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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Covering current developments in high-energy physics and related fields worldwide
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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^{10} 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 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^{32} cm^{-2} s^{-1}, more than twice the maximum value obtained in 2011 (3.5 × 10^{32} cm^{-2} s^{-1}). News from the experiments included LHCb’s measurement of the decay of the B (meson into two muons (μμ)), ATLAS’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 5σ, 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: Ewan Schneider/Unl.)
BOSS gives clearer view of baryon oscillations

In November the Baryon Oscillation Spectroscopic Survey (BOSS) released its second result of 2012, using 48,000 quasars with redshifts up to 3.5 as backlights to map intergalactic hydrogen gas along the line of sight. Over the past six years, BOSS has mapped 1.5 million galaxies and 160,000 quasars. When complete, BOSS will have surveyed 48,000 quasars with redshifts (z) up to 3.5 as backlights to map intergalactic hydrogen gas along the line of sight. Ten countries have already joined the new BOSS consortium, with nine others following the accession process. BOSS’s activities will be harmonized through three functional centres, located at DESY, the Astroparticle Physics and Cosmology laboratory of the French CNRS/CEA, and the INFN’s Gran Sasso National Laboratory. A common action plan to fund the upcoming European activities will be organized through three functional centres, located at DESY, the Astroparticle Physics and Cosmology laboratory of the French CNRS/CEA, and the INFN’s Gran Sasso National Laboratory. It has developed common R&D calls 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.

ALICE takes new directions in charm-suppression studies

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 (lower right) 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, Nie Ross, BOSS Lyman-alpha team, Berkeley Lab; and Springel et al., Virgo Consortium and Max Planck Institute for Astrophysics.)

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 2013, BOSS released its first results on more than 350,000 galaxies up to z = 0.7, 7,000 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


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.
Mysterious long-range correlations seen in pPb collisions

The CMS collaboration has published its first evidence for long-range correlations in proton–antiproton collisions (pPb collisions) (CMS collaboration 2012), related to the observation of a pion–proton event (pPb) collision at the 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, a signal of a high number of particles—which manifests as a ridge-like structure. About once in every 100,000 p 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 were reminiscent of effects seen in nucleus–nucleus collisions first observed by the ALICE collaboration (Heinz’ Heavy Ion Collider (RHIC) and later in collisions of lead–lead nuclei (PbPb) at the LHC (figure 1b) shows a peak in pPb collisions from CMS).

Nucleon–nucleon 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 pPb 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 L. 2012).

In September 2012, the LHC provided a short pilot run of pPb collisions at a centre-of-mass energy of 5 TeV per nucleon, 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 pp 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.

Further reading
V Khachatryan et al. CMS collaboration 2010 JHEP 09 091
Wei L 2012 Mod. Phys. Lett. A27 1330018
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 see 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 signals and, secondly, to determine if the new particle is the mirror image of the Higgs boson of the Standard Model or have they found something new?

Using the full event information, the analysis assigns to each event the probability that it is a genuine Higgs boson, 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 models are correlated – they have attempted to determine if the new particle is the Standard Model Higgs boson or a gateway to a new world.

**N U C L E A R  M E D I C I N E**

**Terbium: a new ‘Swiss army knife’ for nuclear medicine**

A team of scientists from the Paul Scherrer Institute (PSI), CERN’s ISOLDE facility and the Institute Lanclangevis (ILL) has published results from a preclinical study of new tumour-targeting radioisotopes 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.

Radioisotopes 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 employs the short-range radiation (β- 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 radiotherapeutic agents 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: 4.2m, 4.2h, 5.3m and 6.9d for PET, 17.5s, 20.2h and 14.1h for SPECT and 0.5, 6.6, 26, 40, 75 and 149.1 d for therapy with electrons (β– conversion and Auger electrons).

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 4.2m Tb, 20.2h Tb and 14.1h Tb were produced by 1.4 GeV proton-induced spallation in a tandem target and separated with the ISOLDE online isotope separator at CERN. 17.5s 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, 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 folate acid is conjugated with an albumin-hinding 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 monographs in mice to be seen using small-animal PET (17.5s Tb-cm09) and small-animal SPECT (14.1h Tb-cm09 and 20.2h Tb-cm09). In vivo therapy experiments using 14.1h Tb-cm09 (α-therapy) and 17.5s 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 14.1h Tb. At present ISOLDE at CERN is the world’s only source of this isotope.

