WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the June 2014 issue of *CERN Courier*.

In February 2013, CERN's accelerator complex began its first long shutdown in the LHC era. After more than a year, the complex is beginning to reawaken, and the consolidation work on the LHC is reaching its finale. The LHC has produced vast amounts of data, some of which is available for schools to study in the International Masterclasses. These take place in many countries, giving students a real feel for the international side of particle physics. Such collaboration began in Europe with CERN's founding 60 years ago. Now, collaboration with CERN extends to regions such as Latin America. At the same time, new international facilities continue to be built for scientific research. The latest, the European Spallation Source, will provide an intense source of neutrons for a variety of studies.

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CERNCOURIER

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CERNCOURIER

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On the cover: A technician uses a mirror to inspect the positioning of the resistive soldering ovens around the last of 27,120 copper shunts that have been added to the LHC magnet interconnections, as part of the consolidation work of the first long shutdown, LS1 (p5). (Image credit: CERN-PHOTO-201404-092 – 28.)

News

CERN

LS1: reawakening the accelerators

CERN's accelerator complex is gradually restarting, more than a year after the start of the first long shutdown (LS1). On 4 April, a team switched on the proton source and a week later re-commissioning began on Linac2. Beams are scheduled to be sent to the Proton Synchrotron Booster (PSB) at the end of May and then on to the Proton Synchrotron (PS) by mid-June, reaching the Super Proton Synchrotron (SPS) later this year, with the LHC restart on course for early 2015. One LHC sector has already begun the long cool down towards its operating temperature.

Since LS1 began, the Superconducting Magnets And Circuits Consolidation (SMACC) project has formed a "train" of workers in the LHC tunnel, with "wagons" of teams distributed across the eight sectors. The end of April marked the installation of the last of the 27,000 shunts – low-resistance connections to consolidate the 10,000 "splices" that interconnect the superconducting magnet bus bars and can carry currents up to 13,000 A. The shunts provide an alternative path for a portion of this current in the event that a splice loses its superconducting state, to avoid repeating the incident in September 2008 that delayed the start-up of the LHC (*CERN Courier* September 2010 p27).

To install a shunt, the SMACC team had to first open the area around the interconnection, slide custom-built metallic bellows out of the way and remove the thermal shielding within. This revealed a series of metallic pipes linking the magnets to each other. One set of these pipes – the "M lines" – then had to be cut open to access the splices between the superconducting cables. The team opened up the last of the M lines in February this year (*CERN Courier* April 2014 p5), and since then has been continuing to install the shunts, finishing on 30 April.

Now, emphasis is shifting from installation to testing, including short-circuit tests to verify all of the LHC's hardware components – cables, interlocks, energy extraction systems, power converters that provide current to the superconducting magnets, and the cooling system. The most complicated components are the superconducting circuits, which have a myriad of different failure modes with interlock and control systems. Testing these circuits now dramatically reduces the time spent in the tunnel during the powering tests at low temperatures, which are planned to start in August. Although the magnet circuits themselves cannot be tested at warm temperatures, the teams can verify the power converter and the circuits up to where the cables enter the magnets. These circuits are tested at the highest current the power converters can achieve – higher than the nominal current in the machine – for a few hours to a day. Teams then verify that the warming effect of the current stabilizes at a temperature that does not affect the behaviour of the cables. To do this, they use infrared cameras to check the temperature rise of the different parts of the circuit.

As well as short-circuit tests, electrical quality-assurance testing (ELQA) is ongoing. Sector 6-7 showed no non-conformities and, on 7 May, was the first of the LHC sectors to begin the cool down to 1.8 K. The other seven sectors will follow as the long journey of the SMACC train approaches its end and the teams complete their final tasks.

Above: By mid-April, the team welding the M-lines back together after installation of the shunts had entered the last LHC sector to be worked on. (Image credit: CERN-PHOTO-201404-084 – 6.) Right: The last of the 27,000 electrical shunts, installed on 30 April. (Image credit: CERN-PHOTO-201404-092 – 33.)

Sommaire en français

Atmospheric physics

CLOUD sees through the haze

The CLOUD (Cosmic Leaving OUtdoor Droplets) experiment at CERN, which is studying whether cosmic rays have a climatically significant effect on aerosols and clouds, is also tackling one of the most challenging problems in atmospheric science – understanding how new aerosol particles are formed in the atmosphere and the effect that these particles have on climate. Aerosol particles and clouds have a large net cooling effect on the planet and, according to the Intergovernmental Panel on Climate Change, they represent the largest source of uncertainty in present climate models. A new study published by CLOUD now sheds new light on the first steps of cloud formation, helping to improve our understanding of the aerosol–cloud–climate connection.

Cloud droplets form on aerosol particles – tiny solid or liquid particles suspended in the atmosphere – above a size of about 50 nm. Aerosol particles are either emitted directly into the atmosphere (like sea-spray particles) or else form by the spontaneous clustering ("nucleation") of trace atmospheric molecules. Around one half of all cloud seeds are thought to originate from nucleated particles, but the process is poorly understood. Sulphuric acid is thought to play a key role, but previous studies by CLOUD have shown that it cannot form new particles in the lower atmosphere without another ingredient to glue the molecules together and prevent them evaporating (*CERN Courier* October 2011 p28). CLOUD recently showed one such ingredient to be a class of vapours known as amines (*CERN Courier* November 2013 p6). However, these are only found close to primary sources, such as animal husbandry, so another ingredient must be involved.

Vapours at the level of one part in 10^{12} control atmospheric nucleation, so it is a challenge to meet the technological requirements for studies in the laboratory. The chamber used by the CLOUD collaboration has achieved much lower concentrations of contaminants than previous experiments, allowing nucleation to be measured under atmospheric conditions for the first time without the complicating effect of undetected gases. CLOUD uses state-of-the-art instruments to measure these very low concentrations of atmospheric vapours and also to measure the chemistry and growth of newly formed molecular clusters from single molecules up to stable particles. Another unique aspect of the experiment is the capability to measure nucleation arising from ionization by cosmic rays, or from the enhanced ionization provided by a pion beam from CERN's Proton Synchrotron – or with the effects of all ionization suppressed completely by means of a strong electric clearing field.

CLOUD has found that a substance emitted by trees, known as alpha-pinene, plays a key role in the formation of aerosol particles that can give rise to cloud droplets – and also produce the "blue haze" seen when viewing distant mountains. (Image credit: Jon Ingall /Dreamstime.com.)

For the latest results, CLOUD studied particle nucleation involving the oxidation products of a volatile biogenic vapour known as alpha-pinene, which gives pine forests their familiar smell. This and similar volatile biogenic vapours are oxidized in the atmosphere to produce daughter vapours with extremely low volatility. During the past few years, numerous studies have shown the importance of these oxidized biogenic vapours for growing freshly nucleated particles to sizes where they can seed cloud droplets. However, it was not known if these oxidized biogenic vapours could provide the glue to help the first sulphuric acid molecules stick together to form embryonic particles.

Now, CLOUD has shown that oxidized biogenic vapours do form new particles with sulphuric acid and, moreover, that this process can explain a large fraction of particle formation observed in the lower atmosphere. Ions produced in the atmosphere by galactic cosmic rays are found to provide significant additional stability to the clusters, but only when the concentrations of sulphuric acid and oxidized organic vapours are relatively low.

In addition to the experimental measurements, the CLOUD team reported theoretical and global modelling studies. Quantum chemical calculations confirm the stability of the embryonic clusters of sulphuric acid and oxidized organics. Moreover, a global modelling study that includes the new nucleation mechanism has captured – for the first time – the pronounced seasonal variation of new particle production that is observed in the atmosphere. The modelling results establish that trees play a fundamental role in forming new particles in the atmosphere, which is familiar as "blue haze" when viewing distant mountains.

● The CLOUD collaboration consists of the California Institute of Technology, Carnegie Mellon University, CERN, Finnish Meteorological Institute, Helsinki Institute of Physics, Johann Wolfgang Goethe University Frankfurt, Karlsruhe Institute of Technology, Lebedev Physical Institute, Leibniz Institute for Tropospheric Research, Paul Scherrer Institute, University of Beira Interior, University of Eastern Finland, University of Helsinki, University of Innsbruck, University of Leeds, University of Lisbon, University of Manchester, University of Stockholm and University of Vienna.

● Further reading

F Riccobono *et al.* (CLOUD collaboration) 2014 *Science* DOI 10.1126/science.1243527.

***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.

CONFERENCE

Quark Matter 2014: news from ALICE

XXIV QUARK MATTER DARMSTADT 2014

The 25th Quark Matter conference was held on 19–25 May. Here is a foretaste of some of the results from two of the LHC experiments. The will be more to come in later issues.

The new results shown by the ALICE collaboration at the Quark Matter 2014 conference in Darmstadt focus principally on the most recent collisions at the LHC – those of protons and lead nuclei (pPb) performed towards the end of Run 1 in early 2013. Planned mainly as a control experiment for studies of deconfined matter in lead–lead (PbPb) collisions, the pPb run in fact revealed tantalizing possibilities for studying collective phenomena in small systems, but with exceedingly-high-energy densities. This subject, already tackled in several theoretical papers, featured at the conference. Having already published interesting results on flow-like correlations measured via the azimuthal emission patterns of particles, ALICE presented a host of results on particle correlations, extending out to mesons containing charm quarks (D mesons).

The initial-state effects (gluon shadowing) are studied in pPb collisions via the nuclear modification factor, which quantifies the measurement in nuclear collisions with respect to that in pp collisions scaled by the corresponding number of binary collisions. Its dependence on transverse momentum (p_T) for inclusive charged-particle production, already obtained with the data of the pilot pPb run of 2012 has been extended up to p_T of 50 GeV/c (figure 1). The data support the binary-collision scaling up to the highest measured p_T and confirm the predictions from saturation/shadowing models.

ALICE has obtained results for a variety of hadron species, including charmed and beauty hadrons (directly identified or studied via their decays into electrons or muons), as figure 2 shows. An enhancement at p_T values around 5 GeV/c – known from measurements at lower energies as the "Cronin effect" – is found for protons and observed to depend on the "centrality" of the collision. For all hadrons, binary-collision scaling is fulfilled at high p_T in pPb collisions. By contrast, in PbPb collisions, the measured suppression of hadron production is an indication of strong interactions within the hot and dense medium (or jet quenching, measured also with reconstructed jets).

Studies of Bose–Einstein pion correlations with two and three pions demonstrate that, in pPb collisions, the size of the system at freeze-out is closer to that in pp collisions than to PbPb, for events with the same particle multiplicities.

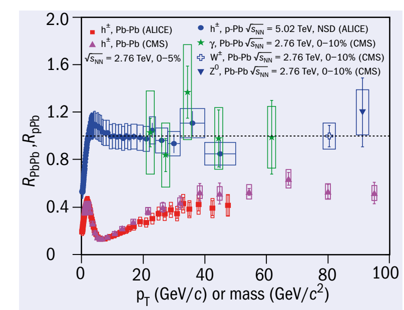
ALICE has also found that the ψ(2S) charmonium state is more suppressed in pPb, compared with expectations from the scaling of production in pp collisions, than its lower-mass sibling J/ψ. No convincing theoretical explanation has been put forward, but the ALICE results might imply a final-state effect, possibly owing to deconfined matter in pPb collisions.

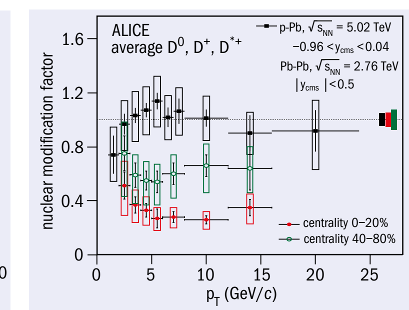
Another interesting measurement presented in Darmstadt is the dependence of open-charm hadrons (D mesons) and charmonium production on the multiplicity measured in pPb collisions.

The interpretation of the above results is complicated by the observation in ALICE that the connection between experimental observables and collision geometry (the impact parameter) is much more complex in pPb collisions than in PbPb. A comprehensive study performed with data on charged-particle production illustrates this, and is likely to imply further challenges to theory: not the geometry, but the "event activity" in terms of the hadron multiplicity in a given region of rapidity will need to be properly modelled in theoretical descriptions of pPb collisions.

Lastly, the pPb data allowed for a first measurement ever in ALICE – that of W-boson production, performed at forward and backward rapidities with triggered data from the muon spectrometer.

The results for PbPb collisions also span a range of observables. A comprehensive study of hadron production was presented, with comparisons across systems, PbPb, pPb, and pp, as well as with measurements at Brookhaven's Relativistic Heavy-Ion Collider (RHIC). Comparison of hadron abundances in PbPb collisions with





Left: Fig. 1. Transverse momentum dependence of the nuclear modification factor R_{pPb} of charged particles ($h^\pm$) measured in minimum-bias (NSD) pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV in ALICE, in comparison with data on the nuclear modification factor R_{PbPb} in central PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV in CMS (arXiv:1405.2737 [nucl-ex]). The PbPb data are for charged particle, direct photon, Z^0 and $W^\pm$ production. All data are for mid-rapidity. Right: Fig. 2. Transverse momentum dependence of the nuclear modification factor for D-meson production in minimum-bias pPb collisions and two centrality classes in PbPb collisions (arXiv:1405.3452 [nucl-ex]).

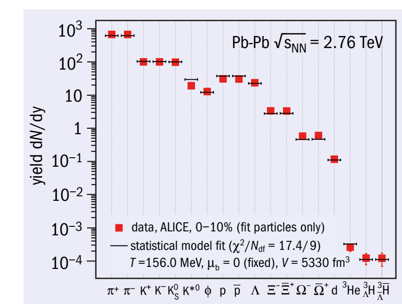


Fig. 3. Measured hadron abundances in comparison with thermal model calculations.

thermal-model calculations lead to a temperature value lower than that extracted from data from RHIC. Some distinct discrepancies between model and data, like that for protons, have been a hot subject of discussion for some time. Those notwithstanding, the measured hadron abundances are, remarkably, predicted by the thermal model at chemical freeze-out (figure 3, p9). The new ALICE data on (hyper)nuclei extend this conclusion to weakly-bound systems, such as the deuteron or the hypertriton.

Insights into collision dynamics are obtained from the analysis of spectra and flow of a variety of hadron species. Among them, the ϕ meson, containing a strange-antistrange quark pair and with a mass close to that of the proton, plays a prominent role. The data show that it is the mass of the ϕ meson, and not its quark content, that determines its p_T spectrum and flow. The measurement of ϒ production in PbPb reveals a rapidity-dependent suppression (figure 4), which finds no explanation in any theoretical model to date. This adds a new facet to the fascinating story of quarkonium in deconfined matter. Here, recent ALICE data on J/ψ agree with the theoretical understanding of charmonium production via (re)generation mechanisms at the chemical freeze-out or during the whole lifetime of the deconfined system.

The new measurement of the nuclear modification factor of electrons from beauty-hadron decays is a first step in

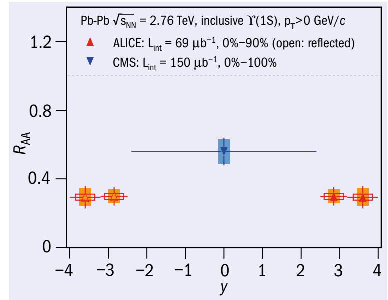


Fig. 4. Rapidity dependence of the nuclear modification factor for Υ(1S) production in PbPb collisions, as measured by ALICE and CMS.

ALICE into the sector of b-quark energy loss. ALICE has also performed the first measurement of coherent ψ(2S) photoproduction in ultra-peripheral PbPb collisions. Albeit not directly a "Quark Matter" topic, this is a relevant measurement because it constrains parton shadowing in the colliding nuclei. Another premiere is the first measurement of particle-type jet fragmentation at hadron colliders, achieved in pp collisions in ALICE with pions, kaons, and protons up to $p_T = 20$ GeV/c.

A host of other results in PbPb collisions, covering jets, particle production and flow, and quarkonia – some already submitted for publication – mark the Quark Matter 2014 conference as a milestone in the ALICE physics output.

Quark Matter 2014: news from CMS

Although the CMS experiment was designed primarily for precise measurements in proton–proton (pp) collisions, in recent years it has demonstrated exceptional capabilities in studying interactions of heavy nuclei. At Quark Matter 2014, the CMS collaboration presented a wealth of new results from their heavy-ion physics programme. The most recent analyses focus on collisions of protons on lead ions (pPb), delivered by the LHC in early 2013.

At the forefront of such studies, CMS continues its investigation of the surprising "ridge phenomenon" (*CERN Courier* January 2013 p9). This long-range particle correlation had previously been observed in nucleus–nucleus (AA) collisions and is interpreted as evidence of the hydrodynamic expansion of the quark–gluon plasma (QGP) created in these collisions. Lighter

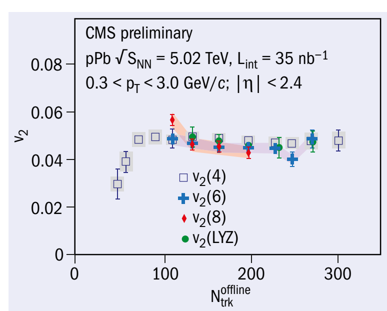


Fig. 1. The elliptic anisotropy parameter, v_2, as a function of the number of reconstructed tracks in pPb collisions using four-, six- and eight-particle cumulants, as well as the Lee–Yang zeros method.

collision systems such as pp and pPb were not expected to produce a dense enough environment to produce such a flow effect,

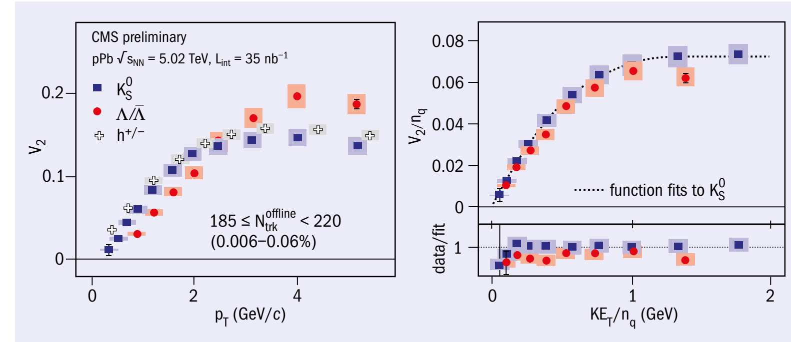


Fig. 2. Left: v_2 for K^0_s, Λ and non-identified charged hadrons vs p_T in high-multiplicity pPb collisions. Right: v_2 per consituent quark vs the transverse kinetic energy per constituent quark.

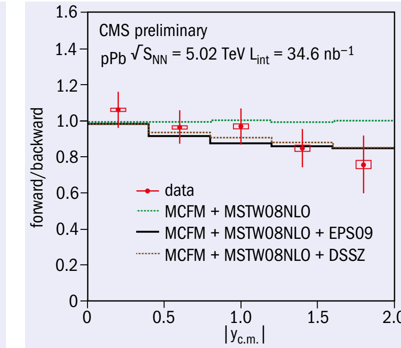


Fig. 3. The forward-to-backward ratio of Z boson production in pPb collisions as a function of rapidity. The data are compared to NLO calculations with and without nuclear effects.

which is thought to arise from the fluid-like behaviour of the QGP. Nevertheless, a similar correlation was observed in collisions with high particle multiplicity in both systems (CMS collaboration 2013).

Previous measurements focused mainly on correlations between particle pairs. However, it is important to address whether the ridge observed in pPb collisions is really collective in nature, and this can be achieved by looking into correlations among a larger number of particles. Flow effects are measured typically by looking at the azimuthal anisotropy of particle momenta using a Fourier decomposition. Figure 1 shows the magnitude of the second Fourier harmonic (v_2), as a function of total particle multiplicity, extracted using a multiparticle cumulant expansion, as well as using Lee–Yang zeros, a technique that probes the correlations among all particles in the event. That v_2 shows little dependence on the number of particles used in the correlation supports the interpretation of long-range correlations as a collective effect.

Further insight into long-range correlations might be gained by exploring their "hadro-chemistry". The CMS silicon tracking system is well suited to identifying hadrons that contain strange quarks, such as the K^0_s meson and Λ baryon, via their decay topologies. Figure 2 (left) shows a clear dependence on species when comparing v_2 for K^0_s, Λ and non-identified charged particles in high-multiplicity pPb events. Within about 10–15%, the data (figure 2, right) are found to obey a scaling relation first seen in AA collisions, whereby the v_2 per constituent quark is independent of particle species for the same transverse kinetic energy per constituent quark. In AA collisions, such a scaling is typically interpreted as evidence of flow developed at a very early time, before the quarks combine into final-state hadrons.

