WELCOME

CERN Courier – digital edition

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

As CERN's 60th-anniversary year comes to an end, *CERN Courier* gives a voice to some of the organization's pioneers who are no longer with us. Extracts from audio recordings in CERN's archives bring to life the spirit of adventure of the early CERN. One of the studies that CERN pioneered was the measurement of the "g-2" parameter of the muon – an experiment that in its latest incarnation is setting up in Fermilab. The year also saw the 50th anniversary of the International Centre for Theoretical Physics in Trieste, and an interview with the centre's current director reveals interesting similarities and contrasts between the two organizations. The end of the year also offers the traditional seasonal Bookshelf. Happy reading!

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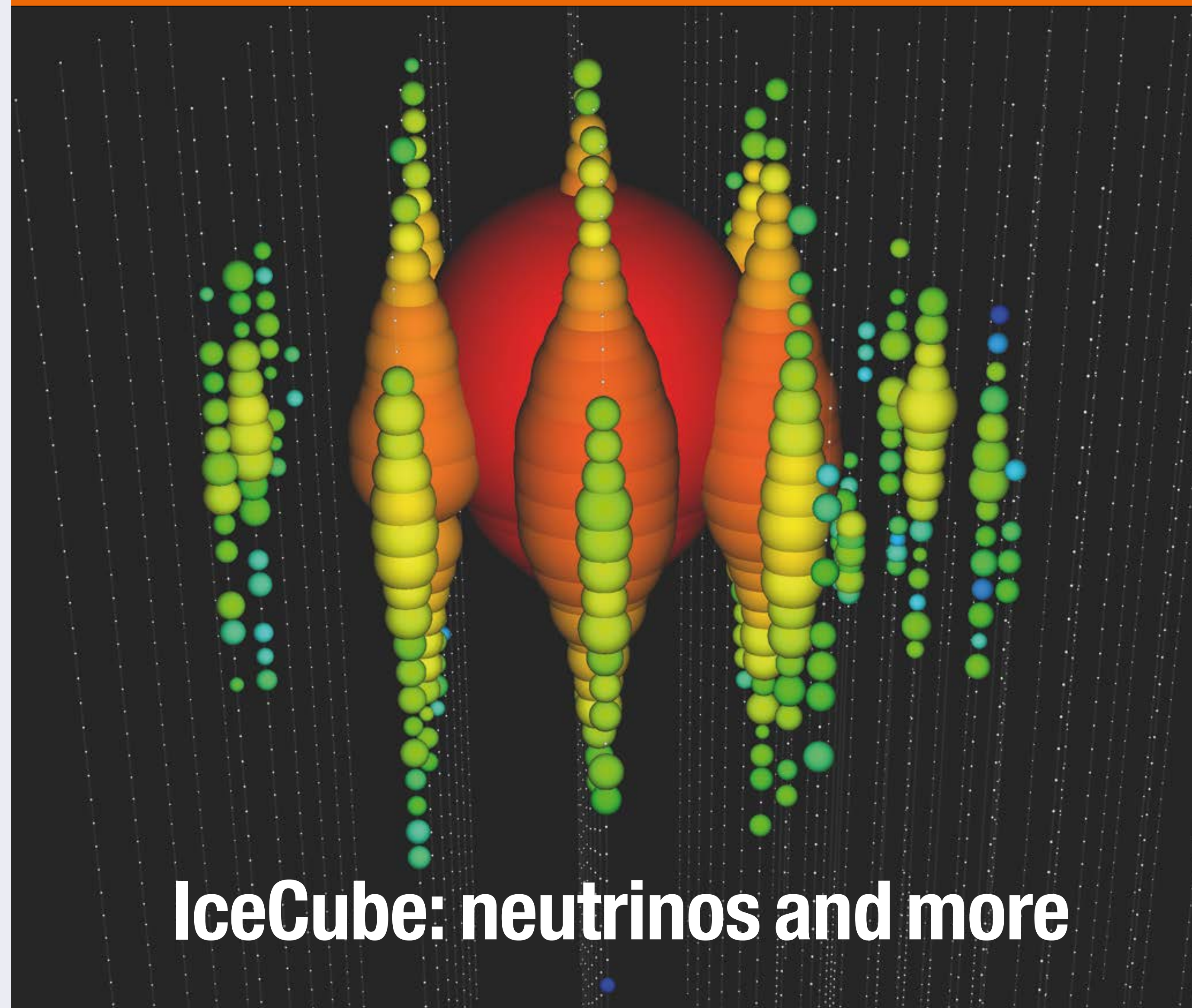