Further reading


**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.

**Fig. 2.** Expected likelihood for a scalar (0+) and a pseudo-scalar boson (0−) (green arrows) shows that the probability that the new boson is 0+ is very small. 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.** PET (a) and SPECT images (b, c) of KB tumour-bearing mice 24 hours after injection of (a) 17.5s Tb-cm09, (b) 14.1h Tb-cm09 and (c) 17.5s Tb-cm09 New boson’s mirror image looks like the Higgs

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Bacteria form living cables on the seabed

Bacteria in marine sediments that have no access to oxygen can instead use electron-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” 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.

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.

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. Tongeren-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

Further reading


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

Further reading


There’s more to cutting than just a sharp edge. (Image credit: kayakheadphoto/Elisan Kars/dreamstime.com.)

Further reading


Further reading

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 the growth rate 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.

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 technologies 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 20 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.

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 S45 Fellowships are in computing, and Uppsala, Sweden, hosted CERN’s 35th Computing School in August, 2012. And interdisciplinary? 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.

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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 p.21). 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, taus 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 →γγ and H →ZZ(∗) → 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 given to aim for analysis of the new data.
LHC physics

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 $\gamma$ and $\ell$-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 4.5 in the $\gamma$ channel and 3.4 in 4 leptons, leading to the reporting of the observation of a new particle with a combined significance of 5.9 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 $\gamma$ and $\ell$-4-lepton results reported at ICHEP, the paper by ATLAS also included the analysis of the $H\rightarrow WW^{\pm}\rightarrow \ell\ell\nu\nu$ channel, which revealed a broad excess with a significance of 2.8$\sigma$ 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 5.8$\sigma$ level (figure 2), ushering in a new era in particle physics.

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 SUSY and non-SUSY 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 20 TeV, 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 to Higgs searches. These measurements, as well as in evaluations of the backgrounds to Higgs searches, have been measured and spin distributions of vacuum technology products, services and systems.

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at 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 $B_s \rightarrow J/\psi K_s$, which was found to be in perfect agreement with the expectation from the Standard Model, and the precise measurement of the $A_{CP}$ 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.

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 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 fournirait 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 mêmes $B_s$. 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 Rawlings, CERN, for the ATLAS collaboration.

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.

The ConfX conference attracted 400 participants from around the world. (Image credit: All photos Hector Martinez/TUM.)
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, $\psi'$ 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. Progress made in the production of $Y$ and other quarkonia states at the LHC experiments are now available. The process in theory together with the new LHC data should soon allow the resolution of the long-standing puzzles about the $\psi'$ 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 (nonrelativistic QCD at finite temperature). Here the shift from QCD in a 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 Andreas Schmitt of the Vienna University of Technology. In a session on the “Colourful world of quark and gluons” given by Yiota Foka of GSI and CERN, the prospects for the precision measurement of the 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.

The gigantic slide of the Mathematics Department at TUM complemented lively discussions during the poster session. 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 Manuel, “The many facets of QCD”, attracted the public from Garching city and from 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 lourds ; déconfinement ; QCD et nouvelle physique ; physique nucléaire et physique des astroparticules ; théories à couplage fort. On a évoqué 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 watershied: the emergence of QCD

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

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 period but dramatic 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, 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 \[1\] and George Zweig \[2\], is reviewed in a nice book by J J J Kokkedee \[8\]. For the model to be of any value, the quarks 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 they existed at all.

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 \[3, 4\] 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 recorded and used to support them. 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 \[1\] and George Zweig \[2\], 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 – quasiparticles with 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, eventually, 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 \[10\] 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 \[11\] 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 \[12\] and that they have baryon number 1/3 \[13\], i.e. that charged partons are quarks.

Quantum field theory and the renormalization group: Martinus Veltman and Gerardus ’t Hooft \[13\] 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, foreseeing a role that should be non-Abelian gauge theory in the study of quantum field theory beyond the limits of perturbation theory. He used them with great success to study critical phenomena. Neither of those developments was directly related to the strong interaction problem but they formed an intellectual background and inspiration. They showed that the possibilities for quantum field theory to describe physical behaviour were considerably richer than previously appreciated. Wilson \[14\] 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 \[15\] were partially successful but ascribed a much more intricate structure to protons than was possible with the simple, 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 symmetries.

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 predictions of quantum field theory. Several workers \[16\] expanded Wilson’s somewhat sketchy indications into a precise mapping between calculable properties of quantum field theories and measurable cross-sections. Similarly, 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 \[16\].)

A few realized that approxi- mate 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 \[17\] expanded Wilson’s notion of almost universal scaling to very small anomalous dimensions. (Strict scaling, which is equivalent to vanishing anomalous dimensions, cannot occur in a non-trivial – interacting – quantum field theory \[16\].)