In addition to their role in elucidating collective effects in small systems, pPb collisions serve as an important reference for phenomena observed in PbPb collisions. Observables intended to probe the QGP might also be influenced by the initial state of the colliding nuclei. Nuclear effects on the parton distribution functions (PDFs) can be constrained with pPb collisions, i.e. in the absence of an extended QGP final state.

Shortly after the first pPb collisions were recorded, CMS demonstrated sensitivity to nuclear effects on the PDFs via a measurement of the dijet rapidity shift (CMS collaboration 2014). In addition to jets, electroweak bosons are excellent observables for studying PDFs, because their production can be calculated precisely and they can be measured to high precision, given sufficient data. For the rapidity range measured by CMS, the production of Z bosons is sensitive to the parton distributions at large Q^2 and Bjorken x in the range 10^{-3}–10^{-1}, a kinematical region that is largely unexplored by previous measurements.

In analysing the 2013 pPb data, the collaboration found more than 2000 Z bosons via their decays to muon pairs. Figure 3 shows the ratio of Z production at forward and backward rapidity in pPb collisions, where forward is the direction of the incident proton. The data are compared to next-to-leading order perturbative calculations produced with the MCFM generator, without and with the nuclear modifications to the parton distributions expected for two different parameterizations of nuclear effects (EPS09 and DSSZ). The data show an indication of the forward–backward asymmetry expected from these calculations. In conjunction with Z boson measurements in the electron channel, as well as other observables such as photons and W bosons, LHC data will soon begin to dominate knowledge of the nuclear parton

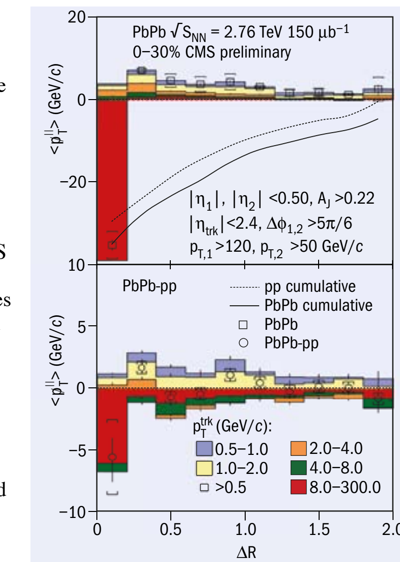


Fig. 4. Top: Missing p_T for unbalanced dijets in central PbPb collisions (0–30%) as a function of ΔR (distance of tracks to the jet axis). Bottom: The difference between the missing p_T distributions in central PbPb and pp collisions.

distributions in some regions of x and Q^2.

In addition to the pPb studies, CMS continues to perform increasingly detailed studies of the jet-quenching phenomenon, which gives rise to the striking dijet p_T asymmetries observed in PbPb collisions (CMS collaboration 2011). Tracing the fate of energy lost by hard-scattered partons in the dense QGP remains a fascinating challenge for the field. To investigate this in more detail, CMS looks at correlations of ▷

charged particles with asymmetric dijets in central collisions. To avoid sensitivity to the bulk of particle production, which is largely unrelated to the jets, the vector sum of the transverse momenta with respect to the dijet axis is considered. This "missing p_T" is shown in figure 4 (top, p11) as a function of the radial distance from the jets in central collisions for all charged particles, as well as individually for different ranges of p_T, for the 30% most central PbPb collisions. The missing-p_T analysis allows the first detailed study of the angular dependence of the momentum balance up to large distances from the jet axis ($\Delta R = 1.8$). By evaluating the difference with respect to the same distribution from pp collisions (figure 4, bottom), the angular pattern of the energy flow is shown to be comparable, although it exhibits a large shift in the momentum spectrum of radiated particles in PbPb collisions. The pattern of energy flow provides the most direct window into the dynamics of the jet–QGP interaction observed yet.

The results summarized here represent only a small fraction of the new results from CMS presented at Quark Matter 2014. All the latest CMS heavy-ion results can be found at https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN.

Further reading

CMS collaboration 2013 *Phys. Lett. B* **724** 213.
CMS collaboration 2014, arXiv:14014433v1, submitted to *EPJC*.
CMS collaboration 2011 *Phys. Rev. C* **84** 024906.

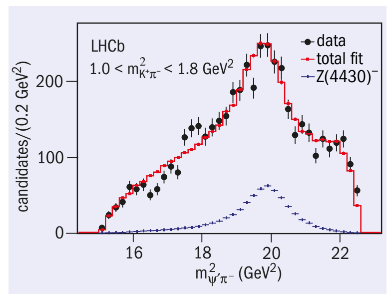
LHC PHYSICS

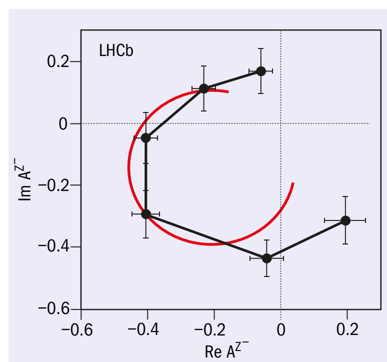
On the trail of exotic particles

Since the quark model was first conceived 50 years ago, physicists have been searching for "exotic" hadrons – strongly interacting particles that are neither quark–antiquark pairs (mesons) nor three-quark states (baryons). Now the LHCb collaboration has published results that for the first time unambiguously demonstrate the exotic nature of one of the candidate exotic hadrons – the Z(4430). At the same time, LHCb's measurements show that the $f_0(500)$ and the $f_0(980)$ states cannot be four-quark states (tetraquarks), contrary to what has long been suggested.

The first evidence for the Z(4430) came in 2008 from the Belle collaboration at KEK's B-factory, KEKB. It appeared as a narrow peak in the $\psi'\pi^-$ mass distribution in $B \rightarrow \psi' K\pi^-$ decays (*CERN Courier* January/February 2008 p7). With negative charge, the Z(4430) cannot be a charmonium state, raising the possibility that it could be a multiquark state, for example $c\bar{c}u\bar{d}$.

LHCb has now analysed about 25,200 decays of the kind $B^0 \rightarrow \psi' K\pi^-$, $\psi' \rightarrow \mu^+\mu^-$ in data corresponding to an integrated luminosity of 3 fb^{-1} of proton–proton collisions at the LHC at centre-of-mass energies of 7 and 8 TeV. The collaboration observes the Z(4430) in the $\psi'\pi^-$ mass distribution with a significance of at least 13.9σ, and determines the quantum numbers J^P to be 1^+, by ruling out 0^-, 1^-, 2^+ and 2^- at more than 9.7σ (LHCb collaboration 2014a). While this emphatically confirms the evidence from Belle, the LHCb analysis also establishes the resonant nature of the observed state. Its Argand diagram (figure 2) shows unambiguously that the Z(4430) really is a particle. Moreover, with a minimal quark content of $c\bar{c}u\bar{d}$, it must be a tetraquark state.





Top: Fig. 1. The measured distribution of the invariant-mass squared for $\psi'\pi^-$, with the contribution from the Z(4430) in blue. Bottom: Fig. 2. The Argand diagram for the Z(4430) follows approximately the circular path expected for a resonant particle state.

In a related analysis, LHCb has also studied the decay $B^0 \rightarrow J/\psi\pi^+\pi^-$, extracting the invariant mass of the $\pi^+\pi^-$ pairs. While this clearly reveals a peak corresponding to the $f_0(500)$ meson, there is no evidence for the $f_0(980)$. This rules out at 8σ the production of the $f_0(980)$ at the rate expected for tetraquarks, which would lead to a much smaller difference in the production rates for the two f_0 mesons. However, the $f_0(980)$ is clearly visible in the corresponding $\pi^+\pi^-$ invariant mass distribution for the decay $B^0_s \rightarrow J/\psi\pi^+\pi^-$. The absence of the $f_0(980)$ in B^0 decays and its presence in B^0_s decays in addition to the presence of the $f_0(500)$ only in the B^0 decays is exactly what is expected if these states are normal quark–antiquark states (LHCb collaboration 2014b).

Further reading

LHCb collaboration 2014a arXiv:1404.1903 [hep-ex].
LHCb collaboration 2014b arXiv:1404.5673 [hep-ex].

ATLAS searches for supersymmetry via electroweak production

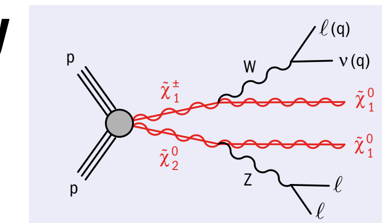
The Standard Model is currently the best theory there is of the subatomic world, but it fails to answer several fundamental questions, for example: why are the strengths of the fundamental interactions so different? What makes the Higgs boson light? What is dark matter made of? Such questions have led to the development of theories beyond the Standard Model, of which the most popular is supersymmetry (SUSY). In its most minimalistic form, SUSY predicts that each Standard Model particle has a partner whose spin differs by ½ and an extended Higgs sector with five Higgs bosons. SUSY's symmetry between bosons and fermions stabilizes the mass of scalar particles, such as the Higgs boson and also the new scalar partners of the Standard Model fermions at high energy. If, as suggested by some theorists, the new particles have a conserved SUSY quantum number (denoted R-parity), the lightest SUSY particle (LSP) cannot decay and primordial LSPs might still be around, forming dark matter.

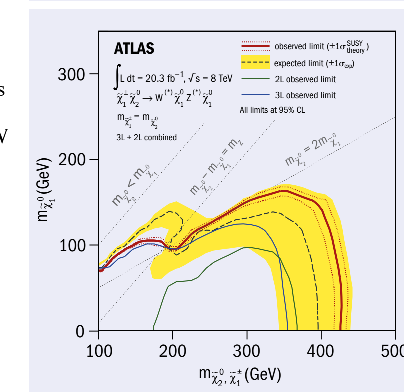
Two charginos, $\tilde{\chi}^{\pm}_{1,2}$, and four neutralinos, $\tilde{\chi}^0_{1,2,3,4}$ – collectively referred to as electroweakinos – are the SUSY partners of the five Higgs and the electroweak gauge bosons. Based on arguments that try to accommodate the light mass of the Higgs boson in a "natural", non-fine-tuned manner, the lightest electroweakinos are expected to have masses in the order of a few hundred giga-electron-volts. The lightest chargino, $\tilde{\chi}^{\pm}_1$, and the next-to-lightest neutralino, $\tilde{\chi}^0_2$, can decay into the LSP, $\tilde{\chi}^0_1$, plus multilepton final states via superpartners of neutrinos (sneutrinos, $\tilde{\nu}$) or charged leptons (sleptons, $\tilde{l}$), or via Standard Model bosons (W, Z or Higgs). If SUSY exists in nature at the tera-electron-volt scale, electroweakinos could be produced in the LHC collisions.

The ATLAS collaboration's searches for charginos, neutralinos and sleptons use events with multiple leptons and missing transverse momentum from the undetected LSP. The two-lepton (e, μ) search has dedicated selections that target the production of $\tilde{l}\tilde{l}$, $\tilde{\chi}^{\pm}_1\tilde{\chi}^{\mp}_1$ and $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2$ through their decays via sleptons or W and Z bosons. Meanwhile, the three-lepton (e, μ, τ) analysis searches for $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2$ decaying either via sleptons, staus (the SUSY partner of the τ), W and Z bosons, or W and Higgs bosons. Charginos and neutralinos decaying via Standard Model bosons are more challenging to search for than the decays via sleptons, owing to the smaller branching ratio into leptons. The main backgrounds in the two(three)-lepton search are WZ and Z+jets ($t\bar{t}$) production, and these are modelled using Monte Carlo simulation and data-driven methods, respectively.

ATLAS has found no significant excess beyond the Standard Model expectation in either the two or three-lepton SUSY searches. This null result can be used to set exclusion limits on SUSY models, narrowing down where SUSY might exist in nature. For example, the two-lepton analysis sets the first direct limits in a simplified SUSY model of $\tilde{\chi}^{\pm}_1\tilde{\chi}^{\mp}_1$, where the chargino decays 100% of the time to a W boson. The selections based on the presence of hadronically decaying τ particles in the three-lepton analysis set exclusion limits for $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2$ decaying via W and Higgs bosons.

In some cases, the results of two or more analyses can be combined to strengthen the exclusion limits in a particular SUSY model. This is done for the two and three-lepton searches in a simplified SUSY model of $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2$, where the $\tilde{\chi}^{\pm}_1$ and $\tilde{\chi}^0_2$ are assumed to decay exclusively via W and Z bosons (figure 1). On its own, the two-lepton analysis excludes $\tilde{\chi}^{\pm}_1$ and $\tilde{\chi}^0_2$ masses from 170–370 GeV, while the three-lepton analysis excludes masses from 100–350 GeV. By combining the two searches, the exclusion limit is pushed out much further to $\tilde{\chi}^{\pm}_1$ and $\tilde{\chi}^0_2$ masses of 415 GeV for a massless $\tilde{\chi}^0_1$ (figure 2).





Top: Fig. 1. Electroweak SUSY production of $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2$ followed by W and Z-mediated decays for the simplified model considered here. Bottom: Fig. 2. Observed and expected 95% confidence level (CL) exclusion regions obtained by the combination of the two and three-lepton searches in the $m_{\tilde{\chi}^0_2,\tilde{\chi}^{\pm}_1} - m_{\tilde{\chi}^0_1}$ plane for the simplified model of $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2$ production followed by W- and Z-mediated decays. Individual search results (observed) are also shown.

So far, no evidence for SUSY has been observed with the first dataset collected by ATLAS. However, in 2015 the LHC will collide protons at higher energies and rates than ever before. This will be an exciting time as exploration of unchartered territories of higher-mass SUSY particles and rarer signatures begins.

Further reading

ATLAS Collaboration 2014 *JHEP* **04** 169.
ATLAS Collaboration 2104 arxiv:1403.5294, accepted by *JHEP*.

Sciencewatch

Compiled by John Swain, Northeastern University

Sliding over wet sand

Sliding on sand has important implications in areas from civil engineering to earthquake dynamics. It also has some glamour, because wall paintings found by archaeologists suggest that wetting of sand was important for construction in ancient Egypt. Daniel Bonn of the University of Amsterdam and colleagues have made a careful experimental study, and show that small amounts of water – but not a great deal – can dramatically reduce sliding friction. The force needed to get a wooden sled to move can be reduced by up to 70% and the force to keep it going at constant speed can be reduced by 40%.

They find that the formation of capillary water bridges increases the shear modulus and helps sliding, but too much water makes these bridges coalesce. Then the friction increases and can be higher than for dry sand. For appropriate amounts of water, sliding over wet sand can be as good as when wooden "sleepers" are used to reduce friction.

Wall painting in the tomb of Djehutihotep, 1800 BC. The figure standing at the front of the sled is pouring water onto the sand.

● **Further reading**
A Fall *et al.* 2014 *Phys. Rev. Lett.* **121** 175502.

Twin Earth found

Astronomers have found the first Earth-sized planet where liquid water could exist. Elisa Quintana of the SETI Institute in Mountain View, California, and the NASA Ames Research Center in Moffett Field nearby, used the Kepler Space Telescope to search around the constellations Cygnus and Lyra. The aim was to find planets via their dimming effect on the stars they orbit as they pass in front.

In this way, the researchers discovered Kepler-186f, a planet that is 1.1 times the size of the Earth and orbiting an M-dwarf star. This star is cooler and dimmer than the Sun, but the planet is at a distance that should allow for liquid water on the surface if the atmosphere has enough carbon dioxide to keep it sufficiently warm – a case where global warming might be a good thing, arguably. The planet is about 500 light-years away, and is the closest to an Earth-like planet found so far.

● **Further reading**
E V Quintana *et al.* 2014 *Science* **344** 277.

Stable hidden states

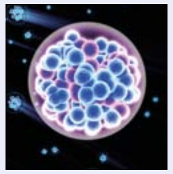
The equilibrium phase diagram of a material might not reflect all of the states in which it can appear. Hidden states can result from a system out of equilibrium. L Stojchevska of the Jožef Stefan Institute in Ljubljana and colleagues have shown that it is possible to switch to such hidden states and that they can be stable.

The group used a 35 s laser pulse on a layered dichalcogenide crystal of the trigonal state of tantalum disulphide to knock it into a hidden state that has a much lower electrical resistance, modified single particle and collective mode spectra and a large change in optical reflectivity. The state is stable until another laser pulse, an electrical current, or heat is applied. As a potential memory device, this beats the current speed record of 40 fs in magnetic materials.

● **Further reading**
L Stojchevska *et al.* 2014 *Science* **344** 177.

Towards the island of stability

The famous "island of stability", hypothesized for transuranic elements around the region where the number of neutrons in the nucleus N = 178 and the number of protons Z = 118, might be in sight. Jadambaa Khuyagbaatar of the Helmholz Institute Mainz and GSI in Darmstadt and colleagues produced nuclei with Z = 117 in ^{48}Ca + ^{249}Bk fusion events at the gas-filled recoil separator TASCA at GSI. Two decay chains associated with ^{294}117 were identified and a new α decay of ^{270}Db (Z = 105) to a new isotope ^{266}Lr (Z = 103) was found with a half-life of $1.0^{+1.9}_{-0.4}$ hours. This is a longer lifetime than any α-decaying nucleus heavier than nobelium (Z = 102), and far longer than the half-lives of approximately 2 min of ^{269}Sg and ^{271}Sg, the longest-lived α-decaying superheavy elements previously known.



Element 117. (Image credit: Kwei-Yu Chu/LLNL)

● **Further reading**
J Khuyagbaatar *et al.* 2014 *Phys. Rev. Lett.* **112** 172501.

Where the xenon went

More than 90% of the xenon expected in the Earth's atmosphere appears to be missing, and while most researchers think that it must be hidden within the planet, all attempts to find a suitable reservoir, such as ice, clathrates, sediments, or silica in the mantle, have failed. However, Li Zhu of Jilin Univeristy in Changchun and University College London and colleagues might now have found its hiding place. They calculate that under the temperatures and pressures at the Earth's core, xenon is expected to react with iron and nickel to form $XeFe_3$ and $XeNi_3$ and other compounds, making the core the likely hiding place of this noble gas.

● **Further reading**
L Zhu *et al.* 2014 *Nature Chemistry* doi:10.1038/nchem.1925.

Designer chromosome

Another breakthrough in synthetic biology is in the title of the paper "Total synthesis of a functional designer eukaryotic chromosome". Narayana Annaluru of Johns Hopkins University in Baltimore and colleagues synthesized an entire chromosome, synIII, with 272,871 base pairs. The synthetic chromosome is based on chromosome III of the native *Saccharomyces cervisiae* yeast – commonly used in baking and brewing – which has 316,617 base pairs, but leaving out genes that appear to be inessential. Placed into yeast, the chromosome seems to work fine, opening the door to designer eukaryotic genome biology.

● **Further reading**
N Annaluru *et al.* 2014 *Science* **344** 55.

Astrowatch

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

New instrument sees intergalactic filaments

A team of US astronomers has taken unprecedented images of the intergalactic medium (IGM) – the diffuse gas that connects galaxies throughout the universe. These first pictures of the IGM were obtained with the Cosmic Web Imager (CWI), an instrument designed and built at the California Institute of Technology (Caltech). It opens the way for a deeper understanding of how galaxies form via accretion of gas from the IGM.

Since the late 1980s and early 1990s, theoreticians have predicted that primordial gas from the Big Bang is not spread uniformly throughout space, but is instead distributed in channels that span galaxies and flow between them. This "cosmic web" is a network of filaments crisscrossing one another over the vastness of space and back through time, to an era when galaxies were first forming and stars were being produced at a rapid rate. The visualization of this sponge-like structure of dark matter and gas has become familiar with the advent of numerical simulations of structure formation (*CERN Courier* September 2007 p11). However, actual observation of this filamentary structure is very difficult. It is only recently that a filament of dark matter was found between two clusters of galaxies (*CERN Courier* September 2012 p14). Detecting much smaller filaments feeding early galaxies is another challenge.