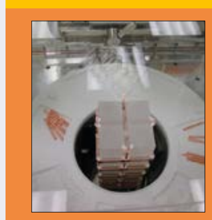

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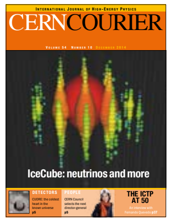


On the cover: One of the first two events from the IceCube Neutrino Observatory produced by a neutrino with an energy of about 1 PeV – and a first hint of the detection of astrophysical neutrinos (p30). (Image credit: IceCube Collaboration.)

News

APPOINTMENT

CERN Council selects next director-general

At its 173rd closed session on 4 November, CERN Council selected the Italian physicist Fabiola Gianotti as the organization's next director-general. The appointment will be formalized at the December session of Council, and Gianotti's mandate will begin on 1 January 2016 and run for a period of five years. She will be the first woman to hold the position of director-general at CERN.

Council rapidly converged in favour of Gianotti. "We were extremely impressed with all three candidates put forward by the search committee," said Agnieszka Zalewska, the president of Council, on the announcement of the decision. "It was Dr Gianotti's vision for CERN's future as a world-leading accelerator laboratory, coupled with her in-depth knowledge of both CERN and the field of experimental particle physics, that led us to this outcome."

Fabiola Gianotti in front of the ATLAS detector. (Image credit: C Marcelloni/ ATLAS CERN-GE-1102058-02.)

Gianotti received a PhD in experimental particle physics from the University of Milan in 1989, working on the UA2 experiment at CERN for her thesis on supersymmetry. She has been a research physicist in the physics department at CERN since 1994, being involved in detector R&D and construction, software development and data analysis, for example for supersymmetry searches by the ALEPH experiment at the Large Electron–Positron (LEP) collider.

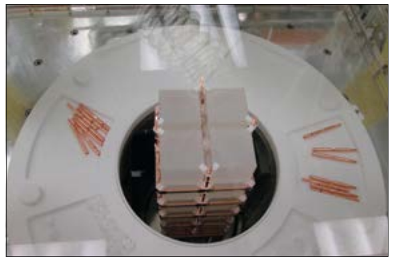
However, it is for her contributions to the ATLAS experiment at the LHC that Gianotti has become particularly well known. She was leader of the ATLAS experiment collaboration from March 2009 to February 2013, covering the period in which the LHC experiments ATLAS and CMS announced the long-awaited discovery of a Higgs boson, which was recognized by the award of the Nobel Prize to François Englert and Peter Higgs in 2013. Since August 2013, Gianotti has been an honorary professor at the University of Edinburgh.

DETECTORS

CUORE has the coldest heart in the known universe

The CUORE collaboration at the INFN Gran Sasso National Laboratory has set a world record by cooling a copper vessel with the volume of a cubic metre to a temperature of 6 mK. It is the first experiment to cool a mass and a volume of this size to a temperature this close to absolute zero. The cooled copper mass, weighing approximately 400 kg, was the coldest cubic metre in the universe for more than 15 days. No experiment on Earth has ever cooled a similar mass or volume to temperatures this low. Similar conditions are also not expected to arise in nature.

CUORE – which stands for Cryogenic Underground Observatory for Rare Events, but is also Italian for heart – is an experiment being built by an international collaboration at Gran Sasso to study the properties of neutrinos and search for rare processes, in particular the hypothesized neutrinoless double-beta decay. The experiment is designed to work in ultra-cold conditions at temperatures of around 10 mK. It consists of tellurium-dioxide crystals serving as bolometers, which measure energy by



The CUORE experiment is based on crystals of tellurium dioxide cooled to a few millikelvin. (Image credit: INFN.)

