth once spun so quickly had seemed impossible but it now appears that the requisite slowdown could arise through a resonant Sun–Earth–Moon interaction.

Further reading

R M Canup 2012 *Science* **338** 1052.

M Ćuk and S T Stewart 2012 *Science* **338** 1047.

Slicing softly: less force, more shear

Push straight down on a blade and it does not cut a soft material as easily as dragging the blade across at an angle in a "slicing" action – when even a piece of paper can cut skin. To understand why this is so, Etienne Reyssat and colleagues at Harvard University have used experiment and numerical simulations to investigate the underlying physics.

They find that a normal cutting force globally deforms the solid, requiring the blade to penetrate deeply. However, with shear added, fractures in the material nucleate and the bulk deformation is smaller, leading to less force being needed. In addition to its practical implications for food preparation and histology work, it also explains the shape of a guillotine blade and the origin of those painful paper cuts.

There's more to cutting than just a sharp edge. (Image credit: EggheadPhoto (Elian Kars)/dreamstime.com.)

Further reading

E Reyssat *et al.* 2012 *Phys. Rev. Letts.* **109** 244301.

Explosive effects of the uncertainty principle

Quantum effects turn out to be important in the ignition and detonation of gases such as hydrogen and acetylene at low temperature and high pressure. AV Drakon of the Russian Academy of Sciences in Moscow and colleagues have tracked large (2 or 3 orders of magnitude) discrepancies between theoretical and experimental data down to quantum effects that arise from the uncertainty principle. These effects increase the high-energy tails of the momentum distributions. As well as showing a novel place for quantum effects to be large, the work has important implications for the safe storage of such gases and for the release of hydrogen at nuclear power plants.

Further reading

A V Drakon *et al.* 2012 *Phys. Rev. Letts.* **109** 183201.

Astrowatch

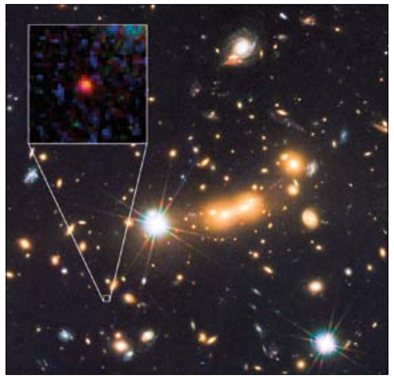
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

Hubble reveals earliest galaxies

Although the Hubble Space Telescope is more than 22 years old, the regular upgrade of its instruments preserves intact its discovery potential as time goes by. Now, its quest to detect the most distant and therefore earliest galaxies in the universe is reaching new frontiers with two candidates at a redshift of around 11. One of them was found in the Hubble Ultra Deep Field, the other using the light amplification of gravitational lensing induced by a cluster of galaxies.

Of all of the scientific satellites, Hubble is the only one that can be upgraded by astronauts. The fourth and final servicing mission was conducted in May 2009 with the space shuttle *Atlantis*. One of the two new instruments installed was the Wide Field Camera 3 (WFC3), which offers a large field of view and broad wavelength-coverage from ultraviolet to infrared light. These characteristics make it an ideal instrument to find rare and extremely distant galaxies.

Identifying such galaxies requires looking for as long as possible in an apparently empty patch of the sky and searching for the faintest spots of light that show up in the infrared image while being absent in the visible range. A remote galaxy will be observed only in the infrared because the wavelength of its visible radiation has been stretched on its journey by the expansion of the universe. This redshift, z, is a direct measurement of the cosmological distance of a galaxy and it can be determined accurately by measuring the shift of well identified spectral lines. Such a spectroscopic determination is out of reach for current instrumentation because the galaxies are too faint. A less robust alternative is to integrate the light in a series of spectral bands with various filters and to locate the bands on each side of the "Lyman break" – a sharp feature that results from the absorption of light by neutral hydrogen in a star-forming galaxy at wavelengths below 91.2 nm, corresponding to the energy (13.6 eV) needed to ionize the atom.



Hubble image of the galaxy cluster MACS J0647.7+7015. The inset is a zoom on a background galaxy magnified about eight times by the cluster's gravitational lensing effect. This dwarf galaxy is observed as it was 420 million years after the Big Bang, when the universe was 3% of its current age. (Image credit: NASA, ESA, M Postman and D Coe of STScI and the CLASH team.)

A team of scientists co-led by Richard Ellis of Caltech and Ross McLure of the University of Edinburgh has made new observations of the Hubble Ultra Deep Field (*CERN Courier* November 2012 p15). The study used one additional filter and undertook much deeper exposures in some filters to improve the reliability of high-redshift determinations. The team identified seven galaxies at redshifts above 8.5 that would represent a previously unseen population of galaxies that formed more than 13 thousand million years ago, when the universe was only about 3–4% of its current age. One of the galaxies, designated UDFj-39546284, was already a candidate for the highest redshift (z around 10) two years ago (*CERN Courier* March 2011 p10). The new observations suggest that it is even further away, at z = 11.9, unless it is an intense emission-line galaxy at z around 2.4. The latter possibility can only be ruled out with a deep infrared spectrum of the kind that the James Webb Space Telescope will provide after its planned in 2018.

Another team, led by Dan Coe of the Space Telescope Science Institute (STScI) in Baltimore, is using a different approach. They look for high-redshift objects around 25 clusters of galaxies observed by Hubble. The clusters are used as magnifying glasses that have the potential to amplify the light of background galaxies by a large factor, thanks to strong gravitational lensing (*CERN Courier* April 2008 p11). The latest discovery is a galaxy, known as MACS0647-JD, with a redshift of 10.8 ± 0.5. It seems to be a tiny galaxy with a mass not exceeding 1% of the mass of the Milky Way and could be one of many building blocks of a spiral galaxy like ours.

● **Further reading**
R S Ellis *et al.* 2013 *ApJ Lett.* in press.
D Coe *et al.* 2013 *ApJ* **762** 32.

Picture of the month

These spectacular jets are the manifestation of an active nucleus in the elliptical galaxy Hercules A. The image combines radio observations from the recently upgraded Karl G Jansky Very Large Array (VLA) in New Mexico, with a deep Hubble image in visible light. The unprecedented details in the jets were achieved by combining VLA images from compact and extended configurations of the 27 antennae, which each have a diameter of 25 m. The jets are traced by synchrotron radiation from electrons spiralling in the ambient magnetic field. They span 1.5 million light-years, suggesting continuous ejection over millions of years of very-high-energy plasma beams at nearly the speed of light by a supermassive black hole in the core of the galaxy. While relativistic effects dim the inner jet in this orthogonal view, they would make it appear as a "blazar" – with strong, variable emission up to gamma-ray energies – if viewed along the axis of one of the jets. (Image credit: NASA, ESA, S Baum and C O'Dea of RIT, R Perley and W Cotton of NRAO/AUI/NSF, and the Hubble Heritage Team at STScI/AURA.)

CERN Courier Archive: 1970

A look back to CERN Courier vol. 8, January/February 1970, compiled by Peggie Rimmer

CERN

On computing

The amount of computing done at CERN doubled annually from 1962 to 1967. Since then the growth rate has decreased somewhat to a doubling every two years. To keep installed capacity in line with the foreseeable demand for about the next two years, an "interim solution" was completed in January. The CDC 6400, which together with the CDC 6600 provides the central computing service, has been converted into a 6500 with the addition of a second processor, an additional 64 K of core store and some peripheral equipment.

Study groups have looked at computing requirements for the coming years, taking into account such predictable items as the number of bubble chamber pictures, the number of events from electronics experiments, the number of physicists at CERN etc. Their studies show that a computer with several times the capacity of a CDC 6600 will be needed from the beginning of 1972. Beyond that requirements are less clear but the improvement programme at the 28 GeV Proton Synchrotron and the start-up of the Intersecting Storage Rings suggest that by about 1975 the capacity will need to be about 10 times that of a CDC 6600.

Computing Fellowships

CERN has recently extended its long established Fellowship programme in particle physics. The new programme provides opportunities, initially on a modest scale, for Member State scientists and engineers to participate in aspects of CERN's work where the facilities and expertise are among the most highly developed in Europe. The field of computers is a predominant example and a limited number of scientists can now come to CERN on Fellowships for up to two years to do computer research.

Computing requirements of the Laboratory are often at, or beyond, the limit of commercially available equipment and systems. This has led to CERN carrying out considerable research into developing new computing techniques and in applying them to physical, mathematical or engineering problems.

Looking ahead, CERN is concerned with overall computer system design, and problems associated with communication networks, multi-processor systems, large volume permanent storage systems and multi-access systems.

Computing school

This year, for the first time, CERN is organizing a "Computing and Data Processing School". It will be held at Varenna in Italy and is open to about 70 young computer scientists and high-energy physicists coming principally from the CERN Member States.

The initiation of this school, which may well become an annual event, recognizes the emergence of computer science during the past two decades as a subject in its own right. It is felt that considerable benefit will come from bringing together computer scientists and computer users. Computer scientists will appreciate the problems of the experimental physicist and may see more clearly the lines of research which could ease them; experimental physicists will appreciate the possibilities and limitations of computers by seeing the current state of the art in computer science.

● Compiled from texts on pp36–37.

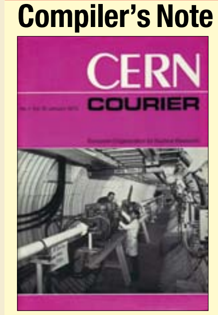
Tower of Babel undermined

Conventional language courses have been available at CERN since 1957, under the auspices of the Staff Association; nearly 350 pupils took these courses in 1969. For just over a month, a "language laboratory" has been in use for those who wish to learn English or French or Russian rapidly. Using the very latest audio-visual methods, it gives a facility, particularly in the field of pronunciation, almost unthinkable with more conventional systems. As soon as the project became known there was a rush to join and over 400 students are now enrolled.

● Compiled from texts on p46.

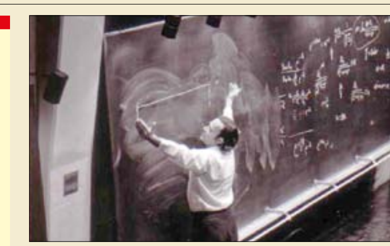
The new "language laboratory" at CERN.

Compiler's Note



At a time when few universities were offering fully fledged computer science degrees, the insatiable need of high-energy physicists for computing power put CERN ahead of the curve. Already primed to tackle problems associated with communication networks and multiprocessor systems, CERN was fertile ground for the invention of the World Wide Web, just 20 years after these articles were written.

And training? Currently 133 of CERN's 545 Fellowships are in computing, and Uppsala, Sweden, hosted CERN's 35th Computing School in August, 2012. And interdisciplinarians? When Nobel laureate Richard Feynman, quantum-computing pioneer, and Nicholas Metropolis, Monte Carlo-method pioneer, grew tired of repairing the mechanical calculators used by human computers working on the wartime Manhattan Project at Los Alamos, they set up a more robust alternative, using IBM punched cards.



Visiting CERN in January was R P Feynman, who has recently been working on strong interaction theory. On 8 January, he packed the lecture theatre, as usual, when he gave a talk on inelastic hadron collisions and is here caught in a typically graphic pose.

● Compiled from texts on p10.

ATLAS in 2012: building on success

In a year where the LHC delivered nearly as much data in a week as it previously did in a month, the ATLAS experiment not only discovered a Higgs-like particle but announced many results based on new searches and refined precision measurements.

There was a keen sense of anticipation and excitement throughout the ATLAS collaboration as 2012 dawned. The LHC had performed superbly over the previous two years, delivering 5 fb^{-1} of proton–proton collision data at a centre-of-mass energy of 7 TeV in 2011, thereby allowing ATLAS to embark on a thorough exploration of a new energy regime (*CERN Courier* December 2011 p23). This work culminated with the first hints of a potential Higgs-like particle at a mass of about 126 GeV being reported by both the ATLAS and CMS collaborations at the CERN Council meeting in December 2011. With the promise of a much larger data sample at the increased collision energy of 8 TeV in 2012, everyone looked forward to seeing what the new data might bring.

The period leading up to the first collisions in early April 2012 saw intensive activity on the ATLAS detector itself, with the installation of additional sets of chambers to improve the coverage of the muon spectrometer, as well as the regular winter maintenance and consolidation work – essential for making sure that the detector was ready for the long year of data-taking ahead. With the promise of high-luminosity data with up to 40 simultaneous proton–proton collisions ("pile-up") per bunch crossing – some 2–3 times more than seen in 2011 – experts from the groups responsible for the trigger, offline reconstruction and physics objects worked intensively to ensure that the online and offline software and selections were ready to cope with the influx of data. Careful optimization ensured that the performance of selections for electrons, τ leptons and missing transverse momentum, for example, were made stable against high levels of pile-up, while still keeping within the limits of the computing resources and maintaining – or even exceeding – the efficiencies and purities obtained in the 2011 data.

Meanwhile, the physics-analysis teams worked to finalize their analyses of the 2011 data for presentation at the winter/spring conferences and subsequent publication, while at the same time preparing for analysis of the new data. Members of the Higgs group focused attention on the two high mass-resolution channels $H\rightarrow\gamma\gamma$ and $H\rightarrow ZZ^{(*)}\rightarrow 4$ leptons (figure 1), where the Higgs signal would appear as a narrow peak above a smoothly varying background. These channels had shown hints in the 2011 data and had the greatest potential to deliver early results in 2012. Using data samples from 2011 and a Monte Carlo simulation of the anticipated new data at 8 TeV, the analyses were re-optimized to maximize sensitivity in the mass region of 120–130 GeV, taking full advantage of the new object-reconstruction algorithms and selections.

The race to Australia

Once data-taking began in early April, the first priority was to calibrate and verify the performance of the detector, trigger and reconstruction, comparing the results with the new 8 TeV Monte Carlo simulation. The modelling of pile-up was particularly important and was checked using a dedicated low-luminosity run of the LHC, where events were recorded with only a single interaction per bunch crossing. Having established the basic conditions for physics analysis, attention then turned to preparations for the International Conference on High-Energy Physics (ICHEP) taking place on 5–11 July in Melbourne, where the particle-physics community and the world's media would be eagerly awaiting the latest results from the new data.

As ICHEP drew nearer, the LHC began to deliver the goods, with up to 1 fb^{-1} of data per week. Each new run was recorded, calibrated and processed through the Tier-0 centre of the Worldwide LHC Computing Grid at CERN, before being thoroughly checked and validated by the ATLAS data-quality group and delivered to the physics-analysis teams on a regular weekly schedule. At the same time, the worldwide computing Grid resources available to ATLAS worked round the clock to prepare the corresponding Monte Carlo simulation samples at the new collision energy of 8 TeV. At first, the analysers in the Higgs group restricted their attention to control regions in data, aiming to prove to themselves and the rest of the collaboration that the new data were thoroughly understood. After a series of review meetings, with a few weeks remaining before ICHEP, the go-ahead was ▷

As ICHEP drew nearer, the LHC began to deliver the goods, with up to 1 fb^{-1} of data per week.

given to "un-blind" the data taken so far – a moment of great excitement and not a little anxiety.

At first only hints were visible but as more data were added week by week and combined with the results from an improved analysis of the 2011 data, it rapidly became clear that there was a significant signal in both the γγ and 4-lepton channels. The last few weeks before ICHEP were particularly intense, with exhaustive cross-checks of the results and many discussions on exactly how to present and interpret what was being seen. With the full 5.8 fb^{-1} sample from LHC data-taking up until 18 June included, ATLAS had signals with significances of 4.5σ in the γγ channel and 3.4σ in 4 leptons, leading to the reporting of the observation of a new particle with a combined significance of 5.0σ at the special seminar at CERN on 4 July and at the ICHEP conference.

Similar signals were seen by CMS and both collaborations submitted papers reporting the discovery of this new Higgs-like resonance at the end of July (*CERN Courier* September 2012 pp43–50). As well as the γγ and 4-lepton results reported at ICHEP, the paper by ATLAS also included the analysis of the H→WW(*)→lνlν channel, which revealed a broad excess with a significance of 2.8σ around 125 GeV. The combination of these three channels together with the 2011 data analysis from several other channels established the existence of this new particle at the 5.9σ level (figure 2), ushering in a new era in particle physics.

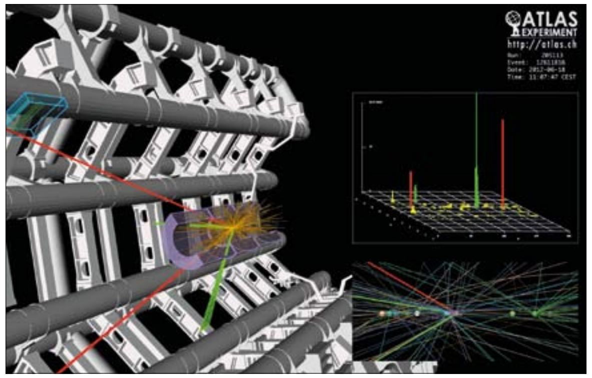


Fig. 1. Event display of a candidate H→ZZ(*)→2e2μ event in the ATLAS detector.

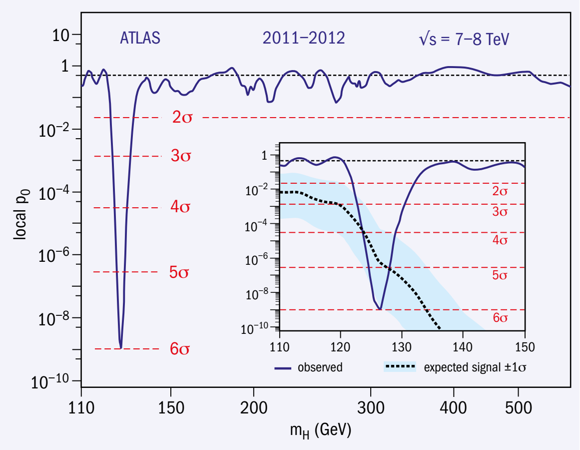


Fig. 2. The probability p_0 for a background-only experiment to be more signal-like than the observation, as a function of the Higgs mass hypothesis, m_H, from the ATLAS discovery paper of July 2012. The solid line shows the observation and the dashed line the expectation for a Standard Model Higgs boson of mass m_H, together with the expected ±1σ fluctuations.