The usual way to probe the IGM is to look for Lyman-α absorption in the spectrum of a distant quasar. A series of hydrogen clouds along the line of sight to the quasar will produce distinct absorption lines at wavelengths corresponding to the redshift – a measure of the cosmic distance – of each cloud. However, analysis of this "Lyman-α forest" of quasar absorption lines probes the gas distribution in only one direction, so it is not possible to use this method to infer the spatial distribution of the gas clouds.

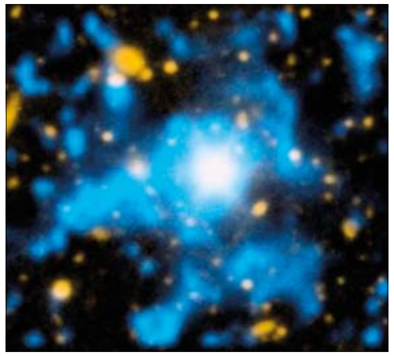


Image of the quasar QSO 1549+19 taken with Caltech's Cosmic Web Imager, showing surrounding hydrogen gas (in blue) and a filament inflowing from the bottom-left direction. (Image credit: Christopher Martin, Robert Hurt.)

To overcome this limitation, Christopher Martin at Caltech conceived and developed the CWI. This novel instrument has been designed to detect faint Lyman-α emission from extended regions with redshifts between 1.5 and 4. It is an integral-field spectrograph mounted on the 200 inch (5.1 m) Hale Telescope at the Palomar Observatory. The instrument takes pictures at many different wavelengths simultaneously, yielding a data cube with the image of a small portion of the sky on one side and high-resolution spectroscopic information along the third axis. The data cube can then be sliced to search for spatial structures emitting a narrow, redshifted Lyman-α line.

The first results from the CWI have now been published in two articles. A first paper describes the observation of a narrow filament of gas flowing towards the quasar QSO 1549+19. The ultraviolet emission of the quasar photo-ionizes the gas and therefore induces the observed Lyman-α emission. The filament is about one-million light-years long and its infall motion is suggested by the progressive increase of the velocity dispersion of the gas towards the quasar. Another target was a Lyman-α emission cloud, found to be surrounded by three filaments of gas that are probably feeding a protogalactic disc with a size about three times that of the Milky Way.

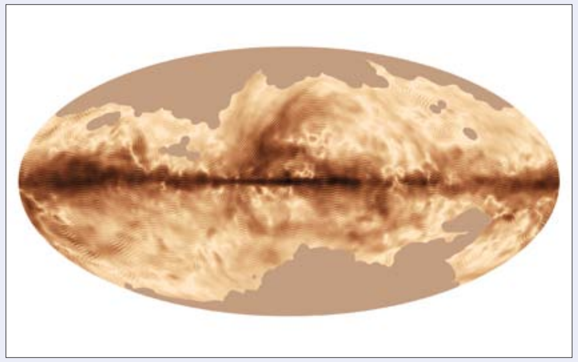
Both objects observed by the CWI date to approximately two-thousand-million years after the Big Bang, a time of rapid star formation in galaxies. They have been chosen because of unusually bright Lyman-α emission. To observe the average intergalactic medium everywhere, Martin's group is now developing the Keck Cosmic Web Imager (KCWI) – a more sensitive and versatile version of the CWI – for use at the Keck Observatory on top of Mauna Kea in Hawaii.

Further reading

D C Martin *et al.* 2014 *ApJ* **786** 106 and 107.

Picture of the month

This image shows the magnetic fingerprint of our Milky Way Galaxy as seen by ESA's Planck satellite. This projection of the full celestial sphere was produced from the first Planck all-sky observations of polarized light emitted by interstellar dust (Picture of the month *CERN Courier* September 2010 p11). Darker regions correspond to stronger polarized emission, and the striations indicate the direction of the magnetic field projected on the plane of the sky. The dark band running horizontally across the centre corresponds to the Galactic Plane. Later this year, Planck scientists will release polarization data covering the entire sky at seven different frequencies, to separate this foreground contamination from the tenuous primordial polarized signal, in particular the famous B-mode pattern discovered by BICEP2 (*CERN Courier* May 2014 p13). (Image credit: ESA and the Planck collaboration.)



CERN Courier Archive: 1971

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

VIEWPOINT

Applications of accelerators

There was a time, not long ago, when science and motherhood were beyond reproach. Today, both are under attack.

Much of the basis for the attack on science is emotional, even irrational. But not all of our troubles can be blamed on unreasoning critics; a substantial part of our misery is self-inflicted. We have not taken seriously that part of our responsibility to society that dictates that we explain, interpret and justify our activities in language understandable to the non-specialist.

To pursue science, one must continually press on the frontiers that are usually at extremes: very high temperatures and very low temperatures; very high pressures and very good vacuums; the very large (cosmology) and the very small (nuclear and sub-nuclear entities).

We could claim that all particle accelerators have value for intellectual and educational pursuits. However, most of us feel that it is particularly the highest energy accelerators that contribute to the acquisition of new basic knowledge about the fundamental properties of the constituents of matter and the forces that govern them.

In addition to these intellectual merits, we can point to other benefits from the construction and utilization of accelerators, for example, the promotion of international collaboration. The research is worldwide and perhaps in no other field is there such open, friendly and practical collaboration across frontiers.

The history of science tells us that up to now the practical results alone have more than paid for all the scientific effort. Even the highest energy accelerators have economic ramifications, for they are producing spin-offs (for example in computer technology, cryogenics, vacuum technology, the art of constructing large magnetic fields, and of fabricating materials that have no electrical resistance) that will have a decisive influence on the technologies required to sustain comfortable life on this planet.

In the United States there are about 1000 accelerators of all kinds, representing about 50% of the world's inventory. Less than 150 are devoted mainly to basic research. Of the remainder, about one-third are devoted to industry and medicine, and the rest to the applied sciences.

(From a talk by Louis Rosen, Director of the Los Alamos Meson Physics Facility, at the 1971 Particle Accelerator Conference held in Chicago in March.)

● Compiled from texts on pp159–160.

VILLIGEN

Progress of SIN cyclotron

The beginning of June saw the start of assembly of the accelerator at Villigen near Zurich, which is being built by the Swiss Institute for Nuclear Research SIN. The aim is for the accelerator to serve as a "meson factory" producing intense proton beams with an energy in excess of 500 MeV, well over the pion production threshold. Intense beams are to be obtained using two-stage acceleration – an injector cyclotron providing more than 100 μA of 72 MeV protons, feeding a ring cyclotron that will complete acceleration to peak energy.

Tests on a prototype r.f. cavity for the ring cyclotron went very well and showed that 500 kV could be obtained reliably across the cavity gap. Four such cavities will be installed around the ring, one between every second magnet, to provide an energy gain of 2 MeV per turn.

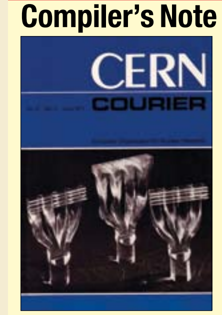
Tests on a prototype sector magnet for the ring cyclotron were also very satisfactory, showing that the stringent field tolerances necessary in an isochronous cyclotron could be met. By now, three of the eight large magnets have arrived at SIN and have been assembled and measured, and the first of these is being installed.

● Compiled from texts on pp164–166.

The prototype r.f. cavity, which achieved accelerating field gradients comfortably in excess of design figures.

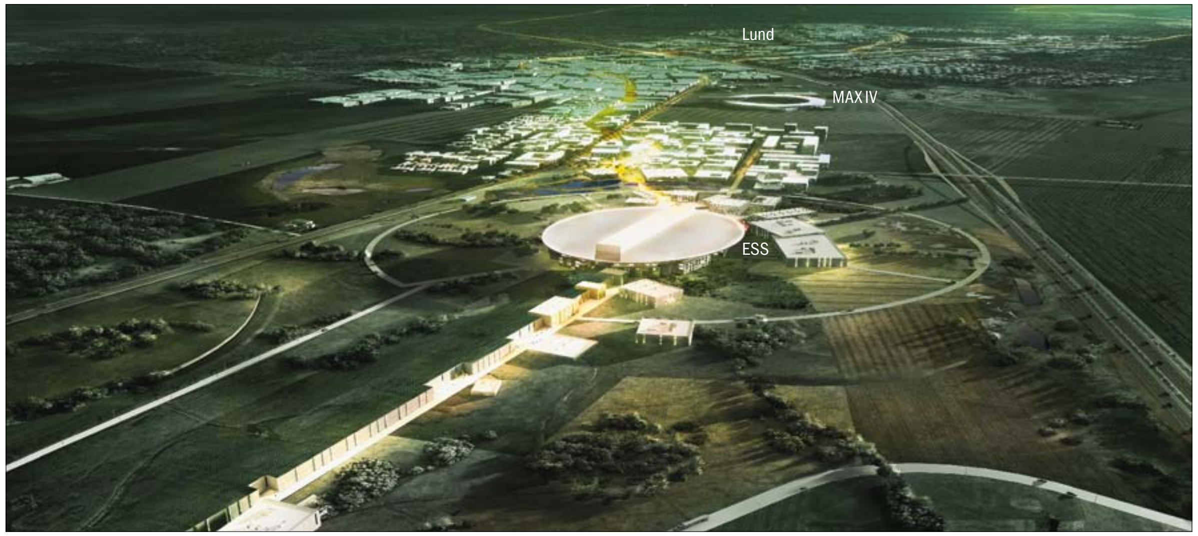
The prototype sector magnet, which confirmed that the design would provide the high-precision fields needed.

Compiler's Note



Louis Rosen did not detail those 1971 attacks on motherhood, but let's trust that they have ceased! However, what is sure is that much of science is now explained – and hopefully justified – in language that is, at some level, understandable to the general public. For example, souvenir tin-trays distributed at the Geneva Escalade Race in December 2012 were printed with a comic strip "Echelles & Dragons", a variation on the ancient Indian board game of "Snakes & Ladders". Squares featured caricatures of notables such as Marilyn Monroe, Professor Tournesol, Queen Elizabeth II, Rafa Nadal and…a Higgs boson.

More seriously, in 1988, SIN and the Federal Institute for Reactor Research amalgamated to form the Paul Scherrer Institute. PSI is now a world-class research centre for solid-state physics, biomedicine, renewable energy and environmental sciences. On the applied side, its proton-therapy facility operates a unique compact gantry with a PSI-developed spot-scanning technique that enables malignant tumours to be targeted with high precision (*CERN Courier* December 2006 p24). For example, in more than 90% of eye tumours, the eye is saved. More than a third of the patients were children and young people below the age of 20.



The European Spallation Source (ESS) is to be built on the outskirts of Lund, Sweden, close to MAX IV, the next-generation synchrotron radiation facility. The ESS will be served by a powerful superconducting proton linac, seen at the lower left in this schematic. (Image credit: ESS/Team Henning Larsen Architects.)

ESS: neutron beams at the high-intensity frontier

Based on a 5 MW superconducting proton linac, the European Spallation Source will be the world's most powerful neutron source, when it comes into full operation.

Today, neutron research takes place either at nuclear reactors or at accelerator-based sources. For a long time, reactors have been the most powerful sources in terms of integrated neutron flux. Nevertheless, accelerator-based sources, which usually have a pulsed structure (SINQ at PSI being a notable exception), can provide a peak flux during the pulse that is much higher than at a reactor. The European Spallation Source (ESS) – currently under construction in Lund – will be based on a proton linac that is powerful enough to give a higher integrated useful flux than any research reactor. It will be the world's most powerful facility for research using neutron beams, when it comes into full operation early in the next decade. Although driven by the neutron-scattering community, the project will also offer the opportunity for experiments in fundamental physics, and there are plans to use the huge amount of neutrinos produced at the spallation target for neutrino physics.

The story of the ESS goes back to the early 1990s, with a proposal for a 10 MW linear accelerator, a double compressor ring and two target stations. The aim was for an H^- linac to deliver alternate pulses to a long-pulse target station and to the compressor rings. The long-pulse target was to receive 2-ms long pulses from the linac, while multiturn injection into the rings would provide a compression factor of 800 and allow a single turn of 1.4 μs to be extracted to the short-pulse target station.

This proposal was not funded, however, and after a short hiatus, new initiatives to build the ESS appeared in several European countries. By 2009, three candidates remained: Hungary (Debrecen), Spain (Bilbao) and Scandinavia (Lund). The decision to locate the ESS near Lund was taken in Brussels in May 2009, after a competitive process facilitated by the European Strategy Forum for Research Infrastructures and the Czech Republic's Ministry of Research during its period of presidency of the European Union. In this new incarnation, the proposal was to build a facility with a single long-pulse target powered by a 5 MW superconducting proton ▷

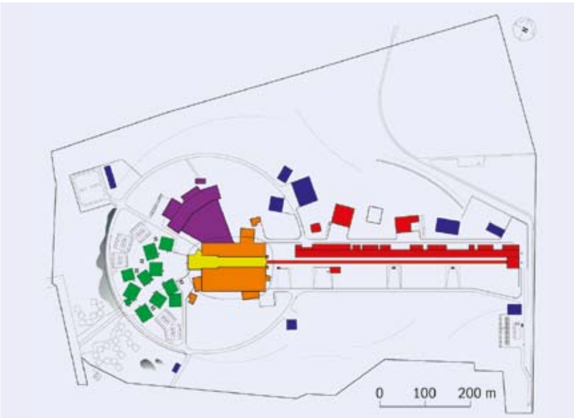


Fig. 1. Schematic diagram of the ESS facility. Red is accelerator buildings, yellow is the target station, orange and violet are experimental halls, green is offices and laboratories, blue is auxiliary buildings.

linac (figure 1). The neutrons will be released from a rotating tungsten target hit by 2 GeV protons emerging from this superconducting linac, with its unprecedented average beam power.

Neutrons have properties that make them indispensable as tools in modern research. They have wavelengths and energies such that objects can be studied with a spatial resolution between 10^{-10} m and 10^{-2} m, and with a time resolution between 10^{-12} s and 1 s. These length- and time-scales are relevant for dynamic processes in biomolecules, pharmaceuticals, polymers, catalysts and many types of condensed matter. In addition, neutrons interact quite weakly with matter, so they can penetrate large objects, allowing the study of materials surrounded by vacuum chambers, cryostats, magnets or other experimental equipment. Moreover, in contrast to the scattering of light, neutrons interact with atomic nuclei, so that neutron scattering is sensitive to isotope effects. As an extra bonus, neutrons also have a magnetic moment, which makes them a unique probe for investigations of magnetism.

Neutron scattering also has limitations. One of these is that neutron sources are weak compared with sources of light or of electrons. Neutrons are not created, but are "mined" from atomic nuclei where they are tightly bound, and it costs a significant amount of energy to extract them. Photons, on the other hand, can be created in large amounts, for instance in synchrotron light sources. Experiments at light sources can therefore be more sensitive in many respects than those at a neutron source. For this reason, the siting of ESS next to MAX IV – the next-generation synchrotron radiation facility currently being built on the north-eastern outskirts of Lund – is important. Thanks to its pioneering magnet technology, MAX IV will be able to produce light with higher brilliance than at any other synchrotron light source, while the ESS will be the most powerful neutron source in the world.

The ESS will provide unique opportunities for experiments in fundamental neutron physics that require the highest possible integrated neutron flux. A particularly notable example is the proposed search for neutron–antineutron oscillations. The high neutron intensity at the ESS will allow sufficient precision to make neutron experiments complementary to efforts in particle physics at the highest energies, for example at the LHC. The importance of the low-energy, precision "frontier" has been recognized widely (Raidal *et al.* 2008 and Hewett *et al.* 2012), and an increasing number of theoretical studies have exploited this complementarity and highlighted the need for further, more precise experimental input (Cigliano and Ramsey-Musolf 2013).

In addition, the construction of a proton accelerator at the high-intensity frontier opens possibilities for investigations of neutrino oscillations. A collaboration is being formed by Tord Ekelöf and Marcos Dracos to study a measurement of CP violation in neutrinos using the ESS together with a large underground water Cherenkov detector (Baussen *et al.* 2013).

Parameter	Value
energy (GeV)	2.0
current (mA)	62.5
pulse length (ms)	2.86
pulse repetition frequency (Hz)	14
average power (MW)	5
power during pulse (MW)	125

Table 1. Top-level linac parameters.

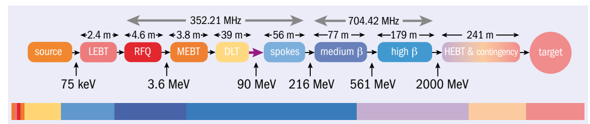


Fig. 2. Overview of the linac layout. The coloured segments of the bar at the bottom illustrate the relative length of the different accelerator sections.

The main components

The number of neutrons produced at the tungsten target will be proportional to the beam current, and because the total production cross-section in the range of proton energies relevant for the ESS is approximately linear with energy, the total flux of neutrons from the target is nearly proportional to the beam power. Given a power of 5 MW, beam parameters have been optimized with respect to cost and reliability, while user requirements have dictated the pulse structure. Table 1 shows the resulting top-level parameters for the accelerator.

The linac will have a normal-conducting front end, followed by three families of superconducting cavities, before a high-energy beam transport brings the protons to the spallation target. Because the ESS is a long-pulse source, it can use protons rather than the H^- ions needed for efficient injection into the accumulator ring of a short-pulse source.

Figure 2 illustrates the different sections of the linac. In addition to the ion source on a 75 kV platform, the front end consists of a low-energy beam transport (LEBT), a radio-frequency quadrupole that accelerates to 3.6 MeV, a medium-energy beam transport (MEBT) and a drift-tube linac (DTL) that takes the beam to 90 MeV.

The superconducting linac, operating with superfluid helium at 2 K, starts with a section of double-spoke cavities having an optimum beta of 0.50. The protons are accelerated to 216 MeV in 13 cryomodules, each of which has two double-spoke cavities. Medium- and high-beta elliptical cavities follow, with geometric beta values of 0.67 and 0.92. The medium-beta cavities have six cells, the high-betas have five cells. In this way, the two cavity types have almost the same length, so that cryomodules of the same overall design can be used in both cases to house four cavities. Figure 3 shows a preliminary design of a high-beta cryomodule, with its four five-cell cavities and power couplers extending downwards.

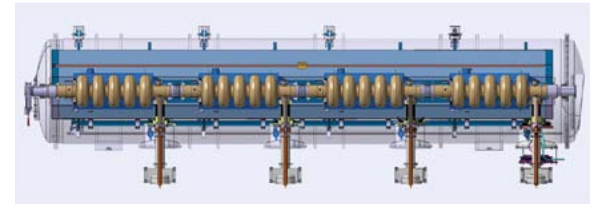


Fig. 3. Preliminary design of a high-beta cryomodule from IPN Orsay and CEA Saclay.

Nine medium-beta cryomodules accelerate the beam to 516 MeV, and the final 2 GeV is reached with 21 high-beta modules. The normal-conducting acceleration structures and the spoke cavities run at 352.21 MHz, while the elliptical cavities operate at twice the frequency, 704.42 MHz. After reaching their full energy, the protons are brought to the target by the high-energy beam transport (HEBT), which includes rastering magnets that produce a 160 × 60 mm rectangular footprint on the target wheel.

The design of the proton accelerator – as with the other components of the ESS – has been carried out by a European collaboration. The ion source and LEBT have been designed by INFN Catania, the RFQ by CEA Saclay, the MEBT by ESS-Bilbao, the DTL by INFN Legnaro, the spoke section by IPN Orsay, the elliptical sections again by CEA Saclay, and the HEBT by ISA Århus. During the design phase, additional collaboration partners included the universities of Uppsala, Lund and Huddersfield, NCBJ Świerk, DESY and CERN. Now the collaboration is being extended further for the construction phase.

A major cost driver of the ESS accelerator centres on the RF sources. Klystrons provide the standard solution for high output power at the frequencies relevant to the ESS. For the lower power of the spoke cavities, tetrodes are an option, but solid-state amplifiers have not been excluded completely, even though the required peak powers have not been demonstrated yet. Inductive output tubes (IOTs) are an interesting option for the elliptical cavities, in particular for the high-beta cavities, where the staged installation of the linac still allows for a few years of studies. While IOTs are more efficient and take up less space than klystrons, they are not yet available for the peak powers required, but the ESS is funding the development of higher-power IOTs in industry.

Neutrons are "mined" from atomic nuclei and it costs a significant amount of energy to extract them.