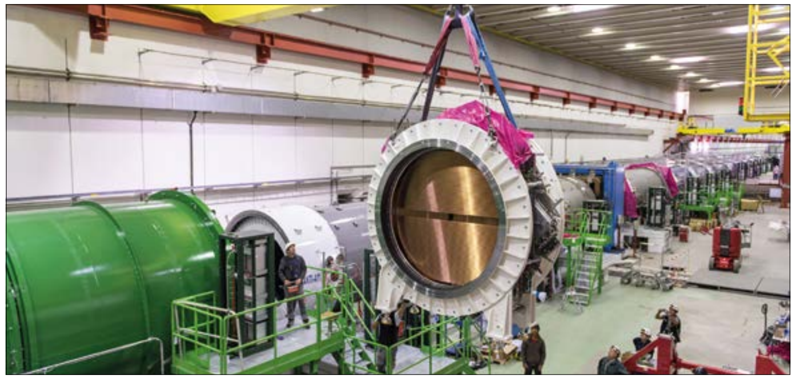
recording tiny fluctuations in the crystal's temperature. When complete, CUORE will contain some 1000 instrumented crystals and will be covered by shielding made of ancient Roman lead, which has a particularly low level of intrinsic radioactivity. The mass of material to be held near absolute zero will be almost two tonnes.

The cryostat was implemented and funded by INFN, and the University of Milano Bicocca co-ordinated the research team in charge of the design of the cryogenic system. The technological solution to the technological challenge of cooling the entire experimental mass of almost two tonnes to the temperature of a few millikelvin was made possible through collaboration with high-profile industrial partners such as Leiden Cryogenics BV, who designed and built the unique refrigeration system, and Simic SpA, who built the cryostat vessels.

Sommaire en français

CERN

NA62 gets going at the SPS



The final straw-tracker module is lowered into position in NA62. (Image credit: CERN-PHOTO-201409-176 – 4.)

With the end in sight for CERN's Long Shutdown (LS1), the accelerator chain has been gradually restarting. Since early October, the Super Proton Synchrotron (SPS) has been delivering beams of protons to experiments, including NA62, which has now begun a three-year data-taking run.

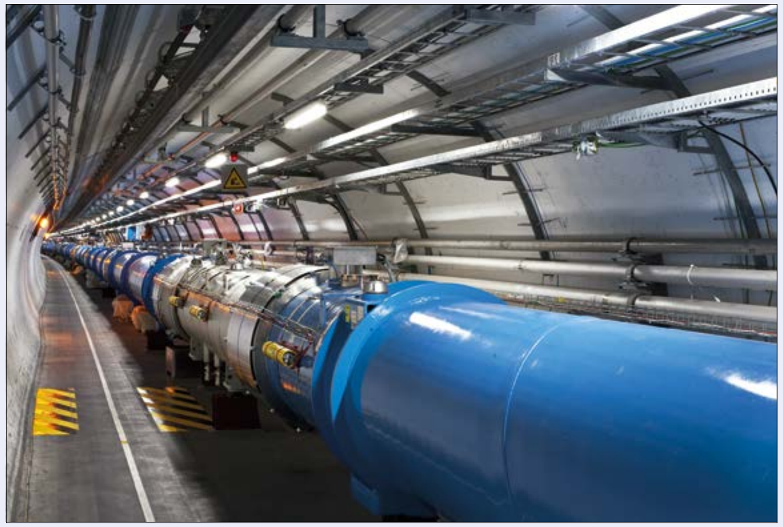
NA62's main aim is to study rare kaon decays, following on from its predecessors NA31 and NA48, which made important contributions to the study of CP violations in the kaon system (*CERN Courier* July/August 2014 p23). To make beams rich in kaons, protons from the SPS strike a beryllium target. The collisions create a beam that transmits almost one billion particles per second, about 6% of which are kaons.