Several workers \[18\] argued that approximate scaling could be achieved in an interacting quantum theory, if the effective interaction approached zero at short distances. They did not suggest that one should look to a non-Abelian gauge theory for the explanation of Bjorken scaling, which has so far eluded field-theoretic understanding. 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) \( \times \) SU(3) as a global symmetry and an SU(3) \( \times \) ”colour” gauge group to provide the strong interactions. That is, the generators of the strong-interaction gauge group commute with ordinary SU(3) \( \times \) SU(3) currents and mix quarks with the same spinos 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 \( \alpha \) is in the domain of attraction of the origin!) essentially that of the free quark model (up to calculable logarithmic corrections) \[19\].” 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 subject of four subsequent papers \[20,21\].

David Politzer’s paper \[22\] contains calculations of the renormalization group coefficients for non-Abelian gauge theories with fermions that appear to be rather 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, eventually, they existed at all.

Our paper, submitted in April 1973 \[23\], alludes directly to these motivations 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-shell mass 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.”

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The confinement of quarks contradicted all previous experience in phenomenology.

David Gross and Frank Wilczek
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 [16]. 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 and Symanzik corroborated – that he announced a negative value of the $\beta$ function for non-Abelian gauge theories with fermions at a conference in Mar- seilles 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. pions 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.

The emergence of a specific, precise quantum field theory for 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.

Further reading

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 11.3 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 (F7P) of the European Commission (EC), this is the first phase of the larger HL-LHC project (CERN Courier March 2012 p9).

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 F7P (CERN Courier June 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 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 (Nb3Sn), 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 Nb3Sn dipole. In summer it was tested at 5 T 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. 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 Nb3Sn 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” and “quarter-wave”) has now been completed successfully. The new Crab Cavity Technical Co-ordination Working Group will, after the first long shutdown (L1), work Packages of the HiLumi LHC FP6 Design Study (WP1 to WP6) within the High Luminosity LHC (HL-LHC) project.

Above: Cross-section for the 150mm Nb3Sn baseline option for the inner triplet quadrupole. Right: An 11 T magnet ready for cryogenic testing at Fermilab. (Image credit: Fermilab.)
of the LHC, overseer 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-stage 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 s00) and Point 5. A further challenge for the HL-LHC project is to relocate equipment such as power converters 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 surfa-e 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 WP6. The European Spallation Source (ESS) in Lund. The workshop held in December on superconducting technologies was therefore based on talks about the HL-LHC Design Study, TARA 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 manufacturer rather than for the full product) can be effective and yield the best value for money.
ICFP 2012 opens up interdisciplinarity

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

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 bear 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. Details can be found in the conference proceedings.

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 Zb 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 Y(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 → Kπμν/ν differs from the expectation by 4σ, while CP violation in the charm sector shows a 3.5σ deviation from the CP-conserving hypothesis. Results were presented on the latest results from the measurements of the rate of τ→μνν, which was used to infer the lifetime of the tau lepton and the branching ratio for the decay of the Higgs boson to τ+τ−.

Participants at ICFP 2012. (Image credit: Helmut Oeschler.)
from the BaBar experiment at SLAC highlight a significant excess of events in $B \rightarrow D^{+}\tau^{-} \bar{\nu}_{\tau}$ 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 1σ 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 $\nu_\tau$, preliminary limits on oscillation parameters from the search for $\nu_\mu \rightarrow \nu_\tau$, and an update on the measurement of neutrino velocity. New results from the T2K experiment in Japan confirm the first evidence for $\nu_\tau$ appearance, preliminary limits on oscillation parameters from the search for $\nu_\mu \rightarrow \nu_\tau$, and 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 it, 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 search 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, Acharamon’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, including David Bohm’s “bohmianism” ideas, were also discussed, providing a link between metrology 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 the island of 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 RHIC 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, thus often outside the “official” programme, were held. 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

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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 S.p.A 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 leaders of the LHC project and the CMS and ATLAS collaborations 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.

Max Klein, a DECISOR expert in magnetic systems for the LHC, received the 2012 Pomeranchuk Prize. He moved to CERN in 2001 to take charge of the construction of the first 25-m-long superconducting coils 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 LHC. He 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 1950 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.