Searching for the unexpected

As well as following up on the hints of the Higgs seen in the 2011 data, the ATLAS collaboration has continued to conduct intensive searches across the full range of physics scenarios beyond the Standard Model, including those that involve supersymmetry (SUSY) and non-SUSY extensions of the Standard Model. More than 20 papers have been published or submitted on SUSY searches with the complete 2011 data set, with a similar number published on other searches beyond the Standard Model. One particular highlight is the search for the dark matter that is postulated to exist from astronomical observations but which has never been seen in the laboratory. By searching for "unbalanced" events, in which a single photon or jet of particles is produced recoiling against a pair of "invisible" undetected particles, limits can be set on the interaction cross-sections of the dark-matter candidates known as weakly interacting massive particles (WIMPs) with ordinary matter. Using the full 2011 data set, ATLAS was able to set limits on such WIMP-nucleon cross-sections for WIMPs of mass up to around 1 TeV; these limits are complementary to those achieved by direct-detection and gamma-ray observation experiments.

Another highlight is the search for new particles that decay into pairs of top (t) and antitop ($\bar{t}$) quarks, giving rise to resonances in the $t\bar{t}$ invariant mass spectrum. The complete 2011 data set gives access to invariant masses well beyond 1 TeV, where the t and $\bar{t}$ tend to decay in "boosted" topologies with two sets of back-to-back collimated decay products (*CERN Courier* November 2012 p11). By reconstructing each top decay as a single "fat" jet and exploiting recently developed techniques to search for distinct objects within the "substructure" of these jets, ATLAS was able to set limits on the production of resonances from the decay of Z' bosons or Kaluza-Klein gluons in the tera-electron-volt range, even though high levels of pile-up added noise to the jet substructure. Such techniques will become even more important in extending these searches to higher masses with the full 2012 data sample.

The search for SUSY continued apace in 2012, with new results from 8 TeV data presented at both the SUSY 2012 conference in August and the Hadron Collider Physics Symposium in November. By looking for events with several jets and large missing transverse energy, limits on the strong production of squarks and gluinos were pushed beyond 1.5 TeV for equal-mass squarks and gluinos in the framework of minimal supergravity grand unification (mSUGRA) and the constrained minimal supersymmetric extension of the Standard Model (CMSSM). The lack of evidence for "generic" SUSY signatures with masses close to the electroweak and top-quark mass scales – together with the discovery of a light Higgs-like object around 126 GeV – has led to much theoretical interest in sce-

narios where only the third generation of SUSY particles (top and bottom squarks, stau lepton) are relatively light. ATLAS performed a series of dedicated searches for the direct production of bottom and top squarks. The latter in particular give rise to final states that are similar to top-pair production, so searches become particularly challenging if the masses of the top squark and quark are similar. Data from 2012 were used to fill much of the "gap" around the mass of the top quark (figure 3, p20).

Precision measurements

The ATLAS search programme described above relies on a thorough understanding of the Standard Model physics-processes that form the background to any search, but are also interesting to study in their own right. Fully exploiting the large statistics of the 2011 and 2012 data samples requires an understanding of the efficiencies, energy scales and resolutions for physics objects such as electrons, muons, τ leptons, jets and b-jets to the level of a few per cent or better, which in turn requires a dedicated effort that continued throughout 2012. This effort paid off in a large number of precise measurements involving the production of combinations of W and Z bosons, photons and jets, including those with heavy flavour. In many cases, these results challenge the current precision of QCD-based Monte Carlo calculations and provide important input for improving the ability to describe physics at LHC energy scales. Studies of high-rate jet production and soft QCD processes have also continued, with measurements of event shapes, energy flow and the underlying event contributing to knowledge of the backgrounds that underlie all physics processes at the LHC. The measurements of WW, WZ, ZZ, Wγ and Zγ production have allowed stringent constraints to be placed on anomalous couplings of these bosons at high energies, in addition to being an essential ingredient in understanding the backgrounds to Higgs searches.

The large top-quark samples available in the data from 2011 and now 2012 have opened up a new era in the study of the heaviest known fundamental particle. The cross-sections for the production of both $t\bar{t}$ pairs and single top quarks have been measured precisely at both 7 TeV and 8 TeV; evidence for the associated production of a W boson and a top quark has also been observed. Limits have been set on the associated production of $t\bar{t}$ pairs together with W and Z particles, and even Higgs bosons, and these studies will be extended with the full 2012 data set. The asymmetry in $t\bar{t}$ production has also been measured with the full 7 TeV data set – although, unlike at the Tevatron at Fermilab, no hints of anomalies have been seen. The polarizations of top quarks and W bosons produced in their decays have been measured and spin correlations between decaying t and $\bar{t}$ quarks observed. Furthermore, ATLAS has begun to characterize the top-quark production processes in detail, looking at kinematic distributions and the production of associated jets – key ingredients in increasing the precision of top-quark measurements, as well as in evalu- ▷

SUSY searches become more challenging if the masses of the top squark and quark are similar.

ating top-quark backgrounds in searches for physics beyond the Standard Model.

In addition, ATLAS has continued to exploit the large samples of B hadrons produced at the LHC, in particular those from dimuon final states, which can be recorded even at the highest LHC luminosities. Highlights include the detailed study of CP violation in the decay $B_s \rightarrow J/\psi\phi$, which was found to be in perfect agreement with the expectation from the Standard Model, and the precise measurement of the Λ_b mass and lifetime.

In late 2011, ATLAS recorded around 20 times more lead–lead collisions than in 2010, allowing the studies of the hot, dense medium produced in such collisions to be expanded to include photons and Z bosons, as well as jets. A new technique was developed to subtract the "underlying event" background in lead–lead collisions, enabling precise measurements of jet energies and the identification of electrons and photons in the electromagnetic calorimeter. Bosons emerge from the nuclear collision region "unscathed", opening the door to using the energy balance in photon-jet and Z-jet events to study the energy loss suffered by jets. In addition, ATLAS has pursued a broad heavy-ion physics programme, which includes the study of correlations and flow, charged-particle multiplicities and suppression, as well as heavy-flavour production. The collaboration looks forward eagerly to the proton–lead physics run scheduled for early 2013.

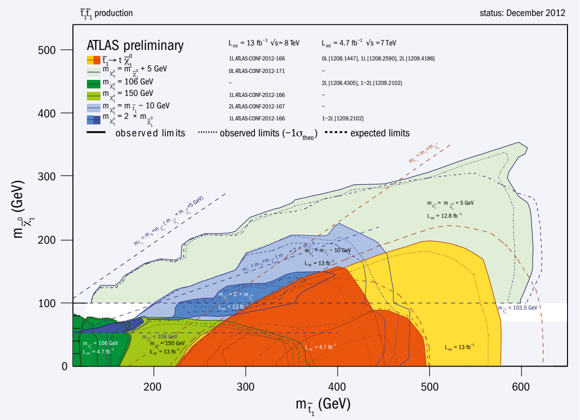


Fig. 3. Summary of dedicated searches by ATLAS for top squark pair production using 4.7 fb^{-1} of 7 TeV and 13 fb^{-1} of 8 TeV collision data, showing exclusion limits at 95% confidence level in the (top-squark, neutralino) mass plane.

What is next?

At the time of writing, ATLAS is on track to record more than 20 fb^{-1} of proton–proton collision data in 2012 and studies of these data by the various teams are in full swing across the whole range of search and measurement analysis. Building on the discovery announced in July, the next task for the Higgs analysis group is to learn more about the new particle, comparing its properties with those expected for the Standard Model Higgs boson and various alternatives. A first step was presented in September, where the July analyses were interpreted in terms of limits on the coupling strength of the new particle to gauge bosons, leptons and quarks, albeit with limited precision at this stage. It is also important to see if the particle decays directly to fermions, by searching for the decays $H \rightarrow \tau\tau$ and $H \rightarrow bb$.

These analyses are extremely challenging because of the high backgrounds and low invariant-mass resolution but first results using 13 fb^{-1} of 8 TeV data were presented at the Hadron Collider Physics Symposium in November. These results are not yet conclusive; the full 2012 data sample is needed to make any definite statements. At that point, it should also be possible to probe the spin and CP-properties of the new particle and improve the precision on the couplings, bringing the picture of this fascinating new object into sharper focus. At the same time, first results from searches beyond the Standard Model with the complete 2012 data set should be available, further increasing the sensitivity across the full spectrum of new physics models. The analysis of this data set will continue throughout the 2013–2014 shutdown, setting the stage for the start of the 13–14 TeV LHC physics programme in 2015 with an upgraded ATLAS detector.

● This article has only scratched the surface of the ATLAS physics programme in 2012. For more details of the more than 200 papers and 400 preliminary results, please see https://twiki.cern.ch/twiki/bin/view/AtlasPublic.

Résumé

ATLAS en 2012 : continuer sur sa lancée

Au cours d'une année pendant laquelle le LHC a fourni presque autant de données en une semaine qu'il en fournissait auparavant en un mois, l'expérience ATLAS non seulement a découvert une particule de type Higgs, mais aussi a annoncé de nombreux résultats s'appuyant sur de nouvelles recherches et des mesures de précision améliorées. Les points marquants sont de nouvelles limites sur d'éventuelles particules de matière noire et sur les particules supersymétriques. Des mesures de précision ont permis des études détaillées de la production de quarks et d'antiquarks top, ainsi que de la violation de CP dans les mésons B_s. Pour connaître plus en détail le nouveau boson, il faudra attendre l'analyse de toutes les données de 2012, qui continue à un rythme soutenu.

Richard Hawkings, CERN, for the ATLAS collaboration.

The ConfX conference attracted 400 participants from around the world. (Image credit: All photos Hector Martinez/TUM.)

Quarks on the menu in Munich

Quarks, their confinement into hadrons and their deconfinement in quark–gluon plasma were among the topics for lively discussion at the ConfX conference.

Some 400 theorists and experimentalists from all around the world convened in Munich on 8–12 October to discuss developments in the theory of strong interactions. They were attending the tenth conference on "Quark Confinement and the Hadron Spectrum" (ConfX) at the Garching Research Campus, hosted by the Physics Department of the Technical University of Munich (TUM), with support from the Excellence Cluster "Origin and Structure of the Universe". Topics included areas at the boundaries of the field, such as theories beyond the Standard Model with a strongly coupled sector and QCD approaches to nuclear physics and astrophysics.

Inaugurated in 1994 in Como, Italy, this series of conferences has established itself as an important forum in the field, bringing together people working in strong interactions on approaches that range from lattice QCD to perturbative QCD, models of the QCD vacuum to phenomenology and experiments, the mechanism of confinement to deconfinement and heavy-ion physics, and from effective field theories to physics beyond the Standard Model. Taking place at a particularly important time for particle physics, with the observation of a Higgs-like particle at CERN, the tenth conference provided a valuable opportunity not only to reconsider what was done on past occasions but also to discuss the perspectives for strongly coupled theories.

The scientific focus of ConfX was spread across seven main ▷

scientific sessions: vacuum structure and confinement; light quarks; heavy quarks; deconfinement; QCD and new physics; nuclear and astroparticle physics; and strongly coupled theories. These subjects are relevant for the physics of B factories (Belle and BaBar), tau-charm experiments (BESIII), LHC experiments (LHCb, CMS, ATLAS), heavy-ion experiments (RHIC, ALICE), future experiments at FAIR-GSI (Panda, CMB) and in general for many low-energy experiments (such as at Jefferson Lab, COSY, MAMI) and some parts of experimental astrophysics.

It is impossible to summarize here the wealth of results presented at the meeting, the intensity of the discussions and the flow of information. What follows is just a brief selection.

The first plenary session began with recent progress in the theoretical calculations of double parton-scattering at the LHC presented by Aneesh Manohar of the University of California, San Diego. The application of soft collinear effective theory to many collider physics processes was then introduced by Thomas Becher of Bern University and followed by a review of quarkonium production by Kuang-Ta Chao of Peking University. In particular, J/ψ production has now finally been calculated at next-to-leading order in nonrelativistic QCD (NRQCD) and the extraction of colour-octet matrix elements from a combined fit to collider data has become possible for the first time. The current picture hints at the universality of the NRQCD matrix elements and a proof of the NRQCD factorization in the fragmentation approach seems to be close. Predictions for the production of Υ and other quarkonia states at the LHC experiments are now available. The progress in theory together with the new LHC data should soon allow the resolution of the long-standing puzzles about the J/ψ polarization and the production mechanism of quarkonium, both at hadron colliders and at B factories.

Heavy ions and more

The study of quarkonium production and suppression at finite temperature in heavy-ion collisions as a probe of quark–gluon plasma was reviewed in the context of a new effective field-theory approach (potential NRQCD at finite temperature). Here the shift in paradigm from the typical phenomenological description is apparent, the quarkonium dissociation being caused by the emergence of a large imaginary part in the quark–antiquark potential rather than by a Debye screening phenomenon as reported by Jacopo Ghiglieri of McGill University. The effective field-theory approach allows a systematic calculation of the thermal modifications in the energy and width of the Υ(1S) as produced at the LHC in heavy-ion collisions.

There has been great progress in developing the capabilities of the lattice approach to calculate the properties of heavy and light quarks, and also in connection to chiral effective field theories, as Peter Lepage of Cornell University, Laurent Lellouch of the Centre de Physique Théorique, Marseilles, and Zoltan Fodor of the University of Wuppertal reported.

The interest and relevance of light scalars, as well as the long-standing controversy dating back to the 1950s about their existence and nature, has been resolved in recent years by means of better data and more powerful theoretical techniques that include effective Lagrangians and dispersion theory, as José Pelaez of the Complutense University of Madrid argued.

Highlights in strong physics beyond the Standard Model presented at the conference include: composite dynamics as put in context by Francesco Sannino of the Centre for Cosmology and Particle Physics Phenomenology, Odense, at the time of the Higgs discovery; gauge gravity duality; holographic QCD explained by Shigeki Sugimoto from Tokyo University; and applications of anti-deSitter/conformal field theory correspondence to heavy-ion collisions contrasted to proton–proton physics at the LHC now and in the future, including the outstanding LHC results, presented by Günther Dissertori of ETH Zurich. This session culminated in a heated discussion about future strongly coupled scenarios, led by Antonio Pich of Valencia University, in which different views of scenarios beyond the Standard Model were discussed but remained unreconciled among the panel members Estia Eichten of Fermilab, Emanuel Katz of Boston University, Juan Maldacena of the Institute of Advanced Study, Princeton, and Stefan Pokorski of the University of Warsaw.

The plenary session on Wednesday morning was dedicated to the impact of QCD on nuclear and astroparticle physics. Opening the session, Ulrich Wiedner of Ruhr University Bochum presented a comprehensive review of the highlights and future of low-energy experiments in hadron physics. An effective field theory and lattice description of a variety of nuclear bound states and reactions, as well as a review of the low-energy interaction of strange and charm hadrons with nucleons and nuclei, were presented by Evgeny Epelbaum, also of Bochum, and William Detmold at Massachusetts Institute of Technology. Charles Horowitz of Indiana University spoke about multimessenger observations of neutron-rich matter, describing the Lead Radius Experiment (PREX) at Jefferson Lab, which measures the neutron density of ^{208}Pb using parity-violating electron scattering. This has important implications for neutron-rich matter and neutron stars. He also described X-ray observations of radii of neutron stars, which are possibly model dependent, and their implications for the equation of state. Gravitational-wave observations of merging neutron stars and r-mode oscillations were discussed in terms of the equation of state, mechanical properties and bulk and shear viscosities of neutron-rich matter. This prepared the ground for the roundtable discussion on "What can compact stars really tell us about dense QCD matter", chaired by Andreas Schmitt of the Vienna University of Technology.

On Thursday morning, Pich gave an overview of the perturbative determination of α_s in which he presented the final value of 0.1187 ± 0.0007 and discussed the impact of the different type of α_s extractions on the final result.

A number of low-energy precision measurements are sensitive to new physics either because the Standard Model prediction for the measured quantity is precisely known – for example, the anomalous magnetic moment of the muon (g-2) – or because the Standard Model "background" is small, as in the case of electric dipole moments (EDMs). Timothy Chupp of the University of Michigan presented several studies that are under way to probe physics beyond the Standard Model, including g-2 and EDMs. He also described the prospects for the precision measurement of the Cabibbo-Kobayashi-Maskawa matrix element, V_{ud}, from neutron decay, i.e. the neutron lifetime and measurement of the axial-vector coupling constant (g_A), as well as couplings beyond the Standard Model accessible from neutron decay. The discussion culminated in the roundtable "Resolving physics beyond the Standard Model at low energy" led by Susan Gardner of the University of Kentucky.

Gerhard Ecker, left, and Thomas Mannel, centre, gave lectures in a session for the public chaired by Andrzej Buras, right.

The gigantic slide of the Mathematics Department at TUM complemented lively discussions during the poster session.

The final plenary session on Friday afternoon started with a talk by Mikko Laine of the University of Bern, in which he drew analogies and relationships between hot QCD and cosmology. John Harris of Yale University went on to review the latest heavy-ion data from Brookhaven's Relativistic Heavy-Ion Collider (RHIC) and the LHC. In particular, the data show how the "soup" of quark–gluon plasma flows easily, with extremely low viscosity – suggesting a near-perfect liquid of quarks and gluons. However, it appears opaque to energetic partons at RHIC and less so to the extremely energetic parton probes available in collisions at the LHC. This review was followed by presentations on the theoretical challenges and perspectives in the exploration of the hot QCD matter, including recent highlights in lattice calculations at finite temperature and finite density as presented by Peter Petreczky of Brookhaven National Laboratory. The session culminated with a roundtable about "Quark Gluon Plasma: what is it and how do we find it out?" chaired by Berndt Mueller of Duke University.

Yiota Foka of GSI and CERN reported on the International Particle Physics Outreach Group, which has developed an educational activity that brings LHC data into the classroom. Each year since 2005, thousands of high-school students in many countries go to nearby universities or research centres for one day to unravel the mysteries of particle physics and to be "scientists for a day". In 2012, 10,000 students from 130 institutions in 31 countries took part in the popular event over a four-week period.

The conference featured a plenary session and seven sessions running in parallel on the subjects of the seven topical sections, with a total of 250 parallel talks. The sections on vacuum structure and confinement and on deconfinement constituted almost two conferences in themselves, with a total of 54 talks in 17.5 hours and 57 talks in 24 hours, respectively. The conference as a whole ended with a visionary talk by Chris Quigg of Fermilab on "Beyond Confinement". The extraordinary scientific discussion and exchange that characterized the conference has served as a trigger for a document "Strongly Coupled Physics: challenges, scenarios and perspectives" that is currently in preparation in collaboration with the section conveners.

During the poster session, participants could also enjoy tasting cheese and a variety of wine from all of the countries represented. A ride down the gigantic slide belonging to the Mathematics Department complemented the lively scientific discussions. An evening session on the "Colourful world of quark and gluons" given by Gerhard Ecker, "The shaping of QCD", and Thomas Mannel, "The many facets of QCD", attracted the public from Garching city and from the many campus research institutes, as well as conference participants. Tours of Munich, glimpses of Bavarian culture at the famous Hofbräuhaus and a social dinner at the Hofbräukeller complemented the opportunity to discover the local campus facilities (the TUM Institute of Advanced studies and the TUM engineering, mathematics and physics departments).