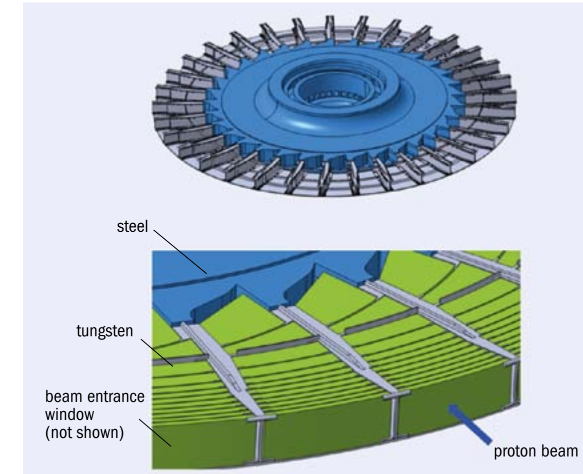


Fig. 4. Target wheel with its frame of steel (upper image) and tungsten elements separated by cooling channels (lower image). (Image credit: Karlsruhe Institute of Technology.)

Neutron production

The ESS will use a rotating, gas-cooled tungsten target rather than, for instance, the liquid-mercury targets used at the Spallation Neutron Source in the US and in the neutron source at the Japan Proton Accelerator Research Complex. As well as avoiding environmental issues that arise with mercury, the rotating tungsten target will require the least amount of development effort. It also has good thermal and mechanical properties, excellent safety characteristics and high neutron production.

The target wheel has a diameter of 2.5 m and consists of tungsten elements in a steel frame (figure 4). The tungsten elements are separated by cooling channels for the helium gas. The wheel rotates at 25 rpm synchronized with the beam pulses, so that consecutive pulses hit adjacent tungsten elements. An important design criterion is that the heat generated by radioactive decay after the beam has been switched off must not damage the target, even if all active cooling systems fail.

With the ESS beam parameters, every proton generates about 80 neutrons. Most of them are emitted with energies of millions of electron volts, while most experiments need cold neutrons, from room temperature down to some tens of kelvins. For this reason, the neutrons are slowed down in moderators containing water at room temperature and super-critical hydrogen at 13–20 K before being guided to the experimental stations, which are known as instruments. The construction budget contains 22 such instruments, including one devoted to fundamental physics with neutrons.

The ESS is an international European collaboration where 17 European countries (Sweden, Denmark, Norway, Iceland, Estonia, Latvia, Lithuania, Poland, Germany, France, the UK, the Netherlands, the Czech Republic, Hungary, Switzerland, Italy and Spain) have signed letters of intent. Negotiations are now taking ▷

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Facilities

place to distribute the costs between these countries.

Sweden and Denmark have been hosting the ESS since the site decision, and a large fraction of the design study that started then was financed by Sweden and Denmark. The project has now moved into the construction phase, with ground breaking planned for summer this year.

According to the current project plans, the accelerator up to and including the medium-beta section will be ready by the middle of 2019. Then, the first protons will be sent to the target and the first neutrons will reach the instruments. During the following few years, the high-beta cryomodules will be installed, such that the full 5 MW beam power will be reached in 2022.

The neutron instruments will be built in parallel. Around 40 concepts are being developed at different laboratories in Europe, and the 22 instruments of the complete ESS project will be chosen in a peer-reviewed selection process. Three of these will have been installed in time for the first neutrons. The rest will gradually come on line during the following years, so that all will have been installed by 2025.

The construction budget of ESS amounts to €1,843 million, half of which comes from Sweden, Denmark and Norway. The annual operating costs are estimated to be €140 million, and the cost for decommissioning the ESS after 40 years has been included in the budget. The hope, however, is that the scientific environment that will grow up around ESS and MAX IV – and within the Science Village Scandinavia to be located in the same area – will last longer than that.

Further reading

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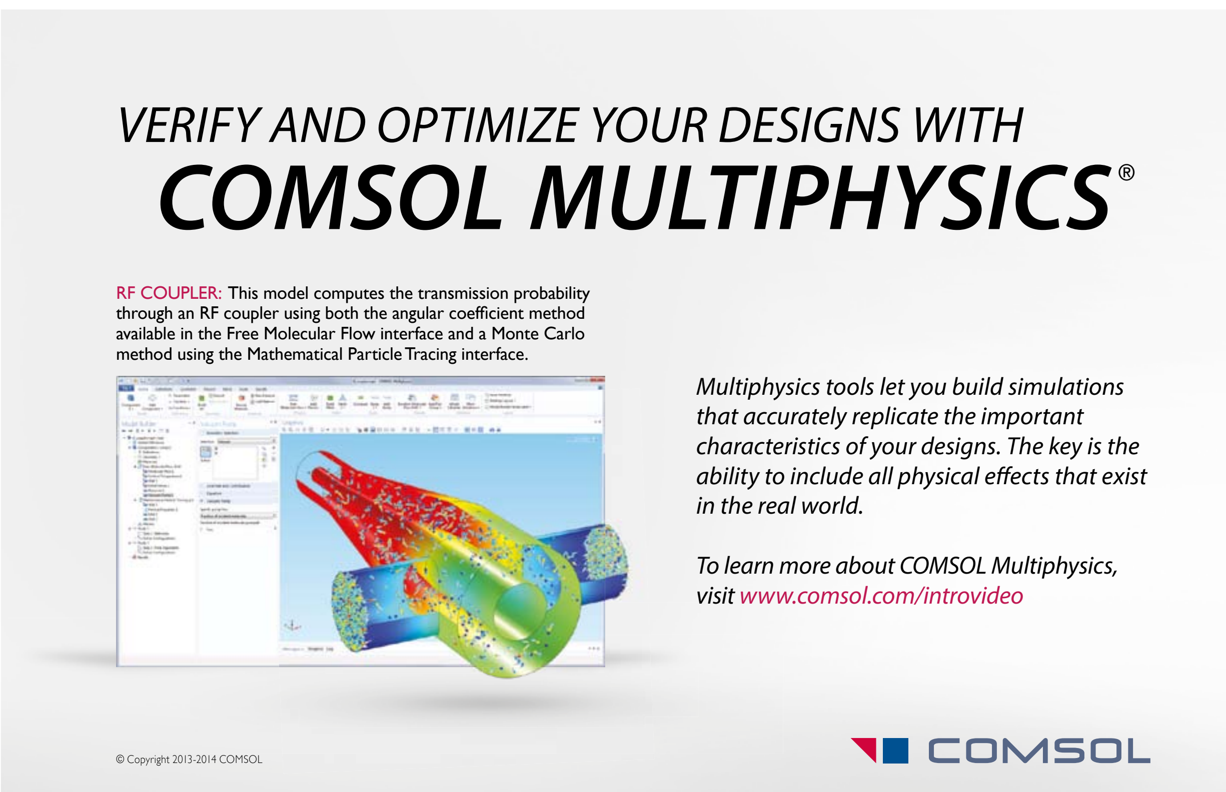
For a more in-depth review of the full scope and possible impact of measurements of the neutron electric dipole moment, neutron decay, the neutron as a quantum wave, etc, see for example:
H Abele 2008 *Prog. Part. Nucl. Phys.* **60** 1.
D Dubbers and M G Schmidt 2011 *Rev. Mod. Phys.* **83** 1111.
H J S Nico and W M Snow 2005 *Ann. Rev. Nucl. Part. Sci.* **55** 27.

Résumé

ESS : des faisceaux de neutrons à la frontière de la haute intensité

L'ESS, source européenne de spallation en construction à Lund, deviendra l'installation de recherche à faisceaux de neutrons la plus puissante du monde une fois qu'elle sera pleinement opérationnelle, au début de la prochaine décennie. Les neutrons seront libérés d'une cible rotative de tungstène lors de l'impact de protons d'une énergie de 2 GeV émergeant d'un linac supraconducteur de 5 MW. Le projet, qui relève de la recherche sur la diffusion des neutrons, offrira aussi des perspectives uniques pour les expériences en physique fondamentale des neutrons, grâce à son flux intégré de neutrons élevé. Il est également prévu d'utiliser pour la physique des neutrinos l'énorme quantité de neutrinos produits à la cible de spallation.

Håkan Danared, Mats Lindroos and **Camille Theroine**, European Spallation Source.



Jim Yeck: a life in big infrastructures

With plenty of experience in managing big science projects, Jim Yeck is well suited for taking charge of construction of the European Spallation Source.


Jim Yeck – a man who delights in seeing things built. (Image credit: ESS.)

To paraphrase lines from the title song of a well-known film: "If there's something big in your neighbourhood, who ya gonna call?" If the neighbourhood is particle physics, then it could well be Jim Yeck, who delights in seeing things built. This enthusiasm has underpinned his leadership of a number of successful big scientific infrastructure projects in the US, including the important US hardware contribution to the LHC and the ATLAS and CMS experiments.

Yeck's first exposure to big science projects was as a graduate engineer in the late 1980s at the Princeton Plasma Physics Laboratory, where there was a proposal to build the $300 million Compact Ignition Tokomak. However, in 1989 the project was cancelled, because plasma ignition could not be guaranteed and the international ITER initiative was on the horizon. "It was a formative experience," says Yeck, and instead of nuclear fusion, he found himself working on risk assessment for large science projects, which was to prove valuable for his future career.

In the autumn of 1990, he was asked by the US Department of Energy (DOE) to become the project manager for the construction of the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory. Like its ancestor – the Intersecting Storage Rings at CERN – RHIC was built with two interlaced rings, but broke new ground by incorporating 1740 superconducting magnets, most of which were made in industry. Looking back, Yeck points out that the project was approved in a different era, "when you knew you had issues that you would have to work out later". Basically underfunded, it was built against a background of tight budget constraints. "Such a project needs strong leadership, which we had in Nick Samios, the lab director, Satoshi Ozaki, the project director, and others," he says.

Yeck remained with RHIC until the autumn of 1997, when the US was in the final stages of signing an agreement to contribute to building hardware for the LHC and the ATLAS and CMS experiments, and to become an Observer State of CERN. The DOE and the National Science Foundation (NSF) appointed him project director for this $531 million contribution, which comprised $200 million from the DOE for the LHC accelerator, and $331 million from the DOE and the NSF for ATLAS and CMS. At the time more than 550 US scientists from nearly 60 universities and six of the DOE's national laboratories were involved.

"This was on the heels of the cancellation of the SSC [the Superconducting Super Collider] and the community recognized that it was imperative that the LHC should work and that the US should be part of it," Yeck recalls. "People rallied together – it was beautiful." There were to be many difficult issues to resolve and compromises to be made, but with a background in engineering rather than particle physics, Yeck had the advantage of being a clearly defined "enabler", with no bias.

In late 2003, with the LHC's progress on firm ground, Yeck moved on again, to become director of a rather different astroparticle-physics project. The IceCube Neutrino Observatory at the South Pole is not only at an exotic location with an international collaboration, it is run principally by the University of Wisconsin, and Yeck says that it interested him to show that a university can take on leadership of a large infrastructure project. IceCube was funded to the tune of $280 million, in this case mostly by the NSF, who had less experience of big projects than the DOE. There was also the interesting logistical challenge of constructing and operating the huge 1 km^3 detector at the South Pole.

During the long construction phase linked to summers at the South Pole, Yeck agreed to help launch construction of the ▷

Interview

National Synchrotron Light Source II back at Brookhaven, and served as deputy project director in the years 2006–2008. Then, 10 years after taking on IceCube, he made his latest change – to another kind of facility, another continent, and a different user community. In March 2013 he became chief executive officer (CEO) of the European Spallation Source (ESS), taking over from the first CEO, Colin Carlile (*CERN Courier* January/February 2012 p54).

The ESS will serve a research community dispersed across many fields of science, with potential users numbering in the thousands. "The old model of a country going it alone doesn't work for such projects," says Yeck. Instead, the ESS is furthering the approach of bringing many nations to work together, and with 17 partner countries it is approaching CERN in terms of the number of members. Using an analogy that should appeal to physicists, Yeck says: "CERN is an existence proof, and others have drawn on this. But the initial conditions have to be right." When setting up rules for the governance of the new facility, ESS based many of the principles on those established 60 years ago for CERN.

Yeck's experience has taught him what is important in making a success of such a project: "The facility has to be a priority for the scientific community", he says. "If you don't have that foundation, it's a problem. Then you need commitments and a strong role from the facility host. And the leadership has to see itself as enabling the success of others." A particular challenge of the ESS is that it is new in more ways than one – a new organization on a green-field site, much like CERN was in 1954. "Such an organization needs experienced people who can catalyse the successful efforts of many," says Yeck. "We also have to establish realistic goals – it's a case of putting experience over hope."

The ESS management has been working hard during the past year on a realistic plan, which was reviewed in November by a committee of 33 members from a broad community, chaired by CERN's Mario Nessi. Yeck learnt to appreciate the value of such reviews during his time in the US. "If you have problems, you can also seek collective ownership of solutions," he explains. "And there will be problems. To pretend that you are not going to have them is a big mistake." However, Yeck is a man who delights in seeing things built and the ESS is no exception. "It's fantastically challenging, with contributions from many people," he says, "but that's what's captivating."

Résumé

Jim Yeck : une passion pour les grandes infrastructures

Jim Yeck aime voir les choses se construire. Il est donc bien placé pour prendre en charge la Source européenne de spallation (ESS) au moment où elle entre dans sa phase de construction. Dans cet entretien, il explique comment il en est venu à s'intéresser à de tels projets, quand son travail d'ingénieur l'a amené à évaluer les risques de grands projets scientifiques. Depuis, il a dirigé avec brio la construction du Collisionneur d'ions lourds relativistes à Brookhaven et de l'Observatoire de neutrinos IceCube au pôle Sud, ainsi que la contribution très importante des États-Unis à la construction de l'accélérateur LHC et des expériences ATLAS et CMS.

Christine Sutton, CERN.

CERN Courier June 2014
60 years of CERN

Snapshots from the early days

CERN's photo archives contain a wealth of black and white photographs from the early days of CERN. Like old family photo albums, they can bring back distant memories or evoke impressions of a bygone age. This selection highlights some images from the time when CERN was first established by the 12 founding member states.

CRÉATION DU C.E.R.N.

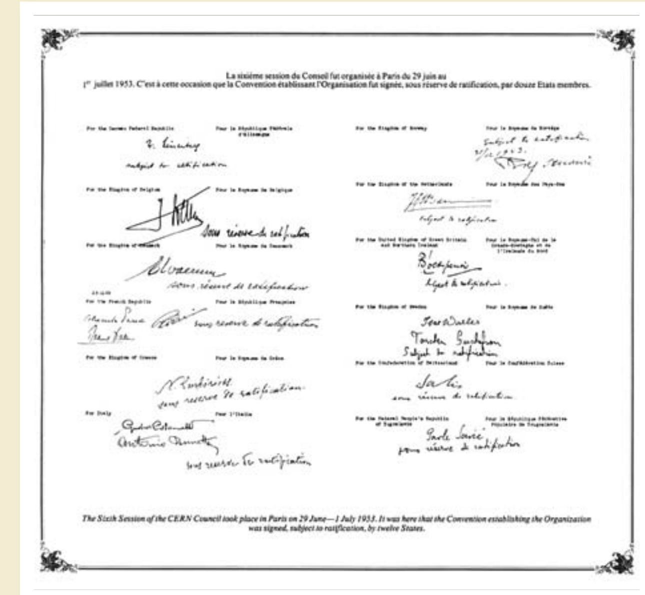
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
ORGANISATION DES NATIONS UNIES POUR L'ÉDUCATION, LA SCIENCE ET LA CULTURE

Genève, 15 février 1952

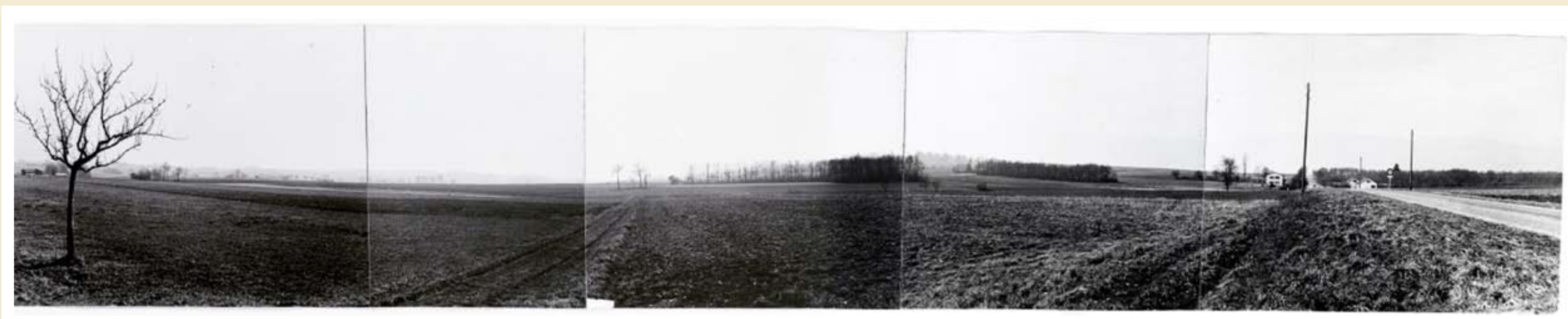
Professor I. Rabi,
Columbia University,
New York, N/Y.

We have just signed the Agreement which constitutes the official birth of the project you fathered at Florence. Mother and child are doing well, and the Doctors send you their greetings.

1952: Far left. The first meeting of the provisional CERN Council on 15 February 1952, with key people including Sir Ben Lockspeiser, Edoardo Amaldi, Felix Bloch, Lew Kowarski, Cornelis Bakker and Niels Bohr (at theback). (Image credit: CERN-HI-5201001.) Left. The letter to Isidor Rabi, dated the same day, tells him of the signing of an agreement to create CERN. (Image credit: CERN-HI-5202017.)



La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.



1953: Above. The convention establishing the organization was signed, subject to ratification, by the representatives of 12 future member states, at the sixth session of the CERN Council in Paris on 29 June–1 July. (Image credit: CERN-HI-5307006.) Left: Could this be the first photo taken of the CERN site? Recently found in the archives, this montage shows the road from Meyrin as it crosses the border into France – now close to the location of the main entrance into CERN. (Image credit: CERN-PHOTO-195401-001 – 1.)

Sur le terrain du futur institut nucléaire

Sous la conduite de M. A. Picot, les membres du Conseil européen pour la recherche nucléaire se sont rendus hier à Meyrin pour reconnaitre le terrain où s'élèvera le Centre nucléaire (voir en Dernière heure)
(Photo Freddy Bertrand, Genève)

La Suisse du 30 octobre 1953

1953: The edition of 30 October of the newspaper La Suisse *shows Albert Picot from the State of Geneva and members of CERN Council visiting the site of the future laboratory the day before. Geneva was selected as the site for CERN at the third Council session in Amsterdam in October 1952, and the choice was approved by a referendum in the Canton of Geneva in June 1953, by 16,539 votes to 7332. (Image credit: CERN-HI-5310001.)*

1954: The Villa de Cointrin at the airport in Geneva was the first seat for CERN's management and administrative offices. It is still visible through fences today. (Image credit: CERN-HI-5408002.)

1954: By November, the foundations of the machine hall and experimental halls for the Synchrocyclotron, CERN's first accelerator, were taking the shape of a rigid "raft". (Image credit: CERN-SI-5401005.)

Electrons at the LHC: a new beginning

A new committee is providing direction on the case for an electron–hadron collider, both at the LHC and at a Future Circular Collider complex.

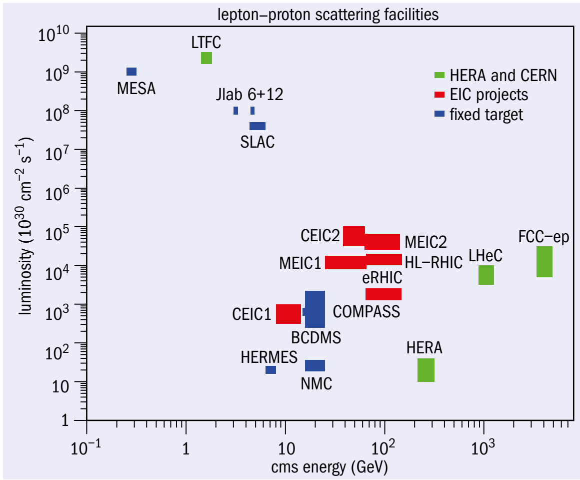


Fig. 1. Lepton–proton scattering projects – using fixed targets (blue), future medium-energy electron–ion collider projects (red), HERA and CERN's electron–proton concepts (green) – in terms of luminosity and centre-of-mass energy.