After almost eight years of design and construction, NA62 was ready for the beam by start-up in October. In early September, the last of the four straw-tracker chambers had been lowered into position in the experiment. The straw tracker is the first of its scale to be placed directly into the vacuum tank of an experiment, allowing NA62 to measure the direction and momentum of charged particles with high precision. From the first design to the final plug-in and testing, teams at CERN worked in close collaboration with the Joint Institute for Nuclear Research in Dubna, who helped to develop the straw-tracker technology and who will participate in the running of the detector now that construction and installation has been completed.

Each straw-tracker chamber weighs close to 5000 kg and is made up of 16 layers of state-of-the-art, highly fragile straw tubes. Although heavy, the four chambers had to be delicately transported to the SPS North Area at CERN's Prévessin site, lowered into the experiment cavern and installed to a precision of 0.3 mm. The chambers were then equipped with the necessary gas connections, pipes, cables and dedicated read-out boards, before beam commissioning began in early October to tune the tracker prior to integrating it with the other sub-detectors for data taking.

This unique tracker, placed directly inside the experiment's vacuum tank, sits alongside a silicon-pixel detector and a detector called CEDAR that determines the types of particles from their Cherenkov radiation. A magnetic spectrometer measures charged tracks from kaon decays, and a ring-imaging Cherenkov detector indicates the identity of each decay particle. A large system of photon and muon detectors rejects unwanted decays. In total, the experiment extends across a length of 270 m, of which 85 m are in a vacuum.

● For more about the installation and construction of NA62, see the CERN Bulletin http://cds.cern.ch/record/1951890.



The giant slowly awakes, as the process to cool down the LHC continues in the final stage of the first long shutdown, LS1. By mid-October, the last remaining sector, 3-4 (seen here in 2009), had begun to cool down, and two of the eight sectors of the machine were already at their final cryogenic operating conditions. By the end of October, cooling and ventilation teams were maintaining systems at point 6. Down in the tunnel, sector 8-1 had completed electrical quality-assurance testing, and preparations were under way for powering tests. Measurements of the continuity of the copper stabilizer were completed in sector 5-6, and ongoing in sectors 7-8 and 2-3. Finally, on 31 October, the first magnet training for the LHC began in sector 6-7, successfully reaching a magnetic field of 5.8 T. (Image credit: CERN-AC-0910152-02.)

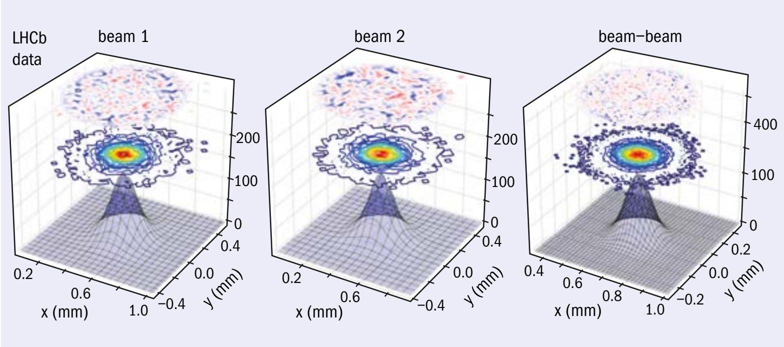
LHC BEAMS

How bright is the LHC?

The LHCb Collaboration has published the results of a luminosity calibration with a precision of 1.12%. This is the most precise luminosity measurement achieved so far at a bunched-beam hadron collider.

The absolute luminosity at a particle collider is not only an important figure of merit for the machine, it is also a necessity for determining the absolute cross-sections for reaction processes. Specifically, the number of interactions, N, measured in an experiment depends on the value of cross-section σ and luminosity L, $N = \sigma L$, so the precision obtained in measuring a given cross-section depends critically on the precision with which the luminosity is known. The luminosity itself depends on the number of particles in each collider beam and on the size of overlap of both beams at the collision point. At the LHC, dedicated instruments measure the beam currents, and hence the number of particles in each colliding beam, while the experiments measure the size of overlap of the beams at the collision point.