• Further reading

For the full programme and details of all of the speakers and presentations, see http://www.confx.de.

Résumé

Des quarks au menu à Munich

Quelque 400 théoriciens et expérimentateurs du monde entier se sont réunis à Munich du 8 au 12 octobre pour échanger sur les dernières avancées de la théorie des interactions fortes. C'était la dixième édition de la Conférence sur le confinement des quarks et le spectre hadronique (ConfX). Les principaux thèmes de discussion ont été répartis entre sept sessions : structure du vide et confinement ; quarks légers ; quarks lourds ; déconfinement ; QCD et nouvelle physique ; physique nucléaire et physique des astroparticules ; théories à couplage fort. Ont été évoqués également des sujets se situant aux limites du domaine, par exemple les approches tendant à l'application de la chromodynamique quantique (QCD) à la physique nucléaire et à l'astrophysique.

Nora Brambilla, chair of ConfX, Technical University Munich (TUM).

A watershed: the emergence of QCD

David Gross and **Frank Wilczek** look back at how QCD began to emerge in its current form 40 years ago.


David Gross and Frank Wilczek, when they received the Nobel prize in 2004. (Image credit: D Gross.)

In a recent article, Harald Fritzsch shared his perspective on the history of the understanding of the strong interaction (*CERN Courier* October 2012 p21). Here, we'd like to supplement that view. Our focus is narrower but also sharper. We will discuss a brief but dramatic period during 1973–1974, when the modern theory of the strong interaction – quantum chromodynamics, or QCD – emerged, essentially in its current form. While we were active participants in that drama, we have not relied solely on memory but have carefully reviewed the contemporary literature.

At the end of 1972 there was no fundamental theory of the strong interaction – and no consensus on how to construct one. Proposals based on S-matrix philosophy, dual-resonance models, phenomenological quark models, current algebras, ideas about "partons" and chiral dynamics – the logical descendant of Hideki Yukawa's original pion-exchange idea – created a voluminous and rapidly growing literature. None of those competing ideas, however, offered a framework in which uniquely defined calculations leading to sharp, testable predictions could be carried out. It seemed possible that strong-interaction physics would evolve along the lines of nuclear physics: one would gradually accumulate insight experimentally, and acquire command of an ever-larger range of phenomena through models and rules of thumb. An overarching theory worthy to stand beside Maxwell's electrodynamics or Einstein's general relativity was no more than a dream – and not a widely shared one.

Within less than two years the situation had transformed radically. We had arrived at a very specific candidate theory of the strong interaction, one based on precise, beautiful equations. And we had specific, quantitative proposals for testing it. The theoretical works [1–5] that were central to this transformation can be identified, we think, with considerable precision.

First clues

Let us briefly recall the key lines of evidence and thought that those works reconciled, synthesized and brought to fruition. They can be summarized under three headings: quarks and colour; scaling and partons; quantum field theory and the renormalization group.

Quarks and colour: A large body of strong-interaction phenomenology, including the particle spectrum and magnetic moments, had been organized using the idea that mesons and baryons are composite particles made from combinations of a small number of more fundamental constituents: quarks. This approach, which had its roots in the ideas of Murray Gell-Mann [6] and George Zweig [7], is reviewed in a nice book by J J J Kokkedee [8]. For the model to work, the quarks were required to have bizarre properties – qualitatively different from the properties of any known particles. Their electric charges had to be fractional. They had to have an extra internal "colour" degree of freedom [9,10]. Above all, they had to be confined. Extensive experimental searches for individual quarks gave negative results. Within the model quark–antiquark pairs made mesons, while quark–quark–quark triplets made baryons; single quarks had to be much heavier than mesons and baryons – if, indeed, they existed at all.

Scaling and partons: The famous electroproduction experiments at SLAC revealed, beginning in the late 1960s, that inclusive cross-sections did not exhibit the "soft" or "form factor" behaviour familiar in exclusive and purely hadronic processes (as explored up to that time). Richard Feynman [11] interpreted these experiments as indicating the existence of more fundamental point-like constituent particles within protons, which he called partons. His approach was intuitive, employing a form of impulse approximation. James Bjorken [12] arrived at related results earlier, using more formal operator methods (local current algebra). Current-algebra sum rules were derived using "quark–gluon" models with Abelian, flavourless gluons. The agreement of these sum rules with experimental results on electron and neutrino deep-inelastic scattering gave strong evidence that charged partons are spin 1/2 particles [13] and that they have baryon number 1/3 [14], i.e. that charged partons are quarks.

Quantum field theory and the renormalization group: Martinus Veltman and Gerardus 't Hooft [15] brought powerful new tools to the study of perturbative renormalization theory, leading to a more rigorous, quantitative formulation of gauge theories of electroweak interactions. Kenneth Wilson introduced a wealth of new ideas, conveniently though rather obscurely referred to as the renormalization group, into the study of quantum field theory beyond the limits of perturbation theory. He used these ideas with great success to study critical phenomena. Neither of those developments related directly to the strong interaction problem but they formed an important intellectual background and inspiration. They showed that the possibilities for quantum field theory to describe physical behaviour were considerably richer than previously appreciated. Wilson [16] also sketched how his renormalization-group ideas might be used to study short-distance behaviour, with specific reference to problems in the strong interaction.

These various clues appeared to be mutually exclusive, or at least in considerable tension. The parton model is based on neglect of interference terms whose existence, however, is required by basic principles of quantum mechanics. Attempts to identify partons with dynamical quarks [17] were partially successful but ascribed a much more intricate structure to protons than was postulated in the simplistic quark models and unambiguously required additional, non-quark constituents. The confinement of quarks contradicted all previous experience in phenomenology. Furthermore, such behaviour could not be obtained within perturbative quantum field theory. There were numerous technical challenges in combining re-scaling transformations, as used in the renormalization group, with gauge symmetry.

But the most concrete, quantitative tension, and the one whose resolution ultimately broke the whole subject open, was the tension between the scaling behaviour observed experimentally at SLAC and the basic principles of quantum field theory. Several workers [18] expanded Wilson's somewhat sketchy indications into a precise mapping between calculable properties of quantum field theories and observable aspects of inclusive cross-sections. Specifically, this work made it clear that the scaling behaviour observed at SLAC could be obtained only in quantum field theories with very small anomalous dimensions. (Strict scaling, which is equivalent to vanishing anomalous dimensions, cannot occur in a non-trivial – interacting – quantum field theory [19].) A few realized that approximate scaling could be achieved in an interacting quantum theory, if the effective interaction approached zero at short distances. Anthony Zee called such field theories "stagnant"(they are essentially what we now call asymptotically free theories) and he [20], Kurt Symanzik [21] and Giorgio Parisi [22] searched for such theories. However, none found any physically acceptable examples. Indeed, a powerful no-go result [23] demonstrated that no four-dimensional quantum field theory lacking non-Abelian gauge symmetry can be asymptotically free.

Our paper, submitted in April 1973 [1], alludes directly to these motivating issues in its opening: "Non-Abelian theories have received much attention recently as a means of constructing unified and renormalizable theories of the weak and electromagnetic interactions. In this note we report an investigation of the ultraviolet (UV) asymptotic behaviour of such theories. We have found that they possess the remarkable feature, perhaps unique among renormalizable theories, of asymptotically approaching free-field theory. Such asymptotically free theories will exhibit, for matrix elements between on-mass-shell states, Bjorken scaling. We therefore suggest that one should look to a non-Abelian gauge theory of the strong interactions to provide the explanation for Bjorken scaling, which has so far eluded field-theoretic understanding."

Thus the tension between scaling and quantum field theory might be resolved but only within a special, limited class of theories. The paper surveys those possibilities and concludes: "One particularly appealing model is based on three triplets of fermions, with Gell-Mann's SU(3)xSU(3) as a global symmetry and an SU(3) "colour" gauge group to provide the strong interactions. That is, the generators of the strong-interaction gauge group commute with ordinary SU(3)xSU(3) currents and mix quarks with the same isospin and hypercharge but different "colour". In such a model the vector mesons are neutral and the structure of the operator product expansion of electromagnetic or weak currents is (assuming the strong coupling constant is in the domain of attraction of the origin!) essentially that of the free quark model (up to calculable logarithmic corrections).*" This was the first clear formulation of the theory that we know today as QCD. The footnote indicated by * refers to additional work, which became the core of our two subsequent papers [3,4].

The confinement of quarks contradicted all previous experience in phenomenology.

David Politzer's paper [2] contains calculations of the renormalization group coefficients for non-Abelian gauge theories with fermions, broadly along the same lines as in our first paper quoted above [1]. It does not refer to the problem of understanding scaling in the hadronic strong interaction. (The reference to "strong interactions" in the title is generic.) Politzer emphasized the importance of the converse of asymptotic freedom – that is, that the effective coupling grows at long distances. He remarks that this could lead to surprises regarding the particle content of asymptotically free theories and support dynamical symmetry breaking. Although we arrived at our results independently, we and Politzer learnt of each other's work before publication, compared results, requested simultaneous publication and referred to one another. The paper by Howard Georgi and Politzer [5] adopts QCD without comment and independently derives predictions for deviations from scaling parallel to the corresponding parts of our papers [3,4].

Further reflections

The preceding account omits several sidelights and near misses, and lots of prehistory. But, although it is incomplete, we do not think it is distorted.

It may be appropriate to mention explicitly contributions by ▷

CERN Courier January/February 2013

QCD

two extremely eminent physicists (with collaborators) that are often cited together with papers 1–5 in ways that can be misleading.

't Hooft, together with Veltman, had developed effective methods for calculating quantum corrections in non-Abelian gauge theories. They had worked out many examples, specifically including one-loop wave function and vertex divergences [24]. It would not have been very difficult, as a technical matter, to re-assemble pieces of those calculations to construct calculations of renormalization group coefficients. 't Hooft attests – and Symanzik corroborated – that he announced a negative value of the β function for non-Abelian gauge theories with fermions at a conference in Marseilles in the summer of 1972. Unfortunately, there is no record of this in the workshop proceedings, nor in the contemporary literature, so there is no documentation regarding the exact content of the announcement or its context. It had no influence on papers 1–5. In his contemporary work on the strong interaction, 't Hooft adopted a completely different perspective from that of Gross-Wilczek and Georgi-Politzer, a perspective from which it would be very difficult to arrive at QCD and its property of asymptotic freedom as we understand them today. Specifically, 't Hooft's work considered a spontaneously broken gauge theory with hadrons as the fundamental objects, e.g. ρ mesons as gauge particles. His relevant publications immediately following papers 1–5 supply alternative methods for calculating renormalization group coefficients but do not propose specific physical applications.

Two contributions involving Gell-Mann and collaborators are sometimes cited as sources of QCD. The first is the "Rochester Conference" at Fermilab in the summer of 1972 [25]. It contains two relevant presentations, Gell-Mann's summary talk and a contributed paper with Fritzsch, entitled "Current Algebra: Quarks and What Else?" In the summary talk, SLAC scaling is mentioned and interpreted in terms of "quarks, treated formally". The discussion is not rooted in quantum field theory; indeed, most of the discussion of the strong interaction, by far, is given over to S-matrix and dual-resonance ideas. The presentation with Fritzsch briefly mentions the possibility of using colour octet gluons, as one among several possibilities for extending light-cone current algebra (again, not within a quantum field theory).

The second contribution [26] appeared after 1–5 and refers to them. From a historical perspective, what is particularly revealing about it is the comment: "For us, the result that the colour octet field theory model comes closer to asymptotic scaling than the colour singlet model is interesting, but not necessarily conclusive, since we conjecture that there may be a modification at high frequencies that produces true asymptotic scaling."

As events unfolded, the most profound and most fruitful aspects of QCD and asymptotic freedom proved to be their embodiment in a rigorously defined, quantitatively precise quantum field theory, which could be tested through its prediction of deviations from scaling. Yet just those aspects are what the authors hesitated to accept, even after they had been analysed.

The emergence of a specific, precise quantum field theory for the strong interaction – featuring beautiful equations – marked a watershed. Remarkable progress ensued on several fronts.

The realization that basic strong interaction processes at high energy could be calculated in a practical, controlled and systematically improvable way opened up many applications (figure 1). The subject now called perturbative QCD, which refines and improves parton model ideas, is a direct outgrowth of papers 1–5 but extends their scope almost beyond recognition. Perturbative QCD is the subject of several large textbooks, dozens of conference proceedings, etc. It has become the essential foundation for analysing experimental results from high-energy accelerators including, notably, the LHC. It justifies, in particular, the identification of "jets" with quarks and gluons (figure 2), and allows calculation of their production rates.

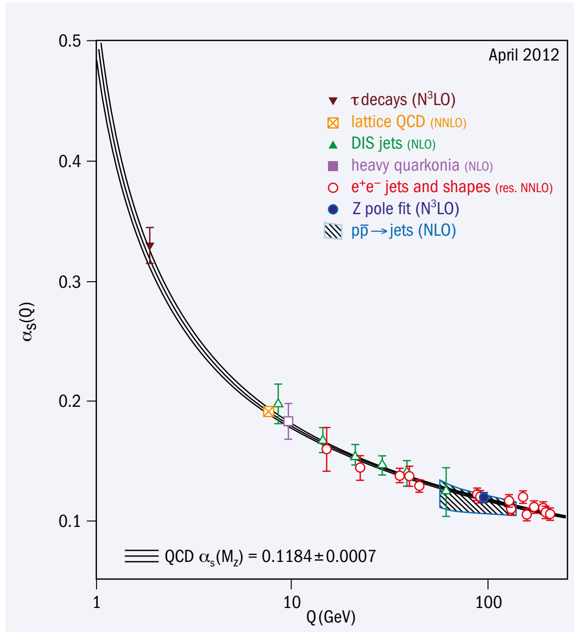


Fig. 1. Asymptotic freedom, a principal dynamical property of QCD, predicts the logarithmic decrease of the strong interaction coupling as energy increases or distance decreases. This figure shows the current agreement of QCD predictions with many experiments.

This was the first clear formulation of the theory that we know today as QCD.

The paradoxical heuristics of the quark model, with its juxtaposition of free-particle properties with confinement, became physically plausible and matured into a well posed mathematical problem [4]. For the growth of the effective coupling with increasing distance, together with the existence of formally massless (colour) charged particles, brought the theory into uncharted territory. Because uncancelled field energy threatens to build up catastrophically, it was plausible that only singlet states might emerge with finite energy. Essentially new mathematical techniques were invented to address this challenge. The most successful of these, based on direct numerical solution of the equations (so-called "lattice gauge theory") has gone far beyond demonstrating confinement to yield sharp quantitative results for the mass spectrum and for many detailed properties of hadrons.

More generally, the dramatic success of a fully realized quantum field theory in yielding a wealth of striking physical phenomena that are not evident in a linear approximation – including emergence of a dynamical scale ("mass without mass"), dynamical symmetry breaking, a rich physical spectrum and, of course, confinement – helped catalyse a renewed interest in the deep possibilities of quantum field theory. It continues to surprise us today.

Prior to papers 1–5, the behaviour of matter at ultrahigh temperatures and densities seemed utterly inaccessible to theoretical understanding. After these papers, it was understood instead to be remarkably simple. That circumstance opened up the earliest moments of the Big Bang to scientific analysis. It is the foundation of what has become a large and fruitful field: astroparticle physics.

The equations of QCD are rooted in the same mathematics of gauge symmetry [27] that underlies the modern theory of electroweak interactions. They are worthy to stand beside Maxwell's equations; one might even say they are an enriched version of those equations. It becomes possible to contemplate still more extensive symmetries, unifying the different forces. The methods used to establish asymptotic freedom – specifically, running couplings – provide quantitative tools for exploring that idea. Intriguing, encouraging results have been obtained along these lines. They suggest, in particular, the possibility of low-energy supersymmetry, such as might be observed at the LHC.

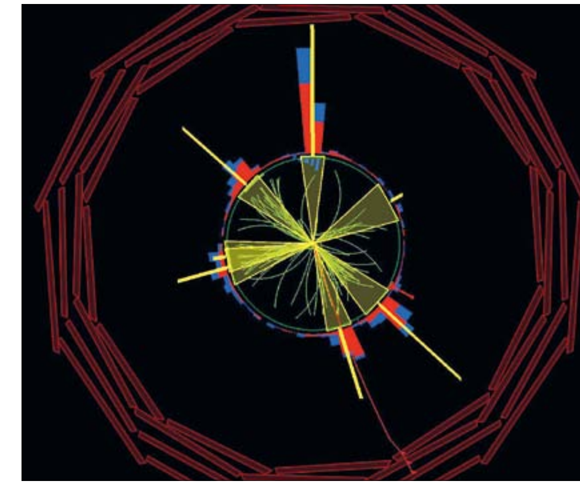


Fig. 2. Hadrons emerging from high-energy collisions at large transverse momentum occur in nearly collinear "jets". According to QCD the jets are initiated by quarks, antiquarks, and gluons, and inherit their energy and momentum. Pictured here is an event from the CMS collaboration at the LHC, which features six jets.

● Further reading

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Résumé

Une étape historique : l'émergence de la QCD

En 1972 il n'existait pas de théorie fondamentale de l'interaction forte, ni de consensus sur la voie à suivre pour en élaborer une. Or en moins de deux ans la situation s'est transformée de façon radicale. Dans cet article, David Gross et Frank Wilczek évoquent la naissance de la chromodynamique quantique, ou QCD, la théorie moderne de l'interaction forte. Ils racontent en détail cette période brève, mais riche en rebondissements, des années 1973–1974, qui a vu l'émergence de la QCD sous sa forme actuelle. Leur propre contribution à cette séquence mémorable leur a d'ailleurs valu un prix Nobel en 2004.

David Gross, Kavli Institute for Theoretical Physics, Santa Barbara, and **Frank Wilczek**, Massachusetts Institute of Technology. See their Nobel lectures for much additional material on the history and impact of asymptotic freedom and QCD.

