WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the January/February 2014 issue of *CERN Courier*.

This year sees the 60th anniversary of when a dozen European countries joined together to establish CERN. In this issue, the current director-general writes on how the organization has amply fulfilled the vision of its founders in providing for collaboration among European states in pure scientific research. Today, CERN welcomes scientists and engineers from around the world, many of whom are working towards the high-luminosity upgrade to the LHC – the laboratory's flagship accelerator – and its experiments. Accelerator R&D is well underway, not only for the LHC but for other front-line future accelerators at CERN and elsewhere.

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CERNCOURIER

VOLUME 54 NUMBER 1 JANUARY/FEBRUARY 2014

Accelerator R&D advances

ANNIVERSARY

CERN celebrates 60 years of science for peace **p58**

FACILITIES

Physics societies facilitate input to planning **p19**

HOW IT ALL BEGAN

The Particle Physics Masterclasses **p34**

Contents

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

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CERNCOURIER

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On the cover: R&D for the High-Luminosity LHC (HL-LHC) programme – now an approved project (p12) – is well underway, for example with work at CERN on new high-field magnets based on Nb_3Sn coils, as in this example. While the EuCARD project has co-ordinated R&D for frontier accelerators, including the HL-LHC (p26), the LHC collaborations have also been preparing for a high-luminosity future (p23). (Image credit: Anna Pantelia/CERN.)

News

INTERNATIONAL

CERN to admit Israel as first new member state since 1999

Following Council's adoption of the resolution to accept Israel as the 21st member state, (left to right) Eliezer Rabinovici, chair of the Israeli Academy of Science's National Committee for High Energy Physics, Eviatar Manor, Israel's ambassador to the UN in Geneva, Rolf Heuer, CERN's director-general, and Giora Mikenberg of the Weizman Institute.

Following a resolution unanimously adopted at the 169th session of the CERN Council on 12 December, CERN is set to admit Israel as the organization's 21st member state. Israeli membership will be effective from the date on which Israel formally notifies UNESCO that it has ratified the CERN Convention. CERN was established under the auspices of UNESCO, and UNESCO remains the depository of the CERN Convention. Israeli has been an associate member of CERN since 2011.

Israel's formal association with CERN began in 1991, when the country was granted observer status by Council in recognition of the major involvement of Israeli institutions in the OPAL experiment at the Large Electron–Positron collider, accompanied by contributions to the running of the accelerator. Today, Israel is involved with the ATLAS experiment at the LHC and the ALPHA and COMPASS experiments, as well as experiments at the ISOLDE facility. In addition, Israel contributes to the LHC and to the CLIC accelerator design study, and operates a tier-2 centre of the Worldwide LHC Computing Grid. Israel also supports the involvement of Palestinian students at CERN.

Israel's forthcoming membership of CERN follows a decision taken by Council in 2010 to enlarge the organization's membership (*CERN Courier* July/August 2010 p7). At the same time, Council established the status of associate membership for countries wishing to have limited participation in CERN's programme, accompanied by limited benefits of membership. All new applicants for full membership must pass through a period of at least two years as an associate member before Council takes a decision on full membership. A country can also apply for associate membership in its own right.

Following this decision, Israel became CERN's first associate member in 2011, followed by Serbia in 2012. Cyprus and Ukraine will become associate members as soon as their national parliaments ratify the accession agreements. Discussions are still underway with Slovenia regarding membership, and with Brazil, Pakistan, Russia and Turkey, all of which have applied for associate membership. Romania has the status of candidate for accession, having applied for full membership before the new procedures came into effect.

CERN's 60th anniversary

On 29 September, it will be 60 years since CERN – the European Organization for Nuclear Research – came into being as the first scientific pan-European endeavour. Just a few years after the Second World War, 12 European countries joined forces and built what has become the world's largest particle-physics laboratory. To mark the anniversary, this year CERN will celebrate 60 years of cutting-edge science for peace. In this issue, CERN's current director-general writes how the organization has fulfilled the vision of its founders to provide for collaboration among European states in pure and fundamental scientific research "with no concern for military requirements" (p58). Celebratory events will take place throughout the year in the member states – now numbering 21 – and at CERN. In particular, at the beginning of July a joint event with UNESCO in Paris will mark the anniversary of the initial signing, in 1953, of the convention that was to establish the organization under the auspices of UNESCO a year later. On 29 September, an event at CERN attended by high-level representatives from all of the member states will celebrate – 60 years to the day – the official birth of the organization in 1954.

- For more about 60 years of CERN in this and future issues of *CERN Courier*, look out for the logo!

Sommaire en français

CERNCOURIER
VOLUME 54 NUMBER 1 JANUARY/FEBRUARY 2014
IOP Publishing

ASTROPARTICLE PHYSICS

IceCube finds evidence for high-energy extra-terrestrial neutrinos

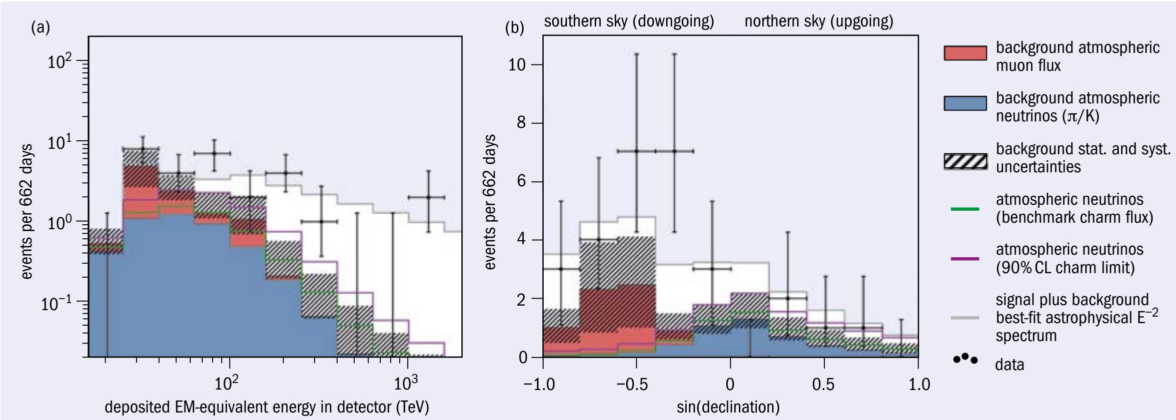


Fig. 1. (a) The deposited-energy spectrum and (b) zenith angle distribution for the 28 signal events, compared to the expected backgrounds from atmospheric muons (red), conventional atmospheric neutrinos (blue, with uncertainties given by the hatched region), perturbative QCD predictions for prompt neutrinos and the 90% upper limit for prompt neutrinos (purple), plus the best-fit E^{-2} astrophysical neutrino spectrum.

The IceCube collaboration has reported evidence, at the 4σ level, for a diffuse (i.e. isotropic) flux of high-energy extra-terrestrial neutrinos, mostly above 60 TeV (Aartsen *et al.* 2013). Using two years of data, the analysis selected 28 events – including the two events previously reported with energies above 1 PeV (*CERN Courier* July/August 2013 p5). This is substantially above the background estimate of 12.1 events.

In the energy range 60 TeV to 2 PeV, the data are well described by a neutrino energy spectrum that varies as E^{-2}, with a flux $E_\nu^2\phi < 1.2 \pm 0.4 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}. This is near the Waxman–Bahcall bound – the flux expected if cosmic-ray nuclei undergoing acceleration interact strongly in their sources and transfer most of their energy to secondary particles (mainly $\pi^\pm$ and $K^\pm$) whose decays produce neutrinos. For an E^{-2} spectrum, the data indicate that there must be a cut-off at a few peta-electron-volts, otherwise more energetic events would have been seen. Alternatively, the energy spectrum might be somewhat softer: an $E^{-2.2}$ spectrum fits the data well.

The analysis combined multiple techniques to isolate the 28 events from a much larger background of downward-going cosmic-ray muons and atmospheric neutrinos. The event selection was simple. It involved choosing events that originated within the detector and produced more than 6000 observed photoelectrons. The origination criteria used the outer portion of the detector as a veto, therefore removing events with early light, which could be from entering tracks. The analysis estimated the muon backgrounds using two independent, nested veto regions around a smaller fiducial volume. Events tagged in the outer veto that missed the inner veto were used to determine the veto-miss fraction. The veto also eliminated energetic, downward-going atmospheric neutrinos, which should be accompanied by a cosmic-ray air shower with energetic muons that should trigger the veto.

The selection criteria were largely insensitive to the event topology, so the analysis selected ν_e, ν_μ and ν_τ interactions, providing they occurred inside the detector. The events fall into two classes: long tracks (muons) from ν_μ charged-current interactions, plus cascades, electromagnetic or hadronic showers from ν_e and most ν_τ charged-current interactions, and neutral-current interactions of any flavour. Most of the events that IceCube sees are atmospheric ν_μ charged-current interactions, but the requirement that the events originate within the detector, depositing 6000 photoelectrons, changes the fraction. Of the 28 events found, only seven are classed as track-like. While this is consistent with the 1:1:1 ratio of ν_e:ν_μ:ν_τ, it is a lower fraction of tracks than expected for atmospheric neutrinos, which are mostly ν_μ.

Figure 1(a) shows the deposited energy for the 28 events, together with the expected backgrounds for muons, conventional atmospheric neutrinos and prompt atmospheric neutrinos from the decay of charmed particles. The atmospheric neutrino fluxes include the effect of the downward-going veto. There is a substantial uncertainty for the prompt flux, which has not yet been observed – the range is based on theoretical estimates, with upper limits from previous IceCube studies. Although the two 1 PeV neutrinos are prominent, the signal rises above the background at energies above 60 TeV. The black line shows the best fit to an E^{-2} astrophysical signal.

Figure 1(b) compares the zenith angle distribution of the data with the same background estimates. The muon background is entirely downward-going, while the atmospheric neutrino background is largely upward-going, owing to a combination of the downward-going veto and the absorption of high-energy neutrinos in the Earth. An isotropic extra-terrestrial signal would also be mostly downward-going because of this absorption. Of the 28 selected events, 24 are downward-going, which is more than expected from the background plus the astrophysical component from the fit. The excess is about 1.5σ. The angular agreement for a purely atmospheric neutrino flux is even worse.

This analysis shows that cosmic accelerators emit a significant fraction of their energies as neutrinos. The collaboration has also studied the arrival directions of the events, but observes no significant clusters. However, follow-up studies should further characterize the radiation and pin down its source. Already, some tantalizing hints have been presented at the 2013 International Cosmic Ray Conference (*CERN Courier* November 2013 p25 and Klein 2013).

Breakthrough of the Year

The first observations of high-energy cosmic neutrinos by IceCube was named 2013 Breakthrough of the Year by *Physics World* and also featured in *Wired*'s list of top scientific discoveries of 2013. *Physics World* highly commended nine other achievements, including the discovery of pear-shaped nuclei at CERN's ISOLDE facility (*CERN Courier* June 2013 p5), the Planck space telescope's most precise determination ever of the cosmic microwave background radiation and the South Pole Telescope's measurement of B-mode polarization in the radiation. *Wired* also listed the dark-matter results from the LUX experiment (*CERN Courier* December 2013 p8).

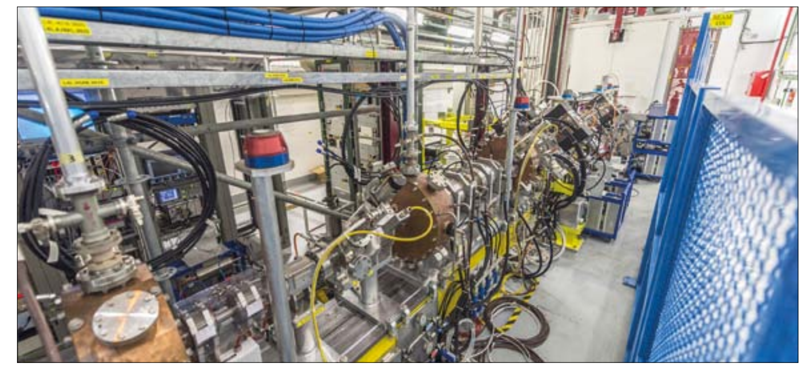
Further reading

M G Aartsen *et al.* IceCube Collaboration 2013 *Science* **342** 1242856.

S R Klein IceCube Collaboration 2013 arXiv:1311.6519 [astro-ph.HE].

LHC NEWS

First negative-hydrogen-ion beam accelerated at Linac4



The Linac4 3 MeV beam line, with the ion source at the back, the RFQ in the middle and the chopping line at the front.

On 14 November, a beam of negative hydrogen ions was successfully accelerated for the first time to 3 MeV in Linac4. This marked the start of a two-year commissioning phase for the new linear accelerator that will replace Linac2 as the low-energy injector in CERN's accelerator complex. When this chain of accelerators that ultimately serves the LHC is in operation, the negative hydrogen ions will be stripped of their two electrons and converted into protons at injection into the Proton Synchrotron Booster.

In the first months of 2013, the Linac4 collaboration commissioned the radio-frequency quadrupole (RFQ) at a dedicated test stand. The 1.5-tonne RFQ, constructed completely at CERN, sits at the start of the Linac4 beam line and takes the beam from 45 keV to 3 MeV in just 3 m.

During the summer, the team moved the RFQ, the medium-energy beam transport (MEBT) line and the diagnostic line to their final location in the Linac4 tunnel. In parallel, a new negative-hydrogen-ion source was assembled, installed and successfully commissioned in the tunnel. After a short RF commissioning period, the beam was accelerated to 3 MeV and transported to the beam dump at the end of the diagnostic line.

By the end of 2013 – only a few months into installation – most of the Linac4 infrastructure was in place. Not only have the RFQ and MEBT, with its fast beam chopper, been placed in their final locations, the majority of the RF klystrons on the surface have also been installed. In parallel, a second-generation negative-hydrogen-ion source has been commissioned on the test stand, delivering a beam in excess of 50 mA just before the end of the year.

Once commissioning to 3 MeV is completed in February, three more RF accelerating sections will be installed progressively to take the ion beam to its final energy. Drift tube linacs (DTL) will take the beam to 50 MeV; cell-coupled DTLs will take it to 100 MeV; and, finally, pi-mode accelerating structures will take it up to 160 MeV.

LHC PHYSICS

ATLAS and CMS observe Higgs-boson decays to fermions

*Last year, the ATLAS and CMS collaborations confirmed that the new boson found in 2012 was indeed a Higgs boson with a mass around 125 GeV (*CERN Courier *May 2013 p21). The discovery relied on the observation of decays to pairs of bosons, namely photons, Ws and Zs – the carriers of the electromagnetic and weak forces – and provided strong support for the idea that the Brout–Englert–Higgs mechanism is responsible for the mass of the W and Z bosons, while leaving the photon massless. Now, with the full LHC data sets from 2011 and 2012, the two collaborations have turned their attention to testing whether the Higgs field also gives mass to fermions, i.e. quarks and leptons.*

The CMS collaboration announced its first results on the coupling of the recently discovered Higgs boson to fermion pairs at the Rencontres de Moriond conference, in March 2013 (*CERN Courier* May 2013 p21). At the time, the search for the Higgs-boson decays to $b\bar{b}$ and $\tau^+\tau^-$ had yielded evidence with a combined significance of 3.4σ for the Higgs coupling to third-generation fermions.

Now, the updated search for decays to $\tau^+\tau^-$, based on an improved analysis of 4.9 fb^{-1} of LHC data collected at a collision energy of 7 TeV in 2011 and 19.7 fb^{-1} collected at 8 TeV in 2012, has revealed a 3.4σ excess at the mass of the Higgs boson in this channel alone. Taken together with the 2.1σ excess found in the earlier searches by CMS for b decays, this gives a combined significance of 4.0σ for the two channels, compared with an expectation of 4.2σ for a Standard Model Higgs boson. The observed rate for Higgs production with subsequent decay into b quarks or τ leptons divided by the expected rate for a Standard Model Higgs gives the ratio $\mu = 0.90 \pm 0.26$, which suggests that the particle does indeed behave like a Standard Model Higgs boson.

By contrast, the search for decays of the Higgs boson to $\mu^+\mu^-$ yields no signal, just as expected from the fact that the μ has nearly 17 times less mass than the τ, making the decays of the Higgs to $\mu^+\mu^-$ some 290 times less frequent than those to $\tau^+\tau^-$. Likewise, the search for the Higgs-boson decay into a pair of electrons – which should be even more rare, given that the electron is 200 times lighter than the muon – returned empty handed. From this, it can be inferred that the couplings of the Higgs boson to leptons of different generations are not universal, in contrast to, for example, the couplings of the Z bosons, which do not distinguish between lepton flavours.

These measurements used the full capabilities of the CMS experiment, combining information from all of the detector's components to reconstruct and measure the energy of each individual particle emerging from the proton–proton collision, via a "particle flow" algorithm. This technique allows τ decays to be identified efficiently, while rejecting the background from "jets" of particles originating from quarks and gluons. The precise charged-particle tracking of CMS helps identify jets coming from b quarks. In the case of Higgs-boson decays to $\tau^+\tau^-$, the data have a strong peak at a $\tau^+\tau^-$ mass corresponding to that of the Z boson, which is produced much more copiously than Higgs bosons. The analysis was developed and optimized in a "blinded" way, i.e. not looking at the signal in the data, to avoid introducing a bias.

By carefully measuring and controlling this background, a clear signal from Higgs decays remains after subtracting the background (figure 1).

Armed with an array of techniques and decay modes with which to study the Higgs boson, CMS will continue to measure its properties ever more precisely – using present and future data – and to search for additional new particles, including possible cousins of the Higgs boson.

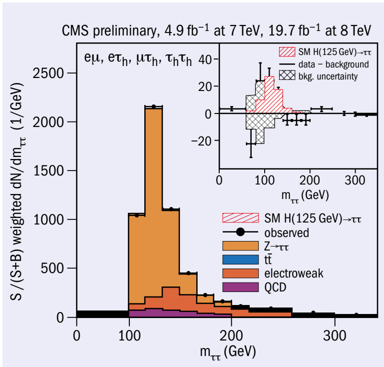


Fig. 1. Weighted mass spectrum for the $\tau^+\tau^-$ system in CMS. The inset shows a background-subtracted view of the spectrum with an excess around the mass of the discovered Higgs boson.

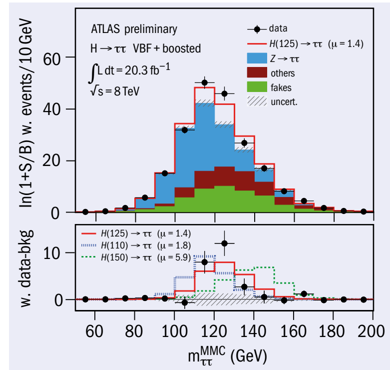


Fig. 2. The invariant mass of the $\tau^+\tau^-$ pair in ATLAS. The excess of data events (black dots) is consistent with the presence of a Higgs boson at 125 GeV, indicated by the red line. The main remaining background is $Z \to \tau^+\tau^-$. Background contributions with $\tau^+\tau^-$ invariant mass away from 125 GeV are suppressed by the analysis.

The ATLAS collaboration presented its first results on fermionic decays of the Higgs boson using the full 2012 data set in the di-muon and $b\bar{b}$ decay channels at the winter and summer conferences in 2013, respectively. However, the results did not yet establish the fermionic decays expected from a Standard Model Higgs boson. ATLAS has now found strong evidence for Higgs decays to fermions, using 20.3 fb^{-1} of LHC data taken at a proton collision energy of 8 TeV in the centre of mass. This is an important test of the Standard Model, which predicts such decays.

Branching ratios for the Standard Model Higgs boson are predicted to scale with the mass-squared of the decay products. Hence the two fermionic final states expected to be most abundant are $b\bar{b}$ quark pairs and $\tau^+\tau^-$ lepton pairs, the most massive of the fermions to which the Higgs boson can decay.

ATLAS has looked for all possible $\tau^+\tau^-$ decay channels, namely to two leptons, to one lepton plus hadrons and to hadrons only. The analysis was optimized to test whether a 125 GeV Higgs boson decays to a $\tau^+\tau^-$ pair and suppresses contributions that have a $\tau^+\tau^-$ invariant mass away from 125 GeV, including the $Z \to \tau^+\tau^-$ background, although the main remaining background is still $Z \to \tau^+\tau^-$. Thanks to the detector's powerful lepton identification capabilities and the application of sophisticated analysis methods, the contamination from backgrounds to the $\tau^+\tau^-$ final state could be reduced greatly. Remaining backgrounds were estimated directly from the data, or taken from simulation with their rates normalized to data in signal-free control regions. To avoid any possible bias, the analysis was developed and optimized without looking at the signal in the data (blinded).

After "unblinding", ATLAS observes an excess of events (figure 2) in a region consistent with the previously measured mass of the Higgs boson (125 GeV) and a statistical significance of 4.1σ, against 3.2σ expected. The ratio of the observed signal to that expected for a Standard Model Higgs decaying to a $\tau^+\tau^-$ pair yields $\mu = 1.4^{+0.4}_{-0.5}$, which is compatible with one.

ATLAS also searched for the decay of a Higgs boson to a muon pair. Because the Higgs boson couples to mass and the mass of the muon is 17 times lower than that of the τ, the $H \to \mu^+\mu^-$ rate is expected to be around 290 times lower than that of $H \to \tau^+\tau^-$. The absence of a signal in the ATLAS $\mu^+\mu^-$ search, setting an upper limit of 9.8 times the $H \to \mu^+\mu^-$ rate predicted by the Standard Model, therefore provides strong evidence that the Higgs boson does not decay to leptons in a flavour-blind way, but favours decays to heavy leptons, as predicted by the Standard Model.