A standard method to determine the overlap of the beams is the van der Meer scan, invented in 1968 by Simon van der Meer to measure luminosity in CERN's Intersecting Storage Rings, the world's first hadron collider. This technique, which involves scanning the beams across each other and monitoring the interaction rate, has been used by all of the four large LHC experiments. However, LHCb physicists proposed an alternative method in 2005 – the beam-gas imaging (BGI) method – which they successfully applied for the first time in 2009. This takes advantage of the excellent precision of LHCb's Vertex Locator, a detector that is placed around the proton–proton collision point. The BGI method is based on reconstructing the vertices of "beam-gas" interactions, i.e. interactions between beam particles and residual gas nuclei in the beam pipe to measure the angles, positions and shapes of the individual beams without displacing them.



Results of a global pluridimensional shape fit of the individual LHC beams (left and centre) and of the luminous region (right), based on the distributions of beam–gas and beam–beam interaction vertices. The results are shown here for a selected colliding bunch pair and a central slice on the longitudinal axis.

To date, LHCb is the only experiment capable of using the BGI method. The technique involves calibrating the luminosity during special measurement periods at the LHC, and then tracking relative changes through changes in the counting rate in different sub-detectors. However, the vacuum pressure in the LHC is so low that for the technique to work with high precision, the beam–gas collision rate was increased by injecting neon gas into the LHC beam pipe during the luminosity calibration periods. This allowed the LHCb physicists to obtain precise images of the shapes of the individual beams, as illustrated in the left and middle graphs of the figure, which unravelled subtle but important features of the distributions of beam particles. By combining the beam–gas data with the measured distribution of beam–beam interactions, which provides the shape of the luminous region (the right graph in the figure), an accurate calibration of the luminosity was achieved.

The beam–gas data also revealed that a small fraction of the beam's charge is spread outside of the expected (i.e. "nominal") bunch locations. Because only collisions of protons located in the nominal bunches are included in physics measurements, it was important to measure which fraction of the total beam current measured with the LHC's current monitors participated in the collisions, i.e. contributed to the luminosity. Only LHCb could measure this fraction with sufficient precision, so the results of LHCb's measurements of the fraction of charge outside the nominal bunch locations – the so-called "ghost" charge – were also used by the ALICE, ATLAS and CMS experiments.

For proton–proton interactions at 8 TeV, a relative precision of the luminosity calibration of 1.47% was obtained using van der Meer scans and 1.43% using beam–gas imaging, resulting in a combined precision of 1.12%. The BGI method has proved to be so successful that it will now be used to measure beam sizes as part of monitoring and studying the LHC beams. Dedicated equipment will be installed in a modified region of the LHC ring near Point 4. This system, dubbed the Beam-Gas Vertexing system (BGV), is being developed by a collaboration from CERN, EPFL and RTWH Aachen. It includes a gas-injection system and a scintillating-fibre tracker telescope, which are expected to be commissioned with beam in 2015.

● Further reading

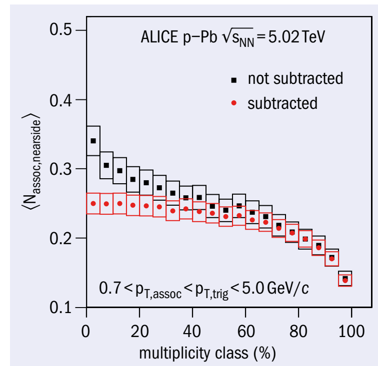
LHCb Collaboration 2014 arXiv:1410.0149 [hep-ex].

ALICE probes the role of minijets in p–Pb collisions…

One of the hottest topics at the LHC is the understanding of potential collective effects in proton–lead collisions, prompted by the discovery of ridge structures in angular correlations of particles (*CERN Courier* January/February 2013 p9). Further insight is expected from studying the role of multiple parton–parton interactions, as well as from investigating the interplay of these ridge structures with jet structures caused by (semi)hard scatterings. A new study by the ALICE collaboration has characterized minijets – jet-like structures in the regime of low transverse momentum (p_T) where the ridge has been observed – to shed light on particle-production mechanisms.