CERN Courier January/February 2013

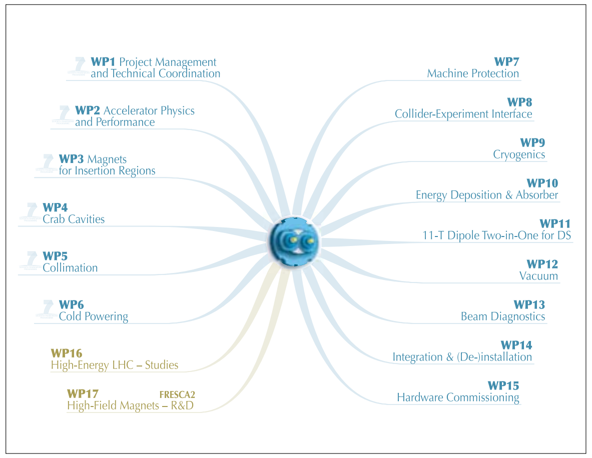
LHC upgrade

Superconductivity leads the way to high luminosity

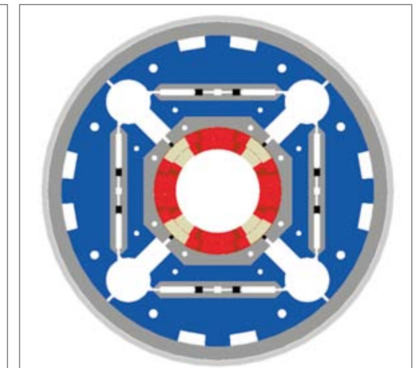
Recent progress and meetings highlight the work that is under way to upgrade the LHC in 10 years' time.

The LHC, the largest scientific instrument ever built, will extend its discovery potential at the beginning of the next decade through a fivefold increase in luminosity beyond the design value, in a new configuration called the High Luminosity LHC (HL-LHC). This extraordinary technical enterprise will rely on a combination of cutting-edge 11–13 T superconducting magnets, compact and ultraprecise superconducting radio-frequency cavities for beam rotation, as well as 300-m-long, high-power superconducting links with zero energy dissipation. In addition, the higher luminosities will make new demands on vacuum, cryogenics and machine protection, and will require new concepts for collimation and diagnostics, as well as advanced modelling for the intense beams.

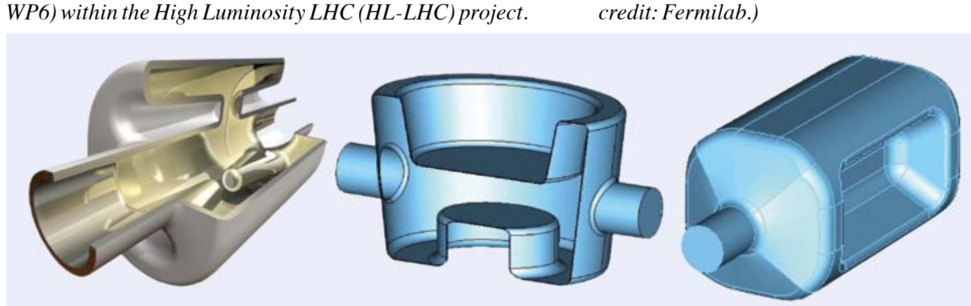
Now, as the LHC nears the end of its first long run – from March 2010 to March 2013 – preparation work for this major upgrade is gathering speed. The past year has seen major developments in some of the key superconducting technologies, in particular for the new high-field magnets and the high-power links. Meanwhile, important decisions have been taken within the HiLumi LHC Design Study, which was launched just over a year ago. Supported in part by funding from the Seventh Framework Programme (FP7) of the European Commission (EC), this is the first phase of the larger HL-LHC project (*CERN Courier* March 2012 p19).



Work Packages of the HiLumi LHC FP7 Design Study (WP1 to WP6) within the High Luminosity LHC (HL-LHC) project.



Above: Cross-section for the 150 mm Nb_3Sn baseline option for the inner triplet quadrupole. Right: An 11 T magnet ready for cryogenic testing at Fermilab. (Image credit: Fermilab.)



Designs for crab cavities. Left, 4-rod (Lancaster/Cockcroft Institute); centre, quarter-wave (Brookhaven); and double-ridge (SLAC/ODU).

Broad collaboration

Towards the end of 2012, two meetings provided the opportunity for people involved at these accelerator frontiers to review progress and plan future activities, not only within their institutes around the world but also with industrial partners. On 14–16 November, the INFN Frascati National Laboratory was host to the 2nd Joint HiLumi LHC–LARP Annual Meeting. This brought together some 130 experts from Europe, Japan, Russia and the US LHC Accelerator Research Program (LARP). Three weeks later, on 4–5 December, a workshop on "Superconducting technologies for next-generation accelerators" took place at CERN organized by the HiLumi LHC Design Study in conjunction with the Test Infrastructure and Accelerator Research Area (TIARA) project, which is also co-funded by the EC under FP7 (*CERN Courier* June 2011 p28). The workshop attracted more than 100 specialists, half from industry and half from laboratories and institutes. The aim was to explore the technical challenges emerging from the design of new accelerators and to match them with state-of-the-art industrial solutions.

Superconductivity has been the most important enabling technology in particle accelerators for the past 30 years – since the time of CERN's Intersecting Storage Rings (the first accelerator to employ superconducting magnets during operation) and Fermilab's Energy Doubler (*CERN Courier* November 2011 p28). The latter, later renamed the Tevatron, was the first large-scale superconducting system and it paved the way for all of the subsequent superconductivity projects, including the HERA collider at DESY, phase II of the Large Electron–Positron collider at CERN, the TRISTAN electron–positron collider at KEK and the Relativistic Heavy-Ion Collider at Brookhaven National Laboratory. Today, superconductivity is the core technology of the LHC, which employs some 1700 large superconducting magnets (dipoles and quadrupoles) and nearly 8000 superconducting corrector magnets, all cooled by more than 100 tonnes of superfluid helium.

The main target for the HL-LHC is to achieve an integrated luminosity of 250 fb^{-1} a year.

The LHC's main dipoles are 8 T superconducting magnets made from coils of niobium-titanium (NbTi) alloy. To allow the installation of additional collimators to deal with the increased luminosity in the HL-LHC, in 2010 CERN's Lucio Rossi suggested replacing some of the 8 T dipoles with shorter 11 T magnets based on niobium-tin (Nb_3Sn), which is superconducting at a higher temperature than NbTi. This idea also interested Fermilab, which has a high-field magnet R&D programme aimed at developing magnets for future machines such as a muon collider. CERN and Fermilab began to collaborate and by the spring of 2012 they completed a 2-m-long Nb_3Sn dipole. In summer it was tested at 1.9 K in the Fermilab Vertical Test Facility, reaching a current of 11.2 kA and a calculated field of 10.4 T.

Such developments feed directly into the HiLumi LHC Design Study, which covers six work-packages (WP) of the larger HL-LHC project. The work of the design study is overseen by project management (WP1), which has CERN's Hermann Schmickler as its new technical co-ordinator. Various committees and bodies, in particular the newly formed HL-LHC Co-ordination Group, ensure the necessary link between the machine-upgrade and the detector-upgrade projects, under the supervision of CERN management. The recent Joint HiLumi LHC–LARP Annual Meeting reviewed their progress as well as the headway that has been made towards a final layout for the accelerator upgrade.

Good progress

The main target for the HL-LHC is to achieve an integrated luminosity of 250 fb^{-1} a year and a total of 3000 fb^{-1} over 12 years. A key step in reaching this target lies in reducing the β* function (related to the focal length) at collision. With this in view, the team working on accelerator physics and performance (WP2) has collaborated closely with members of the LHC injector upgrade project as well as the current LHC operation group. As a result, they have defined possible sets of machine optics (in relation to β* and the crossing angle) and beam parameters (emittance, bunch spacing, bunch charge) that can achieve their goal. A further important development in WP2 is the recent, successful test in the LHC of luminosity-levelling by varying β*.

A reduced β* in turn requires a redesign of the magnets in the insertion regions (IRs) where the collisions occur, which is the task of WP3. One important decision, taken in July in collaboration with WP2 and WP10 of HL-LHC (energy deposition and absorber), was to opt for the maximum possible aperture for the quadrupoles of the inner triplets: 150 mm of coil-free bore. This choice was based on successful tests within US-LARP of a 4-m-long, 90 mm aperture quadrupole and a more recent 1-m-long structure with a 120 mm aperture, both based on advanced Nb_3Sn superconductor (*CERN Courier* January/February 2010 p6). In light of this decision, the teams working on accelerator physics and magnets in US-LARP are adjusting their plans and preparing a construction project for 2015.

While the work of WP3 has focused on providing major input to the choice of the quadrupole aperture, a decision on shielding has been made to use tungsten elements and a beam screen. At the same time, the conceptual design of the new D1 dipoles for the IRs is being steered by the KEK laboratory in Japan, where teams have analysed the performance of three possible apertures. The proposal is to have an 8-m-long magnet operating at 5 T.

To make the decreased β* most effective, the HL-LHC will use superconducting "crab cavities" to rotate particle bunches before they collide. These special radio-frequency cavities, which are the focus of WP4, may also provide levelling of the luminosity during the beam spill. The conceptual and technical design of three compact cavities ("4-rod", "double ridge" and "quarter-wave") has now been completed successfully. The new Crab Cavity Technical Co-ordination Working Group will, after the first long shutdown ▷

Mock-up of an assembly of cables made from 24 twisted-pairs of MgB_2, designed for powering the LHC corrector magnets.

of the LHC, oversee preparation for the integration of crab cavities in the LHC and the preliminary tests in the Super Proton Synchrotron in 2015. Laboratory tests of a prototype 4-rod crab cavity built from bulk niobium superconductor by Lancaster University and the Cockcroft Institute in the UK began in November at CERN, while a prototype of the double-ridge type is under final preparation by a team from SLAC and Old Dominion University (ODU) at Jefferson Lab in the US, with tests foreseen by the beginning of 2013. A prototype of the quarter-wave type is under manufacture at Brookhaven National Laboratory, also using bulk niobium.

The HL-LHC will require higher beam currents, so new collimators will be necessary to protect the magnets from the 500 MJ of stored energy in each beam. The collimation team (WP5) has made the first steps towards the design of new IR collimation, with close collaboration between teams at CERN and from US-LARP. Tracking simulation tools have been set up to calculate losses by performing multi-turn tracking of the collision products, which can induce significant losses in the matching sections and dispersion suppressors at Point 1, Point 2 (with ions) and Point 5.

A further challenge for the HL-LHC project is to relocate equipment such as power convertors away from the tunnel to avoid radiation damage to electronics as well as to ease installation and integration of new equipment near the high-luminosity IRs, which are already crowded. This will require superconducting links that can transport high currents (up to 150 kA DC per line) from power supplies at ambient temperature on the surface to components operating at 1.9 K in the tunnel, some 100 m below ground. Work on this "cold powering" has started well ahead of schedule in WP6, with a study made of possible powering layouts for the new quadrupole magnets in the IRs, based on input concerning features of the optics and magnets agreed with WP2, WP3 and WP7 of HL-LHC (machine protection). Preliminary studies of the integration of the cold-powering system in the LHC machine have also been performed.

In the LHC, current leads that incorporate a high-temperature superconductor (HTS) supply currents of up to 13 kA to the magnets in the tunnel. For the upgrade, CERN has been working with the Italian company Columbus to develop new superconducting wires based on magnesium diboride (MgB_2), which has a lower operating temperature than HTS – the former being superconducting at the operating current at up to 25 K rather than 35–50 K with the latter – but is considerably less expensive. Until now, only flat ribbons of MgB_2 have been available but CERN and Columbus have jointly developed round wires that are more suitable for the higher currents required for the HL-LHC. Cables built from tapes

A semi-flexible cryostat (the black tube) for cooling MgB_2 cables undergoing testing in the new facility in SM18 at CERN. This tube is 20 m long and has a diameter of approximately 16 cm.

of copper and either HTS or MgB_2 have been built and tested at CERN, and multi-cable assemblies have also been designed and constructed. Tests of the first 20 kA superconducting link are now taking place at CERN in the new test-station that has been set up in building SM18.

Advanced know-how

New and more advanced superconducting devices lie at the heart of not only the HL-LHC but of other large projects, such as the Facility for Antiproton and Ion Research at GSI, the XFEL at DESY and the European Spallation Source (ESS) in Lund. The workshop held in December on superconducting technologies was therefore based on talks about the HiLumi LHC Design Study, TIARA and the ESS, interweaved with presentations by representatives from industry. Companies also had stands and meeting points to provide the opportunity to exchange ideas and information.

One point of discussion was the model for laboratory–industry relations. Both the approach based on "turnkey" contracts (where only the main characteristics of equipment are laid down in a functional specification) and an approach based on "built-to-print" contracts (where industry is responsible for a specific manufacture rather than for the full product) can be effective and yield the best value for money. For equipment that

New, advanced superconducting devices lie at the heart of other large projects.

has been fully or even partly developed for previous projects, the turnkey model can probably be used, thus minimizing the human resources required at the laboratory. When R&D is long and based on new types of equipment, such as for the LHC upgrade, the built-to-print model is probably more suitable. However, in both cases, only a close laboratory–industry relationship during construction can avoid misunderstandings and painful extra costs. There were also discussions on how to improve the exchange of information on technologies, processes, materials, facilities, work organization and training of the next generation of engineers and technicians.

In addition to reviewing progress in superconducting technologies for the HL-LHC, the workshop looked forwards in considering items that will need to be procured once the project is approved by CERN Council; in principle in June, in the context of the updated European Strategy for Particle Physics (*CERN Courier* November 2012 p50). The requirements include: 20 large superconducting Nb_3Sn quadrupoles rated for 12–13 T, 10 of which will be supplied by the US; five large 6 T superconducting dipoles (D1) in NbTi from Japan; five large 4–4.5 T superconducting dipoles (D2); five large superconducting twin quadrupoles (Q4) rated for 8 T; six to twenty superconducting 11 T twin dipoles in Nb_3Sn; five large SC twin quads (Q7) rated for 7 T; five to six modules each of three superconducting crab cavities; 3 km of superconducting links rated for 50–150 kA; and a number, still to be defined, of corrector-magnet packages. These will all have their own cryostats and will need new cryogenic plants and vacuum requirements. In addition, there will be new collimators, some equipped with special wire to compensate inter-beam effects near collision, as well as other equipment that is under development.

The workshop was the first step in communicating with industry to find partners for new development and construction, with a goal of maximizing the industrial return and incrementing the industrial capability of the EU. The aim is to achieve full funding of the project, including design and prototyping, totalling around SwFr750 million by 2015, with an additional SwFr200–250 million from external collaboration with the US and Japan. Construction and testing would then take place between 2016 and 2020, ready for installation at the end of 2021.

● The next joint HiLumi LHC–LARP Annual Meeting is planned to take place at the Cockcroft Institute, Daresbury Laboratory, on 12–15 November 2013, while in May 2013 the collaboration will meet at the joint LARP–HiLumi LHC Annual Meeting in the US. For more about the workshop on "Superconducting technologies for next-generation accelerators", see https://indico.cern.ch/conferenceDisplay.py?confId=196164. For more about HL-LHC, see http://cern.ch/hilumilhc.

Résumé

La supraconductivité ouvre la voie à une luminosité élevée

À l'heure où le LHC arrive à la fin de sa première longue exploitation, qui a duré de mars 2010 à mars 2013, les choses s'accélèrent en vue de la première grande amélioration, avec des avancées dans certaines des technologies supraconductrices essentielles, en particulier concernant les nouveaux aimants à champ élevé et les liaisons haute puissance. En même temps, des décisions importantes ont été prises dans le cadre de l'étude de conception HiLumi. Vers la fin de 2012, deux réunions ont permis aux équipes chargées de ces activités de pointe de revenir sur les avancées réalisées et de planifier les activités futures, au sein de différents instituts dans le monde et aussi par des échanges avec des partenaires industriels.

Lucio Rossi, **Christine Sutton** and **Agnes Szeberenyi**, CERN.

Letting young scientists shine

A new section at the 2nd Joint HiLumi LHC–LARP meeting was the "Young Scientist Talk", a session organized to showcase recipients of LARP's Toohig Fellowship, which is awarded each year to two recent PhD recipients in physics or engineering. Toohig Fellows John Cesaratto and Valentina Previtali attended the meeting. Currently based at member institutions of LARP – Cesaratto at SLAC National Accelerator Laboratory and Previtali at Fermilab – they will also spend time at CERN as part of the fellowship. Cesaratto gave a talk on the control of beam instabilities in CERN's Super Proton Synchrotron and Previtali presented first results from simulations of the hollow electron lens. They were joined by Meghan McAteer, a Marie Curie Fellow, who talked about optics measurements in the Boosters at Fermilab and CERN.

The section was convened by John Fox of SLAC and a member of LARP. He is chair of LARP's Toohig Fellowship Committee and is keenly interested in promoting the work of young scientists. He believes that bringing young scientists to the conference is multi-valued, enabling the young Toohig Fellows to meet scientists at CERN and, conversely, allowing young scientists from CERN to meet members of LARP. Such opportunities to meet and strike up collaborations are important for young scientists at US labs, who get few chances to interact with the broader community.

The Toohig Fellowships are awarded in honour of the late Timothy Toohig, a physicist and Jesuit priest who devoted his life to promoting accelerator science and increasing understanding, communication and collaboration among scientists of all nations and religions. The fellowships are for two years, extendable to three, and are explicitly for postdoctoral research and development regarding the LHC.

● *Lori Ann White, SLAC.*

ICFP 2012 opens up interdisciplinarity

A new conference series brings together researchers from different disciplines in fundamental physics.

Participants at ICFP 2012. (Image credit: Helmut Oeschler.)

The International Conference on New Frontiers in Physics (ICFP) aims to promote scientific exchange between different areas of fundamental physics, with particular emphasis on future plans and related open questions. The first in the new series, ICFP 2012, which took place in Kolymbari, Crete, attracted 140 participants from fields ranging from particle physics and cosmology to quantum physics and the foundations of quantum mechanics – a discipline awarded the 2012 Nobel Prize in Physics. The following highlights reflect the main themes of the plenary talks, which were further elaborated in many parallel sessions.

ICFP 2012 was one of the last conferences to hear enticing hints of an imminent Higgs-boson discovery, as the ATLAS and CMS collaborations at the LHC presented candidate signals for the Higgs boson with a local significance of 2.5–2.8σ at a mass of 125–126 GeV. At the same time, the CDF and DØ collaborations from the Tevatron at Fermilab also reported an excess near the same mass region with a local significance of 2.7σ. In other presentations, state-of-the-art theoretical calculations of the cross-section for a Standard Model Higgs boson were described, as well as a prediction for the Higgs boson mass of 121–126 GeV and the supersymmetric spectrum from finite unified theories. Implications beyond the Standard Model of both the mass and the large diphoton rate observed were also discussed. Reports on experimental searches for new physics, such as excited leptons, heavy neutrinos, new bosons, supersymmetry and gravity signatures, went further beyond the Standard Model, as did discussions of string theory and extra dimensions. Results from the LHC on di-jets accompanying vector bosons excluded at 95% confidence level the structure that the CDF experiment saw two years ago.