From time to time, great experimental progress in particle physics suddenly reveals a crisis in theoretical physics. This happened in the early 1960s when a plethora of hadrons had been discovered, while strong-interaction theory dealt with analytical properties of the S matrix and a number of phenomenological models. At that time, Murray Gell-Mann, who had just introduced the notion of quarks, seconded by Georg Zweig, argued for focusing on "a higher-energy accelerator so that we can do more experiments over the next generation and really learn more about the basic structure of matter" (Gell-Mann 1967). The current situation is not so different.

At the LHC, the Standard Model is being subjected to a thorough confirmation, including the remarkable completion of its particle contents with the discovery of a Higgs boson. Important as these results are, however, there is still no indication of the existence of the long-predicted supersymmetric particles or of Kaluza–Klein resonances below a mass scale of about a tera-electron-volt, or of other new phenomena. Of course, the hope is that in the coming years the LHC will discover new physics in exploring the next higher-energy domain with increased luminosity. Yet, to discover all hidden treasures when entering unknown territory, it is a wise strategy to prepare for all possibilities and not to rely on a few choices only.

In this spirit, investigations of electron–proton (ep) and electron–ion (eA) collisions at high energies offer an important prospect, complementary to proton–proton (pp) and electron–positron (ee) collisions. So far, the only collider to exploit the ep configuration was HERA at DESY, where results from the H1 and ZEUS experiments provided much of the base of current LHC physics and also led to surprising results, for example on the momentum distributions of partons inside the proton. Building on the conceptual design study for the Large Hadron Electron Collider (LHeC) – an electron-beam upgrade to the LHC (*CERN Courier* May 2012 p25) – CERN's management decided recently to investigate these possibilities more deeply. It has established an International Advisory Committee (IAC) to report to the director-general, with the mandate to provide "...scientific and technical direction for the physics potential of the ep/eA collider, both at the LHC and FCC [the proposed Future Circular Collider complex], as a function of the machine parameters and of a realistic detector design, as well as for the design and possible approval of an energy recovery linac (ERL) test facility at CERN...". Furthermore, the advisory committee should offer "assistance in building the international case for the accelerator and detector developments as well as guidance to the resource, infrastructure and science policy aspects...". Chaired by Herwig Schopper, the IAC comprises 12 eminent scientists from three continents, together with CERN's director for research and computing, Sergio Bertolucci, and the director for accelerators and technology, Frederick Bordry, as well as the co-chairs of the newly established LHeC Co-ordination Group, Oliver Brüning and Max Klein.

To discover all hidden treasures, it is a wise strategy to prepare for all possibilities.

One of the IAC's first major activities was to hold a well-attended workshop on the LHeC, its physics, and the accelerator and detector development, at Chavannes-de-Bogis in January this year. ▷

Accelerators

At the meeting, Stefano Forte classified deep-inelastic scattering (DIS) physics at the energy frontier – which becomes accessible with ep collisions using the LHC's proton beam (figure 1, p33) – into three major areas. One area consists of high-precision measurements of the Standard Model, with the experimental and theoretical programme aiming for a per mille determination of the strong coupling constant, α_s, and the reduction of uncertainties in searches at the High Luminosity LHC (HL-LHC) at high mass scales as prime examples. A second area concerns exploration of the parameter space, with Higgs physics – including the challenging decays into b and c quarks (figure 2) – as the obvious and most important element. The cross-section for such processes at the LHeC would be about 200 fb, enabling unique measurements of the Higgs properties from WW–H and ZZ–H production in ep scattering. With its unprecedented precision in determination of the parton distributions and of the strong coupling, the LHeC could assist in transforming the LHC into a precision Higgs factory. Lastly, there is what Forte called "serendipity", meaning room for "known or unknown" discoveries. Indeed, a big step to higher energy with perhaps 1000 times the luminosity of HERA could lead not only to new insights but to breakthroughs, especially in the understanding of QCD.

Given the exploration of novel QCD phenomena such as quark–gluon plasma in heavy-ion collisions at the LHC – and also because HERA never scattered electrons off deuterons or heavier ions – a programme of electron–ion physics at the LHeC collider would be of great interest. It would extend the kinematic range in terms of four-momentum transfer squared, Q^2, and the inverse of Bjorken-x, by nearly four orders of magnitude. This could reveal unexpected phenomena and would put the understanding of the partonic structure of the neutron and nuclei, and the exploration of high-density matter, on firmer theoretical ground.

The vision of a 50 TeV proton (and about 20 TeV lead-ion) beam from the FCC opens a further horizon to future DIS measurements, which, for example, would access contact-interaction scales of a few hundreds of tera-electron-volts, could study lepton–quark resonances should these exist, and determine the Higgs self-coupling based on an inclusive Higgs-production cross-section of 2 pb, which is much larger than the "Higgs-strahlung" cross-section at the International Linear Collider or the electron–positron FCC (FCC-ee).

A unique strength of the LHeC rests on the prospect of measuring parton distributions much more accurately than previously and of unfolding them without symmetry assumptions for the first time. This would remove a substantial part of the uncertainty of Higgs production in pp collisions, which dominantly occurs proportional to the square of the gluon distribution (xg) times the strong coupling constant. The measurement of Higgs production across a larger rapidity range in pp scattering at the FCC extends down to extremely small values of Bjorken-x. In this range, which is also of interest for ultra-high-energy neutrino scattering, the extrapolations of the current xg parameterizations no longer have any basis, and they differ hugely. Moreover, it is expected that nonlinear gluon–gluon effects set in, possibly leading to a saturation of gluon-dominated interaction cross-sections. The clarification of the laws of parton evolution at Bjorken-x < 10^{-4}, most likely leading to the end of validity of the linear so-called DGLAP evolution equations, is impossible without a DIS programme of the kind considered here, and is essential for the pursuit of a sound programme in pp physics at the energy frontier at CERN.

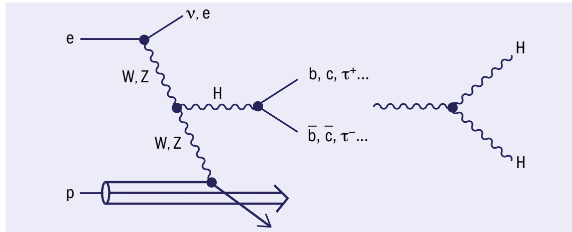


Fig. 2. Leading-order diagram for the production and decay of the Higgs boson in charged-current (W exchange) and neutral-current (Z exchange) deep-inelastic electron–proton scattering. The LHeC would allow precision measurements of the H–bb coupling in WW–H production. The FCC hadron–electron option would extend the reach further and give access to the Higgs self-coupling H–HH.

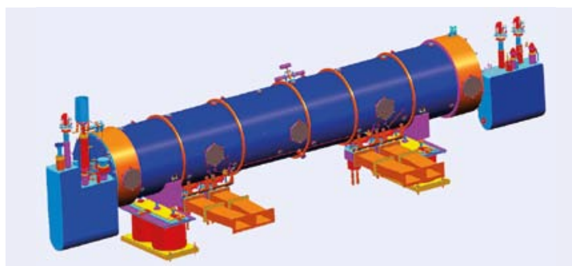


Fig. 3. The cryo-cavity module being designed by the CERN-Jlab-Mainz collaboration. (Image credit: SRF Institute, Jefferson Lab.)

The Higgs discovery has led to a reconsideration of the luminosity needs at the LHeC – a further focus of the Chavannes workshop. The conceptual design report (CDR) was directed at achieving an instantaneous luminosity of about 10^{33} cm^{-2} s^{-1} in synchronous ep and pp operations at the LHC (LHeC Study Group 2012). A substantial increase of this value is desirable, with the goal of producing 10^5 Higgs bosons across a 10-year period of operation. This would open the route to a 1% precision measurement of the decay $H \to b\bar{b}$, thanks to the clean final-state signature and the absence of pile-up. Such an increase of luminosity might be possible owing to the beam brightness of the HL-LHC, which is expected to be 2–3 times higher than assumed in the CDR, through doubling the electron-beam current to 10–20 mA and also by reducing the focusing of the proton beam in the ep interaction region. It is one of the goals of the new ep study initiated by CERN to understand the implications of high-intensity ep operation on the design of the interaction region and on the simultaneous operation of the LHC envisaged.

It has always been the tradition at CERN to plan a long time ahead carefully.

A deeper study of the possibility for an ep and eA collider at CERN shows that development of the technique of energy recovery is necessary. This is possible when the maximum energy beam is decelerated with a phase shift in the same superconducting RF cavity structure used for acceleration. An energy-recovery linac provides a unique opportunity to achieve high energy and high luminosity by efficient use of the available power. In the case of the LHeC design, a beam power of about 25 MW is used. This would correspond to a power of almost 1 GW if there were no energy recovery. In conjunction with the renewed study of ep at CERN, the decision has been made to design and build a set of two cryogenic superconducting RF-cavity modules in collaboration with experts at Jefferson Lab in the US and at Mainz University (figure 3). About 7 m long, one module comprises four cavities of a five-cell low-loss shape with a higher-order-mode coupler and supply end-can. The design is for a frequency of 802 MHz, with a few modules to be built for test purposes at CERN and Jefferson Lab and for the MESA project at Mainz. In a workshop last year, 802 MHz was chosen as a more-or-less optimum value for beam stability, cavity dimensions, RF power, dynamic losses, etc, and in view of the LHC and choices for the FCC developments also.

The two cryo-cavity modules could serve as the initial building blocks for an ERL test facility at CERN – the LTFC (figure 4). Its design, scheduled for 2015, is being undertaken in international collaboration. This test facility would have a variety of important goals: the development of superconducting RF at CERN under realistic operational beam conditions, with high gradients for continuous-wave operation (< 20 MV/m) and of high quality ($Q_0 > 10^{10}$); the development of high-current electron sources, which are also required for the FCC-ee; and further applications, such as magnet quench tests in a low-radiation environment and detector tests with an electron beam on-site of up to 1 GeV energy.

In addition to the many topics in deep-inelastic scattering that can be studied with the LHeC and the hadron–electron FCC (FCC-he), there is also an intimate relationship between ep physics and physics at pp and ee colliders. This was already evident when HERA, the Tevatron, the Large Electron–Positron Collider and the SLAC Linear Collider explored the Fermi scale. It is clear, not only from the example of Higgs studies, that this will also be the case at the energy scales of the LHC and the proposed FCC hh-ee-he complex (*CERN Courier* April 2014 p16). A new energy-frontier ep and eA project would naturally exploit the major investments in hadron beams at CERN. It would not become a flagship activity for CERN, since it would reside essentially at one experimental location, which could not satisfy the majority of the particle-physics community. However, such a project would provide a complementary window for the main upgrade programmes and would potentially lead into the distant future.

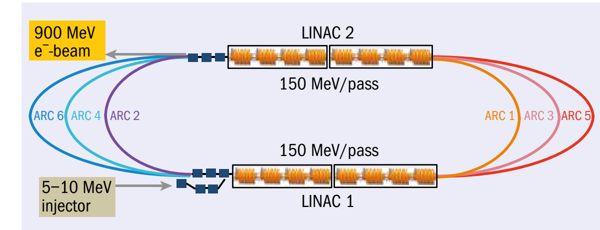


Fig. 4. The final stage of the ERL test facility being designed at CERN. (Image credit: Alessandra Valloni/CERN.)

It has always been the tradition at CERN to plan a long time ahead carefully, with the result that all big projects were achieved on time and to budget, and were also scientifically and technically successful. This is one of the secrets of CERN's success. Close co-operation between theory, experiments and technology was always essential for this to work. One aim of this article is to encourage collaboration on the test facility, on the accelerator, on the ep/eA detector being designed, and on the understanding and evaluation of an electron–proton and electron–ion physics programme at the energy and intensity frontier at CERN that would be worth pursuing.

Further reading

For more about the project, visit https://lhec.web.cern.ch.

LHeC Study Group 2012 *J. Phys. G* **39** 075001.
M Gell Mann 1967 *Proc. XIII Int. Conf. on High-Energy Physics, Berkeley, 1966* University of California Press 3.

Résumé

Des électrons au LHC : un nouveau départ

Le seul collisionneur de particules qui ait, jusqu'ici, exploité les collisions électron-proton à des énergies élevées était HERA, à DESY, où les expériences H1 et ZEUS avaient fourni une grande partie des fondements pour la physique au LHC et obtenu des résultats surprenants. Sur la base de l'étude de conception théorique pour le Grand collisionneur hadron-électron (LHeC) – une amélioration du LHC faisant intervenir un faisceau d'électrons – la Direction a décidé récemment de poursuivre l'étude de ces possibilités et a créé un Comité consultatif international. L'une des premières grandes activités de ce comité a été l'organisation d'un atelier sur le LHeC, sa physique et le développement des accélérateurs et détecteurs.

Max Klein, University of Liverpool, and **Herwig Schopper**, University of Hamburg and CERN.

High-school students from all geographical regions master real event-display programmes, software tools and analysis methods. Having been introduced to the problem, they identify electrons, muons, photons and jets by exploiting their characteristic signals in various detector elements, perform event selection and categorization, and achieve the final analysis goals. (Image credits, left to right: Caroline Hamilton/CoEPP/University of Melbourne, Jayne Ion/iON creative, Franziska Viebach/TU Dresden.)

International Masterclasses in the LHC era

Each year in spring, the International Particle Physics Outreach Group organizes the International Masterclasses, which give students the opportunity to analyse data from the LHC.

The International Masterclasses (IMCs) began in 2005 as an initiative of what was then the European Particle Physics Outreach Group (EPPOG) (*CERN Courier* October 2005 p23). Since then, EPPOG has become the International Particle Physics Outreach Group (IPPOG), and the masterclasses have grown steadily beyond a group of IPPOG member countries. This year, the 10th edition of the IMCs included 200 institutions in 41 countries worldwide. Several of the initiatives have attracted new partners, including some from the Middle East and Latin America, enabling IMCs to be held in diverse locations – from Israel and Palestine to South Africa, and from New Zealand to Ecuador – in addition to the many sites in Europe and North America. Now, well into the LHC era, the masterclasses use fresh data from the world's biggest particle accelerator, as collected by the four big experiments.

All of the LHC collaborations involved acknowledge the potential – and the success – of educational programmes that bring important discoveries at the LHC to high-school students by providing large samples of the most recent data. For example, 10% of the 8-TeV ATLAS "discovery" data are available for students to search for a Higgs boson; CMS approved 13 Higgs candidates in the mass region of interest, which are mixed with a more abundant sample of W and Z events, for "treasure hunt" activities; ALICE data allow students to study the relative production of strange particles, which could be a tell-tale signal of quark–gluon plasma production; LHCb teaches students how to measure the lifetime of the D meson; and particles containing b and c quarks are studied extensively to shed light on the mystery of antimatter in the universe.

Students quickly master real event-display programmes – such as iSpy-online, Hypatia and Minerva – software tools and analysis methods. First, they practice particle identification by exploiting the characteristic signals left by particles in various detector elements, where electrons, muons, photons and jets are recognizable. They go on to select and categorize events, and then proceed with measurements. Typically, two students analyse 50–100 events, before joining peers to combine and discuss data with the tutors at their local IMC institution. Then they join students at several other locations to combine and discuss all of the data from that day in a video conference from CERN or Fermilab (see table 1, p38).

The IMCs make five measurements available. Typically, a local institution selects one that their physicists have deep knowledge of, guaranteeing that experts are available to talk to the students about what they know best.

The ATLAS Z-path measurement relies on invariant mass for particle identification. It is first applied to measure the mass and width of the Z boson, and of the J/ψ and Υ mesons. These ▷

More than 200 institutions in 40 countries and more than 10,000 high-school students participated in the 2014 IMC, analysing LHC data.

Measurement	No. of masterclasses (CERN + Fermilab)	No. of video conferences (CERN + Fermilab)
ALICE	16 (16 + 0)	4 (4 + 0)
ATLAS	132 (118 + 14)	33 (27 + 6)
CMS	70 (46 + 24)	23 (10 + 13)
LHCb	21 (21 + 0)	7 (7 + 0)

Table. 1. Use of the different measurements in 2014.

parameters are all inferred from the decay products – pairs of e^+e^- or $\mu^+\mu^-$ leptons. When a hypothetical new heavy gauge boson, Z′, is mixed with the data, the simulated signal shows up in the dilepton mass distribution. The students apply the same technique to di-photons and pairs of dileptons to search for decays of a Higgs boson to $\gamma\gamma$ and ZZ^*, leading to a four-lepton final state.

The ATLAS W-path deals with the structure of the proton and the search for a Higgs boson. Students look for a W-boson decaying into a charged lepton and a neutrino (missing energy), and build the charge ratio N_{W^+}/N_{W^-}. The simple view of a proton structure of uud quarks leads to a naive approximation of $N_{W^+}/N_{W^-} = 2$. The presence of sea quarks and gluons complicates the picture, bringing the ratio down to around 1.5, compatible with the measurements by ATLAS and CMS. The next challenge is to study events containing W^+W^- pairs, which are characterized by two oppositely charged leptons and neutrinos. Decays of a Higgs boson to W^+W^- would enhance the distribution of the azimuthal angle between the charged leptons at low values.

The CMS measurement is called "WZH" for the W, Z, and Higgs bosons. Based on the signatures of leptonic decays, students determine whether each event is a W candidate, a Z candidate, a Higgs candidate, or background. For W bosons, they use the curvature of the single measurable lepton track to decide if it is a W^+ or W^- and so derive the charge ratio of W-boson production. They can also characterize events as having a muon or an electron to measure the electron-to-muon ratio. For Z and Higgs candidates, students put the invariant masses of lepton and dilepton pairs, respectively, in a mass plot. They discover the Z and Higgs peaks, including a few other resonances they might not have expected.

ALICE's ROOT-based event-display software enables students to reconstruct strange particles (K_s, Λ, $\bar{\Lambda}$) decaying to $\pi\pi$ and $p\pi$. As a second step, they analyse large event samples from lead collisions in different regions of centrality, and normalize to the mean number of nucleons participating in the collision for each centrality region. Data from proton collisions and from lead-ion collisions lead to a measurement of the relative production of strangeness, which the students compare with theoretical predictions.

The LHCb measurement allows students to extract the lifetime of the D^0 meson after having studied and fitted an invariant-mass distribution of identified kaons and pions. The next step is to compare and discuss properties of D^0 and $\bar{D}^0$ decays.

All of these educational packages are tuned and expanded to follow the LHC's "heartbeats". The intention is for the IMCs to bring measurements for new discoveries in the coming years.

A model for science education

The IMCs have led to other masterclass initiatives. National programmes bring masterclasses to students in areas far from the research institutes that host the international programme. In several countries, programmes for teachers' professional development include masterclass elements, as does CERN's national teacher programme. Masterclasses also reach locations other than schools, such as science centres or museums, and other fields of physics, including astroparticle and nuclear physics, have embarked on national and international masterclass programmes.

The largest national programme is the German four-level "Netzwerk Teilchenwelt", which has been active since 2010. In its basic level, more than 100 young facilitators, mostly PhD and Masters' students from 24 participating universities and research centres, take CERN's data to schools. Throughout the year, on at least every other school day, a local masterclass takes place somewhere in Germany. Annually, about 4000 students are invited to further qualification and specialization levels in the network, which can lead to their own research theses. Another example is the Greek "mini-masterclasses" at high-schools, which are usually combined with virtual LHC visits where students link with a physicist at the ATLAS or CMS experimental areas.

Elements of particle-physics masterclasses for teachers' professional development have become standard in most of the national teacher programmes at CERN and in countries such as Austria, France, Germany, Greece, Italy and the US. Masterclasses for the general public have taken place in science centres in Norway and Germany.

Other physics fields are also using the masterclasses as a model for physics education and science communication. For example, in the UK, nuclear-physics masterclasses cover nuclear fusion and stellar nucleosynthesis. Astroparticle physics is also joining the masterclass scene. In Germany, the Netzwerk Teilchenwelt hosts masterclasses that use data from the Pierre Auger Observatory to reconstruct cosmic showers or energy spectra, or data on cosmic muons that the students take themselves using Cherenkov or scintillation detectors. Since 2012, students at the Notre Dame Exoplanet Masterclass in the US have used data and tools from the Agent Exoplanet citizen science project run by the Las Cumbres

Observatory Global Telescope Network to measure characteristics of exoplanets from their effects on the light curves of stars that they orbit during a transit. New international masterclasses on the search for very high-energy cosmic neutrinos at the IceCube Neutrino Observatory at the South Pole will connect three countries in May 2014, with more countries joining in 2015.