These results, which are derived from the LHC's first run, are so far compatible with the Standard Model predictions. The broad physics programme of ATLAS, which includes precision measurements of the properties of the Higgs boson, will continue to test the Standard Model in the years to come.

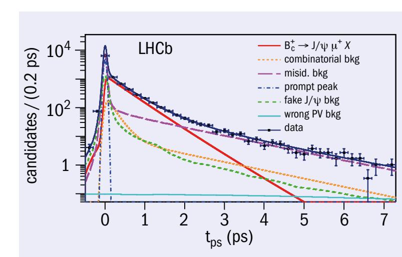
These results from the two collaborations now establish the coupling of the Higgs bosons to fermions. More data will allow testing the Higgs couplings at a deeper level, where other models for physics beyond the Standard Model predict differences. The next LHC run, which begins in 2015, is expected to produce several times the existing data sample. In addition, the proton collisions will be at higher energies, producing Higgs bosons at higher rates.

Further reading
CMS
Standard Model Higgs to $b\bar{b}$: arXiv:1310.3687 [hep-ex], accepted by *Phys. Rev. D*.
Standard Model Higgs to $\tau^+\tau^-$: CMS-PAS-HIG-13-004.
Standard Model Higgs to $\mu^+\mu^-$: CMS-PAS-HIG-13-007.
ATLAS
Higgs to $\tau^+\tau^-$: ATLAS-CONF-2013-108.
Standard Model Higgs to $b\bar{b}$: ATLAS-CONF-2013-079.
Standard Model Higgs to $\mu^+\mu^-$: ATLAS-CONF-2013-010.

How long can beauty and charm live together?

The LHCb collaboration has recently made the world's most precise measurement of the lifetime of the B_c^+ meson – a fascinating particle that has both beauty and charm.

The heavy flavours of beauty and charm are produced in proton–proton collisions at the LHC in quark–antiquark pairs. The resulting hadrons usually contain the original pair, as in the case of quarkonia, or a single heavy quark bound to the abundantly produced light quarks. However, in rare cases, a c quark and a $\bar{b}$ antiquark combine into a B_c^+. Since the top quark, t, decays too quickly to form hadrons, this is the only meson composed of two particles carrying different heavy flavours. As such, it offers a unique laboratory to test theoretical models of both the strong interaction, which accounts for its production, and the weak interaction, via which the meson has to decay. Indeed, the lifetime of the B_c^+ meson is one of the key parameters that provide a test-bench for theoretical models. Knowledge of the lifetime is also essential to develop selection algorithms and to improve the accuracy of the branching-fraction determination for most B_c^+ decay modes.



Lifetime distribution of the B_c^+ candidates, with the fitted components indicated.

Following initial investigation at the Tevatron, the B_c^+ meson is being studied extensively at the LHC. In particular, the LHCb collaboration has already published several observations of new decay channels and the world's most precise determination of the B_c^+ mass. Now, the collaboration has achieved the world's most precise measurement of the lifetime by studying the semileptonic decays $B_c^+ \to J/\psi\mu\nu$, with the subsequent decay $J/\psi \to \mu^+\mu^-$. The particle identification capabilities of LHCb allow a high-purity sample to be selected for these three-muon decays without any requirement on the decay time, therefore not biasing the measured lifetime. Using the data sample collected in 2012, about 10,000 signal decays were selected – the largest sample of reconstructed B_c^+ decays to have ever been reported.

The challenge with semileptonic decays is that the B_c^+ kinematics is not completely reconstructed, because of the impossibility of detecting the neutrino. This effect can be corrected on a statistical basis, although at the cost of introducing an uncertainty owing to the theoretical model of the decay used for the correction. LHCb developed a technique to constrain this model-dependence using data and found that the corresponding systematic uncertainty is small.

The result for the lifetime is 509 ± 15 fs. This is twice as precise as the current world-average from the Particle Data Group, obtained combining measurements by the CDF and D0 experiments at the Tevatron, and opens the door for a new era of precision B_c^+ studies.

Further reading
LHCb-PAPER-2013-063, in preparation.

PUBLISHING

SCOAP³ open-access initiative gets going

After intense preparations and consensus building, the SCOAP³ open-access publishing initiative started on 1 January. With the support of partners in 24 countries, a large proportion of scientific articles in the field of high-energy physics will become open access at no cost for any author: everyone will be able to read them; authors will retain copyright; and generous licences will enable wide re-use of this information. Convened at CERN, this is the largest-scale global open-access initiative ever built, involving an international collaboration of more than 1000 libraries, library consortia and research organizations. SCOAP³ enjoys the support of funding agencies and has been established in co-operation with leading publishers.

Eleven publishers of high-quality international journals are participating in SCOAP³. Elsevier, IOP Publishing and Springer, with their publishing partners, have been working with the network of SCOAP³ national contact points. Reductions in subscription fees for thousands of participating libraries worldwide have been arranged, making funds available for libraries to support SCOAP³.

The objective of SCOAP³ is to grant unrestricted access to articles appearing in scientific journals, which so far have been available to scientists only through certain university libraries, and generally unavailable to the wider public. Open dissemination of preliminary information, in the form of pre-peer-review articles known as preprints, has been the norm in high-energy physics and related disciplines for two decades. SCOAP³ sustainably extends this opportunity to high-quality peer-review service, making the final version of articles available within the open-access tenets of free and unrestricted dissemination of science with intellectual property rights vested in the authors and wide re-use opportunities. In the SCOAP³ model, libraries and funding agencies pool resources that are currently used to subscribe to journals, in co-operation with publishers, and use them to support the peer-review system directly instead.

- Partners in the following countries have formalized their participation in SCOAP³: Austria, Belgium, Canada, China, Denmark, France, Germany, Italy, Japan, Norway, Portugal, Sweden, Switzerland, United Kingdom and the United States of America. Partners in the following countries are completing the final steps to formally join SCOAP³: the Czech Republic, Finland, Greece, Hungary, Korea, the Netherlands, Spain, South Africa and Turkey.

The following publishers and scientific societies are participating in SCOAP³ with 10 high-quality peer-reviewed journals in the field of high-energy physics and related disciplines: the Chinese Academy of Sciences, Deutsche Physikalische Gesellschaft, Elsevier, Hindawi, Institute of Physics Publishing, Jagellonian University, Oxford University Press, Physical Society of Japan, SISSA Medialab, Springer, Società Italiana di Fisica.

News

Upgrades

HiLumi LHC design study moves towards HL-LHC

When the CERN Council approved the updated European Strategy for Particle Physics at a special meeting in Brussels last May, it recognized the High Luminosity LHC (HL-LHC) project as the top priority for CERN and Europe (*CERN Courier* July/August 2013 p9). A month later, after Council had approved its integration into the CERN Medium Term Plan for 2014–2018, the HL-LHC entered a new phase, as it passed from design study to an approved project.

To mark this approval, the 3rd joint annual meeting of the HiLumi LHC Design Study and the US LHC Accelerator Research Program (LARP) took place in conjunction with the HL-LHC kick-off meeting. The event was held in November at Daresbury Laboratory in the UK, bringing together more than 160 scientists from countries around the world, including Japan, Russia and the US. Directors of major accelerator laboratories were present as invited speakers.

The kick-off meeting underlined the role of the HL-LHC as a necessary tool for extending physics beyond the LHC. The important roles of CERN and the high-energy physics community were also emphasized. Developing new technologies – for example, magnets with a field 50% above the present LHC technology – opens the way for a future higher-energy machine requiring even higher magnetic fields, such as the recently proposed Future Circular Collider.

Highlights reported by the design-study work-package leaders at the meeting included final parameters for the layout and finalized main layout for the machine; important developments in crab-cavity hardware; a detailed layout for improving collimation; and the assembly and characterization of two 10-m-long MgB_2 cables that have been tested up to 5 kA and at 20 K in the superconducting-link configuration.

The HL-LHC project is currently in the design and prototyping phase and should release a Preliminary Design Report in the middle of 2014, with the Technical Design Report for construction at the end of 2015.

● https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=257368

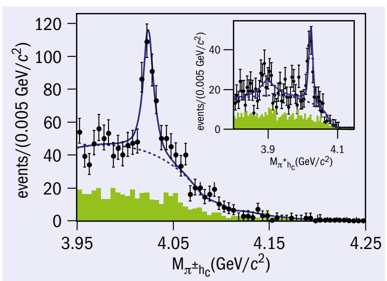
Exotics

New charged charmonium-like states observed at BESIII

In studies at the Beijing Electron–Positron Collider (BEPCII), the international team that operates the Beijing Spectrometer (BESIII) experiment has found evidence for a family of what could well be four-quark states. The new results follow the discovery of the electrically charged $Z_c(3900)$ in March last year (*CERN Courier* May 2013 p7).

These breakthroughs are the result of a dedicated study by the BESIII collaboration of the decays of the puzzling Y(4260) state. Discovered by the BaBar collaboration at SLAC in 2005, this state has a well-established mass that is inconsistent with the interpretation that it consists only of a charm quark, c, and an anti-charm quark, $\bar{c}$. Moreover, it tends to decay to charmonium ($c\bar{c}$ states) plus conventional mesons rather than to a pair of charmed particles, as expected for a particle of this mass. So, more complicated models for its composition need to be considered, such as the addition of more quarks to the system, the existence of excited gluons binding the $c\bar{c}$ system, or even more exotic scenarios. The problem has been to find a way to distinguish experimentally between the different theoretical possibilities.

By tuning the energy at which electrons and positrons annihilate at BEPCII to the mass of the Y(4260), the BESIII collaboration has been able to produce the state directly and collect large samples of its decays. The first surprising result was the discovery of the $Z_c(3900)$, a charged state that decays to $\pi^{\pm} J/\psi$. To decay this way, the $Z_c(3900)$ must contain a charm quark and an anticharm quark (to form the neutral J/ψ), together with something else that is charged, i.e., additional lighter quarks. Hence, it must be (at least) a four-quark object.



Sum of simultaneous fits to the $\pi^{\pm}h_c$ mass distributions for $e^+e^- \rightarrow \pi^+\pi^-h_c$ events at centre-of-mass energies of 4.23 GeV, 4.26 GeV, and 4.36 GeV; the inset shows the fit to the π^+h_c distributions at 4.23 GeV and 4.26 GeV with the $Z_c(3900)$ and $Z_c(4020)$ clearly visible. Dots are data; shaded histograms are normalized sideband background; the solid curves show the total fit, and the dotted curves the backgrounds from the fit.

Since then, the BESIII collaboration has discovered a partner to the $Z_c(3900)$ – the $Z_c(4020)$. The new state appeared in the decay $\pi^{\pm}h_c$ (BESIII collaboration 2013a). Like the $Z_c(3900)$, the $Z_c(4020)$ is electrically charged and decays to a particle consisting of a $c\bar{c}$ – in this case, the h_c – so the interpretation is the same: it must also be a four-quark object. It appears, therefore, that the BESIII collaboration has begun to unveil a whole family of four-quark objects.

One possible clue for the interpretation of the $Z_c(3900)$ and $Z_c(4020)$ is that they appear near the minimum masses required to allow decays to pairs of D mesons (each consisting of a charm quark and an anti-up or anti-down quark). The $Z_c(3900)$ has a mass just above the combined mass of the D and $\bar{D}^*$ and the $Z_c(4020)$ has a mass just more than twice that of the D^*. So one idea is that the $Z_c(3900)$ is a four-quark bound state consisting of a D and a $\bar{D}^*$, each composed of two quarks. Similarly, the $Z_c(4020)$ could be a $D^*\bar{D}^*$ bound state. BESIII has explored this piece of evidence further by studying experimentally the charged $\bar{D}^*D$ and $\bar{D}^*D^*$ systems, both of which show clear enhancements with properties similar to those of the $Z_c(3900)$ and $Z_c(4020)$ (BESIII collaboration 2013b and 2013c).

Another clue to the nature of all of these states came with the discovery of what appears to be a Y(4260) decaying to a photon and another particle, designated the X(3872) (BESIII collaboration 2013d). Unlike the $Z_c(3900)$ and the $Z_c(4020)$, the X(3872) is electrically neutral and has been experimentally established for more than 10 years. It has long been suspected of being a four-quark object, but it has been difficult to distinguish this interpretation from others as it has no electric charge. Now that BESIII has observed it alongside the $Z_c(3900)$ and $Z_c(4020)$, it seems that a definitive theoretical interpretation must be closer at hand.

● **Further reading**

BESIII collaboration 2013a *Phys. Rev. Lett.* **111** 242001.
2013b arXiv:1310.1163, accepted by *Phys. Rev. Lett.*
2013c arXiv:1308.2760, submitted to *Phys. Rev. Lett.*
2013d arXiv:1310.4101, submitted to *Phys. Rev. Lett.*

Sciencewatch

Compiled by John Swain, Northeastern University

Why red paint goes dark

Tests of red paint from a mural in the 14th century Monastery of Pedralbes in Spain helped to solve the puzzling colour change. (Image credit: J Chillida.)

Much of the red colour in old paintings is vermillion – one of the most ancient pigments known to humans. Also known as the mineral cinnabar, it is a form of the chemical compound mercury sulphide, α-HgS. However, vermillion turns black in old artworks, from ancient archaeological sites such as Pompeii to Rubens and Italian masters. Until now no one has known why, but using a combination of many-body theoretical spectroscopy and high-resolution microscopic X-ray diffraction, Fabiana Da Pieve of the Vrije Universiteit Brussel and the University of Antwerp and colleagues have finally unravelled the mystery.

During the past decade, earlier ideas that the mercury sulphide was converted into a black form of the compound gave way to the idea that metallic mercury formed, appearing black in small amounts. However, electrons liberated by incident light do not have enough energy to convert mercury ions into neutral mercury atoms. By combining X-ray-diffraction measurements performed at DESY's PETRA III storage ring with *ab initio* calculations of light-induced reactions of α-HgS, the team found the key to lie with corderoite, a yellow compound of mercury, chlorine and sulphur. Exposed to air, the corderoite develops defects that allow light to convert mercury ions to metallic mercury, small droplets of which appear black. The work suggests useful conservation measures that include preventing chloride salts from reaching the artworks and avoiding exposure to wavelengths that are short enough to trigger the formation of metallic mercury.

● **Further reading**

F Da Pieve *et al.* 2013 *Phys. Rev. Lett.* **111** 208302.

Detection without absorption

Until now, all photon detectors have required that a photon be annihilated to be detected. This precluded any possibility of repeated measurements, but Stephan Ritter of the Max-Planck Institute for Quantum Optics in Garching and colleagues have found a way round the problem. In their scheme, an incoming photon reflects from an optical resonator with a single atom – in this case rubidium-87 trapped in a 3D optical lattice in the centre of a Fabry–Pérot cavity – in a superposition of two states. The reflected photon picks up a phase shift that affects the relative phase of the two states of the atom, which is detectable by cavity-enhanced fluorescence. This permits the detection of photons without annihilating them with an efficiency of 74% and a survival probability of 66%. The efficiency can be increased by repeated observations. The technique could revolutionize quantum logic gates and the preparation of exotic quantum states of light.

● **Further reading**

A Reiserer *et al.* 2013 *Science* **342** 1349.

Digital lollipop

Virtual-reality experiences might soon include taste, thanks to Nimesha Ranasinghe of the National University of Singapore and colleagues. The taste simulator is a lollipop-shaped electrode that you put on your tongue. Using small temperature changes produced by small semiconductor elements that can be made cool or warm, and alternating currents, the "lollipop" reproduces the four major taste categories: sweet, salty, sour and bitter. True taste involves a fifth – the savoury "umami" – and smells and textures, but these are still to come. However, the group has already developed the idea of "taste messaging" and a "taste over internet protocol".

● **Further reading**

N Ranasinghe *et al.* 2013 submitted to *Int. J. Human-Computer Studies*; *New Scientist* 23 November 2013.

Constancy of mass-ratios

Since the identification of a Higgs boson, confirming a mechanism for the "origin of mass", a question is whether particle masses – or, equivalently, the Yukawa couplings – have always been the same. J Bagdonaite of the University of Amsterdam and colleagues have used the Effelsberg 100 m radio telescope in Germany, the Institute de Radio Astronomie Millimétrique 30 m telescope in Spain and the Atacama Large Millimeter/submillimeter Array in Chile to look at methanol absorption lines in PKS1830–211, a benchmark lensing galaxy at a redshift z of 0.89. Using 10 different absorption lines, the researchers looked for variations that could be due to a change in the proton-to-electron mass ratio and found a fractional variation of $1.5 \pm 1.5 \times 10^{-7}$ at one standard deviation for a look-back time of 7.5 thousand million years. So it looks as though things are pretty much the same as they were a long time ago.

● **Further reading**

J Bagdonaite *et al.* 2013 *Phys. Rev. Lett.* **111** 231101.

Ice and the Forbidden City

Workers probably slid massive stones, such as this 300 tonne marble carving in front of the Hall of Supreme Harmony in the Forbidden City, along artificial ice paths.

How did the Chinese transport heavy stones from a quarry west of Beijing in the 15th and 16th centuries? According to historical accounts, stones of more than 300 tonnes were moved 70 km on wooden sleds. After many years of speculation on the details, Jiang Li of the University of Science and Technology in Beijing and colleagues have translated a 500-year-old description of such a transportation and performed a detailed analysis of the engineering. They have confirmed that the key was an artificial ice path. Rather than the more common wood-on-wood sliding or the use of rollers, it turns out that water-lubricated-wood-on-ice sliding works perfectly for the job requirements of heavy loads and low speeds.

● **Further reading**

J Li *et al.* 2013 *PNAS* **110** 20023.

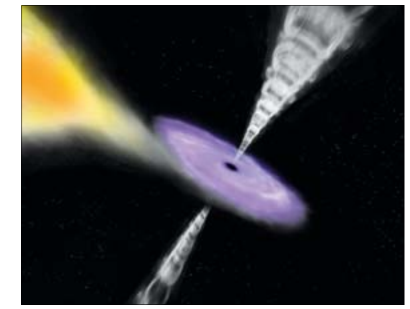
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva, and University of Zurich

Black-hole jets contain heavy nuclei

One of the open questions of astrophysics is the composition of the powerful jets launched by black holes. Are the jets purely leptonic or do they also contain protons and nuclei? The latter are implied by the recent detection of X-ray emission from iron and nickel atoms in the relativistic jets of a stellar-mass black-hole candidate. Strong γ-ray and neutrino emission is expected in such baryonic jets.

Stellar-mass black holes manifest their presence by accreting material from a companion star. Matter flows from the star towards the black hole, forming a disc of plasma around it with a temperature so high that it emits X rays. The circling of the ionized gas at almost the speed of light is thought to generate a twisted magnetic field perpendicular to the disc, which funnels some of the incoming matter away in the form of two powerful jets of particles. The ejected mass and energy prevents the black hole from growing too quickly.

Observations at radio and other wavelengths have already shown that black-hole jets contain highly relativistic electrons (*CERN Courier* July/August 2006 p10). However, until now it was not clear whether the negative charge of the electrons is complemented by their anti-particles – positrons – or by heavier, positively charged particles in the jets, such as protons or atomic nuclei. In a new study, a team of astronomers led by María Díaz Trigo of the European Southern Observatory in Munich has used ESA's XMM-Newton satellite to study a binary system called 4U 1630-47. This system hosts a black-hole candidate and is known to show outbursts of X rays across periods of months and years.



Artist's impression of a binary system where matter flows from a star towards a black hole, forming an accretion disc and two powerful jets of particles. (Image credit: ESA/ATG medialab.)

The researchers observed the source twice in September 2012, using both XMM-Newton and the Australia Telescope Compact Array to study simultaneously its X-ray and radio state. Following a first observation without detectable radio emission from the jets, the team was lucky enough to catch the source soon after jet reactivation. In this second observation, the astronomers found X-ray emission lines from two highly ionized heavy elements – iron and nickel. For iron, there is even a second line displaced in energy, suggesting that it comes from the counter-jet moving away from the point of observation. According to Díaz Trigo, the discovery came as a surprise – and a good one, since it shows beyond doubt that the composition of black-hole jets is much richer than only electrons. With iron emission from both jets moving in opposite directions, the team was able to determine the jet's orientation and its speed at about two-thirds of the speed of light.

This is the first time that heavy nuclei have been detected in the jets of a typical stellar-mass black hole. There is only one other X-ray binary, SS 433, which shows similar signatures from atomic nuclei in its jets, but this source is peculiar, having an unusually high accretion rate. The new observations of 4U 1630-47 should help astronomers to learn more about the physical mechanism that launches jets from a black hole's accretion disc. A model where the jet is powered by the spin of the black hole rather than by the magnetic field induced by the accretion disc is disfavoured as it would produce leptonic jets only.

The authors of the paper published in *Nature* also point out that the presence of mildly relativistic baryons in the jets suggests that γ rays could be produced by interaction with high-energy photons or with protons from the stellar wind of the companion star. This could give rise to a signal that would be detectable by the Fermi Space Telescope and the future Cherenkov Telescope Array. The hadronic interactions should also generate an intense flux of neutrinos. Therefore, high-luminosity outbursts from black-hole X-ray binaries could provide the best opportunities for neutrino detection.

Further reading
M Díaz Trigo *et al.* 2013 *Nature* **504** 260.

Picture of the month

This image of the Hubble Space Telescope shows RS Puppis, a star belonging to a class of pulsating stars known as Cepheid variables, which have relatively long periods – RS Puppis, for example, varies in brightness by almost a factor of five every 40 days or so. What makes RS Puppis unusual, however, is its dusty environment, which enables a phenomenon known as a light echo to illuminate different portions of the thick, dark clouds enshrouding the variable star. Repeated observations over a five-week period have revealed how the regular stellar pulsations produce waves of light streaming through the clouds. The process is similar to the apparent expansion of a gas bubble illuminated by the flaring star V838 Monocerotis (Picture of the month, *CERN Courier* June 2003 p13 and May 2005 p13). (Image credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-Hubble/Europe Collaboration.)