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, coordinate and guide the activities. Physicists taking part in the LHC began in 1980 and since then the collider has delivered more than 10[superscript 9] proton–proton collisions at the record centre-of-mass energy of 7 TeV, at unprecedented luminosity. Collisions between accelerated tritium nuclei in 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 LHC 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), undertook 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 Briand, where the community of physicists and machine experts reached the agreement on a collider for protons and nuclei (CERN Courier October 2008 p8).
CERN theorist awarded 2013 Solvay Chair in Physics

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 have introduced the Solvay Chair in Physics to support scientists who are just beginning their careers.

First prize of Armenian president goes to ALICE member

Armenkuh Abranyan of the A1 Alkilhanyan National Science Laboratory, Yerevan Physics Institute, and a member of the software team of the ALICE experiment, has received the 2013 first prize from the President of Republic of Armenia as the best Bachelor Student in the field of information technology. Abranyan 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 ALICE, the grid infrastructure of the ALICE experiment (CERN Courier April 2012 p31).

For further details, contact Aya Tonooka, e-mail atonooka@murata.co.uk, or see www.murata.eu.

NEW PRODUCTS

FLIR Advanced Thermal Solutions has announced the FLIR SC4500/SC6500 system, designed to provide ultra-sonic, 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 +31 60370000, or e-mail research@flir.com, or see www.flir.com.

Murata Europe Ltd has announced the Murata Power Solutions MEEJ series, a 1-W single-output PCB mounted DC/DC converter designed for applications that require an isolated low-power distributed power supply. The 34-mm-high, open-frame XL330-P54 has a 76-mm × 135-mm footprint to deliver a power density of 15 W/cm² with only 13 cubic feet per minute cooling. The XL350-P54 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 is Power-over-Ethernet (PoE) compatible and the design allows up to four power supplies to be operated in parallel on this output. For more information, contact Bob Covey, e-mail covey@murata.com, or visit www.murata.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 noise. The series consists of five models with different maximum output voltage (+30 kV, +154 kV, ±20 kV, ±25 kV and ±330 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 Carl Coutts, e-mail coutts@trekinc.com, or see www.trekinc.com.

Wind River UK Ltd has introduced the latest version of Wind River Test Tools, 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 superiors other heat exchange materials, having a high porosity (80-90%) and a highly reflective surface area of up to 500 m²/m³ that 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 strangeness sector of QCD: 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. The ECT* conference focuses on QCD, its strangeness sector: experimental and theoretical aspects. It was held at the University of Trento in Italy’s Alto Adige region. Among the recent achievements, the precision measurements of kaonic hydrogen, helium-3 and helium-4 by SIDDHARTA stand out. These results have allowed deeper insights into the strangeness sector at threshold and above, as well as understanding of the underlying interactions and nuclear structure.

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

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 A(1405) resonance, the possible existence of deeply bound kaonic states, which, in recent years gave rise to intense debates; the Λ 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 ideas and as yet unsolved puzzles. The venue in the ideal environment of the workshop, 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 ideas and as yet unsolved puzzles. The venue in the ideal environment of the workshop, the
Symposium
Collisions in Štrbské Pleso, Slovakia

Surrounded by the beautiful High Tatras 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 of a nonzero and surprisingly large value of the third neutrino mixing angle, \( \theta_{13} \), 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 \( \theta_{13} \) all “standard” mixing angles and Am\'s 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 this and studies so far are in good agreement with Standard Model predictions, although the ttbb 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.

Collisions in Štrbské Pleso, Slovakia

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

The conference was organized by the Department of Subnuclear Physics, Slovak Academy of Sciences, Košice in association with the Nuclear and Subnuclear Physics Department of the Faculty of Sciences at JSF J. Saf'arik 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.

Schools
ISAPP: nurturing new astroparticle physicists

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 Institutes from 16 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.
**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 1953 he followed his teacher, Otto Haxel, to Heidelberg where he finished his PhD thesis in 1955. 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 monochromatic scattering on carbon to understand possible differences between mesons and electrons, he focused on studies of the weak interaction, starting with the challenging experiment of pion beta decay (with a 10⁻⁷ 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 established 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, 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 non-magnetic detector consisting of cylindrical drift chambers surrounded by a sodium-iodide–lead-glass calorimeter – which was ready in time to measure properties of the recently discovered J/ψ meson and t 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 drift 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 known–how–gained at PETRA.

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 U.K. 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 baritone, 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.

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**Correction**

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 labelling of Pb₉X₅₄ = 5.02 TeV was correctly placed. Figure 1 should thus be the plot labelled Pb₉X₅₄ = 5.02 TeV.

Apologies to all concerned.

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**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.

● Andre Martin.