Behind the scenes

An international steering group manages the IMCs in close co-operation with IPPOG. Co-ordination is provided through the Technische Universität (TU) Dresden and the QuarkNet project in the US, and funding is provided by institutions in Europe (CERN, the European Physical Society and TU Dresden) and the US (the University of Notre Dame and Fermilab). While the co-ordination based at TU Dresden is responsible for the whole of Europe, Africa and the Middle East, co-ordination through QuarkNet covers North and South America, Australia and Oceania and the Far East. Co-ordinators are in close contact with all of the participating institutions. They issue circulars, create the schedule, maintain websites, provide orientation and integrate new institutions into the IMCs. As QuarkNet is a US programme for teachers' professional development, the co-ordination also includes visiting and preparing educators at schools and at IMC institutions.

One of the highlights of the IMCs is the final video conference, where students present and combine their results with other student groups and moderators at CERN or Fermilab. Co-ordinators take special care to create the schedule so that every video conference is an international collaboration that lets the students explore part of the daily life of a particle physicist, doing science across borders. Young physicists at CERN and Fermilab moderate the sessions and represent the face of particle physics to the students. The co-ordinators maintain excellent collaboration with the moderators, for example arranging training and monitoring video conferences.

IPPOG – an umbrella for more

The IMCs in the LHC era are a major activity of IPPOG, a network of scientists, educators and communication specialists working worldwide in informal science education and outreach for particle physics. Through IPPOG, the masterclasses profit from scientists taking an active role, conveying the fascination of fundamental research and thereby reaching young people. IPPOG offers a reliable and regular discussion forum and information exchange, enabling worldwide participation. In addition to organizing the IMCs and hosting a collection of recommended tools and materials for education and outreach, IPPOG facilitates participation in a variety of activities such as CERN's new Beam Line for Schools project and the celebrations for the organization's 60th anniversary.

IPPOG is poised to support recommendations outlined in the 2013 update to the European Strategy for Particle Physics and the US Community Summer Study 2013, to engage a greater proportion of the particle-physics community in communication, education and outreach activities. This engagement should be supported, facilitated, widened and secured by measures that include training, encouragement and recognition. Many individuals, groups and institutions in the particle-physics community reach out to members of the public, teachers and school students through a variety of activities. IPPOG can help to lower the barriers to engagement in such activities and make a coherent case for particle physics.

● The organizers of the IMCs expect and welcome new partners. For more about the programme, visit http://physicsmasterclasses.org/. For more about IPPOG, see http://ippog.web.cern.ch. For the Netzwerk Teilchenwelt, visit www.teilchenwelt.de; for the Mini-Masterclasses, see http://discoverthecosmos.eu/news/87; and for QuarkNet, see http://quarknet.fnal.gov/.

The LHC and beyond

The International Masterclasses make use of real events from LHC experiments through a variety of activities:

- ATLAS Z-path – http://atlas.physicsmasterclasses.org/en/zpath.htm
- ATLAS W-path – http://atlas.physicsmasterclasses.org/en/wpath.htm
- CMS measurement – http://cms.physicsmasterclasses.org/pages/cmswz.html
- ALICE ROOT-based – http://aliceinfo.cern.ch/public/MasterCL/MasterClassWebpage.html
- ALICE – www-alice.gsi.de/masterclass/
- LHCb measurement – http://lhcb-public.web.cern.ch/lhcb-public/en/LHCb-outreach/masterclasses/en/
- iSpy-online – www.i2u2.org/elab/cms/event-display/
- Hypatia – http://hypatia.phys.uoa.gr/
- Minerva – http://atlas-minerva.web.cern.ch/atlas-minerva/

At the same time, activities are extending beyond particle physics:

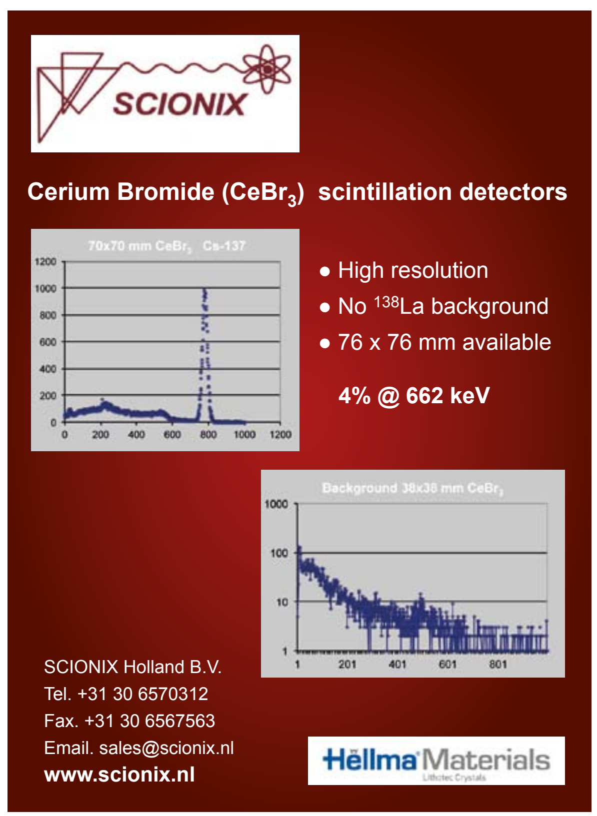
- Nuclear physics – www.liverpoolphysicsoutreach.co.uk/#/nuclear-physics-masterclass/4567674188
- Exoplanet Masterclass – http://leptoquark.hep.nd.edu/~kcecire/exo2013/
- IceCube – http://icecube.wisc.edu/masterclass/participate

Résumé

Cours internationaux à l'ère du LHC

Chaque année, au printemps, le Groupe international de sensibilisation à la physique des particules organise des cours internationaux qui donnent l'occasion à des étudiants d'analyser des données du LHC. Depuis leur lancement en 2005, ces cours se sont développés et ont dépassé le cadre des pays membres du groupe. Cette année, 200 institutions ont participé, dans 41 pays du monde entier – d'Israël et de la Palestine à l'Afrique du Sud, en passant par la Nouvelle-Zélande et l'Équateur, ainsi que dans de nombreux sites en Europe et en Amérique du Nord. Ces cours incluent maintenant l'utilisation de données récentes provenant de chacune des quatre grandes expériences du collisionneur.

Marge Bardeen, Fermilab, **Hans Peter Beck**, University of Bern, **Uta Bilow**, TU Dresden, **Kenneth Cecire**, University of Notre Dame, **Farid Ould-Saada**, University of Oslo, **Michael Kobel**, TU Dresden.



Faces & Places

Awards

Ben Segal joins Internet Hall of Fame

CERN's Ben Segal is one of 24 new inductees into the Internet Hall of Fame, which annually honours individuals selected by the Internet Society for their significant contribution to developing and advancing the internet. At a ceremony on 8 April in Hong Kong, Segal was awarded the honour of Global Connector, for an individual who has made significant contributions to the global growth and use of the internet.

Segal joined CERN's Data Handling Division in 1971 and, as CERN's first official "TCP/IP Co-ordinator", from 1985 to 1988, was responsible for co-ordinating the introduction of internet protocols within the laboratory. He also taught TCP/IP and Unix, and distributed computing in many countries in Europe, Asia and Latin America from 1986 until his retirement in 2002.

Segal continues to work at CERN as an honorary staff member, focussing on volunteer computing using the BOINC infrastructure to harness large amounts of computing power from the public, in projects such as the Citizen Cyberscience Centre, LHC@home and Africa@home (*CERN Courier* September 2006 p62). He joins three other CERN members of the Internet Hall of Fame: World Wide Web innovators Tim Berners-Lee and Robert Cailliau, and internet innovator François Flückiger (*CERN Courier* September 2013 p58).


Ben Segal joins the Internet Hall of Fame. (Image credit: Christiane Segal.)

Canada honours members of ALPHA collaboration

At a ceremony that took place on 3 February in Ottawa, Canadian members of the ALPHA collaboration were presented with the Natural Sciences and Engineering Research Council's John C Polanyi Award by Governor General of Canada David Johnston. The prize "honours an individual or team whose Canadian-based research has led to a recent outstanding advance in the natural sciences or engineering".

ALPHA's Canadian team received this prestigious national award for its contribution to the experiment's successes in trapping and measuring antihydrogen atoms. Using techniques developed by the team, the collaboration measured for the first time the response of trapped antihydrogen to microwaves, which opened the door to comparing it with the well-known response of hydrogen (*CERN Courier* April 2012 p7).

The ALPHA-Canada team includes plasma, atomic, condensed-matter, particle, detector, and accelerator physicists, and students from the University of British Columbia, Simon Fraser University, the University of Calgary, York University and TRIUMF. They contributed particularly in electronics and analysis for the annihilation detector, and the development of the microwave system for measuring antihydrogen's ground-state structure. The engineering and construction of ALPHA-2's atom-trap cryostat was also led by Canadian institutes.


Makoto Fujiwara, leader of the ALPHA-Canada team, left, shakes hands with the Governor General of Canada at the award ceremony. (Image credit: MCpl Vincent Carbonneau, Rideau Hall/Her Majesty The Queen in Right of Canada represented by the Office of the Secretary to the Governor General (2014).)

School

Particle physics in the Philippines

For the first time, a particle-physics school organized in collaboration with CERN has taken place in the Philippines. The venue was the National Institute of Physics at the University of the Philippines Diliman, close to Manila. The eight-day programme of lectures, ranging from basic particle physics to results from the LHC and other interesting frontier experiments, also included a special afternoon for the public. Lecturers came not only from various Manila-based universities and CERN, but also from the south of the Philippines (Mindanao) and from nearby Taiwan.

The school targeted secondary-school students in their final year as well as undergraduates from science and engineering departments in universities across the Philippines. Its success was testified by the numbers: more than 500 students applied to participate and around 100 followed the school throughout. Many of the students expressed an interest in following up the subject further and in applying to CERN's summer student programme. Former CERN summer students gave feedback – at times emotional – on their personal experience of their stays at CERN.

The school would not have been possible without the support of CERN and the Philippines Department of Science and Technology. The plan is to repeat the school a few years from now.


The first particle-physics school in the Philippines, co-sponsored by CERN. (Image credit: André David.)

LHC UPGRADE

CMS travels to the past to plan the future

With the aim of expanding the physics reach of the experiments at the LHC, the High Luminosity LHC (HL-LHC) project will allow the collider to reach an instantaneous luminosity an order of magnitude higher after it is upgraded around 2020. To exploit the full power of the accelerator and to survive the hostile high-radiation environment, as well as to meet the challenge of reconstructing the more than 100 interactions that will occur at each bunch crossing, the detectors at the LHC will need to undergo extensive upgrade programmes of their own.

Between 31 March and 4 April, 264 experts from the CMS collaboration and from 80 institutes worldwide congregated at the Karlsruhe Institute für Technologie (KIT) for a meeting organized by the Institut für Experimentelle Kernphysik (IEKP) – a long-term CMS member institute – to exchange ideas and plan an ambitious upgrade of the CMS detector. The five-day conference focused on the preparation of a technical proposal to be submitted to the LHC Committee at its September session. With 130 presentations in plenary and parallel sessions, accompanied by eight management meetings, this CMS week provided a unique opportunity to review the motivations for the proposed upgrades and to consolidate the organization of the R&D programmes.

The engagement of the collaboration in the HL-LHC upgrade has escalated recently and tremendous progress was reported at the meeting, demonstrating the strength of the programme to fully exploit the HL-LHC and its most challenging physics potential. Major innovations foreseen for the future detector include a new "light" tracker, with selective read-out at 40 MHz for the purpose of enabling a hardware trigger, and an extension of coverage in the forward region, in conjunction with high-resolution and fine-granularity endcap calorimetry, to discern vector-boson fusion or scattering processes. Many new ideas to provide enhanced reduction of background, mitigate the effect of pile-up and improve acceptance for various physics signals were also discussed.

To take a break from the intense discussions and long meeting days, the collaboration took a trip into the past, travelling on a 90-year-old steam train into the Black Forest. Thirty kilometres south of Karlsruhe, the small spa town of Bad Herrenalb – and home town of the organizer of the CMS week, Thomas Muller – welcomed the visitors with a traditional "Schwarzwaldabend". Accompanied by regional food, the participants enjoyed presentations by the local hornblowers and traditional dancers. Another highlight of the evening was the awarding of a model of CMS laser-engraved into a crystal to Simon Weingarten from RWTH Aachen, for the best poster presented at the meeting.

Above: Members of the CMS collaboration on arrival in Bad Herrenalb. Right: CMS spokesperson Tiziano Camporesi in the driving seat. (Image credits: KIT.)

MEETINGS

HF2014, the **55th ICFA Advanced Beam Dynamics Workshop on High Luminosity Circular e^+e^- Colliders – Higgs Factory** will take place on 9–12 October in Beijing, hosted by the Institute of High Energy Physics, Chinese Academy of Sciences. ICFA supports studies of energy-frontier circular colliders and encourages global co-ordination. Topics will range from parameters and optics through superconducting RF to instrumentation and control. The deadline for registration is 31 August. For more details, visit http://hf2014.ihep.ac.cn/.

The **3rd International Workshop on Accelerator-Driven Sub-Critical Systems and Thorium Utilization** will be held on 14–17 October at Virginia Commonwealth University, Richmond, Virginia. The workshop will include working sessions on fast-spectrum and thorium-based systems, and thermal-spectrum systems, as well as superconducting RF ingot niobium technology, accelerator systems and enabling technologies. It will also seek to identify areas of common interest to explore the possibilities of future collaboration. For further information, visit http://adsthu.org/index.html.

CORRECTION

The article "Neutrinos and nucleons" (*CERN Courier* April 2014 p23) erroneously stated that the Gargamelle bubble chamber had been built at Orsay. While André Lagarrigue, who was the inspired leader of the project was at Orsay, the chamber was built at Saclay. Apologies to all concerned.

CERN

ELENA building inagurated

A new building for the future Extra Low ENergy Antiproton (ELENA) ring was inaugurated at CERN on 11 April, less than a year after construction began. Erected at the side of the Antiproton Decelerator (AD), the building will house a cleaning room, workshops and generators for the AD's kicker magnets, to free space in the AD hall where ELENA will be installed.

To make space for the building, some 10,000 tonnes of earth had to be moved by around 500 lorries. The presence of the TT2 transfer tunnel directly beneath the building also posed a number of technical challenges. An 800-mm-thick shielding slab has been implemented to shield the building from radiation.

The demand for low-energy antiprotons at the AD continues to grow, particularly in the field of antihydrogen spectroscopy and measurements of gravitational effects on antimatter, and the AD alone can no longer provide the number of antiprotons needed. ELENA – a small magnetic decelerator ring 30 m in circumference that will fit inside the present AD hall – will slow down the 5.3 MeV antiprotons from the AD to an energy of only 100 keV. This will increase the number of trapped antiprotons in the AD experiments by a factor of 10–100. In addition, ELENA will allow parallel operation of up to four experiments.

The project's Technical Design Report has been published recently and the work is progressing well. ELENA's deceleration ring will be installed in the AD hall in the middle of 2015 and its research programme should begin two years later.

Above: The newly inaugurated ELENA building at CERN. (Image credit: CERN-PHOTO-201404-075 – 1.) Top right: ELENA project leader, Christian Carli, second from left, and François Butin, technical co-ordinator of the project, left, spoke at the inauguration ceremony. (Image credit: CERN-PHOTO-201404-075 – 11.)

Visits

Philippe Courard, the Belgian state secretary for social affairs, families, the disabled and scientific policy, in charge of occupational risks, came to CERN on 28 March. His visit included a descent into the LHC tunnel and the CMS experimental hall at Point 5. (Image credit: CERN-PHOTO-201403-063 – 29.)

During her visit to CERN, also on 28 March, the Italian minister of education, university and research, **Stefania Giannini**, centre, was shown the ATLAS experimental cavern by former spokesperson, **Fabiola Gianotti**, left, and current spokesperson, **Dave Charlton**. (Image credit: CERN-PHOTO-201404-067 – 28.)

Albert Frick, left, president of the Liechtenstein parliament, visited CERN on 1 April. He toured the ATLAS experimental hall, the LHC tunnel and the Globe of Science and Innovation, and met with the director-general, **Rolf Heuer**. (Image credit: CERN-PHOTO-201404-066 – 15.)

Left: On 2 April, the president of Germany, **Joachim Gauck**, right, and his delegation, visited the LHC tunnel and ATLAS underground experimental area, accompanied by the director-general, **Rolf Heuer**. Right: At a round-table discussion with German-speaking scientists in the Globe of Science and Innovation, the panel included, left to right, **Georg Schütte**, state secretary of the German Federal Ministry of Education and Research, **Maria Böhmer**, minister of state at the Federal Foreign Office, **Joachim Gauck**, **Rolf Heuer**, **David Gill**, state secretary and head of the President's Office, and **Otto Lampe**, German ambassador to Switzerland. (Image credits, left to right: CERN-PHOTO-201404-069 – 8, CERN-PHOTO-201404-069 – 56.)

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Faces & Places

Obituaries

Ian Butterworth 1930–2013

Ian Butterworth sadly died on 1 December, two days before his 83rd birthday. He was a major force in European particle physics, from the late 1950s until leaving his post as research director at CERN in 1986 to become the principal of Queen Mary College, London.

Ian obtained his PhD at Manchester in Patrick Blackett's cosmic-ray group and later followed Blackett to Imperial College – a connection he retained for the remainder of his life. In the 1960s and early 1970s, the bubble chamber was the principal device for pictorial examination of particle reactions, and this was Ian's area of expertise. The discoveries of resonant hadronic states dominated research at that time, and the patterns that emerged ultimately established the "Eightfold Way" and led to the quark model. Ian's speciality was investigating these resonances using mass spectra and partial-wave analysis, and he gave plenary talks at many international conferences on both meson and baryon resonances.

Ian had vision. He recognized that innovation and particularly information technology (IT) would not only bring substantial benefit but would also prove essential for advances. Following a stay at Berkeley in the 1960s, he initiated a UK programme to equip groups with Hough–Powell automatic measuring machines, and in the 1970s he was influential in enabling the Imperial College group to engage with a team at SLAC in developing the hybrid rapid-cycling bubble-chamber facility to investigate processes too rare for a conventional chamber. The potentialities of IT fascinated him. While not a software expert, he appreciated the importance of cutting-edge computing and ensured that at Imperial there

Ian Butterworth. (Image credit: Meilin Sancho/Imperial College London.)

would be local state-of-the-art computing facilities. One of his great pleasures as research director at CERN was that his remit covered the data-handling division, so he could discuss these matters with the experts. Later in his career he was one of the first to appreciate the importance of computer networking and the great potential of the web.

Ian's desire to make things happen extended to committees and he proved an excellent committee chair. In the area of particle physics, he was chair of the UK's film-analysis committee and Nuclear Physics Board, and of the Super Proton Synchrotron Committee at CERN. In his later days, he chaired many more committees associated with publishing and European co-operation in education and research.

He held many appointments: head of the Rutherford Laboratory's bubble chamber group (1968–1971), head of the Imperial High-Energy Physics group (1971–1983), head of the Imperial College Physics Department (1981–1983), research director at CERN (1983–1986), principal of Queen Mary College, London (1986–1990) and pro-vice-chancellor of the University of London for European Affairs (1989–1991). He was elected a fellow of the Royal Society in 1981 and to the Academia Europaea in 1989, which reinforced his interest in pan-European approaches to education and research.

Things changed for Ian in 1990 when, at the age of 60, he had a stroke. However, less than a year later he was back at Imperial and active in the ZEUS experiment at DESY with colleagues he had worked with previously while studying baryon resonances. His interests broadened and he became chair of the board of IOP Publishing Ltd, and with his undiminished love for technological advance moved the company to embrace electronic publishing. He was very proud when they published the world's first electronic physics journal and were subsequently the first to move all their publications to the web.

He was soon working tirelessly on his two major interests: the effective use of the web for electronic publishing and the advancement of a coherent European strategy for education and research. Much of this was under the auspices of the Academia Europaea, and he was elected a vice-president in 1997. During the past few years he gave up much of the committee work but retained a deep interest in European culture and continued to enjoy travelling around Europe, not least to follow another passion, excellent food.

Ian was a unique person – warm-hearted, lively and excellent company. He leaves a daughter, Jody, and son-in-law, Nicholas.