CERN Courier Archive: 1971

A look back to CERN Courier vol. 11, February 1971, compiled by Peggie Rimmer

ISR

Colliding beams

In the ISR control room.

On 27 January, colliding beams were achieved at the Intersecting Storage Rings for the first time.

On 25 January, Ring 2 was brought into action. [Ring 1 had been successfully tested in October (*CERN Courier* November 2013 p12)]. At 19.47h, the first beam of protons from the PS was injected, went round and stayed going round, 3.5 mA circulating. At 20.20h, 15 mA were injected and the r.f. accelerating cavities were brought on. At 21.20h, stacking was tried and the circulating current built up to 370 mA. At 22.32h, the peak current of 720 mA was stacked.

On 27 January, it was decided to go for colliding beams. The run began at 10.00h. Shortly after midday, a very clean stack built the current in Ring 1 to 930 mA. After a few minutes, this dropped abruptly to 586.6 mA but didn't change for more than an hour. At 14.30h, well over two hours later, the monitors were reading 586.5 mA, proving that they hadn't got stuck. So good were conditions in the ring that hardly a measurable proton was lost. The decay rate was 5×10^{-8} per second, corresponding to a half-life of many months. One wisecrack was that the ISR had made itself independent of PS shutdowns.

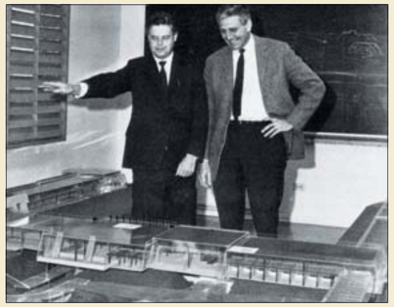
Meanwhile an even more significant event occurred. At 13.26h, a single shot from the PS was fired into Ring 2 and 14.7 mA were left circulating. The one remaining worry was that the big beam in Ring 1 would cause serious loss on the small beam in Ring 2. No such noticeable beam–beam interaction was observed. The last remaining fear of the ISR team, that they would not be able to deliver a usable machine for physics, was swept aside.

Close on top of this came the news from the physicists at the intersections. At first tentatively, then with confidence, they fed to the control room the information that they were recording particles coming from collisions in the intersecting beams. At about 13.40h, Kjell Johnsen moved to the microphone [see the February cover thumbnail] to announce the first ever observation of proton–proton interactions in colliding beams.

● Compiled from texts on pp31–33.

Batavia

Booster beams



Looking over a model of the site at Batavia on 25 January are the director of the National Accelerator Laboratory, R R Wilson (left), and B P Gregory, director-general of CERN until the end of last year. (Photo NAL.)

Another "milestone" en route to completion of the 200–500 GeV accelerator at the National Accelerator Laboratory was passed at the beginning of February when beams were accelerated for the first time in the Booster.

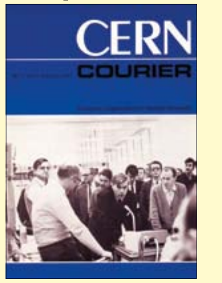
The Booster is designed to take the 200 MeV beam from the Linac and to accelerate it to 8 GeV for injection into the Main Ring. The last of the magnets moved into the Booster ring on 14 December and installation was virtually complete a week later.

On 23, 24 January the beam was injected and taken full circle. A pulsed kicker was installed to push the beam from its injection orbit and on 29 January the first multiple turn tests were carried out. On 6 February, half the r.f. cavities were brought on and protons were accelerated to an energy of 1 GeV. It looks as if the Booster will be in excellent shape to feed beams to the Main Ring in a few months' time.

Construction of the Booster has been brought to completion by Roy Billinge with Helen Edwards as associate section leader. The section are feeling very pleased with themselves.

● Compiled from texts on p47.

Compiler's Note



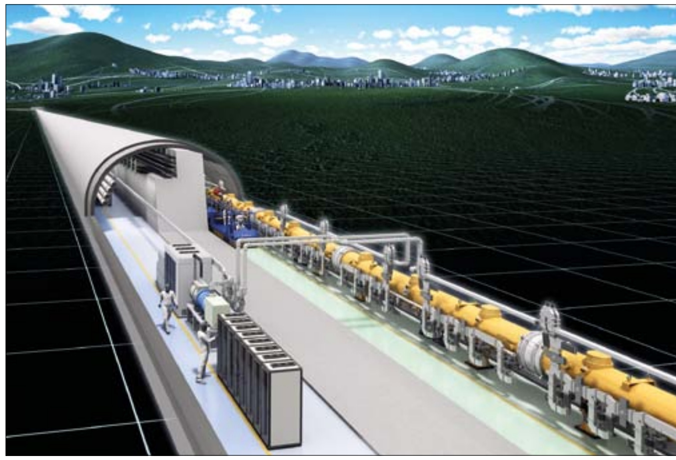
The ISR was shut down in 1984, as CERN shifted its sights to the Large Electron Positron collider, but its legacy lives on (*CERN Courier* January/February 2011 p27).

The machine was to be the proving ground for some pivotal concepts in accelerator physics, most notably stochastic cooling, which made it possible to accumulate antiparticle beams of sufficient intensity for useful physics. This paved the way for proton–antiproton collisions, first in 1981 at the ISR itself and at the Super Proton Synchrotron operating as a collider, and from 1987 in the Tevatron at Fermilab. Since 2006, stochastic cooling has been used at Brookhaven's Relativistic Heavy-Ion Collider.

The first role of the Batavia (later Fermilab) Booster was to accelerate protons from the linac into the 400 GeV Main Ring for fixed-target experiments – and the discovery in 1977 of the bottom quark. In 1983, the Main Ring became injector to the superconducting Tevatron ring, which was soon to be transformed into a proton–antiproton collider. The Booster supplied protons from the linac and antiprotons from a high-intensity source that used stochastic cooling. After acceleration in the Main Ring, these beams were further accelerated in the Tevatron, before colliding at 1.8 TeV in the centre of mass – allowing the discovery of the top quark in 1995. The Tevatron retired in September 2011, as CERN's LHC came into operation (*CERN Courier* November 2011 p28).

Global perspectives on major science facilities

Physics societies in Asia, Europe and the US provided valuable input in 2013 to the planning of future research facilities.



A possible future scenario could see ILC construction in Japan.

Given the broad international collaborations involved in major scientific user facilities, timely formal and informal discussions among leaders of physics societies worldwide contribute to fortifying the scientific case that is needed to justify large, new enterprises. The past year, 2013, proved to be one of focused introspection and planning for major research facilities, conducted by learned societies and by government agencies in Asia, Europe and the US. All three regions developed visions for particle physics and in the US the government developed priorities and plans for a broad spectrum of scientific user facilities.

The Asia-Europe Physics Summit

In July, in Makuhari, Chiba, Japan, the third Asia-Europe Physics Summit (ASEPS3) – a collaboration between the Association of Asia Pacific Physical Societies and the European Physical Society – provided a forum for leaders in the respective physics communities to discuss strengthening the collaboration between Europe and the Asia-Pacific region (Barletta and Cifarelli 2013). These summits have three main goals: to discuss the scientific priorities and the common infrastructure that could be shared between European and Asian countries in various fields of physics research; to establish a framework to increase the level of Euro-Asia collaborations during the next 20 years; and to engage developing countries in a range of physics research. This year's summit centred on international strategic planning for large research facilities. It also included a significant US perspective in three of the four round-table discussions.

Round Table 1 offered perspectives on the technologies that enable major research facilities, while Round Table 2 looked to the issues of policy and co-operation inherent in the next generation of large facilities. High-energy physics programmes received particular focus in the discussion, where the three regions of Asia, Europe and the US have their own road maps and strategies. This round table clearly provided a special opportunity for a number of leaders and stakeholders to exchange their views. Participants in Round Table 4 discussed training, education and public outreach – in particular the lessons learnt and challenges from large research laboratories. Although the science motivations for major user facilities differ widely, many of the underlying accelerator and detector technologies – as well as issues of policy, international co-operation and training the next generation of technical physicists and engineers – are nonetheless in common.

Because both the update to the European Strategy for Particle Physics and the Technical Design Report for the International Linear Collider (ILC) had been issued by the time of the summit, and because the Snowmass process in the US was well under way, major facilities for particle physics set a primary, although far from exclusive, context for the discussions.

The European Strategy for Particle Physics

In January, a working group of the CERN Council met in Erice to draft an updated strategy for medium and long-term particle physics. That document was remitted to the Council, which formally adopted the recommendations in a special meeting hosted by the European Commission in Brussels in May (*CERN Courier* July/August 2013 p9). As expected, the updated strategy emphasizes the exploitation of the LHC to its full potential across many years through a series of planned upgrades. It also explicitly supports long-term research to "continue to develop novel techniques leading to ambitious future accelerator projects on a global scale" and to "maintain a healthy base in fundamental physics research, in universities and national laboratories". In a period in which research funding is highly constrained worldwide, these latter ▷

points are a strong cautionary note that maintaining "free energy" in national research budgets is essential for innovation.

Beyond the focus on the LHC, the strategy recommends being open to engaging in particle-physics projects outside of the European region. In particular, it welcomes the initiative from the Japanese high-energy-physics community to host the ILC in Japan and "looks forward to a proposal from Japan to discuss a possible participation". That sentiment resonated strongly with many participants in the 2013 Community Summer Study in the US, especially in the study groups on the energy-frontier study and accelerator capabilities. In September, the Asia-Pacific High Energy Physics Panel and the Asian Committee for Future Accelerators issued a statement that "the International Linear Collider (ILC) is the most promising electron positron collider to achieve the objectives of next-generation physics."

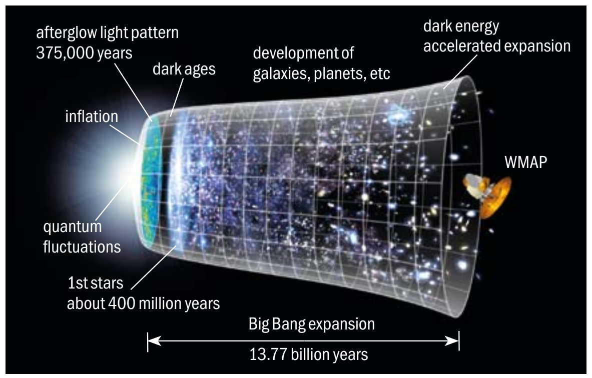
The 2013 US Community Summer Study

In the spring of 2012, the Division of Particles and Fields of the American Physical Society (APS) commissioned an independent, bottom-up study that would give voice to the aspirations of the US particle-physics community for the future of high-energy physics. The idea of such a non-governmental study was welcomed by the relevant offices of both the US Department of Energy (DOE) and the National Science Foundation (NSF). The APS study explicitly avoided prioritizing proposed projects and experiments in favour of providing a broad perspective of opportunities in particle physics that would serve as a major input to an official DOE/NSF Particle Physics Project Prioritization Panel (P5). The study was broadly structured into nine working groups along the lines of the "physics frontiers" – energy, intensity and cosmic – introduced in the 2008 P5 report and augmented with studies of particle theory, accelerator capabilities, underground laboratories, instrumentation, computing and outreach. In turn, the two conveners of each working group divided their respective studies into several sub-studies, each with three conveners, generally.

Beginning with a three-day organizational meeting in October 2012 and culminating in a nine-day session at the end of July/beginning of August 2013 – "Snowmass on the Mississippi" – the 2013 Community Summer Study involved nearly 1000 physicists from the US plus many participants from Europe and Asia. Roughly 30 small workshops were held in 2013 to prepare for the "Snowmass" session at the University of Minnesota, which was attended by several hundred physicists.

Snowmass activities connected with the energy frontier were strongly influenced by the discovery of a Higgs boson at the LHC. Not surprisingly, the scientific opportunities offered by the LHC and its series of planned upgrades received considerable attention. The study welcomed the initiative for the ILC in Japan, noting that the ILC is technically ready to proceed to construction. One idea that gained considerable momentum during the Snowmass process was the renewed interest in a very large hadron collider with an energy reach well beyond the LHC.

The conclusions of each of the nine working groups are presented in a summary report, which defines the most important questions for particle physics and identifies the most promising opportunities to address them in several strategic physics themes:



(Top) Upgrades will keep the LHC at the energy frontier for many years to come. (Above) Mapping the evolution of the universe is one of the strategic themes to emerge from the "Snowmass" process in the US in 2013. (Image credit: NASA/WMAP Science Team.)

- Probe the highest possible energies and distance scales with the existing and upgraded LHC and reach for even higher precision with a lepton collider. Study the properties of the Higgs boson in full detail.
- Develop technologies for the long-term future to build multi-tera-electron-volt lepton colliders and 100 TeV hadron colliders.
- Execute a programme with the US as host that provides precision tests of the neutrino sector with an underground detector. Search for new physics in quark and lepton decays in conjunction with precision measurements of electric dipole and anomalous magnetic moments.
- Identify the particles that make up dark matter through complementary experiments deep underground, on the Earth's surface and in space, and determine the properties of the dark sector.
- Map the evolution of the universe to reveal the origin of cosmic inflation, unravel the mystery of dark energy and determine the ultimate fate of the cosmos.

The study further identifies and recommends opportunities for investment in new enabling technologies of accelerators, instrumentation and computation. It recognizes the need for theoretical work, both in support of experimental projects and to explore unifying frameworks. It calls for new investments in physics

education and identifies the need for an expanded, co-ordinated communication and outreach effort.

Summary

Although the activities of 2013 on possible perspectives and scenarios for major science facilities were neither a worldwide physics summit nor a worldwide physics study, they served to open the door for extensive engagement by physicists to build a compelling science case for major research facilities in Asia, Europe and the US. They identified ways to increase the scientific return on society's investment and to spread the benefits of forefront physics research to developing countries.

During the meetings in 2013, it became clear that a possible future picture could be construction of the ILC in Japan and a long baseline neutrino programme in the US, while Europe exploits the LHC and prepares for the next machine at the energy frontier, which can be defined only after LHC data obtained at 14 TeV in the centre of mass have been analysed. Therefore, despite highly constrained research budgets worldwide, future prospects look bright and promising. They represent today's challenge for the next generation(s) of scientists in a knowledge-based society.

● Further reading

For more on the ASEPS3 round tables, see www.aseps2013.org/roundtables.

For the full text of the update to the European Strategy for Particle Physics, see http://council.web.cern.ch/council/en/EuropeanStrategy/esc-e-106.pdf.

For the statement from the Asian High Energy Physics Community on the ILC, see www.interactions.org/cms/?pid=1033193.

For the Snowmass summary report, see www-public.slac.stanford.edu/snowmass2013/SnowmassWorkingGroupReports.html.

W Barletta and L Cifarelli 2013 *APS News* **22** 10 www.aps.org/publications/apsnews/201311/international.cfm

Résumé

Perspectives mondiales sur les grandes installations scientifiques

Étant donné l'ampleur des collaborations internationales nécessaires pour réaliser des installations scientifiques d'envergure, les discussions, tant formelles qu'informelles, entre les responsables des sociétés de physique dans le monde contribuent à consolider les arguments scientifiques justifiant de nouvelles entreprises d'envergure. L'année 2013 a été l'occasion d'une réflexion approfondie, avec l'élaboration de projets concernant les grandes installations de recherche, de la part des sociétés savantes et des organismes gouvernementaux en Europe, aux États-Unis et en Asie. Les trois régions ont mûri leur vision d'avenir concernant la physique des particules et, aux États-Unis, le gouvernement a établi des priorités et des plans concernant un large spectre d'installations scientifiques ouvertes aux utilisateurs.

William Barletta, Massachusetts Institute of Technology, and **Luisa Cifarelli**, University of Bologna. Barletta was convener of the Snowmass Accelerator Capabilities Study; Cifarelli was one of the conveners of ASEPS3.

Workshop looks towards High-Luminosity LHC

Members of the four big LHC collaborations met in Aix-les-Bains to share results, explore synergies and strengthen links with the machine and theoretical communities in preparation for a high-luminosity future.

CERN's director-general, Rolf Heuer, gave the laboratory's perspective on the HL-LHC programme. (Image credit: Nanni Darbo.)

Following the presentations at the Open Symposium in Cracow in September 2012 and a great deal of work by the European Strategy Group for Particle Physics, the update to the 2006 European Strategy for Particle Physics was published in 2013 and adopted at a special European Strategy Session of CERN Council in Brussels on 30 May (*CERN Courier* July/August 2013 p9). In developing its vision for the future, the updated strategy took full account of the massively important discovery of a Higgs boson at the LHC in 2012 and of the global research landscape. For the programme at CERN, it contains the clear message: "Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark–gluon plasma."

The priority given to the high-luminosity upgrade, dubbed the High-Luminosity LHC (HL-LHC), underlines the importance of the ongoing machine and detector developments for this facility, including supporting studies on performance and physics reach. Indeed, there has been highly active R&D in the required accelerator and detector technologies, following the recommendations of the 2006 strategy document. Much of this work has been conducted within the four large LHC experimental collaborations or – for the accelerator complex – within the framework of the EU-funded HiLumi LHC Design Study (*CERN Courier* March 2012 p19).

A three-day forum

With the recent update of the European Strategy, the HL-LHC project is expanding rapidly and the idea of an HL-LHC Experiments Workshop sponsored by the European Committee for Future Accelerators (ECFA) was conceived to offer a forum for the experimental collaborations to share results, explore synergies and to strengthen links with the machine and theoretical communities.

After a concerted effort, colleagues in theory, the four big LHC collaborations and the accelerator community – co-ordinated through eight preparatory groups – organized three intensive days of workshop at the Centre des Congrès, Aix-les-Bains, on 1–3 October.

After an opening on behalf of ECFA by its chair Manfred Krammer, CERN's Frédérick Bordry presented the latest plans for the accelerator upgrade. The ALICE, ATLAS, CMS and LHCb collaborations then gave overviews of their strategy to follow the planned increase in machine luminosity. This will proceed with staged upgrades, installed across a decade during end-of-year technical stops and two long access periods (long shutdowns) required for the major modifications. Many of the detailed plans are already documented in reports to CERN's LHC Committee (LHCC) and more are in advanced stages of preparation. To round off the first morning, CERN's director-general, Rolf Heuer, gave the laboratory's perspective on the HL-LHC programme, underlining planning for the next 20 years at the LHC and the thinking on future directions, taking CERN forward to its centenary celebrations in 2054.

The experimental collaborations presented many updates to the studies on physics' prospects that were documented at the Cracow Open Symposium and at the "Snowmass" meeting in Minneapolis in summer 2013, based on a better understanding of the expected experimental performance. This was complemented with a broad theoretical survey of the rich physics programme at the energy frontier offered by the HL-LHC facility. The extremely high number of collisions to be recorded in a year at the HL-LHC provides ▷

LHC experiments

the opportunity to look for rare processes, study systems with high mass and make high-precision measurements.

The HL-LHC is designed to deliver in every year of operation 10 times the number of collisions collected at the LHC to date, yielding 10 times more data by the end of HL-LHC operation than the LHC is expected to have delivered by around 2022. This gives unprecedented sensitivity in measurements of a range of properties of the newly found Higgs boson, as well as in searches for new high-mass particles, and allows precision studies of a variety of fundamental particles and processes. In addition, should the 13–14 TeV running this decade lead to further discoveries of new particles, the HL-LHC will be essential to measure their properties.

Discussion then focused on areas where the machine and experiment teams need to work most closely: beam parameters, instrumentation and interfaces, shutdown planning and radiation protection. There were presentations of exciting new ideas that might allow the inherent problem of high-luminosity operation – the huge number of interactions every bunch crossing – to be mitigated by extending the interaction region along the beam direction.

This "pile-up" of interactions, the high data rates and the level of integrated radiation doses, will be the major experimental challenges for operation in the HL-LHC's beam conditions. For the workshop, the areas of detector-upgrade preparations were split into those relating to tracking, calorimetry, muon systems, read-out electronics and triggering, data acquisition, offline software and computing. Each topic was covered in a dedicated session, where joint presentations across the four big experiments addressed the motivation, requirements and conceptual designs for upgrades, as well as the ongoing R&D programmes to provide efficient and cost-effective technical solutions.

For HL-LHC operation, major activities in ATLAS and CMS are related to the replacement of the tracker, owing to the high number of tracks per bunch crossing, the read-out bandwidth limitations and the integrated radiation levels that go far beyond the capabilities of available technologies at the time of their original construction. The much higher data rates also motivate a number of upgrades to other parts of the experiments, especially to their read-out electronics. In particular, the complexity of the collision events will complicate greatly the ability of the vital on-detector data-reduction (triggering) to retain only those events that are interesting to physics. Many improvements are aimed at refining this online selection. The detector, electronics, trigger and data-acquisition upgrades in ATLAS and CMS have been designed to optimize the physics acceptance, especially for the key decay channels of the Higgs boson, including those rare decays that can be reached only at the HL-LHC.

The rich programmes in flavour and heavy-ion physics were discussed from the perspective of all four experiments, but the focus for upgrades was on the dedicated experiments, LHCb and ALICE, which are designed to optimize their sensitivity to these areas of physics. Detector upgrades will extend that sensitivity and allow a greatly increased number of collisions to be recorded, improving the statistical precision for measurements and studies of rare processes significantly. These upgrades do not rely on implementing the HL-LHC machine upgrades and so can be undertaken earlier to bring these improvements sooner.