Talks on hadrons and QCD covered the latest lattice QCD results and presented theoretical predictions and the status of new states with heavy quarks and exotic hadrons, such as the Z_b states discovered in 2011 by the Belle experiment at KEK. The latter are consistent with a minimal content of two quarks and two antiquarks. Within a new extended quark model that has both quarks and diquarks as building blocks, new QCD effects and interpretations emerge; for example, there are no radial excitations in low-energy QCD and hadrons can shrink. Reflecting the interdisciplinary theme of the conference, one approach to the description of the QCD phase diagram that was discussed involves a holographic model; Lorentz violation and holography were also discussed.

Highlights from heavy-ion experiments confirm that the hot and dense medium created in heavy-ion collisions behaves like a strongly interacting, almost perfect liquid – the strongly interacting quark–gluon plasma. The estimates of shear viscosity are consistent with the lower bound of the anti-de Sitter/conformal field-theory correspondence. The generated flow seems to affect even heavy particles, while jets and hadrons with high-transverse momentum are strongly quenched traversing this medium. An analogy was made between the higher-order flow coefficients that originate from the initial fluctuations of the "Little Bang" in central heavy-ion collisions and the measurements of the cosmic microwave background radiation that explore the initial fluctuations of the early universe after the Big Bang. Outstanding results have come from measurements of quarkonia, such as the indication of sequential suppression of quarkonia and of possible J/ψ regeneration at the LHC. The direct Υ(1S) state is not suppressed either at Brookhaven's Relativistic Heavy-Ion Collider (RHIC) or at the LHC, while charmonium and bottomonium states with smaller dissociation temperatures than the Υ(1S), show a suppression at both RHIC and the LHC – as expected for a deconfined plasma of quarks and gluons within a colour-screening scenario.

An overview described the status of rare decays and CP violation, while results on the latter from LHCb and other LHC experiments set strong constraints on models and led to intriguing results that await an explanation either inside or outside the Standard Model. In particular, the isospin asymmetry in $B \to K\mu^+\mu^-$ differs from the expectation by 4σ, while CP violation in the charm sector shows a 3.5σ deviation from the CP-conserving hypothesis. Results ▷

from the BaBar experiment at SLAC highlight a significant excess of events in $B \to D^* \tau \nu$ decays at 3.4σ above the Standard-Model expectation, thus ruling out the type II two-Higgs-doublet model. BaBar has also made a direct observation of time-reversal violation at the 14σ level. The CP violation seen by LHCb in D-meson decays could arise from a fourth generation of quarks and leptons.

In the neutrino sector, an overview described the status of experiments on neutrinoless double-beta decay and their expected reach. According to the "forecast" given, the claimed evidence of the signal reported in 2001 by a subset of the Heidelberg-Moscow collaboration will be checked by the GERDA experiment in the Gran Sasso National Laboratory in the near future. Currently, the EXO-200 experiment sets the most competitive limit in the field and almost completely rules out the claim. The OPERA collaboration reported on new oscillation results from the search for ν_τ appearance, preliminary limits on oscillation parameters from the search for $\nu_\mu \to \nu_e$ and an update on the measurement of neutrino velocity. New results from the T2K experiment in Japan confirm the first evidence for ν_e appearance presented in 2011 and provide a measurement of $\sin^2 2\theta_{13}$. In reactor experiments, the Double Chooz collaboration presented results on $\sin^2 2\theta_{13}$ that exclude the non-oscillation scenario at 3.1σ, while the high-precision measurements of $\sin^2 2\theta_{13}$ presented by the Daya Bay collaboration exclude a zero value for θ_{13} at more than 7σ.

The quest to determine the nature of dark matter is a challenge at the boundary of particle physics and astrophysics. Possible hints, for example from the Fermi Gamma-ray Space Telescope and the PAMELA experiment in space, were discussed in an overview of experimental searches and theoretical implications and expectations. Other results included limits on compact halo objects as dark matter obtained from gravitational microlensing, as well as the status of the Alpha Magnetic Spectrometer (AMS-02), which has been in orbit since May 2011. The status and recent upgrades of the DAMA/LIBRA experiment and its observation at 8.9σ for a candidate signal for dark-matter particles in the galactic halo, through an annual modulation signature, were reviewed at the conference, together with detailed studies of background. Other talks covered primordial scalar perturbations via conformal mechanisms and the experimental status of the Dark Energy Survey.

At a more mathematical level, participants learnt how gravity can be viewed as emerging out of the differential calculus in non-commutative geometry, with effects that include a separation of the inertial and gravitational masses of a test particle as its mass approaches the Planck mass. Aspects of string cosmology included a review of bouncing string-cosmologies in which the Big Bang is no longer regarded as the beginning of time, as well as a presentation on how dilaton-field dominance in early epochs enlarges the cosmologically allowed parameter space for supersymmetry at the LHC.

Talks on quantum physics covered, for example, Aharonov's two-state vector formalism, in which hidden variables may exist if the requirement of causality is relaxed to allow – under appropriate circumstances – the effects of future events on past measurements. Transaction and non-locality in quantum field theory and cosmological consequences of a de Sitter non-local vacuum, involving David Bohm's "holomovement" ideas, were also discussed, providing a link between cosmology and quantum physics, as were classical and quantum information acquisition, measurement and the positive-operator valued measure. An overview of quantum physics with massive objects included among other topics, the possibility of testing the predictions of quantum gravity, as well as the experimental perspectives of atom–photon interactions.

At a broader level, an overview talk presented the European Physical Society and its activities. Moreover, looking forward to the future generations of physicists, a presentation on educational projects was given to high-school teachers in nearby Chania, the second-largest city on Crete.

Sessions during the last two days of the conference addressed the future plans of particle and nuclear physics. These included the status of the eRHIC electron–ion collider project at Brookhaven and the Nuclotron-based Ion Collider facility at JINR, as well as an overview and outlook on heavy-ion collisions at the LHC. There were also presentations on the status and plans of major particle-physics projects, namely the Muon Collider, the International Linear Collider, the Compact Linear Collider and Super B. In addition, CERN's future plans were highlighted, as were the ideas and actions of the European Strategy for Particle Physics group and its update plan, which is currently under preparation. The conference closed with an overview of the activities of the European Committee for Future Accelerators.

To prepare not only the students but all of the audience for an interdisciplinary week, a day of lectures preceded the conference. Discussions during the sessions and more informally, then offered the possibility to explore interdisciplinary knowledge. Results from these interactions appear in the papers contributed to the conference proceedings, which will be peer reviewed and published in the *EPJ Web of Conferences* in 2013.

● Further reading

The conference was organized by the University of Oslo, GSI Darmstadt, the University of Nantes and SUBATECH Nantes; it was sponsored by the University of Oslo, the Research Council of Norway and CERN. For full details of speakers and the presentations, please see http://indico.cern.ch/event/icfp2012.

Résumé

ICFP 2012 : vive l'interdisciplinarité !

La Conférence internationale sur les nouvelles frontières de la physique (ICFP) a pour objectif de promouvoir les échanges scientifiques entre différents domaines de la physique fondamentale, et s'intéresse tout particulièrement aux perspectives futures et aux questions en suspens. La première édition, ICFP 2012, s'est tenue à Kolymbari, en Crète. Elle a rassemblé 140 participants représentant des domaines aussi divers que la physique des particules, la cosmologie, la physique quantique et les fondements de la mécanique quantique, discipline qui a été honorée du prix Nobel de physique en 2012. Des exposés présentés en session plénière ainsi que lors de sessions parallèles ont fourni de nombreux sujets de discussion permettant d'exploiter les richesses de la connaissance interdisciplinaire.

Larissa Bravina, Oslo University, **Panagiota Foka**, GSI, and **Sonia Kabana**, Nantes University and SUBATECH, chairs of ICFP 2012.

Faces & Places

FERMILAB

Pier Oddone announces his retirement

Fermilab director Pier Oddone has announced his intention to retire in July 2013, after eight years at the helm of America's leading particle-physics laboratory. Since he took over as director in 2005, the Tevatron experiments have closed in on the possible mass-range of the long-sought Higgs boson, discovered a suite of exotic particles and shed new light on the relationship between matter and antimatter.

Under Oddone's stewardship, Fermilab has made significant contributions to the LHC and the CMS detector at CERN and played an important role in the analysis of data, leading to the discovery of a new boson, announced on 4 July. The results from the laboratory's neutrino experiments include the most precise measurements of some types of neutrino oscillations, while Fermilab-led projects and programmes have identified possible sources of the highest-energy cosmic rays to hit the Earth's atmosphere and searched for particles of dark matter.

Looking towards Fermilab's future, Oddone has overseen a transition from an era of high-energy collisions with the Tevatron accelerator to an era of research with intense beams of particles. Under his direction, Fermilab has embarked on the world's most advanced neutrino-oscillation experiment, NOvA, and is developing new facilities for research with beams of muons. The laboratory has developed into a world-leading centre for R&D towards future particle accelerators based on superconducting radio-frequency technology, and broken ground on a new facility that will advance accelerator breakthroughs and translate them into applications for society's health, wealth and security.

Pier Oddone, Fermilab's fifth director, will step down in July 2013. (Image credit: Fermilab.)

A 16-member committee has been convened to conduct an international search for the next Fermilab director. The committee has the deadline of 1 May 2013 to submit a short list of candidates to the board of Fermi Research Alliance LLC, which operates Fermilab for the US Department of Energy. The committee has invited the international scientific community to contribute to the search process, input being most useful before 31 January 2013.

● For more information about the search for Fermilab's next director, including a list of committee members, the charge and process, as well as a form to provide written comments, suggestions and nominations, see www.fnal.gov/pub/directorsearch/.

ASTROPARTICLE PHYSICS

SpacePart12: bringing the space adventure to CERN

As 2012 – the year that saw the centenary of the discovery of cosmic rays – drew to a close, the 4th International Conference on Particle and Fundamental Physics in Space (SpacePart12) took place over three days at CERN. As well as the 125 attendees, including space scientists and space-policy makers from around the world, up to 600 people per day joined remotely via the live webcasts.

The conference provided an authoritative review of astroparticle physics, astrophysics and fundamental physics in space, and included public talks from two of the biggest names in space exploration, namely Edward Stone and William Gerstenmaier.

Stone, professor at the California Institute of Technology and project scientist for the *Voyager* probes since 1972, spoke about the extraordinary story of these two probes, launched 35 years ago.

Gerstenmaier, associate administrator for Human Exploration and Operations for NASA and former manager of the ISS programme, discussed the scientific work being conducted on the space station.

Edward Stone, left, with conference chair Roberto Battiston of INFN and Perugia University, Italy, at SpacePart12.

NASA's William Gerstenmaier. (Image credits: Michele Famiglietti/SpacePart12.)

● To see the talks, visit the SpacePart12 website http://spacepart12.web.cern.ch/.

CERN

Discovery of new boson reaps awards

The discovery of a new boson at the LHC, announced by the ATLAS and CMS collaborations on 4 July, has been honoured with two important prizes: a special award of the Fundamental Physics Prize Foundation and the 2012 EPS Edison Volta Prize. "Although these prizes go to individuals, they recognize the work of everyone who have contributed," says CERN's director-general, Rolf Heuer. "The success they celebrate is only possible thanks to the active engagement and commitment of the whole community."

The EPS Edison Volta Prize for outstanding contributions to physics was established by the European Physical Society (EPS), the Centro di Cultura Scientifica "Alessandro Volta" (Centre Volta) and Edison SpA to promote excellent research and achievement in physics. The prize was awarded for the first time in November to Rolf Heuer, together with Sergio Bertolucci, CERN's director for research and computing, and Stephen Myers, director for accelerators and technology. They have been rewarded for "having led, building on decades of dedicated work by their predecessors, the culminating efforts in the direction, research and operation of the LHC, resulting in many significant advances in high-energy particle physics, in particular, the first evidence of a Higgs-like boson in July 2012".

In December, the Fundamental Physics Prize Foundation announced the awarding of two special prizes in fundamental physics. One goes to Stephen Hawking for his discovery of Hawking radiation from black holes and his deep contributions to quantum gravity and quantum aspects of the early universe. The other prize is shared by


The seminar on 4 July emphasized the global involvement in the discovery of the new boson.

the leaders of the LHC project and the CMS and ATLAS experiments from the time that the LHC was approved by the CERN Council in 1994, including: Peter Jenni and Fabiola Gianotti of ATLAS; Michel Della Negra, Tejinder Virdee, Guido Tonelli and Joe Incandela of CMS; and Lyn Evans of the LHC project. They receive the prize for their leadership role in the scientific endeavour that led to the discovery of the new Higgs-like particle by the ATLAS and CMS collaborations at the LHC. Each of the two special prizes is worth $3 million.

The Fundamental Physics Prize Foundation is a not-for-profit corporation established by the Milner Foundation and is dedicated to advancing knowledge of the universe at the deepest level by awarding annual prizes for scientific breakthroughs, as well as communicating the excitement of fundamental physics to the public. According to the Foundation's rules, laureates of all prizes are chosen by a selection committee made up of prior recipients of the Fundamental Physics Prize.

● For more information, see www.epsnews.eu/2012/11/eps-edison-volta-prize-2012/ and www.fundamentalphysicsprize.org.

A worldwide effort with roots in the 1970s

The achievements that these prizes recognize are the result of the efforts made for more than 20 years by thousands of scientists, engineers and technicians working at CERN, and in universities and laboratories around the world, and of the agencies that support, co-ordinate and guide the activities. Physics data-taking runs at the LHC began in 2010 and since then the collider has delivered more than 10^{15} proton–proton collisions at the record centre-of-mass energy of 8 TeV, at an unprecedented luminosity. Collisions between accelerated lead nuclei on the same energy/nucleon-pair scale have also been achieved. Many important physics results have already been published by the international collaborations that built and now run the general-purpose experiments, ATLAS and CMS, and the ALICE, LHCb, TOTEM and LHCf experiments, each of which has a more specific scope.

Initially, the LHC was the vision of a few farsighted scientists. Already at the end of the 1970s, a working group chaired by Antonino Zichichi, and charged by the European Committee for Future Accelerators (ECFA) to define the design of the Large Electron–Positron collider (LEP), underlined in its "White Book" (the ECFA-LEP 1979 *Progress Report*) the importance of building LEP in a 27-km-long tunnel, with a wide enough cross-section to host, after the completion of LEP operations, a ring of superconducting magnets for a proton–proton collider. *LEP Note 440*, published in April 1983 by Stephen Myers and Wolfgang Schnell, gave birth to the LHC concept. The "official kick-off" of the project is generally considered to be the workshop held in 1984 in Lausanne, led by Giorgio Brianti, where the community of physicists and machine experts reached the agreement on a collider for protons and nuclei (*CERN Courier* October 2008 p8).

Maldacena and Belyaev receive Pomeranchuk Prize

Juan Maldacena of the Institute for Advanced Study, Princeton, and Spartak Belyaev of Kurchatov Institute, Moscow, received the 2012 Pomeranchuk Prize in a ceremony at the Institute for Theoretical and Experimental Physics (ITEP) on 11 October. The prize, established by ITEP in 1998 in memory of Isaak Pomeranchuk, is awarded annually to one foreign and one Russian theoretician for outstanding achievements in the field.

Maldacena is honoured for his formulation of duality between string theory in higher


Juan Maldacena, left, and Spartak Belyaev, recipients of the 2012 Pomeranchuk Prize. (Image credit: ITEP.)

space–time dimensions and gauge field theories in four dimensions. This duality has been further generalized to theories with lower supersymmetry and to standard QCD. Its application has proved to be effective for general systems with strong interactions where standard methods of perturbation theory are inadequate.

Belyaev receives the award for outstanding results in quantum many-body theory and their application to nuclear theory. His two papers dated 1958 on interacting Bose gas laid one of the foundations for modern many-body quantum theory. The fundamental "Copenhagen" paper, written during a visit to the Niels Bohr Institute in 1959, established a sound basis for understanding correlations in nuclei. Belyaev presented the full theory of the phenomenon and its manifestations in all nuclear properties – binding, excitation spectra, transition probabilities, collective modes and rotational properties.

Max Klein honoured by Germany and the UK

Max Klein of the University of Liverpool has been awarded the Max Born Medal and prize of the German Physical Society and the UK's Institute of Physics, for "fundamental experimental contributions to reveal the structure of the proton through deep-inelastic scattering". In particular, as a member of the H1 collaboration at the HERA


Max Klein. (Image credit: Uta Klein.)

electron–proton collider at DESY, he played a decisive role in the discovery in the 1990s of a surprisingly large gluon component within the proton.

After studying at Humboldt University in what was then East Berlin and gaining his PhD at the Institute for High Energy Physics in Zeuthen, Klein went to Dubna and joined the Bologna-CERN-Dubna-Munich-Saclay muon experiment. In 1985, he and his team joined the H1 collaboration, which he led between 2002 and 2006, guiding the experiment into a new era of precision measurements of the proton structure and tests of the Standard Model. He joined the University of Liverpool and the ATLAS collaboration in 2006 and currently plays a leading role in the proposal for a Large Hadron Electron Collider (*CERN Courier* May 2012 p25).

Lucio Rossi is named 2013 IEEE fellow

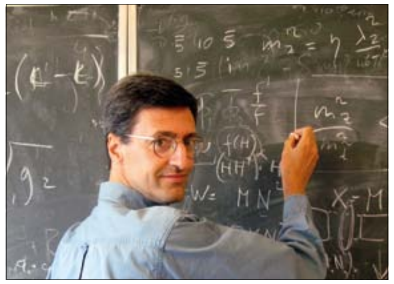
CERN's Lucio Rossi has been named a fellow of the Institute of Electrical and Electronic Engineers (IEEE). He is recognized "for leadership in developing magnetic systems for the LHC". After


Lucio Rossi in the LHC tunnel.

working on the superconducting cyclotron at Milan University, Rossi was in charge of the construction of the first superconducting dipole prototype for the LHC, in a collaboration between INFN and CERN. He went on to lead the development of the 50 kA superconductor and the construction of the first 25-m-long superconducting coils for the ATLAS detector.

He moved to CERN in 2001 to take charge of the industrialization and construction of the main superconducting magnets for the LHC. Since 2011 he has been head of the High Luminosity LHC project (p28).

CERN theorist awarded 2013 Solvay Chair in Physics



Gian Giudice, the 2013 Jacques Solvay Chair in Physics. (Image credit: Gian Giudice.)