The analysis looks at event activity, characterized by particle multiplicity measured at large rapidity. The jet-like correlations are determined by counting the number of associated particles as a function of their difference in azimuth ($\Delta\phi$) and pseudorapidity ($\Delta\eta$) with respect to a trigger particle. The minijets reveal themselves as a peak on the "near side" ($\Delta\phi=0$, $\Delta\eta=0$) and an elongated structure in $\Delta\eta$ on the "away side" ($\Delta\phi=\pi$) on top of the double ridge. The ridge structures themselves are found on the near and away side to be independent of $\Delta\eta$ and almost symmetric around $\pi/2$. The projection of the correlations onto $\Delta\phi$ makes it possible to quantify the particle production in semi-hard processes. The number of particles in the minijets is given by the integral under the peaks and above the background originating from the underlying event.

The black points in the figure show that the average near-side yield per trigger particle increases from the lowest (95–100%) to the highest (0–5%) event-multiplicity class. To separate the jet-like peak structures from the ridge, the contribution from the near-side ridge can be estimated at large $\Delta\eta$, where the jet-like correlations are absent. Owing to the approximate symmetry around $\pi/2$, the near-side ridge is mirrored into the away-side



Average near-side yield per trigger particle, before and after ridge subtraction (see text for more details).

region and subtracted from both sides of the correlation function. Non-symmetric components (e.g. $\cos 3\Delta\phi$) have only small effects limited to the away side. The red data points in the figure show the near-side yield after this ridge subtraction.

While it is not surprising to find agreement between the yields with and without ridge subtraction in the 60-100% event-multiplicity classes, where no significant ridge structures exists, qualitative differences emerge in the 60% highest multiplicity. In this region, there is no dependence on event activity for jet-like per-trigger yields (i.e. after ridge subtraction). This suggests that the hard processes, which are the sources of associated particles, and the soft processes, which together with the hard ones are at the origin of the trigger particles, scale with the same factor with multiplicity. These observations are consistent with a scenario where the minijet yield stems from an incoherent fragmentation of multiple parton–parton scatterings, while the double ridge is not jet related and is additive to the minijets.

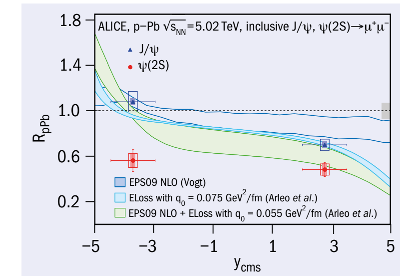
Further reading

ALICE Collaboration 2014 arXiv:1406.5463.

…and investigates suppression of ψ(2S)

Charmonia, bound states of charm (c) and anti-charm ($\bar{c}$) quarks, are probes for the formation of hot quark–gluon plasma (QGP) in heavy-ion collisions. The suppression of charmonium, already observed at the lower energies of CERN's Super Proton Synchrotron (SPS) and the Relativistic Heavy Ion Collider at Brookhaven, has been attributed to the screening of the $c\bar{c}$ binding by the high density of colour charges present in the QGP. However, the modification of charmonium production in heavy-ion collisions can be induced not only by a hot deconfined medium, but also by effects of cold nuclear matter (CNM). The latter can be studied in proton–nucleus interactions, where the temperature and energy density necessary for QGP formation are not expected to be reached.

CNM affects the $c\bar{c}$ pair throughout its time evolution, from a pre-resonant state to the fully formed resonance, and it can be investigated by comparing the behaviour of the tightly bound J/ψ and the weakly bound ψ(2S) charmonium states. Effects present in the early stages of the $c\bar{c}$ evolution – such as nuclear-parton shadowing and initial-state energy loss – do not depend on the final charmonium quantum numbers, and should have similar effects on the J/ψ and ψ(2S). On the other hand, final-state mechanisms, such as the break-up of the bound state via interactions with nucleons or with the hadronic matter produced in the collision, will be sensitive to the binding energy of the resonance, and should have a stronger effect on the ψ(2S) than on the J/ψ.



The ψ(2S) nuclear modification factor, compared with the corresponding quantity for J/ψ and with model calculations based on cold-nuclear-matter effects such as shadowing and coherent energy loss.