There were a number of closing presentations emphasizing the key themes from the workshop, which were formulated in a short report to ECFA at its meeting on 21–22 November. This report reflects the interest of those organizing the sessions in seeing more specialist follow-up meetings and a similar plenary meeting, possibly in autumn 2014.

Pleasant weather allowed the opportunity to continue discussions during lunch outdoors. (Image credit: Nanni Darbo.)

The organizers would like to thank all those who contributed to the work of the preparatory groups, the speakers and chairs, the conference support from CERN and particularly the ATLAS and CMS secretariats. The success of the event was a great testament to the enthusiasm of the 326 registered participants and the many more researchers worldwide working on R&D towards this major further step in the LHC's unique adventure at the high-energy frontier.

● Further reading

For more about the workshop in Aix-les-Bains, see http://indico.cern.ch/conferenceDisplay.py?confId=252045.
Update to the European Strategy for Particle Physics http://council.web.cern.ch/council/en/EuropeanStrategy/esc-e-106.pdf
Cracow Open Symposium http://espp2012.ifj.edu.pl/
Snowmass 2013 www.snowmass2013.org/tiki-index.php
Report to ECFA ECFA-13-284
Reports to LHCC https://cds.cern.ch/collection/LHCC%20Public%20Documents

Résumé

Atelier sur le LHC haute luminosité

Avec la récente mise à jour de la stratégie européenne pour la physique des particules, le projet LHC haute luminosité (HL-LHC) prend un nouvel essor. C'est ainsi qu'est née l'idée d'un atelier sur les expériences auprès du HL-LHC organisé par le Comité européen sur les futurs accélérateurs. Il s'agissait de fournir aux collaborations des expériences un lieu d'échange, où elles pourraient mettre en commun les résultats et explorer les synergies, et également renforcer les liens avec la machine et les communautés de la théorie. Lors de trois journées intensives, du 1er au 3 octobre, au Centre des congrès d'Aix-les-Bains, des membres des quatre grandes collaborations LHC se sont réunis pour préparer l'avenir à haute luminosité.

Phil Allport, University of Liverpool, and **Didier Contardo**, Université Claude Bernard Lyon 1.

EuCARD comes to a successful end

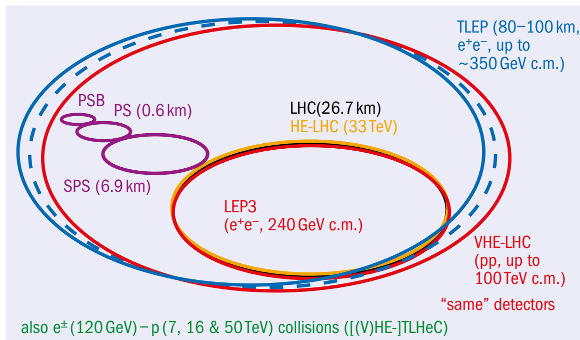
After more than four years, the EuCARD project for accelerator R&D has ended with most of its ambitious objectives fulfilled, including new ones added during its lifetime.

The EuCARD project for accelerator R&D came to an end on 31 July 2013, more than four years after starting on 1 April 2009 (*CERN Courier* November 2009 p16). The project's focus has been generic and targeted R&D for frontier accelerators in the fields of particle physics, nuclear physics and synchrotron radiation applications. Many accelerator infrastructures or projects were involved, including the upgrades for the LHC at CERN; the Facility for Antiproton and Ion Research (FAIR); the European free-electron laser project, XFEL, and FLASH at DESY; and the studies for the Compact Linear Collider (CLIC) and International Linear Collider (ILC).

A framework for collaborative R&D finds its justifications in the extreme technological challenges, the synergies between projects or studies and the complementary competences of laboratories, universities and institutes. R&D naturally precedes the design stage but is not confined to it. It continues during the lifetime of the accelerator to allow the large infrastructures to remain at the forefront of research and make the best use of society's significant investments.

The EuCARD project was initiated by the European Steering Group on Accelerator R&D (ESGARD) as successor to the Coordinated Accelerator Research in Europe (CARE) project, which ran under FP6 from 2004 to 2008. Its total cost was €36 million, with €10 million covered by a European Union Seventh Framework Programme (FP7) grant. The remaining €26 million came through matching funds from the 38 EuCARD partners, who represent most of the European accelerator laboratories, as well as a large number of universities and specialized institutes. CERN provided co-ordination and project management. The project's work was organized around three poles: scientific networks, open access to facilities and collaborative research activities.

Following CARE, the EuCARD networks have consolidated their positions as recognized platforms for the international exchange of ideas and experts – from Europe, Japan, the US, and beyond. Providing support for accelerator centres, they organized more than 50 topical workshops on diverse themes, from electron-cloud mitigation, through RF test stations, crab cavities and so on, to long-term visions of future developments.



(Top) Fig. 1. A vision for proton and lepton accelerator developments for high-energy physics in Europe. (Image credit: EuCARD WP4 and CERN.) (Above) Fig. 2. Transnational access in EuCARD provided new users for CERN's HiRadMat facility.

The networks originally included neutrino facilities, accelerators and colliders (performance and RF technologies). Later, another network was launched on laser-plasma acceleration, with the primary goal of federating the many European research teams around a common road map. The ambitious objective was to collaborate on a transition from the demonstration of the plasma-wakefield concept to operational accelerators. The network bridges the gap between accelerator, laser and plasma communities and after a successful start is now funded fully in EuCARD's successor – EuCARD-2.

A main objective and result of the neutrino networks was to contribute to the update to the European Strategy for Particle Physics by allowing the community to discuss strategies and prepare summary documents, one of which was submitted to the update process. The community acknowledges the conclusions of the updated strategy, which recognizes the need to re-establish an accelerator-based programme at CERN.

(Left) Fig. 3. A high-field 13 T magnet structure in Nb_3Sn with dummy aluminium coil. (Image credit: J Muñoz Garcia and J-C Perez.) (Right) Fig. 4. A cryo-catcher prototype for the FAIR project. (Image credit: GSI.)

A major outcome of the accelerator networks is an ambitious vision for future facilities for high-energy physics, from the LHC luminosity and energy upgrades through unconventional lepton and photon colliders to hadron colliders in the 100 TeV range (figure 1). This effort, which included helping to define key R&D areas for the coming decades, has the potential to guide debates on the future of frontier accelerators at a European level.

Transnational access

Two test facilities were open in EuCARD to transnational access: HiRadMat at CERN's Super Proton Synchrotron (SPS) and MICE at the Rutherford Appleton Laboratory (RAL). The European Commission funding of these activities was dedicated mostly to the support of visits and research by new users.

HiRadMat – the High Irradiation to Materials facility – was constructed at CERN in 2011 to provide high-intensity pulsed beams to an irradiation area where material samples as well as accelerator components can be tested (figure 2). During the duration of EuCARD, nine user projects and 19 users were supported via transnational access (HiRadMat@SPS). When the SPS restarts in autumn 2014, the facility will be open to transnational access in the framework of EuCARD-2. Several communities have already expressed interest.

The UK's Science and Technology Facilities Council (STFC) provided transnational access to a specialized precision beamline at the Muon Ionization Cooling Experiment (MICE) at the ISIS facility at RAL. A total of 19 researchers from eight institutes were supported for 131 visits during EuCARD's lifetime.

Joint research activities had the lion's share in EuCARD, with 87% of the total budget, about 50 objectives that led to concrete results and as many reports containing scientific results. Many of the developments are described in the EuCARD Final Report, soon to be published as a EuCARD monograph. Here are a few highlights.

Under EuCARD, R&D was initiated in Europe for the first time on high-field Nb_3Sn magnets (figure 3) and on high-temperature superconducting (HTS) yttrium barium copper oxide (YBCO) inserts. Together, these initiatives are ushering in the era of magnets with fields in the 20 T range. After overcoming many challenges with these delicate superconductors – such as the high strains, insulation and required resistance to radiation – the work is well advanced, with the final results expected in two years. Success will open the door to a new generation of accelerators at the energy frontier, including the energy upgrade of the LHC. In the nearer future, it will allow the upgrade of CERN's FRESCA test station for superconducting cables, which is used also by the ITER fusion project, for example. Other possible application areas could be nuclear magnetic resonance and magnetic resonance imaging.

The HTS electrical-link demonstrator at CERN is fully operational. It will allow energy-efficient remote powering of magnets. This will have a positive impact on the LHC upgrade, allowing powering away from radiation areas. The principle, studied in collaboration with industry, may also find applications in the energy domain.

Studies of new robust materials for beam collimation have pointed to metal–diamond or metal–graphite composites that offer promising solutions when increasing the energy or power of accelerator beams. The use of HiRadMat was instrumental in the characterization of these novel, more robust materials. The "smart" LHC collimator and the cryo-catcher for FAIR (figure 4) were designed, built and successfully tested with beams.

EuCARD's contribution to linear colliders is deeply integrated in the CLIC and ILC studies. Significant progress was made in the ultra-precise assembly and integration of RF modules, thermal stabilization, ultra-precise phase control to 20 fs and beam control. The active mechanical stabilization of magnets to a fraction of a nanometre is especially impressive, as are the highly sophisticated simulations of RF breakdowns, which show new microscopic mechanisms and offer directions for mitigation. The study of an innovative compact crab cavity also gave momentum to this R&D line, going well beyond the original plans with the fabrication of a bulk-niobium superconducting unit. This is now part of the baseline LHC luminosity upgrade project. ▷

Accelerators

In other work on superconducting RF, the strategy for fabrication and processing of cavities for proton linacs should set a new higher standard for accelerating gradients. This is of relevance for all proton linacs, for example for the European Spallation Source and accelerator-driven systems. Progress has been made on the delicate process of sputtering a thin film of niobium onto a copper RF cavity, but full validation remains to be done. Experts believe that this technique – pioneered for phase 2 of CERN's Large Electron-Positron collider – could reach much higher gradients, well in excess of the performance of bulk niobium, which has reached close to its theoretical limit. High-performance cavities also require higher-performance RF couplers to feed them. The R&D on an automatic cleaning machine is a step forward, needing a demonstrator, and promises to decrease significantly the cost and duration of the processing of couplers for large accelerators.

Fig. 5. Some final statistics for the EuCARD project.

In the field of diagnostics and control, FLASH is benefiting from an upgraded modular low-level RF, with the novelty that it is based on a commercial telecommunication standard. Already being commissioned, it provides a significant gain in field stability. Such a control system could be used by the XFEL or adapted for the ILC.

EuCARD also set aside about 10% of its budget for joint research studies on unconventional concepts, such as crab-waist crossing, diagnostics for the nonscaling fixed-field alternating gradient machine EMMA at Daresbury Laboratory, and emittance measurements for the widely diverging beams of laser-plasma accelerators. This could lead to interesting contributions to the field.

Making an impact

By co-funding scientific research, the European Union (EU) aims to strengthen the collaboration between European institutes and universities, to implement the well-known adage "union is strength". Therefore each project must evaluate its impact on a progressive integration of effort.

EuCARD's main impact has probably been to encourage scientists at accelerator centres to adapt to collaborative working methods that involve distributed work and decision making. Challenges are, in a first phase, the minimization of overheads as a result of collaborative working methods requiring more reporting, for example; and in a second phase, to make best use of the added potential of collaborative work. Like CARE and other European projects, EuCARD has provided invaluable hands-on experience in this context to its members – inspired by the organization of the particle-physics community, but adapted to the field of accelerators with its different boundary conditions.

Beyond this qualitative impact, EuCARD's legacy will include a series of scientific monographs on accelerator sciences. In addition, a quarterly newsletter, *Accelerating News*, created by EuCARD, was extended to all EU accelerator projects and beyond, and now reaches more than 1100 subscribers. Both will continue serving the community via EuCARD-2 and the TIARA project (*CERN Courier* June 2011 p28).

Other impact has been at the EU policy level, where accelerator R&D was ranked highly in a survey among EU project co-ordinators. The project has contributed to the birth of other FP7 ventures, such as HiLumi-LHC, and allowed stronger co-operation via networks with laboratories in the US and with KEK in Japan, the latter now being a full member of HiLumi-LHC. EuCARD also established a bridge with the FP7 project ICAN, with its focus on high-power high-repetition-rate lasers potentially suitable for laser acceleration (*CERN Courier* November 2013 p21).

Experience with EuCARD has enabled the concept for Enhanced European Coordination for Accelerator R&D – EuCARD-2 – to be defined in ESGARD. This next phase of co-ordinated accelerator R&D started on 1 May. It will run for four years with a total budget of €23.4 million and provide a framework for 40 research institutes across the world. EuCARD-2 has networks on innovation, energy efficiency, accelerator applications, extreme beams, low-emittance rings, and novel accelerators. HiRadMat@SPS will continue to provide access for new users, as will the Ionisation Cooling Test Facility – ICTF@RAL. The R&D activities will address the technological limits of current machines with regard to magnetic fields, RF gradients and technologies, and collimator materials. There will also be dedicated activity on plasma-wakefield acceleration as an alternative to current approaches.

Résumé

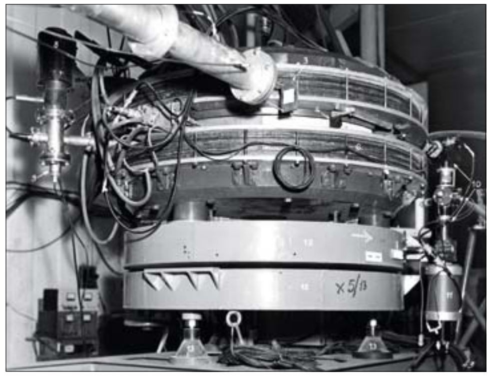
EuCARD arrive à bon port

Après plus de quatre ans d'existence, le projet EuCARD de R&D sur les accélérateurs est arrivé à son terme le 31 juillet 2013, ayant réussi à atteindre la plupart de ses objectifs, pourtant ambitieux. Le projet était axé sur la R&D générale et ciblée pour des accélérateurs de pointe dans les domaines de la physique des particules, de la physique nucléaire et des applications de rayonnement synchrotron. Parmi les aspects abordés, des travaux sur les aimants supraconducteurs à champ élevé et des avancées importantes concernant l'assemblage et l'intégration, avec une précision extrême, de modules radiofréquence pour un futur collisionneur linéaire électron-positon. De plus, deux installations d'essai ont été ouvertes à l'« accès transnational » et un réseau scientifique a été constitué sur le sujet de l'accélération laser dans un plasma.

Jean-Pierre Koutchouk, CERN, EuCARD coordinator, and **Agnes Szeberenyi**, CERN, EuCARD/EuCARD-2 communications.

CERN Courier January/February 2014
Anniversary


Bruno Touschek. (Image credit: INFN.)


AdA installed at LAL, where the first electron–positron collisions were observed. (Image credit: LAL.)


AdA on display today, back at Frascati. (Image credit: LNF/INFN.)


Jacques Haïssinski at the LAL event. (Image credit: LAL.)


The control room of the historic linac at Orsay, now a museum piece. (Image credit: LAL.)


Unveiling the EPS plaque for AdA, with Luisa Cifarelli, left, and Fernando Ferroni. (Image credit: INFN/LNF.)

AdA – the small machine that made a big impact

Fifty years ago, a pioneering machine called AdA moved from Italy to France, where the first experimental evidence of electron–positron collisions in a storage ring was observed.

The story of the world's first electron–positron storage ring, the Anello di Accumulazione (AdA), started in Italy at INFN's Frascati National Laboratory (LNF). Built there under the leadership of Bruno Touschek, it stored its first beams in February 1961. A year later, the machine travelled to France, to the Laboratoire de l'Accélérateur Linéaire (LAL) in Orsay – now part of CNRS/IN2P3 and Paris Sud University – so that it could benefit from the new state-of-the-art linac as injector. The first electron–positron collisions were observed and studied there from late 1963 to spring 1964, laying the foundations for a technique that would revolutionize investigations of fundamental particles and their interactions.

To celebrate this anniversary, LAL and LNF organized a special meeting in the series of Bruno Touschek Memorial Lectures, BTML 2013, which took place at LAL on Friday 13 September – a date chosen to take advantage of the following weekend of European Heritage Days in France. Associated public events took place during the three days, including a public lecture on "LAL and CERN" in the evening of 13 September and open days at LAL on 14–15 September.

The special BTML 2013 meeting began with a talk about Touschek and the memorial lectures. This was followed by recollections from LAL's Jacques Haïssinski – who did his doctoral thesis work at AdA – and by the first showing of a new film on the period when AdA was at LAL. A second session focused on accelerators, their applications in society and the future programmes for both LAL and LNF. The afternoon's more ceremonial events took place in the Pierre Marin hall, which hosts the Anneau de Collisions d'Orsay (ACO) – AdA's successor at LAL (1965–1988) and now the core of the Sciences ACO museum. Events included the inauguration at the museum of the historic linac's restored control room, which has been moved and reassembled exactly as it was.

The linac at LAL delivered its first beam of electrons, at 3 MeV, near the end of 1958. By 1964 the beam energy reached 1.3 GeV – a world record for electron linacs at that time (*CERN Courier* June 2004 p27). However, from 1963, the accelerator was also equipped to deliver a positron beam, and this would become a valuable tool in the implementation of collider and storage rings at LAL, beginning with the pioneering studies on AdA.

The story of AdA

At the start of the 1960s, several groups worldwide were following up ideas for electron–electron and proton–proton colliders. In contrast, Touschek's vision was to make electrons and positrons collide and annihilate in such a way that the centre of mass of the system is at rest in the laboratory frame and to produce time-like photons with enough energy to excite resonant modes of the vacuum corresponding to the masses of the vector mesons. With the blessing of Giorgio Salvini, LNF's director at the time, a small group of inspired physicists started work on designing and building a prototype electron–positron storage ring, which they named AdA (Bernardini 2004).

AdA consisted of a ring-shaped vacuum chamber, 160 cm in diameter, which was embedded in a magnet of 8.5 tonnes to keep beams circulating with energies up to 200 MeV. Challenges included maintaining a high vacuum to guarantee the lifetime of the beam and working out how to inject both electrons and positrons. Injection was achieved through the conversion of γ rays in a tantalum plate installed in the vacuum chamber, the γ rays being produced by bremsstrahlung from the electron beam of LNF's electron synchrotron. The first stored electrons and positrons circulated on 27 February 1961, but difficulties in siting AdA close to the synchrotron meant that the stored intensities were low and proof of collisions had to wait until the storage ring was taken to Orsay.

The move to LAL stemmed from a visit to Frascati in the summer of 1961 by Pierre Marin, who found AdA to be *un vrai bijou*. By the end of the year, preliminary studies for a 1.3 GeV electron–positron storage ring at LAL had started, but the project was soon considered too close to the proposal for the ADONE collider at Frascati. In early 1962, a small group of scientists and engineers from Orsay went to Frascati to discuss, among other items, ways of operating AdA at the Orsay linac to benefit from the high beam intensity and easier photo-injection from the linac. At the beginning of July, AdA was packed onto a lorry and set off across the Alps with a fully evacuated beam pipe, and batteries to last about three days to power the vacuum pumps and avoid losing the high vacuum that had taken months to obtain. A month later, the collider was installed in Orsay – although not without incident. While being positioned by a crane, AdA was almost smashed against a wall. Later, a heavy detector tipped over while being moved close to the ring and broke Marin's foot.

In Orsay, in a series of runs between December 1963 and April 1964, collisions were finally observed and important aspects of beam dynamics studied (Bernardini *et al.* 1964). One important effect was immediately explained by Touschek. Large-angle Coulomb collisions in the electron (or positron) bunches give rise to momentum transfers into the longitudinal phase space, which can in turn lead to particle loss, limiting the machine luminosity. Known as the Touschek effect, it is manifest through a progressive decrease in the beam lifetime while the number of stored particles increases – and it remains one of the factors that limit the beam lifetime in accelerators.

Experiments with AdA ended with these results. The project to build ADONE – a bigger 1.5 GeV collider proposed at the end

AdA and LAL become EPS Historic Sites

In a ceremony on 5 December at the LNF, the European Physical Society (EPS) declared AdA an EPS Historic Site. The ceremony, which was chaired by LNF's director, Umberto Dosselli, featured talks by Giorgio Salvini, LNF's director in 1961 at the time that construction of AdA was agreed, and Carlo Bernardini, who gave a personal recollection of the main steps in building AdA and the exciting atmosphere pervading the LNF at that time. INFN's president, Fernando Ferroni, also had the opportunity to comment briefly on the present status of the laboratory and its future perspectives. EPS vice-president, Luisa Cifarelli, spoke on the EPS Historic Sites initiative and also described the society's foundation, development and links with INFN. The EPS Historic Site plaque was then unveiled by Ferroni and Cifarelli. The programme continued in the afternoon with the Frascati edition of BTML 2013, in which Samuel Ting, of the Massachusetts Institute of Technology, presented the latest results from the Alpha Magnetic Spectrometer, which is studying antiparticle production in cosmic rays (*CERN Courier* October 2013 p22). CERN's Luigi Rolandi then gave a public lecture on the recent discovery of a Higgs boson.

Two months earlier, during the special edition of BTML 2013, LAL and the LURE complex became the 8th EPS Historic Site. AdA's shutdown at LAL was followed by the start-up of the ACO ring in 1965, allowing important measurements in accelerator and particle physics. Later, ACO and then SuperACO became leaders in the use of synchrotron light for other research fields, such as materials science and chemistry. The Laboratoire pour l'Utilisation du Rayonnement Électromagnétique (LURE) was created in 1973 to develop this activity, becoming independent from LAL in 1985. Today, LURE has led to the SOLEIL synchrotron on the Saclay plateau, a first-class third-generation light source.