Gian Giudice, a theoretical particle physicist at CERN, has been awarded the 2013 Jacques Solvay Chair in Physics. The International Solvay Institutes of Physics and Chemistry were founded by Ernest Solvay in 1912 and 1913, respectively, and merged in 1970. Their aim is to promote the advancement of physics, chemistry and related areas through international collaborations and conferences. The Solvay Chair in Physics has been awarded each year since 2006 to an outstanding scientist with exceptional achievements. These include, to date, two Nobel laureates: David Gross and Serge Haroche. As 2013 winner, Giudice is invited to Brussels for a period of 1–2 months to give lectures on his work – phenomenology of the Standard Model and beyond, as well as cosmology and astroparticle physics – to researchers from international universities.

First prize of Armenian president goes to ALICE member

Armenuhi Abramyan, right, with the Armenian president, Serzh Sargsyan. (Image credit: President of Republic of Armenia.)

Armenuhi Abramyan of the A I Alikhanyan National Science Laboratory, Yerevan Physics Institute, and a member of the software team of the ALICE experiment, has received the 2012 first prize from the President of Republic of Armenia as the best Bachelor Student in the field of information technology.

Abramyan receives the award for excellence in academic studies and for her Bachelor Diploma thesis, which presents her work on the development of a series of unified-modelling language diagrams that describe the functionality of the services of AliEn, the Grid infrastructure of the ALICE experiment (*CERN Courier* April 2012 p31). She was presented with the award by the Armenian president on 4 October.

New products

FLIR Advanced Thermal Solutions has announced the FLIR SC8400/SC6500 system, designed to provide ultrasensitive, accurate measurements in a compact, yet full-featured, thermal-imaging camera. Providing high-definition images of 1280 × 1024 pixels, the cameras can detect temperature differences of typically 18 mK. Using FLIR's "lock-in" facility differences as small as 1 mK can be made clearly visible. Temperatures up to 3000°C can be measured with an accuracy of +/–1°C or +/–1%. For further details, tel +33 1 6037 0100, e-mail research@flir.com, or see www.flir.com.

Murata Europe Ltd has announced the Murata Power Solutions MEE1 series, a 1 W single-output PCB mounted DC/DC converter designed for applications that require an isolated low-power distributed supply. These converters, up to 86% efficient, come in a variety of models accommodating nominal input voltages of 3.3, 5, 12, 15 or 24 VDC, with output voltages of 3.3, 5, 9, 12 or 15 VDC. Murata has also introduced the RBE series of fully isolated DC/DC converters designed, for example, for distributed power-based applications used in servers, wireless base-stations, data storage, telecom switches and networking equipment. For further details, contact Aya Tonooka, e-mail atonooka@murata.co.uk, or see www.murata.eu.

N2Power, a division of the **Qualstar Corporation**, has announced a new 330 W AC/DC power supply. The 34-mm-high, open-frame XL330–54 has a 76 mm × 135 mm footprint to deliver a power density of 15 W/cubic-inch with only 13 cubic feet per minute cooling. The XL330–54 has two primary outputs, 54 V/6.1 A and 12 V/9 A, plus a 12 V/1 A auxiliary output. The 54 V output is Power-over-Ethernet (PoE) compatible and the design allows for up to four power supplies to be operated in parallel on this output. For more information, contact Bob Covey, e-mail covey@qualstar.com, or visit www.n2power.com.

TREK Inc has introduced the Model 2300 Series of high-voltage DC power supplies, offering five configurations each with 300 W output power. Active circuitry on the high-voltage output reduces noise and ripple, while maintaining low output-capacitance and low energy. The series consists of five models with different maximum output voltage (+10 kV, +15 kV, +20 kV, +25 kV and +30 kV). Line regulation is better than 0.02% for a minimum-to-maximum voltage change. Load regulation is 0.02% for a 5% to 100% load change. For further details, contact Brian Carmer, e-mail brian.carmer@trekinc.com, or see www.trekinc.com.

Wind River UK Ltd has introduced the latest version of Wind River Test Management, a fully automated software optimization framework that allows customers to identify high-risk areas of production code and prioritize quality assurance (QA) activities. For more information, contact Tony Mays, e-mail tony.mays@windriver.com, or visit www.windriver.com.

Goodfellow has announced a cost-effective aluminium foam that offers superior heat exchange and impact absorption. High porosity (80–90%) and a highly relative surface area of up to 500 m^2/m^3 facilitate the movement of fluids and the recovery of heat, even at low speeds. The foam exists in standard sheets of 40 mm × 100 mm × 172 mm with a cell size of 10 mm and one surface clad in a solid aluminium sheet. Other sizes or foams without a solid cladding on one surface are available. For details, see www.goodfellow.com or e-mail info@goodfellow.com.

QCD

New trends in the low-energy strangeness sector

Experts and young researchers from around the world met to discuss recent developments and trends at the international workshop "New trends in the low-energy QCD in the strangeness sector: experimental and theoretical aspects", held at the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), Trento, on 15–19 October 2012.

The field of strangeness physics is evolving rapidly, with new results coming from a host of recent experiments – HADES, FOPI, COSY-TOF, COSY-ANKE, SIDDHARTA, KLOE – and from reanalyses of older ones, namely DISTO and FINUDA. Other experiments are planned at the DAΦNE, GSI, FAIR, MAMI and JPARC facilities, and even more are in the proposal phase.

Among the recent achievements, the precision measurements of kaonic hydrogen, helium-3 and helium-4 by SIDDHARTA stand out. These results have allowed deeper insight into the kaon–nucleon interaction at threshold and, as Wolfram Weise of the Technical University of Munich showed, they have far reaching implications in astrophysics in the equation of state of neutron stars. The recent finding by FINUDA, of the neutron-rich $^{6}_{\Lambda}$H hypernuclei discussed by Tullio Bressani of Torino University opens the door to an improved understanding of the underlying interactions and nuclear structure.

On the theoretical side, refined calculations and methods – such as chiral perturbation theory, lattice QCD, many-body calculation methods and potential models – are producing accurate results. When combined with the experimental findings, these results are allowing a better and more detailed understanding of the processes governing the still mysterious, low-energy sector of QCD.

Wolfram Weise describes the implications for astrophysics of the latest results on low-energy strangeness physics. (Image credit: C Curceanu.)

As emerged from the discussions, some of the basic issues that still need further study play a key role: the single- or double-pole nature of the Λ(1405) resonance; the possible existence of deeply bound kaonic nuclear states, which, in recent years gave rise to intense debates; the Σ and doubly strange hypernuclei and their binding energies; the kaon-nucleus and hyperon-nucleus interactions and their possible implications in astrophysics. These physics cases are now being approached with complementary experimental techniques that range from employing low- or high-energy kaons to using beams of protons or heavy ions, so creating a variety of different environments.

One important success of the workshop was that young people formed about half of the 40 participants. Moreover, the participants came from a range of countries, including, for example, Israel and Iran. This made it an occasion not only for scientific exchanges but also for cultural and social ones, proving once again that scientists are part of society with an important role and impact in solving its problems.

The workshop showed that the future of the field looks bright and that it is in good health, demonstrated by an ideal mixture of experts and young researchers, theoreticians and experimentalists, with understood items and as yet unsolved puzzles.

The venue in the ideal environment of ECT* contributed in a significant way to the success of the workshop, which was organized by Catalina Curceanu and Carlo Guaraldo (LNF-INFN, Frascati), Laura Fabbietti (TU München), Jiri Mares (Nuclear Physics Institute, Rez Prague) and Johann Marton (SMI-Vienna).

● For full details of the workshop, see: www.smi.oeaw.ac.at/conference/ect_star_2012/.

Appointment

ECT* selects Weise as its next director

Wolfram Weise, professor emeritus for theoretical nuclear and particle physics at the Technical University of Munich, is the new director of ECT*, the European Centre for Theoretical Studies in Nuclear Physics and Related Areas in Trento. On 1 November, he took over from Achim Richter, who has returned to the Institute of Nuclear Physics at the Technical University of Darmstadt after four years as director of ECT*.

Weise has already been director of the ECT* from 2001 until 2004. His scientific interests span a range of physics, from QCD, symmetries in hadrons and nuclei, though to quark–gluon matter under extreme conditions as occurred in the early universe and is now explored experimentally in high-energy collisions between nuclei at the LHC.

Wolfram Weise, right, has taken over from Achim Richter. (Image credit: ECT.)*

Symposium

Collisions in Štrbské Pleso, Slovakia

Participants against a mountain backdrop. (Image credit: O Bruncko/PIC2012 LOC.)

Surrounded by the beautiful High Tatra Mountains, the 32nd Physics in Collision symposium took place in Štrbské Pleso on 12–15 September. The venue is the highest settlement in Slovakia and, with the large glacial mountain lake of the same name, it has been a popular ski, tourist and health resort since the end of the 19th century.

The programme of the Physics in Collision symposium series, which began in 1981 in Blacksburg, Virginia, consists of invited review talks and contributions to a poster session. The invited oral presentations focus on updating key topics in elementary particle physics in which new results have been published over the past year or are likely to be released before the next symposium. The aim of the talks is to encourage informal discussions of the new results and their implications. A small number of presentations are usually reserved for "hot topics" and become available nearer the time of the symposium.

Topics cover a range of physics from experimental and theoretical accelerator-based particle physics to astroparticle physics. In particular, they include electroweak phenomena, QCD, neutrino physics, heavy-flavour physics and beyond-Standard-Model physics. The poster session is open to contributions on all topics having potential interest to the particle-physics community – such as current experimental measurements, detectors, future experiments and facilities, theoretical ideas – thus covering a broader range than the invited review talks. Many interesting topics and results were presented at this year's conference, including the discovery at the LHC of a new boson consistent with the expectation for a Standard Model Higgs, presented by ATLAS and CMS collaborations.

Among other highlights was the news that a nonzero and surprisingly large value of the third neutrino mixing-angle, θ_{13}, was measured in 2012. The result is important as it opens the way to future searches for CP violation in the lepton sector. Neutrino mass is the only well established observation that lies beyond the Standard Model. With θ_{13}, all "standard" mixing angles and Δm^2s have been observed and the data are consistent with neutrino and antineutrino oscillation.

A significant improvement in results on the W mass was reported from the experiments at Fermilab's Tevatron: the mass and width are consistent with the Standard Model, leaving little room left for new physics. The results of $t\bar{t}$ and t studies so far are in good agreement with Standard Model predictions, although the $t\bar{t}$ asymmetry from the Tevatron measurements is larger than the theoretical prediction. No deviations from the Standard Model were reported from the LHC, with all top-quark properties consistent with Standard Model expectations.

The conference was organized by the Department of Subnuclear Physics, Institute of Experimental Physics, Slovak Academy of Sciences, Košice in association with the Nuclear and Subnuclear Physics Department of the Faculty of Sciences at PJ Šafárik University in Košice, the Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava and the Physics Institute, Slovak Academy of Sciences, Bratislava.

● For more about the conference and the proceedings see www.saske.sk/PIC2012.

Conference

RUPAC accelerator forum comes to St Petersburg

RUPAC 2012, the 23rd Russian Particle Accelerator Conference, took place on 24–28 September at St Petersburg State University (SPbSU) in the St Petersburg suburb of Peterhof. The meeting, which attracted 262 participants from 19 countries, including the host country, was organized by the Faculty of Applied Mathematics and Control Processes of SPbSU, Efremov Scientific Research Institute of Electro-Physical Apparatus and the Budker Institute of Nuclear Physics (BINP), under auspices of the Scientific Council for Accelerators of the Russian Academy of Sciences (RAS). Attendees represented 71 institutions and enterprises, five of which organized a small ad hoc industrial exhibition, followed by a round-table discussion.

The conference provided a forum for discussion and the exchange of new information in the field of accelerator science and engineering, covering particle beam physics, new particle-collider projects, new accelerator designs and the modernization of existing accelerator facilities for basic and applied research. A wealth of new scientific results from national and international accelerator facilities, as well as plans for new projects, were presented among the 73 talks and 171 poster contributions.

The RUPAC Prizes for young physicists and engineers for the best work presented at the conference were awarded during the meeting. Yaroslav Getmanov of BINP received first prize, for his report on the longitudinal stability of an energy-recovery linac with two accelerating RF structures. Two second prizes went to Nickolay Azaryan of JINR, for his paper on "Dubna-Minsk activity on the development of a 1.3 GHz superconducting single-cell RF cavity", and to Konstantin Nikiforov of SPbSU, for his paper on "Non-gated field emission array as a low-energy electron source: experiment and simulation".

A memorial session, chaired jointly by Andrew Sessler of the Lawrence Berkeley National Laboratory and Alexander Skrinsky of BINP, was dedicated to the legacy of two acknowledged experts in the field – Dieter Möhl of CERN and Andrey Lebedev of the Physical Institute of RAS – who have recently passed away.

The Peterhof region of St Petersburg is important for its park and palace ensembles. Often referred to as a "capital of fountains", the undisputed centre of attraction in the region is the Grand Cascade and Samson Fountain. Conference participants were able to enjoy a St Petersburg city tour, a night tour on the rivers and canals and an excursion to the famous Hermitage museum.

The proceedings of RUPAC 2012 will be published on *JACoW* website www.jacow.org. The next meeting in the biennial series will be held in autumn 2014.

RUPAC 2012, held at St Petersburg State University attracted 262 participants from 19 countries. (Image credit: SPbSU, St Petersburg/Peterhof.)

School

ISAPP: nurturing new astroparticle physicists

The 2012 ISAPP schools on La Palma (top) and in Paris (above). (Image credit: ISAPP.)

The International School on Astroparticle Physics (ISAPP) completed its tenth year of organizing European doctoral schools on astroparticle physics with two schools, attended by more than 60 PhD students from 12 countries. The first school, "Multimessenger approach in High Energy Astrophysics", was held in Paris and was devoted to high-energy phenomena from cosmic rays to gamma rays, high-energy neutrinos and gravitational waves. The second, "CMB and High Energy Physics", was held on La Palma in the Canary Islands and covered topics from the early universe to clusters of galaxies and large-scale structures.

The ISAPP schools are organized by the ISAPP network, which includes 33 Institutions from 10 different European countries. They are dedicated to European doctoral students from nuclear-particle physics and cosmology and astrophysics, who traditionally do not mix together. The schools, which began in 2003 in Italy aim at creating a new type of specialist: the astroparticle physicist (*CERN Courier* October 2011 p41).

The format is designed to address topics that are relevant to astroparticle physics. Therefore, each school covers one topic selected from high-energy astrophysics, neutrinos in physics and astrophysics, dark matter, dark energy, cosmology, the cosmic microwave background, the early universe and gravitational waves. The formal training is complemented by discussions and poster presentations by the students.

ISAPP is planning two schools for 2013. The first will be organized in Spain at the Canfranc Underground Laboratory. Held on 14–23 July, it will be dedicated to "Neutrino Physics and Astrophysics". The second will be organized in Sweden, on 29 July – 6 August, and will cover "Dark Matter Composition and Detection".

● For more information on the ISAPP network, as well as the programmes, organizers, teachers and classes for the 2013 schools and all previous schools, see http://isapp.ba.infn.it/.

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IOP Publishing

Visits

On 15 November **His Holiness the XIIth Gyalwang Drukpa, Jigmé Pema Wangchen**, visited CERN together with an entourage of Buddhist nuns. During his trip to CERN he received a general introduction to CERN's activities and toured the LHC superconducting magnet test hall, the ATLAS Visitor Centre and the *Universe of Particles* exhibition in the Globe of Science and Innovation.

Deputy minister for science and technology empowerment for the Republic of Indonesia, **Idwan Suhardi**, right, was welcomed to CERN on 25 October by CERN's director for research and scientific computing, **Sergio Bertolucci**. The deputy minister's visit also included tours of the LHC superconducting magnet test hall and the Antiproton Decelerator facility.

During a visit to CERN on 26–27 November, **Brittany Michelle Wenger**, Google Science Fair Grand Prize Winner, centre, and her mother, **Camilla Glazer Wenger**, right, passed through the CERN Control Centre accompanied by **Mike Lamont**, CERN Beams Department, Operation Group Leader, left. Wenger won the 2012 Grand Prize for her project that uses an artificial neural network to diagnose breast cancer – a non-invasive technique with significant potential for use in hospitals.

SLAC

Celebrating synchrotrons and a special scientist

Friends, family and colleagues past and present gathered for a one-day symposium, "Instruments of Discovery: Past and Future of Synchrotron Light Sources," held at SLAC on 2 October to honour accelerator physicist Herman Winick. His 50-plus years as a builder of synchrotrons and as a champion of synchrotron radiation as a tool for discovery and development began at the Cambridge Electron Accelerator in 1959. However, these activities really took off when he arrived in Stanford in 1973 to lead the technical design of what was then known as the Stanford Synchrotron Radiation Project and is now the Stanford Synchrotron Radiation Lightsource (SSRL).

Herman Winick enjoying the symposium held in his honour. (image credit: D Slutsky.)

The symposium immediately preceded the SSRL/LCLS Users' Meeting at SLAC and included speakers who talked about Herman's contributions to the development of specialized magnets, insertion devices and free-electron lasers, as well as his activities in promoting both human rights and the development of synchrotron sources around the world.

Acknowledgement

In my recent article about Maurice Lévy (*CERN Courier* December 2012 p41) I should have noted that Laurent Lévy gave me crucial information about the career of his father and improved the style. I apologise for this omission.
● *André Martin.*

Corrections

The article on de-squeezed beams in the December issue (p5) implied that ALFA is an independent experiment, whereas it is a sub-detector of ATLAS, as its full name makes clear: Absolute Luminosity For ATLAS.

In the same issue, the two figures were inadvertently swapped in the article on first results from proton–lead collisions in ALICE (p6), although the captions were correctly placed. Figure 1 should thus be the plot labelled p-Pb, $\sqrt{S_{NN}} = 5.02$ TeV.

Apologies to all concerned.

Obituaries

Joachim Heintze 1926–2012

Joachim Heintze, emeritus professor of physics at the University of Heidelberg and eminent particle physicist, passed away unexpectedly on 31 March at the age of 85. An outstanding scientist and inspiring teacher, he made a lasting impact on particle physics.

Born in Berlin on 20 July 1926, Heintze began to study electrical engineering immediately after the Second World War, but soon switched to study physics in Berlin and Göttingen, where his interest in particle physics and in building experiments began. In 1951 he followed his teacher, Otto Haxel, to Heidelberg where he finished his PhD thesis in 1953. Shortly after the discovery of parity violation in weak interactions, in 1957, he conceived of and performed an extremely elegant experiment showing that electrons emitted in beta decay are polarized, providing another proof of parity violation.

In 1959 Heintze moved to CERN, where the recently completed Synchrocyclotron and Proton Synchrotron offered exciting opportunities for research in the emerging field of particle physics. After studying muon scattering on carbon to understand possible differences between muons and electrons, he focused on studies of the weak interaction, starting with the challenging experiment of pion beta decay (with a 10^{-8} branching ratio), which showed the conservation of vector currents.