**Faces & Places**

On 15 November His Holiness the 13th Gyalwang Drukpa, Jigmé Pema Wangchen, visited CERN together with an entourage of Buddhist monks. 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 University of Paris–Sud exhibition in the Globe of Science and Innovation.

**Visits**

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 Lambert, CERN Beam 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. St Johnston.)

The symposium immediately preceded the SSRL/LCLS Users’ Meeting at SLAC in November and included speakers who talked about Winick’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.
Dieter Möhl, an accelerator physicist of world renown who made essential contributions to CERN, died on 3 November. Born in Frederiksberg, Denmark, Möhl was one of the pioneers at CERN, where he 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 ultrashort 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 Decellerator ring (AD), after the 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 region 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 experimental solid-state physics 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 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 or protons 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 ASCCuA 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 and later a chairman 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 everyone was 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.

Hi friends and colleagues in high-energy physics.

AEPHSEP

New school links Europe and the Asia-Pacific region

The first Asia–Europe-Pacific School of High-Energy Physics (AEPHSEP) 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, South Korea, Spain, Switzerland, Taiwan and the UK.

The programme required the active participation of all the students, with a specific emphasis on 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 took place until long after the teaching of the following morning.

Collaborative student projects in which groups of about 14 students worked together on an in-depth study of a published experiment in the series, to be held in India in 2014, aims to build on the success of the first school.
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 a chemistry student 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.

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.

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.)

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.)

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.

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.icrc.ru/english/ LomCon16/lo6con16/moin.html.

For CERN, the participation of the Turkish students provides a valuable bridge between CERN and Turkey, a link that is currently being enhanced.

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

M E E T I N G S

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 during conference registration on 12 May.

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.)
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For further information contact
Dr. Richard Kutz (email: r.kutz@lsu.edu) or
Prof. V. Suller (email: vsuller@lsu.edu)

Required Qualifications: Baccalaureate 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 electronics instrumentation for the production of synchrotron 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.

Special Requirements: Must be able to work some nights and weekends. An offer of employment is contingent on a satisfactory pre-employment background check.

Application deadline is March 30, 2013 or until a candidate is selected.

Please apply online and view a more detailed ad at: https://lsustemcareers.lsu.edu. Position #012760

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:
Eraso Heltweit
Executive Secretary for the Fermilab Director Search Committee
Fermilab Research Alliance, LLC
Suite 400
1111 15th Street, NW
Washington, DC 20036 USA
e-mail: heltweit@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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Department

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The Department of Physics and Technology at the University of Bergen, Norway, 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 national and international research partners. This includes defining research 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.

Starting salary for full professors is currently NOK 572,700 gross p.a., for associate professors NOK 400,400 gross p.a.

For full details and to apply please visit www.jobs.ox.ac.uk (ID nr B58959).

For further information about the position please contact Professor Bjørn Støvring, phone (+47) 55 96 27 90, e-mail bjørn.støvring@ifi.uib.no, or Professor Geir Anton Johansen, Head of Department, phone (+47) 55 96 27 60, e-mail geir.anton.johansen@ifi.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 £42,063 to £57,581 with substantial additional College benefits, including a permissible housing allowance of £9,086 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: 0044-1865-273319.

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

Applications are particularly welcomed from women and black and minority ethnic candidates, who are under-represented in academic posts in Oxford. The University is an Equal Opportunities Employer.
Leon Rosenfeld: Physics, Philosophy, and Politics in the Twentieth Century
By Anja Szark Jacobson
World Scientific
Hardback: £76.99
Paperback: £22.50
$35

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 Szark 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. Postwar and 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 interest 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.

LHC Physics
By T. Broom, C. Butler, 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 second chapter of 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 overview the topic of multivariate classifiers (with emphasis on “boosted decision trees”) and readers will probably appreciate the concluding remark that “while their use will not 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.

More information is available at iopscience.iop.org/subjects
Inside Story

Llewellyn Smith, world scientist

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

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 Electron–Positron collider. He was knighted in 2001 for his services to particle physics.

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<table>
<thead>
<tr>
<th>Model</th>
<th>Output Voltage</th>
<th>Maximum Current</th>
<th>Resolution</th>
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<tbody>
<tr>
<td>NDT1400</td>
<td>8kV</td>
<td>200 μA</td>
<td>50 nA</td>
</tr>
<tr>
<td>NDT1401</td>
<td>5.5kV</td>
<td>300 μA</td>
<td>5 nA</td>
</tr>
<tr>
<td>NDT1419H</td>
<td>5.5kV</td>
<td>20 μA</td>
<td>1 nA (50 pA)</td>
</tr>
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