Anniversary

LAL today

Although the large linear accelerator, which gave its name to LAL, was turned off at the end of 2003, the lab's involvement in the particle-accelerator field continues to be important. R&D activities at PHIL – a 10 MeV electron accelerator built in the lab and recently completed – will allow the development of future particle injectors (*CERN Courier* September 2008 p9). The facility will also be open to a large community that will use its unique beam-properties for dedicated experiments. The lab is also responsible for the building and conditioning of the 640 couplers for the new free-electron laser, XFEL, under construction at DESY.

In addition, LAL has started the construction of an innovative X-ray source, ThomX. This first-class equipment – designated Equipement d'Excellence by the French National Research Agency in 2011 – will have many applications, from medical research to non-invasive studies of art masterpieces. Thanks to its small size and limited cost, it is likely to interest many labs and private companies worldwide. More fundamental activities are also ongoing, such as the commissioning of beams with record emittance at the Accelerator Test Facility 2 at KEK, in Japan, and the UA9 experiment at CERN, which is investigating a new collimation method for beam-halo studies in the Super Proton Synchrotron and LHC.

of 1960 by Touschek and his collaborators – had already been approved at LNF and was to start up in 1967. However, despite AdA's short scientific life, it remains a milestone in the history of science because it set the stage for many future electron–positron colliders. The configuration became one of the most powerful tools in modern high-energy physics, allowing, in 1974, the discovery of the J/ψ – a particle built of a new type of quark, charm, and its antiquark – and culminating in the late 1980s with the Large Electron–Positron collider at CERN.

Further reading

C Bernardini *et al.* 1964 *Nuo. Cim.* **34** 1473.
C Bernardini 2004 *Phys. Perspect.* **6** 156.

Résumé

AdA – petite machine, gros impact

Il y a cinquante ans, une équipe travaillant avec un petit collisionneur de particules appelé AdA trouvait la première preuve expérimentale de collisions électron-positon dans un anneau de stockage, ouvrant ainsi une nouvelle ère de la physique des particules. Cette histoire a commencé en Italie, au Laboratoire national de Frascati. Construit sous la direction de Bruno Touschek, l'AdA a stocké ses premiers faisceaux en 1961. Un an plus tard, la machine était transportée en France, au Laboratoire de l'Accélérateur linéaire, à Orsay, dont elle a pu utiliser le nouveau linac comme injecteur. Les premières collisions électron-positon y ont été observées et étudiées de la fin de 1963 jusqu'au printemps 1964.

This article is based on material in the brochure that accompanied the special BTML 2013 events, available from the website in English, French and Italian. Visit **http://events.lal.in2p3.fr/BTML2013/index-en.html**.

How the Particle Physics Masterclasses began

As the international masterclasses in particle physics for schools prepare for their 10th year, Roger Barlow looks back at their origins in the UK in 1996.

Today, the Particle Physics Masterclasses are so well established that they seem always to have been there. As many as 10,000 school students in 37 countries participate each year at an international level. Perhaps those who are involved in these events that enthuse and inform the younger generation never wonder about how they started. But there was a time when there were no such things as masterclasses in particle physics and they had to be invented.

The start can be dated precisely: it was in a discussion between Ken Long and myself that took place during a coffee break at the committee meeting of the UK Institute of Physics (IOP) High-Energy Particle Physics (HEPP) group on 17 October 1996. We were frustrated at difficulties with outreach – or the public understanding of science, as it was then called – to schools. Particle physics had a great story to tell, with fine pictures and enthusiastic speakers, but schools were slow to respond to our offers to visit and give talks. Our words and pictures could not compete with the colour and noise of chemists and the experiments they included in their lectures. Surely it was impossible to show real particle physics in the classroom? As Ken and I talked, bits of the answer came together and more followed over e-mail discussions in the succeeding weeks:

- Rather than go to schools and talk to a dozen pupils, we would invite them to come to us, in university lecture theatres that could accommodate hundreds of people.
- A full-day event would make the trip worth their while and allow time for a range of topics and activities.
- We would run the event from local universities but consider it a national event and organize publicity centrally using the IOP.
- Most important, we would use the new computer clusters that were being installed for undergraduates but not used much outside of university term time.

The computer clusters could run serious software experiments directly related to real particle physics – participants could learn through doing. The World Wide Web, which was new at that time, could be used for distributing the programs and data. Today, we just

The Particle Physics Masterclasses became international in 2005. Here students participate at Orsay, France, in 2011. (Image credit: CNRS/LAL.)

point and click, but in the early days we had to be concerned with network speed, so the programs were painstakingly pre-loaded to each PC before the sessions.

I suggested the name "Masterclasses" with some hesitation because it seemed pretentious: we were not offering one-to-one violin tuition with Yehudi Menuhin. However, it did capture something of what we were trying to do and the name has stuck. At the meeting of the IOP HEPP group committee in January 1997, Ken and I presented our plans for Imperial College and Manchester University (where I worked then), and people liked them. Christine Sutton at Oxford, Mike Pennington at Durham and Tim Greenshaw at Liverpool decided to take part. These were the individual enthusiasts but we also received tremendous support from many colleagues, both in the particle-physics groups and from the computing staff.

Particle physics had a great story to tell, with fine pictures and enthusiastic speakers.

We decided that although we could not provide a big-name speaker for every session, we could distribute a video of a public session arranged as part

The use of computer clusters – here at Queen Mary University of London – that were not used much outside of university term time, was a key part of the original idea. (Image credit: QMUL.)

National labs also took up the idea. Here students get down to some basic physics with the "left-hand rule" at the 2012 classes organized by the Cockcroft Institute and Daresbury Laboratory. (Image credit: STFC.)

of the IOP HEPP group conference, which in 1997 was to be held in Cambridge to celebrate the centenary of J J Thomson's discovery of the electron at the Cavendish Laboratory. Ken arranged for video recording (with all of the legal and copyright details) of the talks given by Stephen Hawking and Frank Close. The videos were shown at the masterclasses just a few days later and each participating school was given a copy to take home.

While Ken was arranging the video, I was organizing the universities. On 13 February we had a planning meeting in Manchester, with Swansea and Lancaster joining as well. We also discussed publicity, arrangements and the provision of "goody bags" for pupils and teachers. We tried out the software, which included the Lancaster relativistic-kinematics package and Terry Wyatt's web-based "Identifying Interesting Events at LEP".

The real thing

Terry's package was revolutionary in that it gave school students real particle-physics data and real tools, and asked them to make decisions. Presented with simple Z decays from the OPAL experiment at CERN's Large Electron–Positron (LEP) collider, the students had to classify them as electron, muon, tau or quark decays, according to the patterns in the detector. The only difference from actual analysis was that such a classification would not be done by a physicist, but by a program using criteria devised by a physicist. Terry and I had spent a lot of time puzzling over the OPAL event display to understand the detector for the first muon-pair results, so I can certify that this exercise was close to real research.

After the annual IOP conference in Cambridge I came back to Manchester, and the next day – 11 April – we ran our first Particle Physics Masterclass. In my journal I wrote "nice talks, kids co-operate and teachers are enthusiastic and appreciative". The only glitch was that we under-estimated appetites and lunch ran out. We learnt our lesson and the following year we provided smaller plates. The other pilot sites were similarly positive. There was high demand from the schools – some places ran a second day – and both pupils and teachers who attended were enthusiastic afterwards.

The basis for the masterclasses was "Think globally, act locally". It was a national campaign – we always specifically referred to it as the National Particle Physics Masterclass – with central publicity and preparation of materials. However, the shows were run by local groups, in their own way and with local variations. They could plug their own institution as much as they pleased – the Oxford website managed to include the word "Oxford" six times on one small page – and adapt the material freely, using events from the DELPHI experiment, rather than OPAL, for example.

The scheme was written up in the HEPP group newsletter (January 1998), stressing what we saw as the key parts of the scheme:

- It is not just talks. Using PC clusters can get the participants involved in an activity that is not far from real research.
- A central organization spreads the administrative load.
- A national scheme spreads the publicity.
- It runs every year at the same time, linked to the annual IOP HEPP group conference in the spring vacation, so there is no problem in deciding when to do it.

The basis for the masterclasses was "Think globally, act locally".

The idea snowballed, so that in 1998 nearly every university particle-physics group in the UK ran a masterclass – and have done ever since. The national Rutherford and Daresbury labs joined a year or so later.

The Particle Physics Masterclasses have flourished. There was continued strong support ▷

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Education

from the IOP HEPP group – Val Gibson took over the co-ordination when I came off the committee – and from the Particle Physics and Astronomy Research Council, where Andrew Morrison did a splendid job of liaison. They provided co-ordination and literature, respectively, but not money. We received repeated offers of financial assistance but turned them down as the scheme basically cost nothing. It was run by enthusiast particle physicists who did not need extra support.

Onwards and upwards

The masterclasses have adapted with time. The LEP events were replaced by ones from the Tevatron and from the LHC. The number of pupils who have attended the classes must be into the tens of thousands. A prime minister has been photographed with participants, and the masterclasses idea has spread to continental Europe and across the Atlantic.

I think this success comes from a combination of many factors. Particle physics has, of course, a great story to tell. Masterclasses are run by enthusiasts who do it purely for fun and because they want to, and they treat the material with familiarity rather than respectful awe. We grasped the technical development of the university PC clusters for analysis and the power of the web for distribution at the right moment.

This success has brought benefits: applications to study physics in UK universities are rising, and the public and the media are interested and excited about the LHC and the Higgs boson. Agreed, the masterclasses cannot claim all of the credit for this, but they can certainly claim some of it.

Now, the Particle Physics Masterclasses face the challenge of evolving as technology moves on and people – especially young people – change with it. I hope they see continued success by building on the basic ideas that they started with, and that they will continue to provide fun for students and organizers for many years to come.

Résumé

Master classes *en physique des particules : comment tout a commencé*

Les master classes *en physique des particules font tellement partie du paysage qu'on a l'impression qu'elles ont toujours existé : pas moins de 10 000 élèves de 37 pays y participent chaque année. Et peut-être que les personnes qui contribuent à ces manifestations, qui attirent tant de jeunes enthousiastes, ne se demandent jamais comment tout cela a commencé. Cependant, il fut un temps où les* master classes *de physique n'existaient pas. Ici Roger Barlow, l'un des « inventeurs », revient sur les idées qui ont inspiré la création de ces ateliers au Royaume-Uni, en 1996.*

Roger Barlow, Huddersfield University.

Faces & Places

AWARDS

CERN receives UNESCO Niels Bohr Gold Medal

Left to right: Getachew Engida, deputy director-general of UNESCO, Jens Jørgen Gaardhøje, Niels Bohr Institute and chair of the UNESCO-Niels Bohr awards, Princess Marie of Denmark, Jimmy Wales, Rolf Heuer and Alain Aspect. (Image credit: Hasse Ferrold.)

In a ceremony that was held on 5 December in the Ceremonial Hall of the University of Copenhagen, the UNESCO Niels Bohr Gold Medal was awarded for special contributions to ground-breaking research in physics and open international collaboration. CERN received the medal "in recognition of its outstanding global action in promoting scientific co-operation across borders", which is particularly appropriate given the themes of the 60th anniversary this year (p5 and p58). Also honoured with the medal were Jimmy Wales, the founder of Wikipedia – in recognition of "his invaluable contribution to free, quality knowledge access" – and Alain Aspect of Ecole Polytechnique, "for his contribution to understanding the non-locality of quantum mechanics". Rolf Heuer, CERN's director-general, accepted the medal on behalf of the laboratory.

The medal, which UNESCO created in 1985 to commemorate the centenary of Niels Bohr's birth, was awarded previously in 1998, 2005 and 2010. The 2010 laureates included Sir Tim Berners-Lee, who created the World Wide Web while at CERN. The award ceremony this year took place during the "An Open World conference", held as part of the University of Copenhagen's celebrations of the centenary of Bohr's atomic model. In 1950, Bohr wrote an open letter to the United Nations (UN) in which he urged world leaders to address the challenges of new technologies. His ideal was "an open world" with free sharing of knowledge and international co-operation. The conference aimed to reinvigorate Bohr's vision and analyse the relevance of openness in today's context. It concluded with the writing of a new open letter to the people of the world, the UN and UNESCO.

IEEE honours Lyn Evans with 2014 Simon Ramo Medal

Lyn Evans, currently director of the Linear Collider Collaboration and formerly project leader of the LHC at CERN, has been awarded the 2014 IEEE Simon Ramo Medal, for "systems leadership of the LHC Project from conceptual design through completion of construction". Evans, who joined CERN in 1970 as a research fellow in the Proton Synchrotron Division, was appointed Associate Director of Future Accelerators in 1993 and became responsible for the design of the LHC and preparation of the project for approval by the CERN Council. He was project leader from 1994 until first beam in 2008.

The Simon Ramo Medal, which is given "for exceptional achievement in systems engineering and systems science", is one of the IEEE's most prestigious honours, awarded each year to a small number of individuals whose "outstanding contributions have made a lasting impact on technology, society and the engineering profession". Evans will receive the award at the IEEE Honours Ceremony to be held on 23 August in Amsterdam.

Lyn Evans in the LHC magnet test hall in 2008.

***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.

Karl-Ludwig Kratz receives 2014 Hans Bethe Prize

Karl-Ludwig Kratz. (Image credit: Wikipedia Commons CC-BY-SA-3.0-DE.)

The American Physical Society has awarded the 2014 Hans Bethe Prize to Karl-Ludwig Kratz, professor for nuclear chemistry at the Johannes Gutenberg University of Mainz and adjunct professor of physics at the University of Notre Dame, Indiana. The award recognizes "outstanding work in theory, experiment or observation in the areas of astrophysics, nuclear physics, nuclear astrophysics, or closely related fields".

Katz receives the prize "for his ground-breaking and visionary work towards developing a cohesive picture of the r-process by employing novel experimental techniques to study the decay of nuclei far from stability, working with observations of astronomers, models of astrophysicists and nuclear theorists, and the geochemical analyses of meteorites". His research has taken him to the Institut Laue–Langevin high-flux reactor in Grenoble and to various international accelerator facilities including ISOLDE at CERN, for experiments on isotopes relevant to the astrophysical r-process.

Rafael Ballabriga wins IEEE NPSS award

Left to right: Michael Campbell, spokesperson for the Medipix2 and 3 collaborations, Rafael Ballabriga and Xavier Llopart of the Medipix design team. (Image credit: Paula Collins.)

CERN's Rafael Ballabriga, co-designer of the Medipix3RX chip, has been awarded the 2013 Radiation Instrumentation Early Career Award of the IEEE Nuclear and Plasma Sciences Society for the "implementation of a new approach to spectroscopic X-ray imaging, with registration of photon energies, using semiconductor devices with in-pixel processing for each individual incident photon".

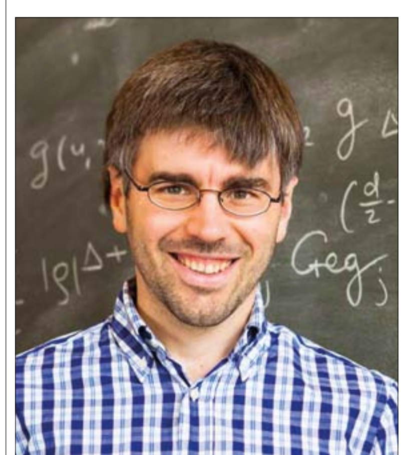
Ballabriga received the award at the 2013 Nuclear Science Symposium and Medical Imaging Conference in Seoul, on 28 October. This award, presented annually, recognizes an individual, early in their career, who has made significant and/or innovative technical contributions to the fields of radiation instrumentation and measurement techniques for ionizing radiation.

New Horizons Prize rewards young theoreticians

On 5 November, the Fundamental Physics Prize Foundation announced the 2014 winners of the New Horizons in Physics Prize. Theorist Vyacheslav "Slava" Rychkov from CERN and the Pierre-and-Marie-Curie University was one of the recipients. He received the award for developing new techniques in conformal field theory, reviving the conformal bootstrap programme for constraining the spectrum of operators and the structure constants in 3D and 4D theories.

Also honoured are Freddy Cachazo of the Perimeter Institute, for uncovering numerous structures underlying scattering amplitudes in gauge theories and gravity, and Shiraz Naval Minwalla of the Tata Institute of Fundamental Research, for his pioneering contributions to the study of string theory and quantum field theory, in particular his work on the connection between the equations of fluid dynamics and Albert Einstein's equations of general relativity.

The Fundamental Physics Prize Foundation is a not-for-profit corporation established by the Milner Foundation. The New Horizons Prize is awarded to up to three promising junior researchers in fundamental physics research.



Slava Rychkov in his office at CERN. (Image credit: Luisa Doplicher.)

The European Organization for Nuclear Research came formally into being on 29 September 1954, retaining the acronym, CERN, of the Conseil européen pour la recherche nucléaire that had preceded it and done much preparatory work. The choice of Geneva as the site had already been agreed in 1953 and the first ground broken in May 1954 in fields close to the village of Meyrin, near the border between Switzerland and France. The aerial photograph taken in January 1963, left, shows how much the laboratory grew during its first 10 years. The wheel-like structure marks the Proton Synchrotron, which had come on line in 1959, with the large building of the East Hall to its lower right. Below it are the first blocks of offices and small labs – including Buildings 1–4 and the Main Building. Further up the photo lie snow-covered fields in France. Clearly visible is the triangular shape that was to become part of CERN when the laboratory extended into France in 1965 to construct the Intersecting Storage Rings. The aerial view from January 2004, right, shows how the site filled up during the following 40 years. The East Hall is still visible, near the centre of the photo, but buildings extend from those that provide offices for the LHC collaborations, at the left of the image, to the far apex of the triangle on French territory, top right.

Learned society

Giudice becomes member of Accademia Galileiana

On 10 November, Gian Giudice, of the theory group at CERN, was nominated to become a member of the Accademia Galileiana for his work on supersymmetry and extra dimensions.

Accademia Galileiana is one of the oldest learned societies still active today. It was founded in Padua, Italy, in 1599 under the name Accademia dei Ricovrati by 25 renowned scholars, including Galileo Galilei. In 1669, unusually for the time, the academy admitted a female member, Elena Cornaro Piscopia, the first woman in Europe to receive a university diploma. In 1997, the academy changed its name to Accademia Galileiana di Scienze Lettere ed Arti in Padova, therefore honouring the most illustrious co-founder of the institution.

Gian Giudice (left) receiving the diploma from Carlo Giacomo Someda, president of Accademia Galileiana. (Image credit: Accademia Galileiana.)

Honours

University recognitions for Peter Jenni

Universities in Denmark, Germany, Sweden and Switzerland have recently honoured Peter Jenni, in particular for his numerous years of leadership with the ATLAS experiment at the LHC, preparing the ground with many colleagues for the recent discovery of a Higgs boson.

After joining CERN in 1980 to work with the UA2 experiment – which together with UA1 discovered the W and Z bosons – from 1984 Jenni worked on studies for the LHC and was spokesperson for ATLAS for many years after its approval (1995–2009). Following his retirement from CERN in April 2013, he became a guest scientist at the Albert-Ludwigs-Universität Freiburg, continuing his deep involvement with ATLAS. He is now an honorary professor there.

Jenni's close collaboration with physicists in Stockholm was recognized with the award of an honorary doctorate from Stockholm University on 27 September, which he received during a ceremony in the famous City Hall. A few weeks later, he was in Denmark to receive an honorary doctorate at the 2013 Commemoration at Copenhagen University, on 15 November. This annual event – which is attended by the Danish royal family – celebrates the university's founding in 1479. The following day it was the turn of ETH Zurich to celebrate the 158th "ETH Day". Jenni, who gained his doctorate in physics at ETH in 1976 for studies undertaken at CERN's Proton Synchrotron, was awarded a second doctorate – this time honorary – during the celebrations.

Peter Jenni, underground at the ATLAS experiment. (Image credit: C Marcelloni.)

DETECTORS

Nuclear emulsions under scrutiny in Romania

Experts from Italy, Japan, Russia and Switzerland came to Romania on 13–18 October to attend the Workshop on Nuclear Track Emulsion and its Future, which took place in the south Carpathian Mountains in Predeal, near Sinaia. The meeting was hosted by the Institute for Space Science (ISS), Bucharest, where a group has been involved in research using nuclear emulsion since 1958, mainly in collaboration with JINR Dubna.

Nuclear emulsions have a long history dating back to the use of photographic film by Henri Becquerel at the end of the 19th century, and they remain unsurpassed when high spatial resolution is required in detecting the tracks of ionizing particles. An outstanding example of the modern (tracking) emulsion technique is represented by the OPERA experiment at the Gran Sasso Laboratory, which features 10 million emulsion films and a large number of state-of-the-art automatic microscopes.

The workshop in Predeal reviewed all aspects of the technique and notable projects in both fundamental and applied science. Reports from the Slavich Company in Russia and the group at Nagoya University in Japan described new insights into the production of emulsion gels with features tailored to specific applications. Other speakers addressed progress in the building of modern scanning systems, for example, with super-fast image read-out and tracking based on graphic processing units.

Experiments employing emulsions were reviewed in the fields of astrophysics, neutrinos, heavy-ion physics, searches for dark matter and – last but not least – gravitational effects on antimatter, as in the AEgIS experiment at CERN. Reports on results from JINR demonstrated that new automatic technology could provide a boost to the traditional applications of emulsions for nuclear research. Several interesting applications were also presented in medical physics, muon radiography and neutron dosimetry. A group at the Lebedev Institute has developed an interesting technique incorporating emulsions with neighbouring solid plastic detectors, used in the search for exotic transuranic elements in olivine meteorite inclusions.

Particpants outside the Rozmarin Hotel where the workshop took place. (Image credit: ISS.)