In November 1964 he returned to Heidelberg as professor and director of the institute of physics, where he began establishing particle physics as one of the main research fields. For the next few years, he and his group continued experiments at CERN, studying key properties of weak interactions in hyperon beta decays and rare decays of K mesons. Around 1972 he became increasingly interested in electron–positron physics, as a result of an observed excess in hadron production at the Frascati laboratory. He therefore shifted his research to the DORIS storage ring under construction at DESY, where he initiated one of the first experiments – a nonmagnetic detector consisting of cylindrical drift chambers surrounded by a sodium-iodide and lead-glass calorimeter – which was ready in time to measure properties of the recently discovered J/ψ meson and τ lepton.

Inspired by the construction of PETRA, Heintze joined forces with other teams from Germany, Japan and the UK to build the JADE experiment. His team took on the responsibility for designing and building the central tracking detector, based on a new concept of the drift chamber, the so-called jet chamber. JADE was one of the experiments that provided clear experimental evidence for the existence of gluons, by observing three-jet and four-jet events, as well as a wealth of other results. Later Heintze considered JADE to be the best and most interesting experiment of his career. With the plans for the Large Electron–Positron collider taking shape at CERN, he and many other colleagues from JADE became a nucleus for the OPAL experiment there, building on all of the know-how gained at PETRA.

Joachim Heintze. (Image credit: Heintze family.)

Heintze was a truly gifted and imaginative experimental physicist. When coming to Heidelberg, he put emphasis on establishing and continuously improving a modern technical infrastructure. This was of vital importance for a field in which he excelled – detector development – where he was motivated by new questions in physics and the challenge to make them accessible through novel detectors. In this respect, the concept of multiwire drift chambers, proposed by his student Albert Heinrich Walenta, became a new standard for modern tracking detectors. Based on this concept, Heintze and his group developed and built powerful detector systems for precision measurements of particle tracks. The first experiment in which these chambers were used was performed in 1972 at CERN to study rare K-decays. At electron–positron colliders, Heintze and Walenta pioneered cylindrical drift chambers, which later, in the form of jet chambers, became a core element of the JADE and OPAL experiments and a model for many other tracking detectors at colliders.

Heintze shaped physics at Heidelberg in a major way. As dean of the physics department in the early 1970s he had the foresight to initiate a chair in environmental physics, the first of its kind at a German university. He developed a new concept for teaching physics to first-year science students, which included modern developments in physics. His lectures were full of original insights and demonstrated his love for and deep understanding of physics. These insights were to be published as a textbook, which unfortunately he was not able to finalize completely.

As a teacher he shared his enthusiasm with his students, inspiring them and teaching them the essence of physics and the skills of an experimenter. It is no surprise that a number of them later became leaders in the field of particle physics. Working as his research student was not only inspiring but also highly demanding, as no idea or result remained unchallenged until proven correct.

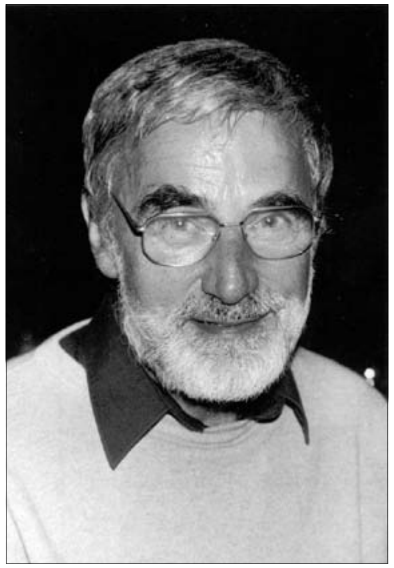
His scientific achievements were honoured by two major distinctions: the Physikpreis of the German Physical Society in 1963 and the Max-Born Prize of the German Physical Society and the UK Institute of Physics in 1992.

Joachim Heintze was motivated and inspired by a deep love for physics, and was open to new insights while remaining critical and not inclined to reach hasty conclusions. Scientific truth was essential for him. Late in life, severe personal losses led him to start playing the cello, which he loved and played with friends. He was a great personality, an unconventional scientist and an enthusiastic teacher. Nobody could escape his spell. His friends and colleagues will always remember him thankfully and with great admiration.
● *Volker Soergel, University of Heidelberg, and Albrecht Wagner, DESY.*

Dieter Möhl 1936–2012

Dieter Möhl, an accelerator physicist of world renown who made essential contributions to many projects both at CERN and elsewhere, passed away on 24 May. His theoretical work was unique in terms of the understanding, improvement and extension of beam-cooling techniques to many accelerators and storage rings. At CERN his name will be tied forever to the success from the beginning of the antiproton programme, but he also made substantial contributions to the project for the upcoming Facility for Antiproton and Ion Research (FAIR) in Germany and to many storage rings where beam cooling was an essential ingredient.

Dieter was one of the pioneers at CERN who demonstrated with the Initial Cooling Experiment (ICE) that stochastic cooling was a viable proposition. This was essential for the approval of CERN's antiproton programme and its subsequent success. He then became a leading member of the team that initiated and designed the Low Energy Antiproton Ring (LEAR) where the first ultraslow beam extraction to the experiments, extending for hours, was performed. Following the decision to stop LEAR, he actively participated in the study and design of a simplified antiproton source, which later became the Antiproton Decelerator ring (AD), after the



Dieter Möhl. (Image credit: Karin Möhl.)

SUPERLEAR project – of which he was one of the prominent promoters – was not approved. In 1982 he initiated the concept of the Extra-Low ENergy Antiproton ring (ELENA) at the AD and was extremely happy to see that this project to provide antiprotons with a kinetic energy as low as 100 keV was finally approved in 2011.

In addition, Dieter made important contributions to electron cooling. A token of this work is found in the AD and in the modification of the LEAR machine to become the Low Energy Ion Ring (LEIR), which acts as a buffer and accumulation ring between the fast-cycling ion linac, Linac 3, and the slow-cycling Proton Synchrotron. LEIR is an essential element in the LHC's ion injector chain.

Dieter was not only a renowned accelerator physicist. He also played an important role in human rights issues, in particular as a founding father of the Orlov Committee, which was created at CERN to provide efficient help to Soviet dissidents in the 1970s and 1980s.

Although he retired in 2001, he was at work nearly every day to help with our projects and give us advice. Even the day before his untimely death he was at CERN to discuss the ELENA project with us. He was one of the kindest and gentlest people we have ever known, with an infinite patience and a proverbial generosity. We gratefully remember Dieter's human quality and miss his wise counsel.

● *His friends and colleagues.*

Hans Henrik Andersen 1937–2012

Hans Henrik Andersen, physicist and founder of *Nuclear Instruments and Methods in Physics Research B*, passed away on 3 November.

Born in Frederiksberg, Denmark, Hans Henrik qualified in engineering at the Technical University of Copenhagen, before gaining a PhD from the University of Aarhus in 1972. He then worked at the Risø research centre and Aarhus University and as visiting professor at IBM Research, Yorktown Heights, and Fudan University, Shanghai. In 1982 he became a professor in experimental solid-state physics at the Niels Bohr Institute. He was professor emeritus from 2004 and was often at the institute.

Hans Henrik made important contributions to atomic and solid-state physics, especially

Hans Henrik Andersen. (Image credit: Ulrik Egede.)

in the field of the stopping power of matter for fast charged particles, where the accuracy of his measurements remains unsurpassed. His results were achieved by measuring the amount of heat deposited in foils at the temperature of liquid helium (4 K). Together with collaborators, he succeeded in showing that the stopping power for fast α particles is more than four times larger than for protons. This showed that the stopping power is not exactly proportional to the square of the atomic number, Z, as the simple Bethe formula predicts, and provided additional proof of the existence of the Barkas effect. His scientific career ended with participation from 1986 onwards in the ASACUSA experiment at CERN, where he compared the scattering of protons with that of antiprotons at the Antiproton Decelerator.

In addition to his scientific work, Hans Henrik was a member of many committees, for example in the Danish Physical Society. He was a member of the board of the Natural Science Faculty at Aarhus University, later becoming dean there, and of the board of the university itself. After moving to Copenhagen, he became a board member of the Natural Science Faculty of Copenhagen and for a few years he was on the board of the Niels Bohr Institute.

Hans Henrik held many positions in the administration of science in Denmark. He was chair of the Danish Natural Science Research Council and later a member of the Planning Commission for Research. He was also a council delegate at CERN in 1985 and the Danish member of the Scientific Council of the EU Research Centre in the years 1985–1987. In addition, he was the founder, and subsequently co-editor, of *Nuclear Instruments and Methods in Physics Research B*, an activity he followed until the end.

Always kind and interested in what we were doing in high-energy physics, Hans Henrik participated in many of our meetings. He had a profound knowledge of experimental physics and often asked precise, much appreciated questions about particle physics. He is missed by all of us and by his family for whom he was a much loved husband, father and grandfather.

● *His friends and colleagues in high-energy physics.*

AEPSHEP

New school links Europe and the Asia-Pacific region

The first Asia-Europe-Pacific School of High-Energy Physics (AEPSHEP) took place in Fukuoka, Japan, on 14–27 October.

The high degree of interest in this new school was reflected in the large number of applications – almost 200. A competitive selection was made based on the application forms and letters of recommendation from professors and supervisors, taking into account the area of study and the level of the candidates. An important criterion in the selection was the potential of the student to pursue a successful career in particle-physics research.

A total of 83 students attended the school from institutes in 21 different countries. About 70% of whom were from Asia-Pacific countries, with most of the others coming from Europe. More than 80% of the participants were working towards a PhD, while most of the others were advanced Masters students. Some 80% of the students were experimentalists, although the school was also open to phenomenologists. The lecturers and discussion leaders also came from many different countries, including Australia, China, France, Germany, India, Japan, Korea, Russia, Spain, Switzerland, Taiwan and the UK.

AEPSHEP brought students of different nationalities together. (Image credit: AEPSHEP.)

The programme required the active participation of the students. In addition to discussion sessions that addressed questions from the lecture courses, there was an evening session in which many students presented posters about their own research work to their colleagues and the teaching staff. The high level of interest could be gauged by the fact that discussion of the posters continued into the early hours of the following morning.

Collaborative student projects in which groups of about 14 students worked together on an in-depth study of a published experimental data analysis were an important activity. This required working together, outside the formal teaching sessions, with colleagues from different countries and different cultures. A student representative of each of the six groups presented a short summary of the conclusions of the group's work in a special evening session whose attendees included the directors-general of CERN and KEK, both of whom also delivered lectures on the final day of the school.

A strong team from KEK, as well as from Kyushu and Saga Universities, provided excellent local organization. The staff and students were housed in comfortable accommodation in the Luigans resort, which also provided excellent conference facilities and a pleasant environment for informal interactions between participants.

In addition to teaching an intensive scientific programme, the school aimed at fostering cultural exchange between participants of different nationalities. The organizers mixed students from different countries when they assigned them to shared bedrooms and to the six discussion groups that met most afternoons. Leisure activities included a full-day excursion to the Mt Aso volcano, and a half-day excursion to Dazaifu where the group visited a Buddhist temple and a Shinto shrine as well as the Kyushu national museum.

Feedback from the participants after the school was extremely positive in terms of the appreciation of the scientific programme, the quality of the teaching, the practical organization and, especially, the aspects of cultural exchange and of building working relationships between promising young scientists from different countries. The next event in the series, to be held in India in 2014, aims to build on the success of the first school.

CERN

CAS introduces accelerator physics in Spain

The CERN Accelerator School (CAS) and the University of Granada jointly organized a course on Introduction to Accelerator Physics in Granada, on 28 October – 9 November 2012. The course attracted more than 200 applicants from which 139 students were selected to attend, representing 25 different nationalities and coming from countries as far away as Australia, China, Guatemala and India.

The programme comprised a mixture of lectures, seminars, tutorials, a poster session and seven hours of guided and private study. Feedback from the students praised the expertise of the lecturers, as well as the high standard and quality of their lectures. In addition, CERN's director-general, Rolf Heuer, presented a public lecture about the LHC at the Parque de las Ciencias. The students also had the opportunity to visit the well known caves at Nerja and the famous Alhambra site.

Participants at the CAS course in Granada. (Image credit: F Maldonado Roman, Granada.)

The next CAS course will be a specialized one on Superconductivity for Accelerators, to be held in Erice on 24 April – 4 May 2013. The next course on general accelerator physics will be at a higher level and held in Norway in late summer. For further information, see www.cern.ch/schools/CAS.

UBS supports Turkish summer students

Every year, CERN invites undergraduate students from around the world to work at the laboratory as part of its summer student programme. The students stay at CERN for 8–13 weeks, working for research teams and attending a dedicated lecture series. The programme gives them the opportunity not only to develop their skills as physicists, computing specialists or engineers, but also to network.

Two students from Turkey, supported by the Swiss bank UBS, were among the 269 participants in 2012, who together represented 71 nationalities. Çağlar Kutlu is currently studying physics and electronics engineering at Istanbul Technical University, and Firat Yilmaz is studying physics, electrical engineering and computing at Bilkent University, Ankara. Two representatives from the UBS Turkey desk in Geneva – Edward Ipekdjian and Mustafa Karadag – took the opportunity to meet the students for lunch during their time at CERN. This was the third time that the bank has provided support for Turkish students.

The students Çağlar Kutlu, centre left, and Firat Yilmaz are welcomed at the UBS office in Geneva by Edward Ipekdjian, left, and Mustafa Karadag, right. (Image credit: E Ipekdjian.)

UBS has made this commitment to bringing young people from Turkey to CERN's summer student programme to contribute in a small way to the education of future talents in a country that has a future not only in the banking sector, but also in education, innovation and science. For CERN, the participation of the Turkish students provides a valuable bridge between CERN and Turkey, a link that is currently being enhanced.

Meetings

The fourth **International Particle Accelerator Conference, IPAC'13**, will take place at the Shanghai International Convention Center, Shanghai on 12–17 May 2013. The programme includes plenary sessions and parallel sessions with invited and contributed presentations. There will also be poster sessions, including a special poster session for students, held during conference registration on 12 May. An industrial exhibition will take place on 13–15 May and there will be a special session for industry on 15 May. For a detailed conference programme, as well as information on registration (before 13 March for lower fees) and reservation of accommodation, see www.ipac2013.org.

The **16th Lomonosov Conference on Elementary Particle Physics** will be held at Moscow State University on 22–28 August 2013. It will open on the centenary of Bruno Pontecorvo's birth, and a special memorial international meeting dedicated to this anniversary will be held during the conference. The programme will include: electroweak theory, tests of Standard Model and beyond, neutrino physics, astroparticle physics, gravitation and cosmology, developments in QCD, heavy quark physics, and physics at present and future accelerators. For details and registration, see www.icas.ru/english/LomCon/16lomcon/16lomcon_main.htm.

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SCIENTIFIC STAFF

Computational Center for Particle and Astrophysics

The Excellence Cluster 'Origin and Structure of the Universe' at the Technische Universität München (TUM) and the Ludwig-Maximilians University (LMU) invites applications for **4 staff scientists to support the activities of the Computational Center for Particle and Astrophysics (C2PAP)**. C2PAP is a new collaborative element that focuses on scientific research at the computationally intensive frontier. Scientific projects range from particle physics simulations and studies using data from the Large Hadron Collider to astrophysical simulations and multi-wavelength studies of cosmology and structure formation in the Universe, using data from, e.g. the South Pole Telescope, the Dark Energy Survey, eROSITA and Planck.

C2PAP's success depends on the new team members, who will work alongside Universe Cluster scientists, supporting the development of new algorithms and managing their deployment on C2PAP hardware. Our primary hardware is the newly launched **SuperMUC system at the Leibniz Rechenzentrum (LRZ)** with a 2048 core extension dedicated to C2PAP activities. Moreover, we plan to investigate the use of new computing architectures, such as GPUs, INTEL MIC/PHI or ARM, for our applications in particle and astrophysics.

We are seeking applicants with experience in **high performance scientific computing**. The team members will focus in the areas of simulation, data processing and calibration. We expect to invest significant effort in developing new algorithms that improve the accuracy and efficiency of codes both in astrophysics and particle physics. **More specifically, we seek: (1)** staff scientist with experience in data processing and databases within an astronomy/cosmology context (PhD preferred), **(2)** staff scientist with background in numerical physics and experience in parallel coding and algorithm development (PhD preferred), **(3)** staff scientist in particle physics with experience in high-throughput data processing and data reduction, used e. g. at LHC (PhD preferred), and **(4)** IT expert for particle physics with background in algorithm development, experience with databases or novel computing platforms.

APPLICATION

Application documents (in PDF format) including a cover letter describing your interest in this position, a CV, your PhD/diploma certificate, a list of publications, and a detailed list of IT and computing experience should be uploaded under **www.universe-cluster.de/about-us/jobs/**. Please have three letters of recommendation sent to **job@universe-cluster.de**. We especially encourage applications from women. Disabled persons will be given preference to other equally qualified applicants. The fixed term appointments will end on 31st October 2017, with a salary according to the German public service pay agreement (TV-L E13). **Application deadline is 28th February 2013.**

CONTACT

Excellence Cluster Universe
Prof. Joseph Mohr · jmohr@physik.lmu.de · Scheinerstraße 1 · 85679 München · Germany

LSU

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For further details you may contact
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Prof. V. Suller (email:vsuller@lsu.edu).

Required Qualifications: Bachelor's degree with four years of related experience in engineering, physics, or a related area OR Master's degree with two years of related experience in engineering, physics, or a related area OR Ph.D.; professional experience in the operation or electron accelerators for the production of sychrotron radiation; should be familiar with the main components of a storage ring system (RF, Control System, Linac, etc.); leadership, administrative skills and some experience in organizing a larger group of people; and some background in design and operation of insertion devices.

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The Board of Directors of Fermi Research Alliance, LLC (FRA) has initiated a search for a new Director of the Fermi National Accelerator Laboratory in Batavia, Illinois. The position, for a term of five years with the possibility of extension for a mutually agreed time, will be available July 1, 2013.
The Search Committee welcomes applications and nominations for this position. It is recommended that applications be accompanied by curriculum vitae and other information bearing on the candidates' qualifications for the Directorship. Relevant qualifications include visionary leadership capability, internationally recognized scientific achievement, management experience and accomplishments at a national laboratory or complex research setting, and broad communications skills.