● *Peter Dornan, Imperial College London.*

Giorgio Giacomelli 1931–2014

Giorgio Maria Giacomelli, professor emeritus of experimental physics of the Alma Mater Studiorum – University of Bologna – died on 30 January. He was one of the leading scientists who contributed significantly to the university's excellence in experimental particle physics.

Born in Cagli in 1931, Giorgio received a degree in physics from the University of Bologna in 1954, followed by a PhD in physics from the University of Rochester, New York, in 1958. He was appointed professor of general physics at the University of Padua in 1971 and then at the University of Bologna in 1974. He was director of the Institute of Physics and later of the Department of Physics of the Alma Mater.

Countless universities and international research laboratories beyond Italy had the privilege of Giorgio's collaboration and teaching – the University of Rochester, CERN, the Atomic Energy Research Establishment at Harwell, the Brookhaven National Laboratory, the Institute of High-Energy Physics in Serpukhov, Fermilab, the University of Kyoto, and the University of California, at Berkeley and Riverside. He was a committed advocate for co-operation and science dissemination in universities and laboratories in developing countries, initiating collaborations with Oujda, Kolkata, Islamabad, Bamako, São Paulo and Recife.

At the Alma Mater, Giorgio trained and mentored generations of students and researchers, supervising hundreds of undergraduate and postgraduate theses in Italy and abroad. His scientific attitude, an uncompromising refusal of any approach that was not scientifically founded, a rare ability to synthesize and identify solutions – all of these combined with an uncommon physics insight to make him recognized as a master in the field.

Among his important results, the following are worth mentioning: total and elastic hadronic cross-section measurements from a few million electron-volts to 1.8 TeV; the discovery of around 10 new structures/resonances (Brookhaven 1966–1970); the discovery of rising K^+p total cross-section (Serpukhov 1970–1971), $\pi^{\pm}p$, K^-p and $\bar{p}p$ total cross-sections (Fermilab 1974–1980, 1988–1990); hadron production in pp, pN and $\bar{p}p$ collisions from a few giga-electron-volts to 1.8 TeV (CERN Intersecting Storage Rings, Serpukhov, Fermilab, 1968–1984) at low transverse momentum (p_t); the determination of simple scaling laws and of the main features of hadron production, leading to the four-jet structure in high-p_t hadron collisions; detection of $\bar{d}$, $^3\bar{H}$ and $^3\overline{He}$ in an intense RF-separated beam at CERN's Super Proton Synchrotron (1977–1978); the study of K^+N collisions at 0.6–2 GeV (1964–1970); and the study of (anti)ν–deuteron collisions in the Big European Bubble Chamber (CERN 1980–1988).

Giorgio Giacomelli. (Image credit: Stefano Cecchini.)

Giorgio was a member of the OPAL collaboration and its leading committees. He was co-spokesman of the MACRO experiment at the Gran Sasso National Laboratory, which in 1998 co-discovered, with Soudan-2 and Super-Kamiokande, neutrino oscillations in the atmospheric sector. MACRO also yielded the best direct limits on grand-unified-theory magnetic monopoles (*CERN Courier* May 2003 p21). He contributed to the ANTARES and OPERA experiments, being an active member until the end.

He was author of more than 800 publications in scientific journals, 450 reports and conference proceedings, and 50 scientific monographs. He was also a member of many national and international scientific committees, which included the European Committee for Future Accelerators and committees of CERN, Fermilab and INFN. At the time of his death, he was still a collaborator with INFN and CERN, a fellow of the American Physical Society, "*socio benemerito*" of the Italian Physical Society, and a member of the European Physical Society, the Accademia delle Scienze di Bologna and the New York Academy of Sciences.

From the late 1960s, Giorgio was a respected and admired group leader. He had a unique ability to identify an individual's natural talent, whatever its nature, whether it be theoretical or experimental, organizational or communication skills. Undergraduates and graduate students, technicians and researchers, young and old – he was able to find, appreciate and value their best qualities, which became a resource for the whole team.

Giorgio coupled leadership with kindness. His natural respect for people, his lack of any cultural or gender bias, and his gentle but determined nature created a friendly and efficient work environment where everyone always felt welcome and valued. A natural communicator, in later years he increased his dedication to the popularization of science, and was chairman of the University of Bologna's popularization website, www.scienzagiovane.unibo.it.

● *His privileged and affectionate collaborators and friends.*

Jean Perez y Jorba 1930–2013

An important personality in the world of particle physics, Jean Perez y Jorba passed away on 10 January 2013, after an accident at the age of 82.

Jean Perez y Jorba entered the Ecole Normale Supérieure in 1949. From the beginning it was obvious that he was extremely gifted. He oriented himself in experimental nuclear physics, beginning with a stay in Saclay, before moving to the laboratory of Hans von Halban in Oxford. When Halban moved to the Ecole Normale, Perez y Jorba came back with him, and then followed Halban to Orsay, to the Laboratoire de l'Accélérateur Linéaire (LAL), where a linear electron accelerator was being built.

As the machine was beginning to function, Pierre Lehmann and Perez y Jorba came to CERN to consult the theory division, where I worked, early in 1961. Their problem was that, because of the structure of the beam, they could not make coincidence experiments, but could only measure the energy and angle of the outgoing electron, and they asked what to do. Together with Sergio Fubini, we started working on the blackboard and concluded that they could measure two and only two functions of two variables. These were what were later called the "structure functions", which maybe we were the first to discover. In July of the same year, I learnt that James Bjorken had obtained the same result.

Jean Perez y Jorba. (Image credit: LAL.)

Perez y Jorba went on to perform many important experiments in Orsay and trained many students. He became a full professor at the University of Paris XI in 1963. From 1975 to 1986 he was director of LAL. He was a member of many committees, both in France and elsewhere, especially at CERN, where he was a member of the Research Board and of the Scientific Policy Committee. He was also a member of the European Committee for Future Accelerators and of the scientific committee of the DESY laboratory in Hamburg. In 1994 he became a French delegate at CERN Council.

In 1986, Perez y Jorba founded the Magistère de Physique Fondamentale in Orsay. Because of his scientific rigour and insistence on quality, this high-level course, which he ran until 1998, became a flagship in the teaching programme of the university, where he was also dean of the faculty of sciences from 1991 to 1996.

Perez y Jorba was demanding of himself and of others – something that not everyone appreciated, but he cared a great deal for those with whom he worked, and was deeply human.

This text is based largely, with kind permission, on an obituary by Alain Cordier, published in *l'Archicube*, the periodical of the alumni of the Ecole Normale.

● *André Martin, CERN.*

Ioana Videau 1937–2014

It is with great sorrow that her colleagues and friends learned that Ioana Videau passed away on 1 April. She had a very productive career in physics, combining a flair for analysis with an excellent technical competence in data acquisition and computing techniques.

In 1967, Ioana came from Romania to France to do her PhD at the Ecole Polytechnique on a bubble-chamber experiment. There she met her husband, Henri Videau, with whom she collaborated on many experiments throughout the years. From 1969 to 1978, she worked on the hyperon-beam experiment, for which she had already played a key role in the data-acquisition system. She then spent a few years in the US at the Lawrence Berkeley National Laboratory. Working on the Mark II detector at the SPEAR electron–positron collider at SLAC, she engaged in studies of the then poorly known charmed mesons and baryons.

Returning to Europe, Ioana participated in the conception and construction of the ALEPH detector at CERN's Large Electron–Positron Collider. She took responsibility for the data-acquisition modules and programs for the electromagnetic calorimeters that were built in France and the UK. At the start of data taking, in a period of difficulties, she was asked by the collaboration to lead the online data-acquisition group. With her characteristic mixture of technical skills, dedication, strong convictions, and sensitivity toward human relationships, she united the group's efforts and allowed ALEPH to proceed with an excellent and efficient team. With an acute interest in data analysis, she focused on B physics and determination of electroweak parameters, and mentored a number of graduate students.

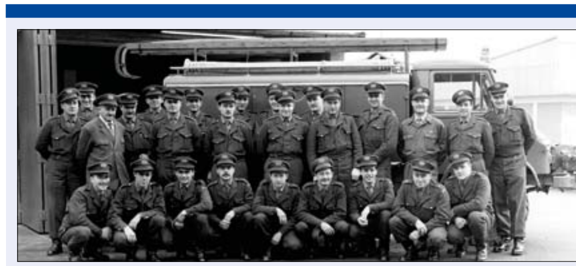
Ioana Videau. (Image credit: Videau family.)

Ioana moved to the Laboratoire de l'Accélérateur Linéaire, Orsay, in 1992, and served as deputy director in the years 1996–1997. In 1997, she joined the LHCb collaboration and participated in the conception of the calorimeter electronics and its use in the trigger. However, her main impact was in unifying control of the electronics in the cavern with a system that is immune to single-event upsets.

At the request of Tatsuya Nakada, spokesman of the collaboration, Ioana served as LHCb's deputy spokesperson from 1999 to 2001. At the end of her term, she was asked by the leader of CERN's Experimental Physics (EP) Division to become his deputy. She then set up a group with experts from the EP and IT divisions to develop software tools common to all the four big LHC experiments. That this was a success owes a great deal to Ioana's skills, leadership and professional relationships.

She will be missed greatly. We offer our deepest condolences to her husband Henri and their children.

● *Colleagues and friends.*



Left: The fire brigade in January 1961. The majority of the firefighters were recruited from the Paris professional Fire Brigade. Right: CERN's Fire Brigade team in April 2011. CERN's Fire and Rescue Service (FRS, GS-FB Group) currently consists of 58 professionals. These are highly sought-after positions: for just a handful of vacancies, hundreds of applications are submitted from all over Europe. only professional firefighters with at least five years' experience at a centre with high levels of operational activity may apply…and they must also have a good command of at least one of the Organization's two official languages. In 2010, the Fire Brigade welcomed its first female firefighter, quickly followed by two more. For many years, the members of CERN's Fire Brigade went on call-outs clad in their work trousers and fire-rescue coats, which only afforded them partial protection. Today, textile manufacturing techniques have moved on a long way and CERN's firefighters are now kitted out with state-of-the-art personal protective equipment. The coat and trousers are three-layered, comprising fire-resistant aramide, a protective membrane and a thermal lining. (Image credits: CERN-SA-6103294 CERN-GE-1104113 01.)

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
Tel +44 (0)117 930 1264 Fax +44 (0)117 930 1178 E-mail sales@cerncourier.com
Please contact us for information about rates, colour options, publication dates and deadlines.

EBG MedAustron GmbH is currently building and, in the future, operates a state-of-the-art centre for ion beam therapy and research in Wiener Neustadt, Austria. After the centre's completion, patients will be treated using proton and carbon ion radiation. Currently, only three centres worldwide offer these two radiation treatment options at the same location.

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Scientist (f/m) (tenure-track position)

DESY

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The position

- Participate in experimental and theoretical accelerator research and development for the synchrontron light source PETRA III
- Study the linear and nonlinear dynamics of the electron beam for future upgrade scenarios of PETRA III toward a higher beam quality
- Participate in the operation of PETRA III
- Assist the supervision of master and Ph.D. students

Requirements

- Ph.D. in physics or engineering science
- Several years of experience in accelerator physics
- Experience in computer simulations and numerical methods (the knowledge of commonly used codes within the accelerator physics community is an advantage)
- Ability to communicate research results effectively, both orally and in writing, within the team and at international conferences
- Basic knowledge of German is advantageous

For further information please contact Rainer Wanzenberg, +49 40 8998-2496, rainer.wanzenberg@desy.de

The position is limited to 3 years, tenure track with possibility of getting a permanent position.
Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is a bilingual kindergarten on the DESY site.

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Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: EM065/2014
Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-3392 |
E-Mail: recruitment@desy.de
Deadline for applications: 26 June 2014
www.desy.de

The Helmholtz Association is Germany's largest scientific organisation.
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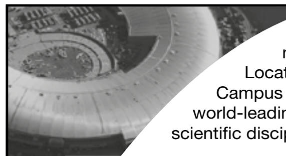

Diamond Light Source is the UK's national synchrotron science facility. Located at Harwell Science and Innovation Campus in Oxfordshire, Diamond enables world-leading research across a wide range of scientific disciplines and industrial applications.

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Power Supply Engineer Ref: DIA0908C/NH

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Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

NOMINATIONS SOUGHT FOR THE POSITION OF DIRECTOR

at the Max Planck Institute for Gravitational Physics (or Albert Einstein Institute), Potsdam-Golm, Germany

The Albert Einstein Institute (AEI), with approximately 400 scientists, employees, and students, is the world's largest research organization devoted to the study of the general theory of relativity (GR) and gravity. The AEI campus has three divisions (Astrophysical and Cosmological Relativity, Quantum Gravity and Unified Theories, and Mathematical Relativity) located in Potsdam-Golm, near Berlin, and two divisions (Laser Interferometry and Gravitational Wave Astronomy, Observational Relativity and Cosmology) located in Hannover.

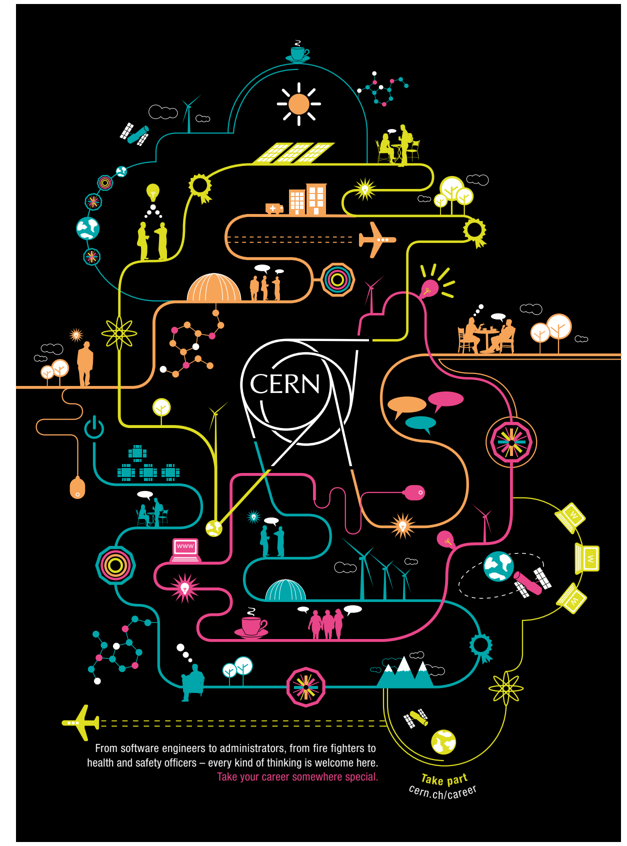
The AEI is seeking a new Director following the departure of Prof. Gerhard Huisken, former Director of the Mathematical Relativity division. The successful candidate will have established a record of original and creative research at the highest international level, and will have demonstrated the ability to inspire and lead a substantial group of younger scientists. The search will span the following areas: Mathematical Relativity, Classical General Relativity and Gravity, Theoretical Cosmology, and Quantum Gravity.

Nominations can be submitted with a deadline of 1 July 2014 by registering at the following link: **http://NewDirector.aei.mpg.de**

Upon registration nominators will receive a password that will allow them to enter their nomination (multiple nominations are possible). Nominations must include a short description of the nominee's background and most significant scientific accomplishments. Self-nominations are not permitted. All nominations will be treated confidentially.

The Max Planck Society is an equal opportunity employer, and seeks to increase the percentage of female Directors. It is also committed to employing more individuals with disabilities. Nominations in these categories are particularly welcome.

MAX-PLANCK-GESELLSCHAFT



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Albert-Ludwigs-Universität Freiburg

UNI FREIBURG

The Institute of Physics of the Faculty of Mathematics and Physics at the University of Freiburg invites applications for a

Professorship (W3) of Experimental Physics (Succession of Prof. Königsmann)

to be filled until **October 1, 2015**. The professorship represents the field of Experimental Physics in research and teaching with a focus on Astroparticle Physics. The appointed professor will be expected to bear an appropriate share of the teaching duties of the faculty as well as of the academic self-administration.

Candidates should possess the German Habilitation in physics or an equivalent research qualification. The University of Freiburg seeks to increase the number of female scientific faculty members and therefore especially encourages suitably qualified women to apply. Applicants with a physical handicap will be given preference over other candidates provided they are equally qualified.

Applications should be submitted using the application form (http://www.zuv.uni-freiburg.de/formulare/bewerbungsbogen_englisch.pdf) together with the usual references (curriculum vitae, a list of lecture courses and publications, a list of their 3 to 5 most prominent papers, copies of academic degree certificates and awards) and a portfolio of their teaching competence (see http://www.zuv.uni-freiburg.de/formulare/lehrkompetenzportfolio-formblatt.doc). Please don't send original documents, since no documents will be sent back.

Please send your application before **June 30th, 2014** either as a pdf-file to dekanat@mathphys.uni-freiburg.de or via mail to the **Dean of the Faculty of Mathematics and Physics, University of Freiburg, Eckerstr. 1, D-79104 Freiburg, Germany**.

European Commission

Senior scientist post in Quantum communication technologies

At: Institute for the Protection and Security of the Citizen
Deadline: 30 June, 2014
Location: EC JOINT RESEARCH CENTRE, Ispra (Va), Italy
45° 48' 50.2488" N, 8° 36' 43.4808" E

Position for: Senior scientist
The project concerns a study on the present state of quantum communication technologies, and the nature and timing of expected developments, and the preparation of a proposal for the role of the Joint Research Centre in the domain.

Background: Quantum communication technologies, such as polarisation-based optical quantum key distribution and quantum random number generation, are already in use for certain applications. New technologies, currently at very different levels of technical maturity, offer the promise of much wider application.

Tasks: The successful candidate will carry out an extensive study on the current state of quantum communication technologies, defining and investigating future expected developments, in terms of their content and their timing. He or she will assist JRC senior management in defining the JRC role, which could include the establishment of a quantum communication technology test-bed and/or demonstrations of quantum communication technology for specific applications. This will include planning laboratory or field campaigns which might be conducted and the equipment required for them. In the course of this study, EU policy implications will be investigated, both in terms of areas suggested for research and development work, and in any standardisation activity to be pursued, whether at EU or global level.

Qualifications: A candidate will need a Ph.D. degree in a relevant scientific subject, and a minimum of 15 years' professional work after graduation or 10 years after obtaining a Ph.D. Substantial experience in quantum communication technology research or development and an excellent command of English, both written and spoken, are required. The following skills are also desirable:

- wide understanding of quantum communication technologies and their potential and weaknesses; excellent academic qualifications, including a good record of publications;
- experience in public policy-related scientific evaluation;
- understanding of the development and marketing of innovative technologies, and of their technological assessment;
- experience of standardisation work in leading- edge technological domains;
- and an awareness of the European industrial landscape in the development of quantum communication technologies.

Institute Unit Project: Institute for the Protection and Security of the Citizen
Further information: http://ipsc.jrc.ec.europa.eu
Indicative duration: 24 months
Preferred starting date: ASAP
Site: Ispra
Country: Italy
Rules:
Grantholders: http://ec.europa.eu/dgs/jrc/downloads/jrc_grantholder_rul es.pdf
Applications: http://recruitment.jrc.ec.europa.eu/?type=GH
More info from: neil.mitchison@ec.europa.eu

Senior scientist post in Quantum computing and related technologies

At: Institute for the Protection and Security of the Citizen
Deadline: 30 June, 2014
Location: EC JOINT RESEARCH CENTRE, Ispra (Va), Italy
45° 48' 50.2488" N, 8° 36' 43.4808" E

Position for: Senior scientist
The project concerns a study on the present state of development of quantum technologies, and the nature and timing of expected developments, and the preparation of a proposal for the role of the Joint Research Centre in the domain, covering quantum computing, sensors based on quantum effects and all quantum technologies outside the communications field.

Background: Quantum technologies are being developed to cover a wide variety of applications, at very different levels of technical maturity. A particularly interesting area is the development of computers exploiting quantum parallelism; other areas addressed include single-photon optical communication and SQUID magnetometry. Further potential quantum applications include Josephson junction computers and new types of sensors. Quantum computers might have wide applications in simulation and modelling; they might also be able to break the cryptographic protocols currently used to secure modern communications system, including the internet. It is an open question whether it will be possible to develop new forms of cryptography to respond to this potential threat.