The workshop ended with a round table. Participants decided to strengthen co-ordination of worldwide R&D efforts and create a unified standard for emulsion-data digitization for archiving emulsion images from past and future experiments.

● For more information, see www.spacescience.ro/wnte2013.

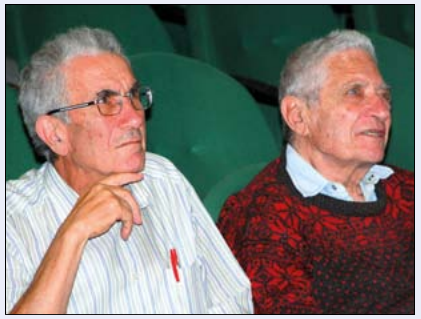
MEETINGS

An **Advanced Workshop on LHC Physics and Cosmology** will be held in Cairo on 3–14 February 2014. Organized by the World Laboratory for Cosmology and Particle Physics, the Egyptian Center for Theoretical Physics and the International Center for Theoretical Physics, it is designed to complement graduate education, especially in African countries, and provide direct contact with leading researchers. While open to any young researchers, it is primarily intended to serve the African academic community, so MSc and PhD students and young postdocs from the southern countries are particularly encouraged to apply. The workshop will bring together cosmologists and particle physicists with the intention of discussing implications for the two fields of recent LHC results on QCD matter. For more details and the registration form, visit http://wlcapp.net/confs/ICTP_2014_SMR2619/ScientificProgram.html.

QCD 14, the **17th Montpellier International Conference on Quantum Chromodynamics**, will take place on 30 June–14 July in Montpellier. The meeting, which traditionally involves equal mixtures of experimentalists and theorists, and of young and senior physicists, will cover different aspects of QCD – perturbative, non-perturbative and the interface with other fields. For further information, see www.lupm.univ-montp2.fr/users/qcd/qcd14/.

CORRECTION

The short article on the bi-centenary of the Scuola Normale Superiore in Pisa unfortunately omitted to name Lorenzo Foa among the particle physicists who had been students there. There was also another Nobel laureate who was educated there: Giosuè Carducci, who received the Nobel Prize in Literature in 1906.



Last year, Italo Mannelli, left, celebrated his 80th birthday. A former research director at CERN and chair of the Scientific Policy Committee, he is well known for his work on the measurement of direct CP violation with the NA31 experiment at CERN and its successor NA48, which provided incontrovertible proof for the effect in 1999. Mannelli is seen here with Jack Steinberger at the centenary celebrations held for Bruno Pontecorvo in Pisa last September. The two have known each other since they worked together in 1957 and found the asymmetry in the decay $\Lambda \to \pi p$, which demonstrated that parity violation is not an effect caused by neutrinos. After joining CERN in 1968, Steinberger worked again with Mannelli, in particular on NA31, the first experiment to find evidence for direct CP violation. (Image credit: G Fausto.)

This year is the 50th anniversary of the discovery of CP violation in the kaon system at Brookhaven Laboratory in 1964. The breakthrough work led to the award of the Nobel Prize in Physics to James Cronin and Val Fitch in 1980.

EXHIBITION

The LHC comes to life

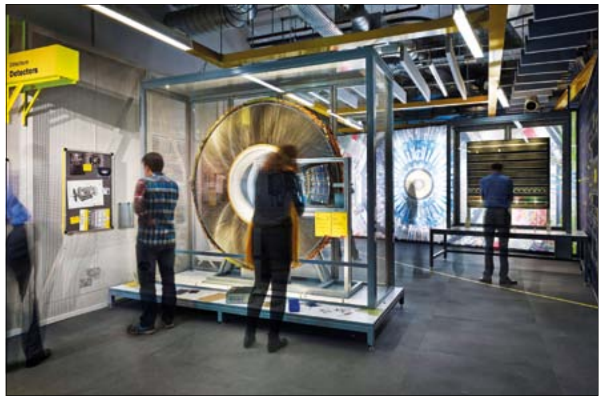
Collider, a new exhibition about the LHC, opened to the public on 13 November at London's Science Museum. It will run until 6 May before a planned international tour.

The exhibition blends theatre, video and sound art with real artefacts from CERN. It begins in a small amphitheatre, where visitors get the feeling of sitting in the laboratory's main auditorium during the 2012 Higgs boson announcement. On-screen actors bring to life the excitement while explaining the basics of particle physics.

What follows gives visitors the sense of a real visit to the laboratory. They can wander through recreations ranging from the LHC tunnel to the corridor of Building 2, complete with posters and cartoons. Notes scribbled on whiteboards and life-size video recordings of people at CERN explain the engineering and science behind the LHC. The real objects on display range from RF cavities to detector electronics, while an immersive video animation conveys the scale of the particles and detectors.

The exhibition's launch was preceded by a series of webcast events on 12 November, during which Peter Higgs answered questions from high-school students. There was also an audience with Stephen Hawking and a discussion about science and art with writer and Man-Booker-Prize-winner Ian McEwan and theorist Nima Arkani-Hamed.

● To find out more about *Collider*, see www.sciencemuseum.org.uk/collider. Tickets are available via the Science Museum website and entry is free for CERN access-badge holders.



Visitors examine examples of the transition-radiation tracker in ATLAS (left) and the time-projection chamber in ALICE (right), just some of the artefacts on display at the Collider *exhibition. (Image credit: Nick Rochowski for the Science Museum.)*

AFRICA

Developing high-energy physics in Madagascar

The 6th High-Energy Physics International Conference in Madagascar, HEP-MAD 13, took place on 4–10 September at the Ministry of Foreign Affairs in Antananarivo. This series of conferences – initiated in 2001 by Stephan Narison of the Laboratoire Univers et Particules in Montpellier and formerly supported by IN2P3/CNRS – alternates with the series of QCD conferences that Narison started in Montpellier in 1985. There were around 50 participants, including 12 from other countries.

New results from the ATLAS, CMS and LHCb experiments were presented, as well as from NA48 at CERN, Belle at KEK and Babar at SLAC. There were also theoretical contributions on Higgs-like models and QCD non-perturbative approaches such as QCD spectral sum-rules. In addition to high-energy physics, this conference series includes contributions from national researchers on other branches of physics such as climatology, nuclear physics and the environment. This allows researchers in Madagascar to have international visibility and publication of their research in the SLAC eConf online proceedings.

The HEP-MAD conferences are part of a programme for promoting high-energy physics in Madagascar and, more generally, developing countries, according to the ideas expressed by the late Abdus Salam while Narison was a postdoc at the International Centre for Theoretical Physics (ICTP) in Trieste in 1979. (He continues to be supported by ICTP as a consultant.)

In addition to the HEP-MAD conferences, two other main activities have been established. The creation of a high-energy-physics research institute in Madagascar in 2004 provides a platform for training PhD students, some of whom have gone to CERN as summer students and worked for up to two months with LHCb, thanks to the effort of John Ellis, who was one of CERN's advisers for non-member states, and the LHCb collaboration. Some of the students also participated in the African School of Physics (*CERN Courier* November 2012 p36). A second activity centred on the popularization of high-energy physics at high schools and the general public in different regions of Madagascar. An elementary introduction to the field – the book *Particle Physics: From the Ionian School to the Higgs Boson* – is under preparation.

Participants at HEP-MAD 13, with Stephan Narison at front, centre right. (Image credit: HEP-MAD.)

To manage these various activities and other developments, Narison created the Association Gasy Miara-Mandroso (AGMM) – Malagasy growing and advancing together – in 2009. More recently, the University of Antananarivo offered land inside the campus for construction of a high-energy-physics research institute.

In recognition of these activities and for developing science in Madagascar, Narison was nominated Grand Officier de l'Ordre National Malgache in January 2012 and Associate Member of the Malagasy National Academy in February 2013.

● For more about HEP-MAD 13, see www.lupm.univ-montp2.fr/users/qcd/econf13/index13.htm.

WORKSHOP

Theory and experiment study strangeness in the universe

Experts and young researchers from across the world converged on the European Centre for Theoretical Studies in Nuclear Physics and Related Areas – ECT* – in Trento, Italy, on 21–25 October for the international workshop "Strangeness in the Universe? Theoretical and Experimental Progress and Challenges". They discussed the most recent achievements and challenges in antikaon nuclear physics, as described by low-energy QCD, and its possible role in astrophysics and the universe.

Strangeness nuclear physics has a wide impact on contemporary physics. Lying at the intersection of nuclear physics and particle physics, it also has significant implications for astrophysics. It is a rapidly evolving field, with new data coming from numerous experiments.

Among recent results, the first exploratory measurement of kaonic deuterium by SIDDHARTA at the DAΦNE facility at the Frascati National Laboratory now allows detailed planning of the precision measurement at SIDDHARTA-2. When combined with SIDDHARTA's measurement of kaonic hydrogen, this will enable the first extraction of the isospin-dependent antikaon–nucleon scattering lengths, which are fundamental quantities in the understanding of low-energy QCD in the strangeness sector. The experiments E15 at the Japan Proton Accelerator Research Complex (J-PARC) and AMADEUS at DAΦNE have gained preliminary results in the search of the deeply-bound kaonic states, but these are not yet conclusive. Further studies are necessary

Participants outside the Villa Tambosi, home to ECT. (Image credit: C Curceanu.)*

to assign the status of these states.

On the theoretical side, refined calculations and methods – such as effective field theories, lattice calculations, few- and many-body approaches – are yielding results with steadily improving precision. Combined with the experimental findings, these allow a better and more accurate understanding of the processes occurring in the low-energy QCD sector. However, many open problems are still to be solved, some of which play a key role. These include the nature of the Λ(1405), on which new results are coming from AMADEUS; the kaon–nucleon/nucleus and hyperon–nucleon/nucleus interactions at very low energies – including the possible existence of deeply bound kaonic nuclear states – where a proposal for J-PARC was discussed; and the issue of hyperon–hyperon interactions and systems with double strangeness, which will be studied in the proposed PANDA experiment at the Facility for Antiproton and Ion Research.

Another rapidly evolving field – based on increasing amounts of experimental data in strangeness physics and advances in microscopic theories, together with new data coming from astronomy and astrophysics – is the study of the possible role of strangeness in the universe. Items such as the equation of state for neutron stars including strangeness (hyperons or kaons), or even (strange) quark stars or strangelets, are flourishing fields of research. Wolfram Weise, director of ECT*, presented a fascinating report on these issues, starting from the discovery of neutron stars of two solar masses (*CERN Courier* December 2010 p10). Isaac Vidaña of the Center for Computational Physics, University of Coimbra, gave an ECT* colloquium where he explored in detail the connection between hyperons, quarks and neutron stars. Japanese plans in this direction, under the Neutron Star Matter Project, were discussed by Hirokazu Tamura of Tohoku University.

In addition, a special event on 23 October was dedicated to "Paul Kienle's Scientific Heritage", where his broad scientific and managerial activities were reviewed, together with memories of his unique personality (*CERN Courier* May 2013 p47).

The workshop was organized by Catalina Curceanu (LNF-INFN, Italy), Carlo Guaraldo (LNF-INFN, Italy), Jiri Mares (Nuclear Physics Institute, Rez Prague, Czech Republic), Johann Marton (SMI-Vienna, Austria) and Johann Zmeskal (SMI-Vienna, Austria).

● For full details and the presentations, see http://hades.smi.oeaw.ac.at/ect_star_2013/.

EDUCATION

School joins the MoEDAL collaboration

The principal investigator for any institute joining an experimental collaboration is generally a self-assured researcher with evident leadership skills and in-depth knowledge of their subject gained over many years. Katherine Evans fits the brief in every respect, except that she is 17 years old and her research institute is the Langton Star Centre, based at the Simon Langton Grammar School for Boys.

Students from Simon Langton Grammar School for Boys, with Katherine Evans (right), and teacher Becky Parker (left), in the MoEDAL experimental area.

The school has just joined the MoEDAL collaboration – a small-scale experiment at the LHC that is designed to search for magnetic monopoles and other highly ionizing stable massive particles (*CERN Courier* September 2012 p10).

Under the leadership of teacher Becky Parker, Langton school has taken a ground-breaking approach to science, encouraging its students to participate in fundamental research alongside established research institutes and universities. Students there have been working with Timepix chips on a variety of projects for some time (*CERN Courier* May 2010 p22). It is this knowledge of Timepix, and specifically using it to monitor radiation, that interested MoEDAL.

SUMMER SCHOOL

Heidelberg focuses on diffraction at the LHC

With the interest of the diffractive-physics community currently focused on results from the first run of the LHC, the status and prospects of the ALICE, ATLAS, CMS, LHCb and TOTEM experiments were key topics for the 2nd Wilhelm and Else Heraeus School on Diffractive and Electromagnetic Processes at High Energies, which took place in Heidelberg on 2–6 September with 48 participants. The programme consisted of invited talks on diffractive research at HERA – DESY's former electron–proton collider – the Tevatron proton–antiproton collider at Fermilab and the LHC. Participating students also had the opportunity to present their own research results.

The lectures began with an introduction by Alan Martin from the Institute of Particle Physics Phenomenology, Durham. CERN's Martin Poghosyan then summarized the general principles of diffractive scattering, and Laszlo Jenkovzsky from the Bogoliubov Institute of Theoretical Physics, Kiev, discussed diffractive processes with low-mass proton excitations. A model that treats the pomeron as effective rank-two tensor exchange was discussed by Otto Nachtmann from the Institute of Theoretical Physics, Heidelberg. Connecting Regge phenomenology with quantum field theory, the model is based on a formulation of effective vertices and propagators for C=+1 and C=–1 singlet exchanges. Such a formulation naturally incorporates equal-sign coupling of the pomeron to protons and antiprotons, as opposed to vector exchange, which implies an opposite-sign coupling.

Strong electromagnetic field effects in ultra-relativistic heavy-ion collisions were covered by Valeriy Serbo from Novosibirsk State University and ultra-peripheral heavy-ion reactions were discussed by Joakim Nystrand from Bergen University. Wolfgang Schäfer from the Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN), Cracow, summarized diffractive processes in hadron-nucleus and photon-nucleus reactions and Mike Peardon of Trinity College Dublin discussed the hadron spectrum in lattice QCD.

Reviews of the lessons learned at CERN's Intersecting Storage Rings and at HERA were presented by Mike Albrow from Fermilab and by Lidia Goerlich and Jan Figiel, both from IFJ PAN. The results from the Tevatron were summarized by Christina Mesropian from Rockefeller

Participants at the school in front of the new building of the Physikalisches Institut in Neuenheimer Feld, Heidelberg. (Image credit: Rainer Schicker, Heidelberg.)

University. Suh-Urk Chung from CERN/TU-Munich discussed the latest results on diffractive excitations of the pion from the COMPASS experiment and reviewed the status of searches for glueballs in central production in the WA76, WA91 and WA102 experiments, all at CERN.

Several speakers covered the on-going programme in diffractive physics at the LHC. The status of diffractive and forward physics in the CMS and ATLAS experiments was discussed by Katerina Kuznetsova from KIT Karlsruhe and Christoph Royon from IRFU Saclay, respectively, and CERN's Mario Deile reviewed the latest results from TOTEM. LHCb's programme of diffractive and forward physics was presented by Ronan McNulty from University College Dublin and Gerardo Herrera Corral from CINVESTAV Mexico discussed diffractive physics with ALICE.

The lecture programme ended with a review of exclusive processes by Antoni Szczurek from IFJ PAN. The prize for best poster was awarded to Hector Bello Martinez from Puebla University for his work on event-shape analysis in ALICE. Participants were also able to learn about the history of physics in Heidelberg in an evening lecture by Peter Glässel from Heidelberg University, and had the opportunity to visit the old part of the town in a guided tour.

● For more about the school, visit http://school-diff2013.physi.uni-heidelberg.de.

Despite bad weather, almost 1600 people visited the ALBA synchrotron near Barcelona during its open day on 16 November. Following an itinerary of about 1.5 hours, they had the opportunity to learn from ALBA's scientists and technicians what a synchrotron is, how it works and what the main applications are. Visitors were also able to see the accelerator tunnel. Activities for children – one of the novelties this year – proved very successful. The open day is part of an outreach programme that also includes guided tours inside the facility, and in 2013 ALBA received more than 5000 visitors in total. (Image credit: Pepo Segura.)

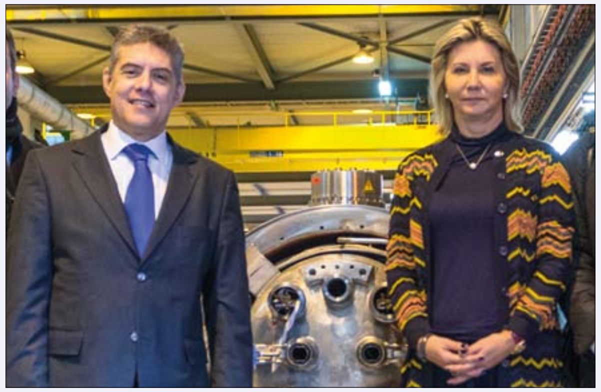
Visits

Miguel Temboury Redondo, left, deputy secretary of the Spanish Ministry for Economic Affairs and Competitiveness, visited CERN on 21 October, with **Maria Luisa Poncela García**, the ministry's secretary-general for science, technology and innovation, and **Jaime Pérez Renovales**, deputy secretary of the ministry for the presidency, right. Here they are seen in the LHC superconducting magnet test hall.

Peter Gluckman, chief science adviser to the prime minister of New Zealand, visited CERN on 22 October. After a general introduction to CERN's activities by director-general **Rolf Heuer**, he visited the CMS underground experimental area.

Former US vice president **Al Gore** visited the CMS experimental cavern and the LHC tunnel on 28 October, before signing the guest book alongside **Sergio Bertolucci**,CERN's director for research and scientific computing.

On 29 October, **Hans Blix**, former director-general of the International Atomic Energy Agency, left, visited CERN on the occasion of the Thorium Energy Conference (ThEC13). He toured the LHC tunnel with **Egil Lillestol**, middle, chair of the ThEC13 organization committee, and **Arjan Verweij**, of CERN's Technology Department.



Greek deputy minister of health **Zoi Makri**, right, visited CERN on 27 November with governor of Thessaly, **Konstantinos Agorastos**, left. After a visit to the ATLAS underground experimental area and the LHC tunnel, they visited the LHC superconducting magnet test hall, where they are seen here, and the Antiproton Decelerator.

Obituaries

Gustav-Adolf Voss 1929–2013

Gustav-Adolf Voss, an eminent and highly respected accelerator scientist, passed away in Hamburg on 5 October at the age of 84, after a short serious illness.

Voss was director of the DESY accelerator division from 1973 to 1994. He had a major impact on the development of both the DESY laboratory and the field of particle accelerators worldwide. With his strong, charismatic personality, sharp mind and extraordinarily high motivation, he also had a formative influence on many people who had the privilege to work closely with him.

After obtaining his PhD at the Technical University of Berlin, Gustav-Adolf Voss had his first contact with DESY in 1958/1959. He was sent to Harvard University in the US to study injector concepts for the new electron accelerator that was to be built at DESY. He then decided to stay at Harvard and join the bypass project to upgrade the Cambridge Electron Accelerator (CEA) to a colliding electron–positron beam facility. This extremely challenging project generated a number of innovations to which he made essential contributions. Voss himself spoke about these years with the small but outstandingly competent and innovative CEA team as the most influential, exciting and challenging time of his career. Here the foundation was also laid for what later became known as the legendary "Voss style".

In 1973, Voss was appointed a member of the DESY directorate (and as professor at Hamburg University in 1975) and took over as head of the accelerator division. The DORIS electron–positron storage ring was commissioned in 1974 and, soon after, plans for a much larger storage ring, PETRA, began to take shape. This project was successfully implemented under

Gustav-Adolf Voss. (Image credit: DESY.)

the competent leadership of Voss during 1975–1978 and became an outstanding success. The construction time was about one year shorter than planned and the cost was well below budget. PETRA was ahead of the competing project PEP at Stanford and, shortly after commissioning, one of DESY's most outstanding scientific successes was obtained there with the discovery of the gluon in 1979.

The HERA electron–proton collider project started in 1984, led jointly by Björn Wiik and Voss, with Voss in charge of the electron ring, buildings and technical infrastructure. First colliding electron and proton beams were obtained in 1991. One unique feature of the electron ring was the possibility of longitudinal spin-polarization, which was successfully established in 1993 and then available for many years of experimentation at HERA.

During the HERA construction and commissioning phase, Voss realized the potential of linear accelerators and discussed with an initially small group of scientists both conventional and innovative approaches towards a next-generation colliding beam facility. After retirement in 1995, he remained closely connected to DESY and was often a curious and constructively critical partner in discussions on topics where advice or technical-scientific discourse was sought. In later years he became passionately engaged in the synchrotron radiation facility SESAME, which is under construction in Jordan. As an international project, SESAME brings together in science the states in the Middle East.

For his long-standing accomplishments in science, his essential contributions to the development of particle accelerators, his commitment to supporting scientists from eastern Europe after the breakdown of the Soviet Union and for his dedication to SESAME, Voss received numerous awards, among them the Order of Merit of the Federal Republic of Germany, the honorary doctorate of the University of Heidelberg, the Wilson Prize of the American Physical Society and the Tate Medal of the American Institute of Physics. For his numerous contributions to DESY, in 2009 he became the first person to receive the DESY Golden Pin of Honour.

With the death of Gustav-Adolf Voss, the accelerator-based scientific community has lost one of its most influential figures and an outstanding personality to whom many of us owe a great debt.

● *Reinhard Brinkmann, Norbert Holtkamp and Herman Winick.*

Kenneth Wilson 1936–2013

Physics visionary Kenneth G Wilson, winner of the 1982 Nobel Prize in Physics for his research at Cornell, died on 15 June. He was 77. In the words of fellow Nobel laureate Steven Weinberg, "Ken Wilson was one of a very small number of physicists who changed the way we all think, not just about specific phenomena, but about a vast range of different phenomena."