The membership of the Search Committee, its charge, and provision for submitting confidential input to the Committee are posted at **http://www.fnal.gov/pub/directorsearch**

Communications should be sent as soon as possible, preferably before January 15, 2013, and should be addressed to:

Ezra Heitowit
Executive Secretary for the Fermilab Director Search Committee
Fermi Research Alliance, LLC
Suite 400
1111 19th Street, NW
Washington, DC 20036 USA
e-mail: heitowit@fnal.gov

The two members of FRA are the University of Chicago and Universities Research Association, Inc. FRA operates Fermilab under contract with the U.S. Department of Energy.
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The Department of Physics and Technology (http://www.uib.no/ift/en) has a vacancy for a professor/associate professor in theoretical particle physics. The successful applicant is expected to have a strong research record in one or several fields of theoretical particle physics: Particle physics at colliders and in particular the LHC, Beyond the Standard Model physics, and Astroparticle physics.

The successful applicant should be able to initiate relevant research activities, attract funding and conduct research in collaboration with relevant external and internal research partners. This includes defining thesis topics and supervising students of theoretical particle physics at the MSc and PhD level. Good interpersonal and communications skills are important. He/she will also be required to take part in the general teaching programme at the department. For this particular position it is expected that the candidate can teach graduate courses in Quantum field theory and the Standard Model.

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For further information about the position please contact Professor Bjarne Stugu, phone (+47) 55 58 27 69; e-mail bjarne.stugu@ift.uib.no, or Professor Geir Anton Johansen, Head of Department, phone (+47) 55 58 27 60; e-mail GeirAnton.Johansen@ift.uib.no.

Closing date: 1 February 2013

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University Lecturer in Experimental Particle Physics

Mathematical and Physical Sciences Division
Department of Physics in association with Jesus College

Applications are invited for a University Lecturer in Experimental Particle Physics to work on the LHCb experiment, from 1 October 2013, or earlier. The successful candidate will be offered a Tutorial Fellowship at Jesus College, under arrangements described in the further particulars. The combined University and College salary will be on a scale currently from £42,883 to £57,581 with substantial additional College benefits, including a pensionable housing allowance of £9,986 per annum payable to non-residential Tutorial Fellows, a responsibility allowance of £1,451 per annum, and a choice of schemes for research and teaching expenses, amounting to between £1,250 and £1,700 per annum. Jesus College operates an equity sharing scheme, to assist Fellows in purchasing their house. The appointment will be initially for five years at which point, upon completion of a successful review, the post-holder will be eligible for reappointment to the retiring age. While preference may be given to candidates working in the area of flavour physics, candidates currently working in related areas of particle physics can also be considered.

The successful candidate will have a doctorate in particle physics or a related field and a record of high-quality research in experimental particle physics at international level. He/she will be expected to join the Oxford effort on the LHCb experiment and its upgrade, planned to take data in 2019. The Oxford group is a major contributor to the physics analysis, and to the ring-imaging Cherenkov and silicon vertex detectors of the experiment. The candidate will be expected to play a leadership role in both LHCb physics and hardware initiatives. He/she will also contribute fully to undergraduate teaching and graduate supervision, and will undertake tutorial teaching and administration at Jesus College.

Further particulars of this post and information on how to apply are available at **http://www.physics.ox.ac.uk/pp/jobs/Lecturership-Fp-January2013.pdf** or from Mrs Sue Geddes, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, UK, email: s.geddes@physics.ox.ac.uk, Tel 0044-1865-273353. Informal enquiries about this post may be made to Professor Neville Harnew, n.harnew@physics.ox.ac.uk, Tel 0044-1865-273316.

The application deadline is 29th January 2013. Interviews will be held on 15th February 2013.

Applications are particularly welcome from women and black and minority ethnic candidates, who are under-represented in academic posts in Oxford.

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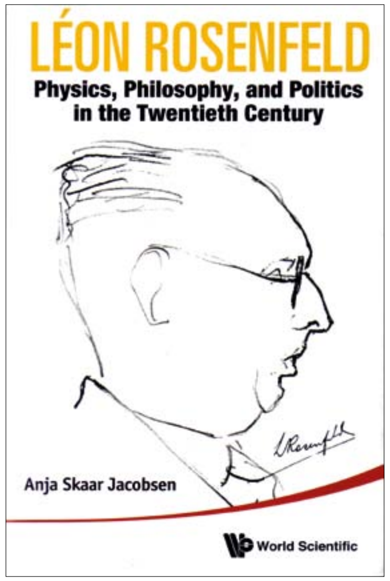
Bookshelf

Léon Rosenfeld: Physics, Philosophy, and Politics in the Twentieth Century

By Anja Skaar Jacobsen
World Scientific
Hardback: £56
E-book: £69



The life of Léon Rosenfeld (1904–1974) spanned all of the three main epochs of the development of physics during the 20th century, at least according to the classification that Vicky Weisskopf expressed in a colloquium at CERN entitled "The development of science during this century". So it should not be surprising that, as Anja Skaar Jacobsen of the Niels Bohr Archive demonstrates, the activities of this outstanding Belgian physicist cannot be grouped into a single category. Rosenfeld, who was extremely curious and erudite, contributed substantially to electrodynamics, to the Copenhagen interpretation of quantum mechanics and to the problem of the measurability of quantum fields. He was also a science historian, a tenacious political activist and, last but not least, the founding editor of the journal *Nuclear Physics*.

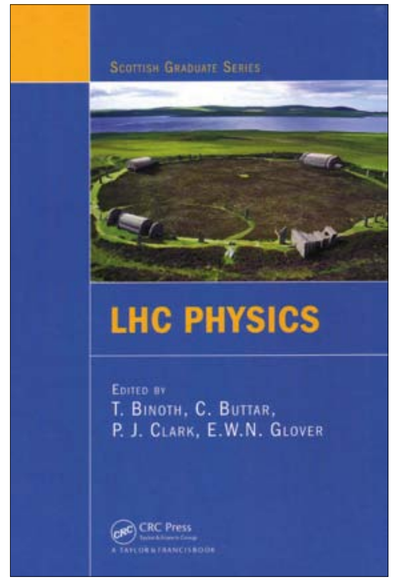
The first and second of the six chapters follow Rosenfeld's life and interests through the 1930s up to the period where he actively participated in the formulation of the so-called Copenhagen interpretation of quantum theory and collaborated with Niels Bohr. The interface between science and politics in this period is specifically addressed in the third chapter. Rosenfeld never joined the communist party but progressively became a convinced leftist intellectual. Prior to the Stalinist purge in the second half of the 1930s, Copenhagen was also at the heart of political debates, hosting many leaders such as Lev Trotsky who visited Denmark in 1932. The fourth chapter describes how Rosenfeld survived the war in Utrecht where he took over the position of George Uhlenbeck, who left for the US in 1939. The final two chapters focus on his political commitment during the Cold War and on heated discussions surrounding the attacks on the Copenhagen interpretation, which Rosenfeld fiercely defended throughout his life.

The interests of Rosenfeld and the second "quantum generation" implicitly encourage debates. In a purely scientific context, there is the broad problem of the interpretation of quantum mechanics. The quantum theory of measurement was perceived as essential in the 1930s and throughout the 1940s. How does a classical object interact with a quantum system? Does it make sense to separate the world into quantum systems (the observables) and classical observers? The discussions leading to the most successful applications of quantum mechanics are a continuous source of reflection, from the early Einstein-Bohr controversy to Bell's inequalities via the Bohmian interpretation of quantum theory. Quantum mechanics is not reducible either to a successful computational framework or to a philosophical perspective. It is, rather, a complicated mix of ideas that matured in one of the most difficult periods of European history. To understand quantum mechanics also means to understand the history of the first part of the 20th century: this is probably one of the main legacies, among others, of the life of Léon Rosenfeld.

● *Massimo Giovannini, CERN and INFN Milan-Bicocca.*

LHC Physics

By T Binoth, C Buttar, P J Clark and E W N Glover (eds.)
Taylor & Francis
Hardback: £76.99



LHC Physics collects the written versions of lectures delivered at the Scottish Universities Summer School in Physics that took place in August 2009, in St Andrews, and covers many relevant issues for people working on the analysis of LHC data. The first nine chapters include discussions about QCD, the Higgs, B physics, forward physics, quark–gluon plasma and physics beyond the Standard Model, complemented by lectures on the LHC accelerator and detectors. The last three chapters cover Monte Carlo event-generators, statistics for high-energy-physics data analyses, and Grid computing. The lecturers are top-level experts and the book provides a nice introduction to many topics in high-energy physics, making it a valuable addition to many libraries around the world, including those of the hundreds of universities and institutes that participate in the LHC experiments.

The chapter on statistics is particularly useful as an introduction for the PhD students and postdocs who are heavily involved in data analyses. It addresses the relevance of Bayesian approaches and of the Markov-chain Monte Carlo tool, as well as the importance of providing results in the form of posterior probability distributions and how to deal properly with systematic uncertainties. It also overviews the topic of multivariate classifiers (with emphasis on "boosted decision trees") and readers will probably appreciate the concluding remark that "while their use will no doubt increase as the LHC experiments mature, one should keep in mind that a simple analysis also has its advantages".

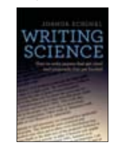
Despite the book being published in 2012, it already seems somewhat old – a clear testimony to the amazing speed at which LHC results are being produced. Since the school took place, around 500 physics papers have been published by the LHC collaborations (a really impressive achievement), including many results that have significantly improved our understanding of most of the topics addressed in this book. While holding such summer schools is obviously important, one might wonder about the usefulness of the corresponding proceedings, especially when published more than two years after the school took place.

● *Carlos Lourenço, CERN.*

Books received

Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded

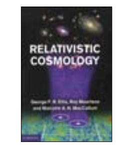
By Joshua Schimel
Oxford University Press
Hardback: £60 $99
Paperback: £22.50 $35



Success is not necessarily defined by getting papers into print but by getting them into the reader's consciousness. *Writing Science* is built on the idea that successful science writing tells a story. It shows scientists and students how to present their research in a way that is clear and that will maximize reader comprehension. This book takes an integrated approach, using the principles of story structure to discuss every aspect of successful science writing, explaining how to write clear and professional sections, paragraphs and sentences. The final section deals with challenges such as how to discuss research limitations and write for the public.

Relativistic Cosmology

By George F R Ellis, Roy Maartens and Malcolm A H MacCallum
Cambridge University Press
Hardback: £80 $130
E-book: $104



Using a relativistic geometric approach, this book focuses on the general concepts and relations that underpin the standard model of the universe. Part I covers foundations of relativistic cosmology. Part II develops the dynamical and observational relations for all models of the universe based on general relativity. Part III focuses on the standard model of cosmology, including inflation, dark matter, dark energy, perturbation theory, the cosmic microwave background, structure formation and gravitational lensing. It also examines modified gravity and inhomogeneity as possible alternatives to dark energy. Anisotropic and inhomogeneous models are described in Part IV, and Part V reviews deeper issues, such as quantum cosmology, the start of the universe and the multiverse.

Quantum Gravity (Third Edition)

By Claus Kiefer
Oxford University Press
Hardback: £65 $117

The search for a quantum theory of the gravitational field is one of the great open problems in theoretical physics. This book covers the two main approaches to its construction – the direct quantization of Einstein's general theory of relativity and string theory. There is a detailed presentation of the main approaches used in quantum general relativity: path-integral quantization, the background-field method and canonical quantum gravity in the metric, connection and loop formulations.

Inside Story

Llewellyn Smith, world scientist

On 20 November CERN hosted a symposium to mark the 70th birthday of Chris Llewellyn Smith.

Left to right: (back) Rolf Heuer, Peter Jenni, Lyn Evans, Chris Llewellyn Smith, Steve Cowley, Zehra Sayers, David Gross, Chris Allsopp, Robert Jaffe, Bikash Sinha; (front) Geoffrey West, Álvaro de Rújula, John Ellis.

Chris Llewellyn Smith's role in world science is considerable and diverse: from frontier fields such as particle physics and fusion energy, through the promotion of international scientific co-operation, to the advancement of peace through scientific endeavour. He has served as director-general of CERN, president and provost of University College London, director of UKAEA Culham Division, which holds the responsibility of the UK's fusion programme and operation of the Joint European Torus, and chair of the International Thermonuclear Experimental Reactor Council. He is currently director of energy research at the University of Oxford and president of the council for the new international centre for Synchrotron light for Experimental Science and Applications in the Middle East (SESAME). His leadership has contributed towards the many achievements of these institutions, most notably the approval and launch of the LHC at CERN and the upgrade of the Large Electron–Positron collider. He was knighted in 2001 for his services to particle physics.

As Lyn Evans, who was the LHC project leader for many years, underlined in his opening presentation, Llewellyn Smith's diplomatic skills were key in getting the LHC approved in CERN Council and in building up the international collaboration of member and non-member states that was essential for the LHC's construction. As director-general, he successfully negotiated major contributions from Canada, India, Japan, the Russian Federation and the US, a fact that Bikash Sinha of the Variable Energy Cyclotron Centre recalled fondly when he spoke about Llewellyn Smith's diplomacy in the negotiations with India.

Peter Jenni, founding spokesperson of the ATLAS collaboration, took a trip back in time to thank Llewellyn Smith for having launched the LHC on a journey to new territories of physics. Jenni noted that the LHC is a global scientific adventure, combining the accelerator, the experiments and the worldwide computing Grid as well as a fourth, essential element – the constant driving motivation of the theorists, of whom Llewellyn Smith was one of the pioneers promoting LHC physics. Among Llewellyn Smith's many notable contributions are his studies of heavy vector bosons at supercolliders and the physics case for a multi-tera-electron-volt hadron collider, both presented at the CERN-ECFA Workshop in Lausanne in 1984.

Fellow theorist John Ellis, who has long been a familiar face at CERN, looked ahead to the implications of the results from the LHC. He focused on the recent results from the search for the Higgs boson and other ongoing studies at the LHC that seek answers to some long-standing questions. Why are there so many types of matter particles? What is the dark matter in the universe? Is there a unification of fundamental forces? And is there a quantum theory of gravity?

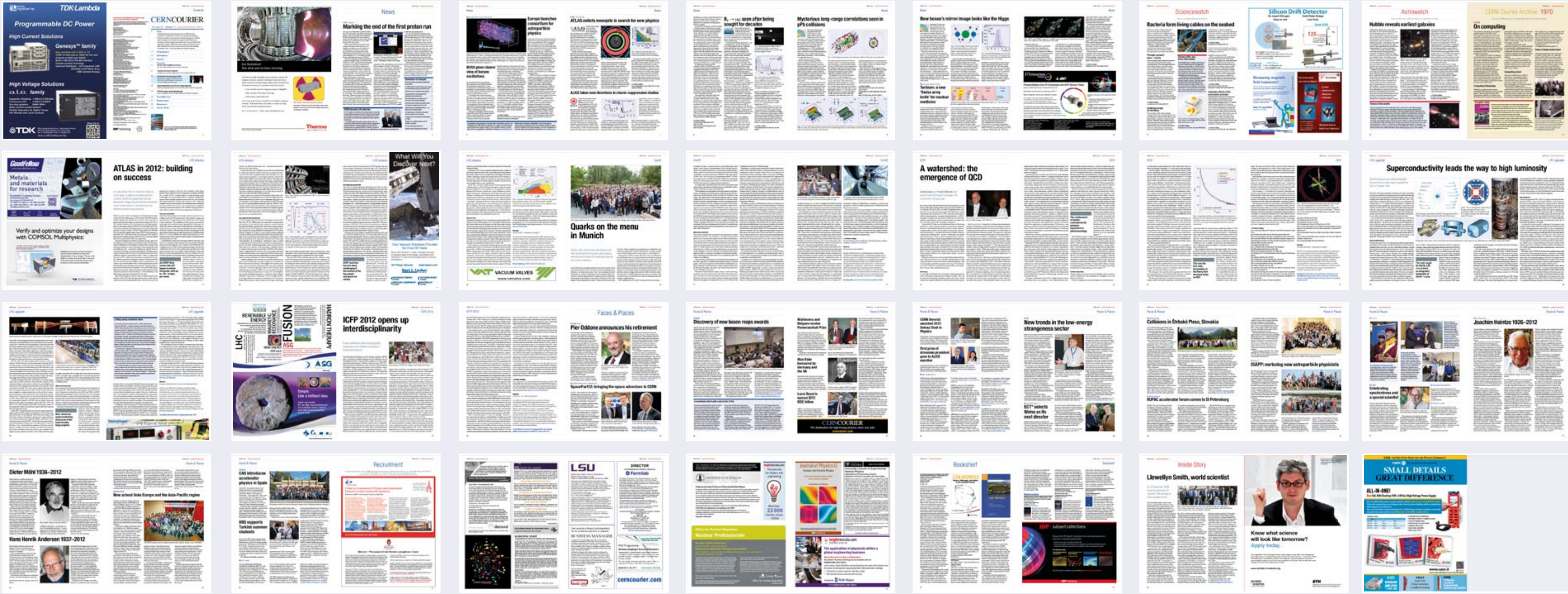
Moving beyond CERN, Zehra Sayers of Sabanci University recalled Llewellyn Smith's contributions to SESAME, as a committed leader and supporter of the international centre currently under construction in Jordan. The project to build a third-generation light-source owes much to the dedication and support of Llewellyn Smith, whose efforts have been a guiding force in bringing nations together through science in this region of the world and beyond.

In recent years, Llewellyn Smith has devoted himself to the issue of energy, the common topic for Chris Allsopp of the Oxford Institute for Energy Studies, Robert Jaffe of the Massachusetts Institute of Technology and Steve Cowley of the Culham Centre for Fusion Energy. Allsopp underlined the challenges that lie ahead in reconciling needs with expectations and getting the balance right in the mixture of energy sources. Jaffe discussed current endeavours to identify new sources of energy that might lead to efficient, clean, renewable and at least CO_2-neutral technologies. Cowley recalled Llewellyn Smith's considerable contributions to fusion energy. As director of UKAEA Culham, he developed and vigorously promoted the "Fast Track" approach to the development of fusion power, which provides a tentative road map of the achievements required for large-scale electricity production and has been adopted by the European Commission.

On a still grander scale, Geoffrey West of the Santa Fe Institute spoke about universal scaling laws – the quantitative, unified theories of biological and social structure and dynamics, applicable from the microcosm of cells to the macrocosm of cities. The work tries to answer some deep questions: Are we sustainable? Are there quantitative predictive laws of life?

Last, David Gross, joint recipient of the 2004 Nobel Prize in Physics, reviewed Llewellyn Smith's contributions to theoretical particle physics and gave an outlook for fundamental physics. He recalled with much delight the pioneering work that they did together in the late 1960s on high-energy neutrino–nucleon scattering, current algebra and partons.

● See the presentations and a video recording at http://indico.cern.ch/conferenceDisplay.py?confId=199172.



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