Tasks: The successful candidate will carry out an extensive study on the current development of quantum technologies, other than communications technologies, defining and investigating future expected developments, in terms of their content and their timing, as well as monitoring the development of "post-quantum" computing. He or she will assist JRC senior management in defining the JRC role. In the course of this study, EU policy implications will be investigated, both in terms of areas suggested for research and development work, and in any standardisation activity to be pursued, whether at EU or global level.

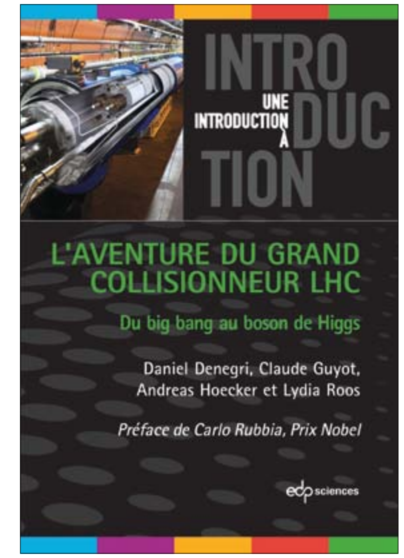
Qualifications: A candidate will need a Ph.D. degree in a relevant scientific subject, and a minimum of 15 years' professional work after graduation or 10 years after obtaining a Ph.D. Substantial experience in the analysis of quantum technologies, or in quantum technology research or development, as well as an excellent command of English, both written and spoken, are required. The following skills are also desirable:

- wide understanding of quantum technologies and their potential and weaknesses; excellent academic qualifications, including a good record of publications;
- experience in public policy-related scientific evaluation;
- understanding of the development and marketing of innovative technologies, and of their technological assessment;
- experience of standardisation work in leading- edge technological domains;
- and an awareness of the European industrial landscape in the development of quantum technologies.

Institute Unit Project: Institute for the Protection and Security of the Citizen
Further information: http://ipsc.jrc.ec.europa.eu
Indicative duration: 24 months
Preferred starting date: ASAP
JRC Site: Ispra
Country: Italy
Rules:
Grantholders: http://ec.europa.eu/dgs/jrc/downloads/jrc_grantholder_rul es.pdf
Applications: http://recruitment.jrc.ec.europa.eu/?type=GH
More info from: neil.mitchison@ec.europa.eu

Bookshelf

Une introduction à L'aventure du grand collisionneur LHC: Du big bang au boson de Higgs
By Daniel Denegri, Claude Guyot, Andreas Hoecker and Lydia Roos
EDP Sciences
Paperback: €34
Also available at the CERN bookshop



The authors, leading figures in the CMS and ATLAS experiments, have succeeded in writing a remarkable book, which I enthusiastically recommend to anyone interested in learning about the recent progress, open questions and future perspectives of high-energy physics. Throughout its 300 pages, it offers a broad coverage of the present status of particle physics, adding a few chronological accounts to place things in an historical context.

Despite being published in a collection that targets the general public, the book delves into several topics to a deep level and will be useful reading for many professional physicists. To accommodate different audiences, the authors have organized the book nicely in two "layers", the standard flow of chapters being complemented by extra boxes giving "further reading". Still, the reader is often told that some sections might be left aside in a first reading. It seems to me that this is a well-balanced solution for such a book, although I wonder if most readers from the "general public" would agree with the claim that the text is written in a "simple and pedagogical form". The first chapter, describing the Standard Model, is particularly demanding and long, but these 40 pages should not deter: the rest of the book provides easier reading.

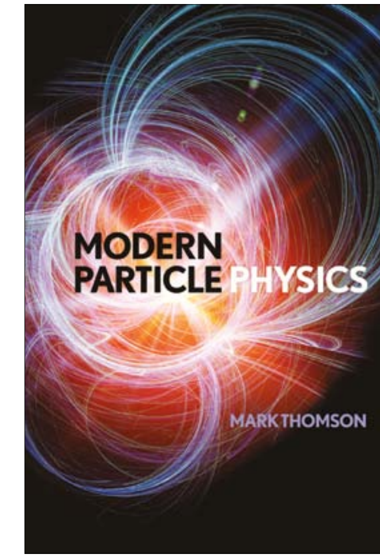
I was impressed particularly by the care with which the authors prepared many figures, which in some cases include details that I have not seen in previous works of this kind – for example, the presence of gluon lines and quark–antiquark loops inside the cartoon representing the pion, besides the standard valence quarks. Such representations are common for the proton, especially when discussing deep-inelastic scattering measurements, but it is rare to point out that any hadron – including the π or the Υ – should equally be characterized by "parton distribution functions". The profusion of high-quality figures and photographs contributes significantly to making this book well worth reading.

A few things could be improved in a future edition. For instance, the number of footnotes is excessive. While meant as asides not worth including in the main body of the text, they end up disrupting the fluidity of the reading, especially when placed in the middle of a sentence. Most footnotes should be integrated in the text, deleted, or moved to the end of the book, so that the reader can ignore them if preferred. While understanding that this book is addressed to a French audience, I would nevertheless recommend "smoothing out" some French-specific choices. For instance, I was pleased to read that Pierre Fayet, in Paris, had an important role in the development of the MSSM extension to the Standard Model, but I was puzzled to see no other name mentioned in the pages devoted to supersymmetry.

Being one of the "LHC adventurers" myself, I read with particular curiosity the chapters devoted to the construction of the LHC accelerator and experiments, which include many interesting details about sociological aspects. I would have liked this part to have been further expanded, especially knowing by personal experience how fascinating it is to listen to Daniel Denegri, when he tells all sorts of anecdotes about physics and physicists.

All in all, this is a highly recommendable book, which provides an interesting guided tour through present-day high-energy physics while, at the same time, offering opportunities for non-French people to learn some French expressions, such as "*se faire coiffer au poteau*". Note, however, that the enjoyable reading comes mixed with harder sections, which require extra effort from the reader: this book, like the LHC data, provides "*du pain sur la planche*".

● *Carlos Lourenço, CERN.*



Modern Particle Physics
By Mark Thomson
Cambridge University Press
Hardback: £40 $75
Also available as an e-book, and at the CERN bookshop

Mark Thomson has written a wonderful new introductory textbook on particle physics. As the title suggests, it is modern and up-to-date. It contains several chapters on the latest developments in neutrino physics, B-meson physics, on the LHC and of course also on the Higgs boson. All the same, as new data pour in, the latter part on the Higgs boson will have to be updated in future editions, of which I expect there to be many.

The book is aimed at students who are already familiar with quantum mechanics and special relativity, but not quantum field theory. Interestingly, although written by an experimentalist, I would say that this book, in level, is most closely comparable to the well-known textbook by Francis Halzen and Alan Martin, both theorists. However, it is an improvement in many ways.

It starts out with an extensive discussion on what can be measured by detectors, as well as the basics of scattering theory, and the Klein–Gordon and Dirac equations. Thomson then guides the reader carefully through pedagogical steps to the computation of matrix elements and

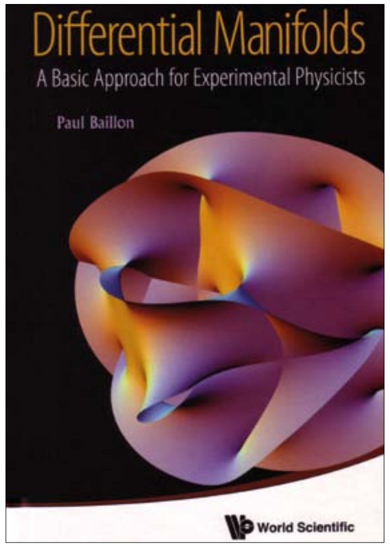
Bookshelf

cross-sections for scattering processes at fixed-target experiments and colliders. He uses the helicity-eigenstate basis, which helps to make the underlying physics in the reactions more evident. As a theorist, I might have enjoyed an emphasis on two-component fermions, but this might not be so readily digestible for experimentalists.

I found the chapter on flavour SU(3) well written and elucidating. The chapter on neutrino physics discusses the implications of the measurements of θ_{13} nicely, and presents the MINOS and Sudbury Neutrino Observatory experiments and their relevance to the determination of the neutrino parameters. Regarding neutrino oscillations, Thomson points out rightly the necessity of the wave-packet treatment, but unfortunately gives no reference to a more detailed discussion, such as the paper by Boris Kayser. The gauge principle and spontaneous symmetry breaking are explained in great detail. The emphasis throughout is always on explicit and concrete computations.

The book is well written – it is easy to read, with clear pedagogical lines of reasoning, and the layout is pleasing. There are numerous homework problems at the end of each chapter. My only criticism would be that since Thomson is an experimentalist, I expected a modern version of Don Perkins' book, with many details on experimental techniques – that is, a different book. However, as I am teaching an introduction to theory this autumn, I will definitely be using this book.

● *Herbert Dreiner, University of Bonn.*



Differential Manifolds: A Basic Approach for Experimental Physicists

By Paul Baillon
World Scientific
Hardback: £57
Also available at the CERN bookshop

The theory of differential manifolds is a common substratum of much of our current theoretical descriptions of physical phenomena. It has proved to be well adapted to many branches of classical physics – mechanics, electromagnetism, gravitation – for which it has provided a framework for a precise formulation of fundamental laws. Its use in quantum physics has led to spectacular discoveries associated with the unification of electromagnetic, weak and strong interactions. In this connection, manifolds appear not only in the description of the substratum of these phenomena but also in the description of the phenomena themselves, in terms of the so-called gauge theories.

This mathematical theory constitutes an important body of contemporary mathematics. Baillon's book, which aims at making the subject accessible to a readership that is rich in a completely different culture, adopts an unconventional expository style. Instead of appealing to intuition based on mathematically non-rigorous images and analogies – a common practice – it insists on providing complete proofs of most of the elementary mathematical facts on which the theory is grounded.

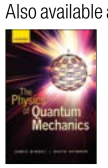
A substantial part of the book is devoted to a detailed description of the necessary mathematical equipment. Applications culminate in an introduction to some delicacies of the electroweak theory, as well as of general relativity.

● *Raymond Stora, CNRS.*

Books received

The Physics of Quantum Mechanics

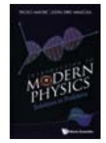
By James Binney and David Skinner
Oxford University Press
Hardback: £49.99
Paperback: £24.99
Also available as an e-book



The aim of this book is to give students a good understanding of how quantum mechanics describes the material world. It shows that the theory follows naturally from the use of probability amplitudes to derive probabilities. It emphasizes that stationary states are unphysical mathematical abstractions that enable solution of the theory's governing equation – the time-dependent Schrödinger equation. Every opportunity is taken to illustrate the emergence of the familiar classical, dynamical world through the quantum interference of stationary states.

Introduction to Modern Physics: Solutions to Problems

By Paolo Amore and John Dirk Walecka
World Scientific
Paperback: £32



John Dirk Walecka's *Introduction to Modern Physics: Theoretical Foundations*, published in 2009 (*CERN Courier* January/February 2010 p45) aimed at covering a range of topics in modern physics in sufficient depth that things would "make sense" to students, so that they could achieve an elementary working knowledge of the subjects. To this end, the book contained more than 175 problems. Now, *Introduction to Modern Physics: Theoretical Foundations* provides solutions to these problems.

An Introduction to Birth, Evolution and Death of Stars

By James Lequeux, translated from the original Naissance, évolution et mort des étoiles, *published by EDP Sciences*
World Scientific
Paperback: £17

How stars form from interstellar matter, how they evolve and die, was understood only relatively recently. All of these aspects are covered in this book by Lequeux, who directed the Marseilles observatory from 1983 to 1988 and served for 15 years as chief editor of the European journal *Astronomy & Astrophysics*. The text is accompanied by many images, while the theory is explained as simply as possible, but without avoiding mathematical or physical developments when they are necessary for a good understanding of what happens in stars.

Boundary Conformal Field Theory and the Worldsheet Approach to D-Branes

By Andreas Recknagel and Volker Schomerus
Cambridge University Press
Hardback: £65 $99
Also available as an e-book

Boundary conformal field theory is concerned with a class of 2D quantum field theories, which display a rich mathematical structure and have many applications, ranging from string theory to condensed-matter physics. This comprehensive introduction to the topic reaches from theoretical foundations to recent developments, with an emphasis on the algebraic treatment of string backgrounds.

Viewpoint

Latin America comes to CERN

Luciano Maiani on forging new links between Europe and the New World.

International collaboration in physics was born in Europe, after the Second World War, to explore subnuclear particle physics. An entirely new world, unveiled by the interactions of cosmic rays in the Earth's atmosphere, could be studied only with particle accelerators so big that no country in Europe could afford to build them. The vision of distinguished European scientists and statespersons led to CERN's creation in 1954.

In the 1980s a mutation took place as CERN entered the era of the Large Electron Positron (LEP) collider. The experiments needed large human and financial resources, which CERN could not provide. Universities and their associated countries formed large-scale collaborations, with extensive funds for the construction and operation of detectors and to support the travel of professors and students to collect and translate into new physics the data produced at LEP. This phenomenon has since repeated itself, on a larger scale, with the LHC. Today CERN has more than 10,000 "users" from around the world.

At the end of 2003, Juan Antonio Rubio, Verónica Riquer and I realized that a major obstacle for Latin American scientists to take part in experiments at the LHC was the lack of regular funds for their, and their students', mobility. The outcome was the High-Energy physics Latin-American European Network – HELEN – financed by ALFA, a programme created by the European Union (EU) to facilitate the scientific interchange between Europe and Latin America (*CERN Courier* October 2005 p26).

High-energy physics already had a considerable tradition in Latin America. In the early 1930s, Manuel Sandoval Vallarta in Mexico discovered the "east-west effect", which showed that cosmic rays are charged particles. (Bruno Rossi obtained a similar result with an expedition in Africa.) Cesar Lattes and Beppo Occhialini created a vital school in experimental particle physics in

Luciano Maiani. (Image credit: CNR.)

Brazil, which produced important physicists such as Roberto Salmeron, Alberto Santoro and many others. On the theory side, Marcos Moshinski made significant contributions to group theory in nuclear physics, and the beginning of the Standard Model witnessed important results by José Leite Lopez, Juan José Gianbiagi, Carlos Guido Bollini, Miguel Virasoro and many others. Richard Feynman's lectures in Rio had a profound influence, and the efforts of Leon Lederman definitely oriented the experimental school in South America towards Fermilab.

The aim with HELEN was to change the tendency to work with the US, which had been only marginally affected by the participation of Brazilian groups in LEP. Among the objectives for mobility, we listed training of the younger generations, through participation in advanced experiments, and access to technological benefits in accelerator, detector and information technology. The result was a network of 22 universities from eight Latin American countries, 16 universities from six European countries, CERN and the Pierre Auger Observatory in Argentina.

Starting in July 2005 and ending in April 2009, HELEN enabled mobility totalling 1596 man months, mainly from Latin America to Europe, but also from Europe to Latin America, and within Latin America – where the grants helped to foster collaboration. The total cost was €3.0 million, with €2.7 million coming through EU support.

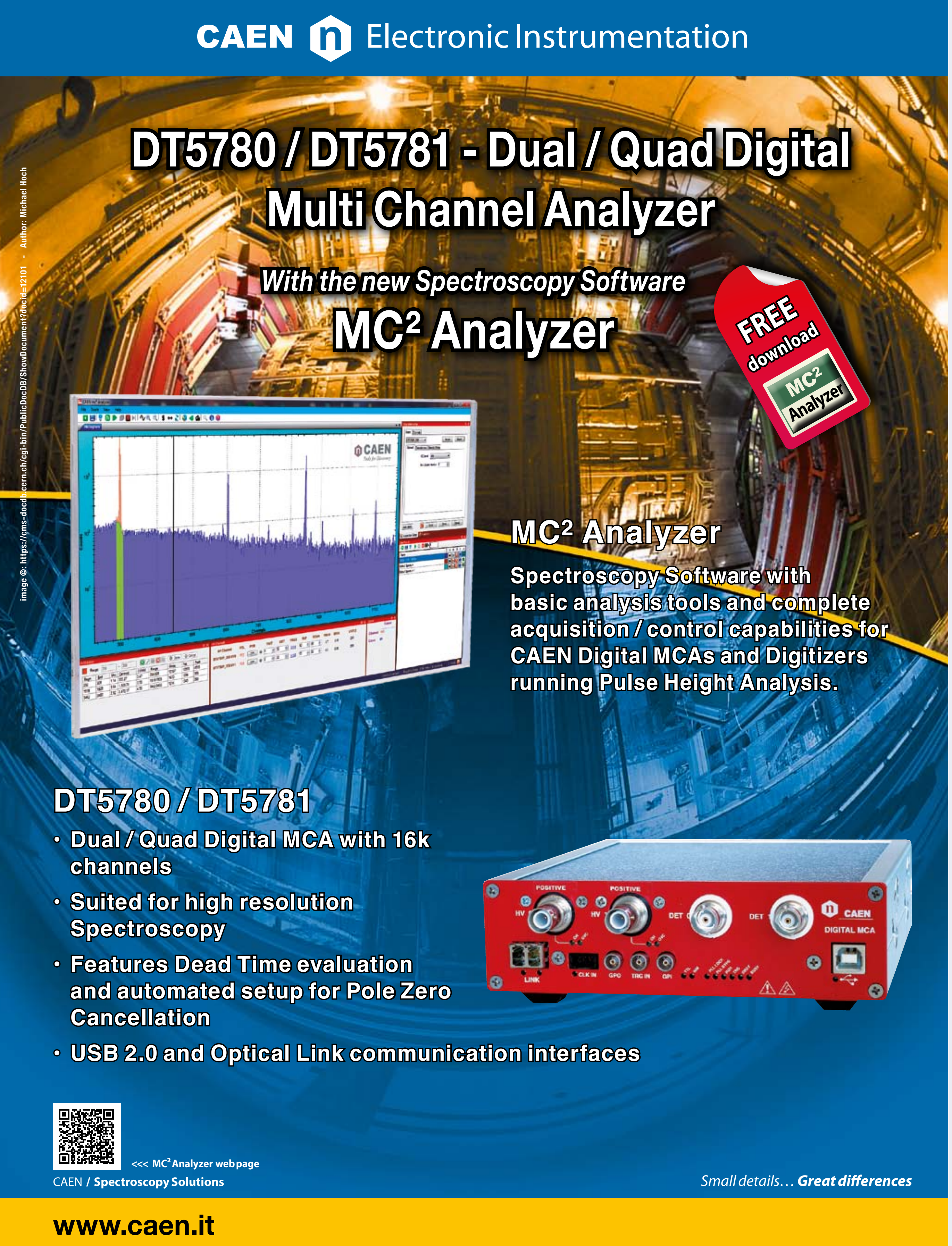
The exciting adventure of creating a Latin-American community in the scientific heart of Europe started in January 2006, with the arrival at CERN of the first HELEN grant-holders from Latin America. Several events were organized by HELEN in Argentina and in Mexico to transfer CERN technologies in accelerator physics and computing. For example, members of the CMS collaboration travelled to Brazil to help set up an LHC Computing Grid Tier-2 centre for CMS at the Rio de Janeiro State University and in Sao Paulo.

Prompted by the success of HELEN, in 2009 we proposed a new project that started in February 2011 – the European Particle physics Latin-American NETwork (EPLANET), funded by the EU in the Marie Curie Actions of the 7th Framework Programme. Supported by EPLANET, professors and graduate students can participate in the exciting research that began at the LHC in 2010, when the first physics run started.

The objective of EPLANET is to train scientific personnel in the collaborating institutions through participation in world-class experiments performed at CERN and the Pierre Auger Observatory. The rules of the Framework Programme allowed the admission of only four countries from Latin America – namely Argentina, Brazil, Chile and Mexico. CERN has provided additional funds to continue the collaboration with Colombia, Peru and Venezuela that started with HELEN.

All in all, HELEN and EPLANET are perceived in the high-energy physics community as unprecedented and successful efforts to integrate the particle-physics communities of Europe and Latin America. HELEN made possible the full participation of Latin American groups in the LHC experiments and as a consequence, Latin American physicists contributed to the discovery of a Higgs boson by the ATLAS and CMS experiments. Now, EPLANET continues to promote sustainable collaboration between Europe and Latin America in high-energy physics and its associated technologies. I am confident that the two initiatives will have a major impact on multilateral Latin America–EU co-operation.

● *Luciano Maiani, Universita' di Roma "La Sapienza", and CERN director-general (1999–2003). From a talk given at Ciencia, Tecnologia, Innovacion e Industrialización en America del Sur, Rio de Janeiro, 2–4 December 2013.*



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