Wilson was born on 8 June 1936 in Waltham, Massachusetts. He earned his PhD in 1961 from the California Institute of Technology, studying under Murray Gell-Mann. Subsequently, as a junior fellow at Harvard, while waiting for output from a computer, he proved a mathematical conjecture proposed by Freeman Dyson.

In 1963, Wilson joined the Cornell physics department and was soon given tenure even though he had hardly published. As he later said in his Nobel autobiography, "My very strong desire to work in quantum field theory did not seem likely to lead to quick publications; but I had already found out that I seemed to be able to get jobs even if I didn't publish anything so I did not worry about publish or perish."

Wilson's Nobel-Prize-winning research stemmed from work on phase transitions by Michael Fisher and Benjamin Widom at

Cornell and Leo Kadanoff at the University of Illinois. Their findings motivated Wilson to ask whether his own work on quantum fields would be amenable to a similar approach, for all of these phenomena involve huge numbers of variables describing a range of length scales. In the 1970s, this inspired Wilson to formulate a mathematical scheme called the renormalization group, for which he received the Nobel Prize.

Following this work on phase transitions, Wilson turned again to quantum field theory and quantum chromodynamics (QCD), then newly proposed. He created a version of QCD on a space–time lattice that made it possible for the first time to analyse the strong force that binds quarks together.

"He was decades ahead of his time with respect to computing and networks as well," says Paul Ginsparg, professor of physics and information science, who was one of Wilson's advisees when he was a graduate student at Cornell in the 1970s. "After inventing lattice gauge theory in 1974, he found he didn't have adequate computing power to solve the theory numerically, so he wanted easy ways to use large numbers of parallel processors." So Wilson became a pioneer in the field of supercomputing, and was instrumental in the US National Science Foundation's establishment of five national scientific supercomputing centres, one at Cornell.

Kenneth Wilson, centre, with Hans Bethe, right, and Boyce McDaniel, left, at Cornell, celebrating the award of the Nobel Prize in Physics to Wilson in 1982. Bethe had received the Nobel Prize in 1967 and McDaniel was the lab director from 1967 to 1985. (Image credit: Cornell-LEPP Laboratory.)

Wilson was widely recognized for other scientific accomplishments, with awards including Israel's Wolf Prize in Physics in 1980 and an honorary doctorate of science from Harvard University in 1981. In 1987, he left Cornell for Ohio State University, where he helped to found the Physics Education Research Group and focused on physics and science education.

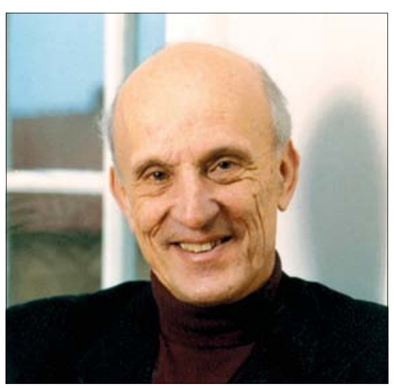
Wilson is survived by his wife, Alison Brown, his brother, David Wilson, a professor of molecular biology at Cornell, four other siblings and a stepmother.

● *Based – with permission – on the obituary on the* Cornell Chronicle *website, http://news.cornell.edu/stories/2013/06/physics-nobel-laureate-kenneth-wilson-dies.*

Bengt Lörstad 1941–2013

Bengt Lörstad passed away all too soon on 19 November after a two-year struggle with cancer.

Bengt's remarkable career started with PhD studies in elementary particle physics at the Collège de France and Orsay where he received his *docteur d'etat ès sciences* in 1969. He was then employed at Lund University, first working with an experiment at the Lund electron synchrotron but soon also participating in the experiments of the British–Scandinavian collaboration at CERN's Intersecting Storage Rings. He was a CERN fellow during 1973–1975 and afterwards became involved in the Axial-Field Spectrometer (R807), the NA34 and NA44 experiments at the Super Proton Synchrotron, and finally the DELPHI experiment at the Large Electron–Positron Collider. During this "golden" period of new understanding of the phenomena of the strong interaction he contributed in particular through measurements of pion–pion and kaon–kaon interferometry – the so-called Bose–Einstein correlation. This interest carried on into the 1990s, when he started a Buda–Lund collaboration with Tamas Csörgö, which resulted in several papers with many citations. The analysis from this work also included a fit to data from Brookhaven's Relativistic Heavy-Ion Collider, for example the various hydrodynamical scaling relationships of the elliptic flow v_2.



Bengt Lörstad. (Image credit: Lund University.)

Besides his scientific skills, Bengt also possessed a remarkable social and administrative talent, which led to his election as head of the physics department in Lund during 1988–1998, and in 1999–2004 an appointment as president of Kristianstad Högskola, a college for higher education. When finishing there he became a senior adviser to the vice-chancellor of Lund University. At CERN, Bengt was a member of the Advisory Committee on Computing and Data Handling Policy and also contributed to the High-Energy Physics Network, and locally in Lund to the Swedish University Network and the Lund University Computer Centre for many years.

Bengt was an excellent flute player, early on playing with Bleckhornen – the Lund University brass band – and later as a soloist in classical chamber-music groups. He was a devoted golfer, sharing the interest of his wife Ylva, and until the end remained positive and in remarkably good spirits. We all miss him very much.

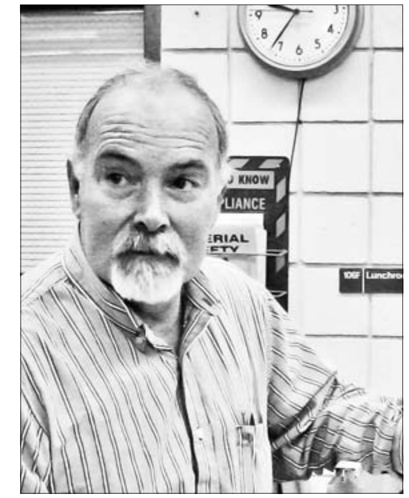
● *Göran Jarlskog and Torsten Åkesson.*

James White 1953–2013

In 2010, the Texans came to Valencia and brought with them the field cage of NEXT-DEMO, a large prototype of the NEXT detector – a high-pressure xenon time-projection chamber to search for neutrinoless double beta decay events, now being constructed at the Canfranc Underground Laboratory in Spain. It was a beauty – the sleek cylinder, the dented peek bars, which made the backbone that held the aluminum rings, the Teflon panels, arranged in a pretty hexagon that shone in blue after we coated them with wavelength shifter. We assembled it in two days of frenzy. None of us moved from the lab, except for pizzas, showers and a few hours of sleep, until it was ready to go in. "Will it work, James?" I dared to ask finally, before we switched on. "Sure it will," he said. "These things are easy."

Yes, these things were easy for James White. He was, as aptly put by a close colleague and friend, "one of the top practitioners in the art of experiment".

James was born in El Paso, Texas, in 1953 and grew up close to the border between Texas and Mexico, in the words of another friend, "chasing snakes, scorpions and any other varmints that he might find entertaining". He attended graduate school at the University of California, San Diego, and in 1986 he arrived at Texas A&M University, where he would eventually become a full professor.



James White. (Image credit: Bob Webb.)

His career spanned many areas, from the measurement of hadronic cross-sections to collider physics – he was the leader of the D0 TAMU group and part of the team that discovered the top quark. At some point, however, James became a knight in the quest for the holy grail of finding new stuff. Inevitably, that led him to searches for dark matter, first with the ZEPLIN experiment, then with LUX and LZ. He was a major player in each of those experiments.

It is widely recognized that James was one of the very few physicists in the US who had appreciated the scientific opportunities available with the noble elements in the gas phase. His contributions in the area advanced the field. Indeed, without his help, expertise and know-how, launching the NEXT project would have been much more difficult, if possible at all.

Beyond his wizardry as an instrumentalist and his can-do approach that made impossible problems "easy", James was a friend, teacher and role model for all of us who had the privilege to work with him. He was, and always will be, our own, private, Texan hero.

● *Dave Nygren, Bob Webb and Juan José Gómez-Cadenas, on behalf of NEXT, LUX and LZ collaborators, and friends and colleagues everywhere.*

New products

Elytt Energy has announced the Capacitive Discharge Generator CDG 7000. The CDG Series is designed for the detection of insulation failures in wound products such as magnets, solenoids or motors. With a capacitive discharge of up to 7000 V through the device under test and maximum output peak current of 500 A, it is possible to detect insulation failures by graphical comparison of the waveforms of a sound device and the device under test. In addition, the high-voltage test can provide the value of the inductance and information about the output waveform. For more details, e-mail leticia.vaquero@elytt.com or visit www.elytt.com.

Hamamatsu Photonics has introduced an updated range of Multi-Pixel Photon Counter (MPPC) detectors. The MPPC detectors use a Geiger-mode pixelated avalanche photodiode structure for ultra-low-level light detection. Each pixel contains a quenching circuit so that simultaneous photon events can be counted separately and accurately. The detectors feature gains from 250,000 to several million and high photon detection efficiency from 320 nm to 900 nm. They can be operated at low voltage (<80 V) and are insensitive to magnetic fields. For further information, e-mail info@hamamatsu.eu or visit www.hamamatsu.com.

Maxon Motor AG has expanded its DCX series with two new DC motors. The DCX 10S is a shorter version of the DCX 10L. With an output power of up to 1.4 W in a 10 mm diameter, it works at approximately 35 dBA. The DCX 22L is the new longer version of the DCX 22S. With a diameter of 22 mm, it outperforms the RE 25, while achieving the same power but with 30% less volume and weight. The GPX 22 gearhead is also available in a version with reduced noise level and with ceramic axes. For more details, tel +41 41 666 15 00, fax +41 41 666 16 50 or visit www.maxonmotor.com.

Murata has announced the MEU1 series of ultra-miniature single isolated output 1 W DC–DC converters. Measuring 8.30 × 6.10 × 7.55 mm, a total of 14 models are available across the series, catering for input voltages of 3.3, 5, or 12 VDC and providing outputs of 3.3, 5, 9, 12, or 15 VDC. Murata has also announced the D1U54P series of 54 mm wide, 1200 W front-end power supplies. With efficiency above 94% and power density greater than 28 W per cubic inch, the units measure 54.5 × 321.5 × 40 mm and fit the 1U package format. For further information, contact Aya Tonooka: tel +44 1252 811666, e-mail atonooka@murata.co.uk, or visit www.murata.eu.

The RUBIS-PRECIS/MICROPIERRE/HTC group has developed new assemblies in high-tech materials, including titanium and ceramics used in new leading markets such as space, aeronautics, medicine and analysis. The assembly technologies used are metallizing and brazing, laser welding and crimping. These high-tech assemblies can solve many difficult problems, such as wear or corrosion resistance in harsh environments, insulation at ultra-high temperature or voltage, resistance in ultra-high vacuum or high pressure. For more details, e-mail rubis@rubis-precis.com or visit www.rubis-precis.com.

Recruitment

Deputy Director, Accelerator Division

Brookhaven National Laboratory – National Synchrotron Light Source II

The Accelerator Division of the new NSLS-II synchrotron, which will start delivering beam to users by the Fall of 2014, is seeking a Deputy Accelerator Division Director. The successful candidate will report to the Division Director and provide support in managing the operations of the NSLS-II accelerator, executing upgrade projects, and reporting status to Laboratory management and DOE. The Deputy will also assist in supervising and providing guidance to the excellent technical and scientific staff of the accelerator division.

Qualifications Required:

- PhD in Physics or a related discipline
- Proven record as a successful accelerator physicist/engineer recognized in the accelerator community
- 10 years experience in operating accelerators
- Success in managing accelerator projects
- Experience in overall project management, operations management, and the management of human resources
- Understanding of typical interface issues in a multifaceted complex synchrotron environment
- Excellent communication and interpersonal skills and the ability to interact effectively with a diverse group of technical staff
- Comprehensive organizational skills and demonstrated success in roles requiring execution of multiple tasks while responding to multiple priorities
- Strong supervisory or mentoring abilities.

Please apply at **www.bnl.gov/hr/careers** and apply to Job ID# 16555.

BROOKHAVEN NATIONAL LABORATORY
NSLS-II

Cornell University

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Postdoctoral Associate

The Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE) invites applications for a Postdoctoral Associate position with its effort on Fermilab E989, the Muon g-2 experiment. The Cornell group plays significant roles in the development of both the detector and the muon storage ring beam instrumentation. Hardware responsibilities range from for development of a new, fast injection kicker, which is required to store the muon beam, to the development of the electromagnetic calorimeter electronics for detecting decay electrons. The Cornell group also plays a leading role in a broad range of simulation and analysis efforts covering muon beam dynamics, detector performance, and the spin precession analysis. The successful applicant will assume key responsibilities in the electronics design and construction projects, as well as in the development of reconstruction and analysis techniques for the determination of g-2, and in the commissioning / analysis activities of the experiment. To maintain continuity of effort, the postdoc position will ideally begin late Spring or early Summer, 2014.

Applicants must have a PhD in experimental high energy, nuclear or accelerator physics. Applications should be submitted at https://academicjobsonline.org/ajo/jobs/3676 and should include a CV, a list of publications, a statement of research interests, and three letters of recommendation. All materials, including all letters of recommendation, must be received by January 31, 2014. For information about the position, contact Prof. Lawrence Gibbons at lawrence.gibbons@cornell.edu.

Cornell University is an equal-opportunity/affirmative action employer.

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Students will join an internationally leading education program with 40+ PhD students at the Cockcroft Institute. Students will be placed in one of the partner universities (Lancaster, Liverpool or Manchester) in either Physics or Engineering departments, depending on the applicant's aptitude, preference and suitability to the posts.

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More detail on individual projects can be found at:
http://www.cockcroft.ac.uk/education/informationPhd.htm
Queries can be sent to Dr G. Burt.
Email: graeme.burt@cockcroft.ac.uk

Prospective students should forward a CV and supporting materials to: Janis Davidson,
Email: janis.davidson@stfc.ac.uk
Closing date for applications: 28th February, 2014

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DESY

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

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- ultimate optimization of high brightness electron beams by generating 3D ellipsoidal electron bunches, and
- beam driven plasma acceleration experiments on the self-modulation of particle beams and on the efficient generation of beam driven plasma wakes.

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- Development of innovative concepts and techniques for the diagnostics of high-quality laser and electron beams
- Perform numerical simulations to study and optimize subcomponents of the photo injector with respect to applications of high brightness electron beams for FELs and in plasma acceleration experiments
- Participate in the shift operation of PITZ for accelerator R&D

Requirements

- Excellent university degree in physics or engineering (for Postdoc applicants: PhD degree)
- Knowledge of accelerator physics and accelerator techniques
- Knowledge of laser and incoherent optics and/or plasma acceleration is of advantage
- Experience in beam dynamics simulations and numerical methods is useful
- Very good knowledge of English is required and knowledge of German is of advantage

For further information please contact Dr. Frank Stephan, phone +49 33762-77338.

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

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Deadline for applications: Until the positions are filled
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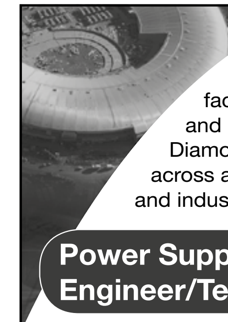

Diamond Light Source is the UK's national synchrotron science facility. Located at Harwell Science and Innovation Campus in Oxfordshire, Diamond enables world-leading research across a wide range of scientific disciplines and industrial applications.

Power Supplies: Head of Group/ Engineer/Technician Vacancies

Diamond's accelerators contain over 1200 magnet power supplies of various types including DC, cycling and pulsed systems. High stability, reproducibility and reliability are essential for these systems which are critical to the operation of the facility. Diamond is now seeking a number of staff to work in the Power Supply Group at various possible grades.

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Senior Power Supply Engineer (DIA0889-b/NH)/ Power Supply Engineer (DIA0889-c/NH)

You will play a key role in the Power Supply Group, leading power supply design and development projects that are required to meet the evolving requirements of the accelerators. You will also coordinate planning and maintenance activities and analysing fault statistics to identify power supply enhancements that will improve reliability.

Senior Power Supply Technician (DIA0889-d/NH)/ Power Supply Technician (DIA0889-e/NH)

You will contribute to the work of the Power Supply Group, including planned maintenance activities and the installation and commissioning of new power supplies that are required to meet the evolving requirements of the accelerators.

These positions offer comprehensive benefits, competitive salary, dependent on qualifications and relevant experience, and a relocation package where applicable.

Closing date: 31 January 2014.

For further information on these vacancies see www.diamond.ac.uk

www.diamond.ac.uk
diamond

Diamond Light Source Ltd, Diamond House, Harwell Science and Innovation Campus, Didcot, Oxfordshire OX11 0DE

RWTH AACHEN UNIVERSITY

Full Professor (W3)
in Theoretical Astroparticle Physics and Cosmology
Faculty of Mathematics, Computer Science, and Natural Sciences

We are seeking qualified applicants for teaching and research in the area of theoretical astroparticle physics and cosmology. The starting date is the winter term 2014/15. The professorship should establish theoretical astroparticle physics and cosmology as a central reasearch activity at the RWTH Aachen University and at the Forschungszentrum Jülich through the Jülich-Aachen research alliance JARA-FAME. A close collaboration with the groups of theoretical particle physics and experimental astro particle physics will be appreciated. Contributions to the teaching in our bachelor porgram in physics and in our international master's program in physics is expected.

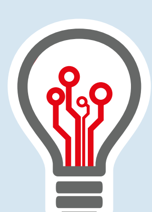
A Ph.D. degree is required; additionally, Habilitation (post-doctoral lecturing qualification), an exemplary record of research achievement as an assistant / an associate / a junior professor or university researcher and/or an outstanding career outside academia are highly desirable. Ability in and commitment to teaching are essential. German is not necessary to begin but will be expected as a teaching language within the first 5 years.

The application should include supporting documents regarding success in teaching.

Please send a cover letter stating research aims and a CV to: An den Dekan der Fakultät 1 der RWTH Aachen, Prof. Dr. Stefan Kowalewski, 52056 Aachen, Germany. The deadline for applications is February, 28th, 2014.

This position is also available as part-time employment per request. RWTH Aachen University is certified as a family-friendly university and offers a dual career program for partner hiring. We particularly welcome and encourage applications from women, disabled people and ethnic minority groups, recognizing they are underrepresented across RWTH Aachen University. The principles of fair and open competition apply and appointments will be made on merit.

brightrecruits.com



The jobs site for physics and engineering

TECHNISCHE UNIVERSITÄT DARMSTADT

The Department of Physics at the Technische Universität Darmstadt has an opening for a

Full Professor (W3) in "Theoretical Nuclear Physics"

(Code. No. 475)

The Professorship is part of the new Theory Center at the Institute for Nuclear Physics.

We are seeking an outstanding individual who will broadly contribute to theoretical physics in research and teaching, and enhance the activities at the Institute for Nuclear Physics. Applications are invited in the area of the field-theoretical description of strongly interacting systems within the framework of Quantum Chromodynamics. Active participation in existing and future collaborative research activities of the Institute of Nuclear Physics and the Department of Physics is expected. Present initiatives include the Helmholtz International Center for FAIR, the Helmholtz Extreme Matter Institute (EMMI), and the Collaborative Research Center 634.

The position is tenured with a remuneration package commensurate with experience and qualifications, following the German "W-Besoldung". The regulations for employment are specified under §§ 61 and 62 HHG (Hessisches Hochschulgesetz).

The Technische Universität Darmstadt intends to increase the number of female faculty members and encourages female candidates to apply. In case of equal qualifications applicants with a degree of disability of at least 50 or equal will be given preference.

Applications including a curriculum vitae, list of publications, as well as a description of research and teaching activities should be sent by **February 28, 2014** to the Head of the Department of Physics, Technische Universität Darmstadt, Pankratiusstr. 2, D-64289 Darmstadt, Germany.

NUI MAYNOOTH

Ollscoil na hÉireann Má Nuad

The National University of Ireland Maynooth (NUI Maynooth) is the fastest growing university in Ireland with over 8,500 students and outstanding research and scholarship in the sciences, humanities and social sciences. The university is now entering a new and exciting phase of its development, with a new strategic plan centred on further enhancing our academic programmes, providing a distinctive student experience of the highest quality, focusing our research activities on a small number of priority themes, and further internationalising the university. To support this development, the university is seeking to recruit outstanding academics, with a strong track record of research and teaching, to the following position:

Assistant Lecturer / Lecturer in Mathematical Physics

For job specification and application information, please see http://humanresources.nuim.ie/vacancies.shtml

The deadline for applications is 2nd March 2014.

National University of Ireland Maynooth is an equal opportunities employer

EUROPEAN SPALLATION SOURCE

The European Spallation Source is preparing to construct a world-leading European materials research centre in Lund, Sweden. ESS is an international partnership of 17 European countries.

Be part of the future!

We are looking for a highly qualified:

Technical Director

ESS Technical Directorate is responsible for delivery of the ESS Accelerator, Target and Integrated Control Systems. The Technical Director provides leadership and professional direction to the staff, and manages the planning and implementation of the Directorate's work scope.

For more details, have a look at:
http://europeanspallationsource.se/vacancies

Stony Brook University

Endowed Chair in Theoretical Physics

Stony Brook University seeks a senior faculty appointment in theoretical physics at the level of full professor to occupy the Chen Ning Yang-Deng Wei Chair, now being established. This appointment will be in the C.N. Yang Institute for Theoretical Physics, with affiliation to the Department of Physics and Astronomy. Candidates should have demonstrated exceptional scholarly achievement and potential in research. The ability to attract external funding and leadership potential will also be considered for this position. The position will include an independent research fund and carry a nationally-competitive salary.

The C. N. Yang Institute for Theoretical Physics was established in 1966 and is named for its founding director. It carries on a proud tradition of front-line research and committed education and training. Its faculty, graduates and post-doctoral alumni are active throughout the international scientific community. Current faculty carry on research in a wide range of theoretical physics, including field and string theory, particle phenomenology, statistical mechanics and quantum information. The research interests of candidates for this position may be in any area of theoretical physics, astrophysics and cosmology.

The Institute is an independent unit of Stony Brook University, reporting to the Provost. It has numerous collaborative interactions with the Department of Physics and Astronomy, the Department of Mathematics and the Simons Center for Geometry and Physics, and with other departments at Stony Brook University and with nearby Brookhaven National Laboratory. Stony Brook University is located on the scenic North Shore of Long Island. It has active cultural programs and is convenient to New York City. It has numerous leading graduate programs, and its 1,100 acre campus and 13,500 faculty and staff serve over 24,000 students. The University is a member of the Association of American Universities and co-manager of Brookhaven National Laboratory, a multidisciplinary research laboratory supporting world-class scientific programs utilizing state-of-the-art facilities.

To view application procedure, full position description or to apply online visit **www.stonybrook.edu/jobs** (**Ref. # F-8330-13-11**). Nominations and suggestions from our colleagues as well as direct applications are welcome at **http://max2.physics.sunysb.edu/chairsearch/**.

Stony Brook University/SUNY is an equal opportunity, affirmative action employer.

FACULTY POSITION
Physics
NYU SHANGHAI

NYU Shanghai's Department of Physics is currently inviting applications for a faculty position at all levels (assistant, associate, and full professor) in the general areas of hard condensed matter, atomic molecular and optical physics and quantum information. The opening is for a theoretical physicist, but experimental physicists will also be considered.

Candidates must have completed a Ph.D. and are expected to establish a leading research program in their field, as well as teach at the undergraduate level. This position is part of an initiative to create a strong program in this area, through the hiring of several faculty, with the aim of establishing research programs that relate strongly to those at other NYU campuses. The appointment could begin as soon as September 1, 2014, pending administrative and budgetary approval.

New York University has established itself as a Global Network University, with three degree-granting campuses - New York, Shanghai, and Abu Dhabi - complemented by twelve additional academic centers across five continents. NYU Shanghai is the first Sino-US higher education joint venture to grant a degree that is accredited in the U.S. as well as in China. A research university with liberal arts and sciences at its core, it resides in one of the world's great cities which is also a vibrant intellectual community (http://shanghai.nyu.edu/). NYU Shanghai will recruit scholars who are committed to our global vision of transformative teaching and innovative research.

The terms of employment in NYU Shanghai are comparable to U.S. institutions. Faculty may also spend time at NYU New York and other sites of the global network, engaging in both research and teaching opportunities.

Applicants should submit curriculum vitae, statement of research and teaching interests, electronic copies of up to five recent relevant publications, and the names and email addresses of three references. *The search will remain open until the position is filled, but review of applications will begin* ***January 21, 2014***.

Please visit our website at **http://shanghai.nyu.edu/about/open-positions-faculty** for instructions and other information on how to apply. If you have any questions, please e-mail **shanghai.faculty.recruitment@nyu.edu**.

NYU SHANGHAI

NYU Shanghai is an Equal Opportunity/Affirmative Action Employer.

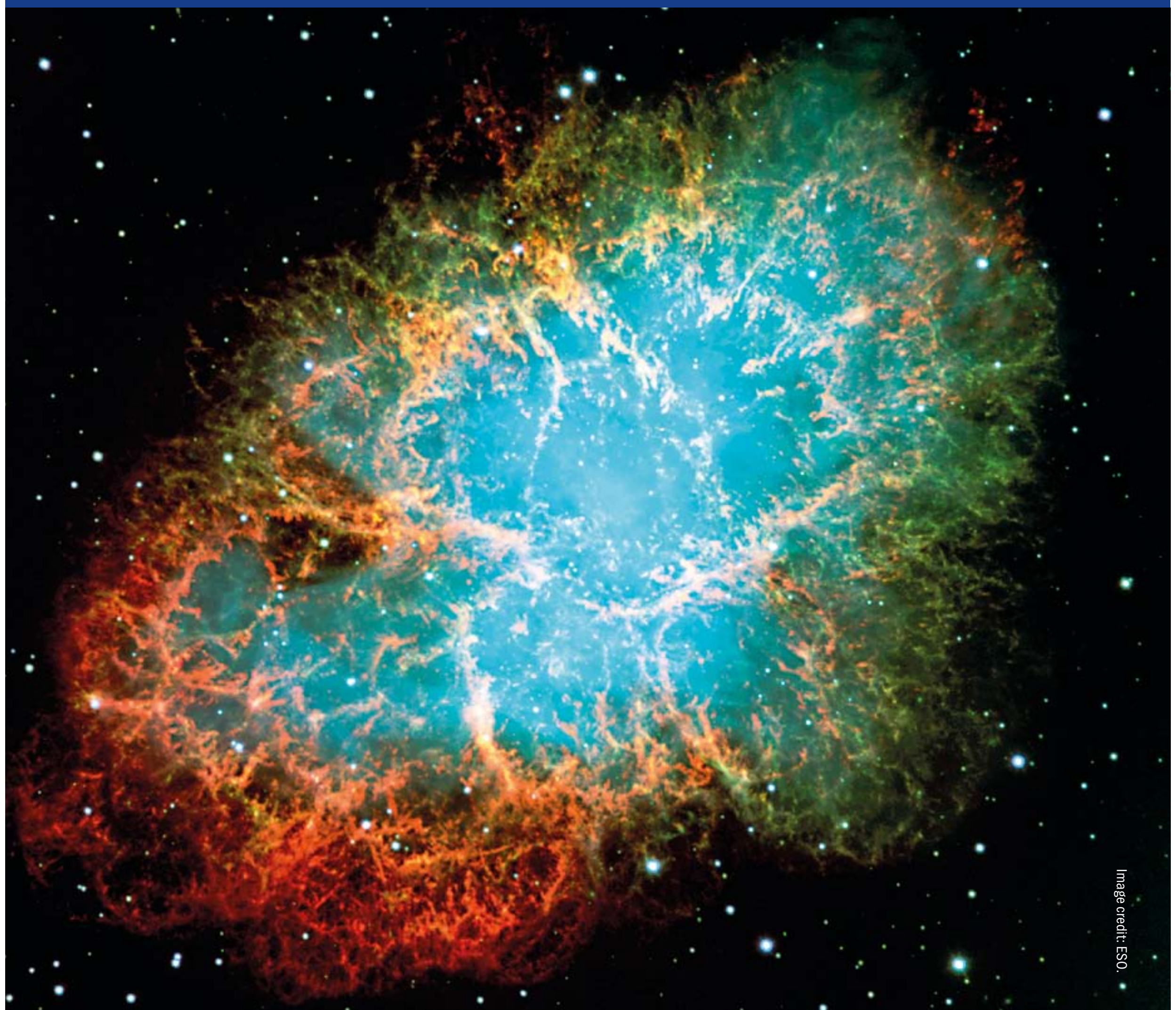
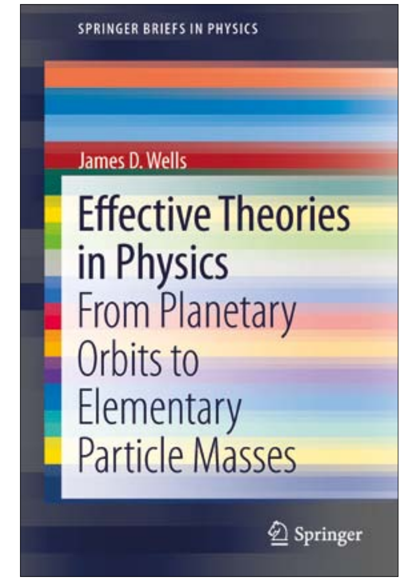
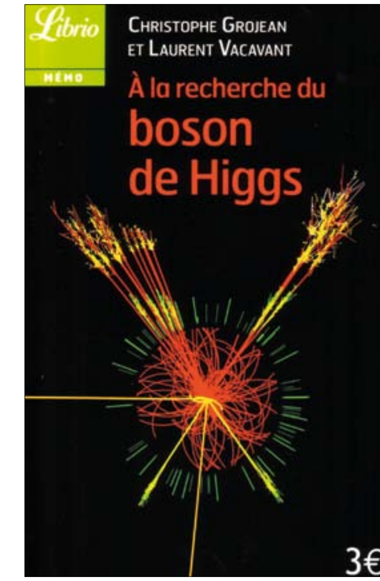


Image credit: ESO.

CERN Courier January/February 2014

Bookshelf





Effective Theories in Physics: From Planetary Orbits to Elementary Particle Masses
By James D Wells
Springer Verlag
Paperback: £44.99 €52.70 $49.95
E-book: £35.99 €41.64 $39.95

This remarkable and charming book introduces the idea of effective field theories from a novel point of view, making the concepts natural and – in retrospect – inevitable. As the author makes clear, all theories are effective theories. At just 73 pages, it is easily accessible to a graduate student or a bright undergraduate. It will also be welcomed by professional physicists for its readability and clear, compelling style.

In introducing the idea of effective theories, the author begins by considering Galileo's law for falling bodies, neglecting air resistance. Keeping the symmetries assumed for the problem – here translational invariance – and the idea that the constant downward acceleration might be an approximation to a more complete theory that involves a dependence of *g* on height above the ground, Wells derives the form of the leading correction by taking into account Newton's law of gravitation without explicitly invoking the inverse square law. Such an effective theory could have been used to search for an extension to Galileo's law or to accommodate data, even in the absence of Newton's more complete theory of gravity. The second chapter continues the discussion of gravity, this time assuming circular orbits (and the simple harmonic oscillator) and the sorts of deviations that might be allowed for, using the ideas of effective theories to analyse deviations from perfect circularity.

Chapter 3 considers effective theories of classical gravity, arguing for the general expectation of perihelion precession and that something like black holes could have been predicted and the Schwarzschild radius estimated before the discovery of general relativity. Using both Lagrangian and Hamiltonian formulations of the problem, this discussion is not only enlightening but a delight to read. The presentation of effective theories in these simple contexts – requiring neither field theory nor even quantum mechanics – makes their meaning, importance and universality clearer than the usual, more advanced introductions.

Assuming some knowledge of the Standard Model, chapter 4 shows how the Fermi theory can be thought of as an effective field theory that approximates it. Here the author considers in some detail the origin of mass and in particular neutrino masses beyond the Standard Model. He then concludes with a discussion of naturalness and the hierarchy problem – all from the viewpoint of effective theories.

The fifth and final chapter is more philosophical in nature, emphasizing how and why effective theories are more than truncations of more comprehensive theory. It also looks at how one can go about choosing between theories, before closing with implications for the LHC.

I was pleasantly surprised by this book. The approach is original and makes the whole concept of effective theories clear and natural. I will be urging all of my students to take an afternoon to read this wonderful introduction – and to think carefully and deeply about the many points that the author makes so well.

● *John Swain, Northeastern University.*

À la recherche du boson de Higgs
De Christophe Grosjean et Laurent Vacavant
Librio
Broché : €3

Vous n'avez rien compris au boson de Higgs ? Alors ce petit livre est peut-être fait pour vous. Il faut saluer en effet le très grand effort des auteurs pour tenter de rendre accessible à tous les concepts qui se cachent derrière l'une des plus grandes découvertes de ces dernières années.

De la relativité au mécanisme qui donne leur masse aux particules, en passant par la physique quantique, cet ouvrage aborde le plus simplement possible les notions qui permettront à chacun d'appréhender le monde complexe des particules ainsi que les lois du Modèle standard. Les nombreuses analogies – souvent drôles – aident à rendre concrets des phénomènes le plus souvent abstraits que seul le formalisme mathématique est en mesure de réellement retranscrire. Vous découvrirez notamment dans cet ouvrage pourquoi le père Noël ne peut être qu'un objet quantique vu son comportement (c'est de saison), ou encore pourquoi la recherche du boson de Higgs revient à chercher un tibia de mammouth dans un immense cimetière d'éléphants !

Bien sûr, les spécialistes et les puristes trouveront certainement des défauts à certaines analogies : nul doute que nous n'avons pas terminé de discuter sur la meilleure manière de présenter simplement le mécanisme de Higgs… L'avantage de ce petit livre, c'est aussi qu'en moins d'une centaine de pages, il aborde les grandes étapes de l'aventure du LHC en les replaçant dans le contexte historique et international. Il rend également compte des stratégies et technologies mises en œuvre dans les expériences ATLAS et CMS pour enregistrer et traiter une quantité de données vraiment phénoménale.

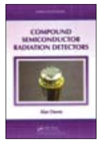
Je recommande donc sans hésitation la lecture de cet ouvrage pour sa concision, sa simplicité et son approche légère qui devrait

Bookshelf

ravir tous ceux dont la vue d'une simple équation est en mesure de provoquer une indigestion.
● *Amaud Marsollier, CERN.*

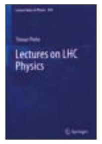
Books received

Compound Semiconductor Radiation Detectors
By Alan Owens
CRC Press
Hardback: £82
Also available as an e-book



Bringing together information scattered across many disciplines, this book summarizes the status of research in compound semiconductor radiation detectors. It examines the properties, growth and characterization of compound semiconductors as well as the fabrication of radiation sensors, with emphasis on the X- and γ-ray regimes. It explores the limitations of compound semiconductors and discusses current efforts to improve spectral performances, pointing to where future discoveries might lie. A resource for the established researcher, this book serves as a comprehensive and illustrated reference on material science, crystal growth, metrology, detector physics and spectroscopy. It can also be used as a textbook for those who are new to the field.

Lectures on LHC Physics
By Tilman Plehn
Springer
Paperback: £40.99 €47.43 $59.95
E-book: £31.99 €35.69 $39.95



Anyone trying to apply the solid knowledge of quantum field theory to actual LHC physics – in particular to the Higgs sector and certain regimes of QCD – inevitably meets an intricate maze of phenomenological know-how, common lore and intuition, often historically grown, about what works and what does not. These lectures are intended to be a brief but sufficiently detailed primer on LHC physics that will enable graduate students and any newcomer to the field to find their way through the more advanced literature, as well as helping them to start work in this timely and exciting field of research.

The Conceptual Framework of Quantum Field Theory
By Anthony Duncan
Oxford University Press
Hardback: £77.50
Also available as an e-book

This book attempts to provide an introduction to quantum field theory by emphasizing conceptual issues. The aim is to build up the theory systematically from clearly stated foundations. The first section, "Origins", consists of two historical chapters that situate quantum field theory in the larger context of modern physical theories. The three remaining sections follow a step-by-step reconstruction of this framework, beginning with a few basic assumptions: relativistic invariance, the basic principles of quantum mechanics, and the prohibition of physical action at a distance embodied in the clustering principle. Problems are included at the ends of the chapters and solutions can be requested via the publisher's website.

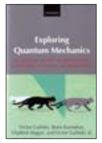
Silicon Solid State Devices and Radiation Detection
By Claude Leroy and Pier-Giorgio Rancoita
World Scientific
Hardback: £89
E-book: £67

Using their many years of experience both in research with silicon detectors and in giving lectures at various levels, Leroy and Rancoita address the fundamental principles of interactions between radiation and matter, together with working principles and the operation of particle detectors based on silicon solid-state devices. They cover a range of fields of application of radiation detectors based on these devices, from low- to high-energy physics experiments, including those in outer space and medicine. Their book also covers state-of-the-art detection techniques in the use of such radiation detectors and their read-out electronics, including the latest developments in pixellated silicon radiation detectors and their applications.

Quantum Field Theories in Two Dimensions: Collected Works of Alexei Zamolodchikov (2 volumes)
By Alexander Belavin, Yaroslav Pugai and Alexander Zamolodchikov (ed.)
World Scientific
Hardback: £124

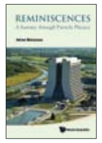
These two volumes contain original contributions of Alexei Zamolodchikov (1952–2007), who was a prominent theoretical physicist of his time. Volume 1 contains his work on conformal field theories, 2D quantum gravity and Liouville theory. Volume 2 includes his pioneering work on non-perturbative methods in 2D quantum field theory and on integrable models. Both volumes can be used as an advanced textbook by graduate students specializing in string theory, conformal field theory and integrable models of quantum field theory. They are also highly relevant to experts in these fields.

Exploring Quantum Mechanics: A Collection of 700+ Solved Problems for Students, Lecturers, and Researchers
By Victor Galitski, Boris Karnakov, Vladimir Kogan and Victor Galitski Jr
Oxford University Press
Hardback: £95 $165
Paperback: £45 $84.99
Also available as an e-book



Mastering quantum physics is a non-trivial task and a deep understanding can only be achieved through working out real-life problems and examples. It is notoriously difficult to come up with new quantum-mechanical problems that would be solvable with a pencil and paper, within a finite amount of time. This book presents more than 700 original problems in quantum mechanics, together with detailed solutions covering all aspects of quantum science. Collected during 60 years, first by the late Victor Galitski Sr, the material is largely new to an English-speaking audience. New problems were added and the material polished by Boris Karnakov. Finally, Victor Galitski Jr, has extended the material with problems relevant to modern science.

Reminiscences: A Journey through Particle Physics
By Adrian Melissinos
World Scientific
Hardback: £28
E-book: £21



A personal account as a research physicist for more than 50 years in areas of particle physics and related fields, Adrian Melissinos's insights into the ways that general research was carried out and the evolution of particle physics from 1958 to 2008 will prove interesting to science-history enthusiasts and particle physicists alike. Through this mix of personal reminiscences and professional journey, readers can relive the joy and excitement of research and teaching in small groups during those early years, while gaining a partial historical perspective of particle physics since the late 1950s.

Viewpoint

A celebration of science for peace

At the start of CERN's 60th anniversary year, the current director-general looks at the organization's role in bringing nations together.

On 17 May 1954, the seeds for peaceful scientific research were sown as the first shovels of earth were turned on CERN's Meyrin site.

On 29 September 1954, the European Organization for Nuclear Research officially came into being, after the convention to establish the organization had been ratified by a sufficient number of the 12 founding member states. Since then, CERN has in many ways become a model for what Europe can do when it unites, bridging nationalities and bringing different cultures together to work towards a common goal.

During the past 60 years, CERN has grown to become a world-leading physics laboratory, fulfilling the dreams of its founders as summarized in the convention, which states that "The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available." The convention goes on to assert that, in addition to the construction of accelerators, experiments and infrastructure, the basic programme should encompass international co-operation in research, along with the promotion of contact between scientists, training of scientists and dissemination of knowledge across borders.

Times have changed, but the spirit of openness and peaceful collaboration enshrined in the visionary words of the convention continues to shape CERN to this day. The nature of the laboratory's research has gone far beyond the atomic nucleus to encompass the basic particles of matter and how they interact through fundamental forces to form the fabric of the universe. The organization's collaboration now extends far beyond the boundaries of Europe, as scientists and engineers from around the world work together at CERN – and those from CERN contribute to projects around the world. The dissemination of information, education and training also continue to be key guiding factors in the programme today – all in the spirit of the convention. Knowledge gained through the laboratory's frontier research is made available for applications that benefit society. CERN schools held in many different countries allow a new generation of scientists and engineers not only to learn about frontier research but also to form friendships across national boundaries.

As we advance further into the 21st century, the organization is still going strong and maintaining its attraction of international scientific collaboration. It has grown steadily since 1954, with the latest country to join – Israel – bringing the total number of member states to 21. Other countries are in the stages leading up to becoming members or associates and still others are expressing interest. CERN is becoming a global success, while retaining its original, European flavour.

This year's events for the 60th anniversary will celebrate the theme of international collaboration. In particular, there will be activities in all of the member states, reflecting the fact that CERN is their laboratory. While the main celebration at CERN will be on 29 September – the exact anniversary of when the organization came into being – an earlier event will take place at the headquarters of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in Paris on 1 July. CERN was born under the umbrella of UNESCO, and it was in Paris on that day in 1953 that the convention was signed.

What drives this huge collaborative effort is, of course, the science – the fundamental physics remains as exciting as ever and continues to attract people to CERN, from bright young scientists and engineers to the general public of all ages and from all walks of life. The discovery of a new particle at the LHC and the confirmation last year that it was indeed a Higgs boson, emissary of the Brout–Englert–Higgs mechanism that endows fundamental particles with mass, has been the latest success – and a major reward for the effort, in many countries, that went into the design, construction and running of the LHC and its experiments. The award of the 2013 Nobel Prize in Physics to François Englert and Peter Higgs (Robert Brout sadly passed away in 2011), which recognized the importance of this key piece of fundamental physics, was a marvellous early 60th birthday present.

The result of more than two decades of effort by thousands of scientists and engineers from around the world, this discovery exemplifies the collaborative nature of research at CERN. It also reflects the freedom to work together with open minds towards a common goal – a freedom that has underpinned advances in science throughout the ages. This freedom to think and to communicate was prominent in the minds of those who came together more than 60 years ago to establish an organization in which fundamental science could flourish. Thanks to the work of the many people who have been involved with the organization since then, I believe that CERN has more than fulfilled the hopes and dreams of advancing science for peace.

● *Rolf Heuer, CERN.*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• Compact
• Cost Effective
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SY5527LC Universal Multichannel System Low Cost (4 slot)
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CERNCOURIER

Volume 54 Number 1 January/February 2014

Contents

CERNCOURIER

Volume 54 Number 1 January/February 2014

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