ALICE has studied the production of J/ψ and ψ(2S) in proton–lead collisions at $\sqrt{s}=5.02$ TeV, in both the proton-going direction (rapidity $2.03 < y_{cms} < 3.53$) and the lead-going direction ($-4.46 < y_{cms} < -2.96$). The modification of the production yields induced by CNM, with respect to the corresponding proton–proton yield scaled by the number of nucleon–nucleon collisions, is quantified through the nuclear modification factor R_{pA}, which is shown in the figure for J/ψ and ψ(2S). The ψ(2S) suppression is large, and stronger than for the J/ψ, in particular in the backward rapidity region, where the J/ψ is not suppressed at all. This observation implies that final-state effects play an important role, as initial-state mechanisms alone (see also the theory predictions in the figure relative to a pure initial-state scenario) would lead to the same behaviour for both charmonium states.

Such a result was also observed at lower energies (at the SPS, Fermilab and HERA at DESY), where it was related to break-up effects by the nucleons in the nucleus. However, at LHC energies, the resonance formation time (around 0.1 fm/c) is significantly smaller than the time spent by the $c\bar{c}$ pair in the nucleus, implying that CNM cannot affect the final-state charmonia. This suggests that the difference between the J/ψ and ψ(2S) suppression is due to the interaction with hadrons produced in the proton–lead collision. A detailed study of this effect, still in progress on the theory side, is expected to provide quantitative information on the density and characteristics of such a hadronic medium.

Further reading

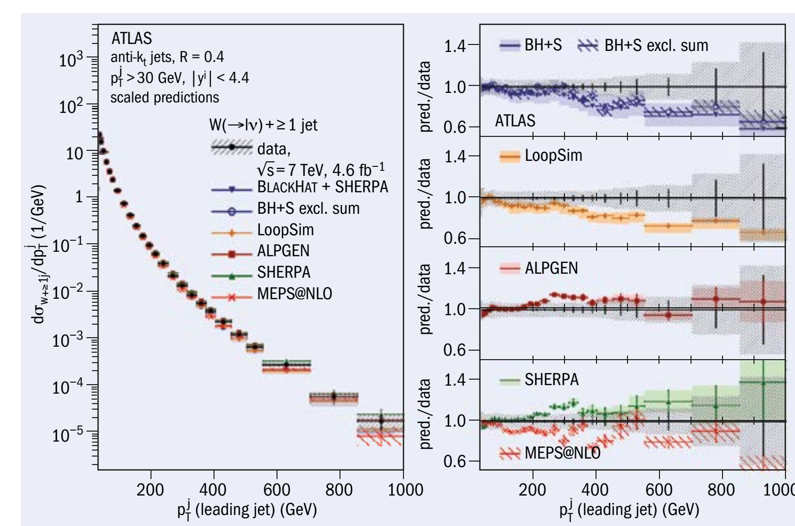
B Abelev *et al.* (ALICE Collaboration) 2014 *JHEP* **1402** 073.

B Abelev *et al.* (ALICE Collaboration) 2014 arXiv:1405.3796, submitted to *JHEP*.

ATLAS takes a closer look at W+jets

The ATLAS collaboration has updated its measurement of the production of W bosons in association with jets (W+jets), which is an important channel at the LHC for precision comparisons with QCD. A precise understanding of these event topologies is also vital for searches for physics beyond the Standard Model because many new models predict a similar experimental signature.

In recent years, the analysis and understanding of W+jets production has undergone two major advancements. The first is the large amount of data available from the LHC, and the extended kinematic reach that results both from the collider's centre-of-mass energy – which allows for measurements of jets with a transverse momentum (p_T) of up to 1 TeV and multiplicities of up to seven jets – and the expanded detector coverage, which can measure jets at large rapidities. Unlike at previous colliders, where the p_T values for the jets were a few hundred giga-electron-volts at most, the transverse momentum of the jets at the LHC can be more than an order of magnitude



Cross-sections for production of W+jets as a function of the leading jet p_T. Left: differential cross-sections, right, the ratios between the different predictions and the data.

larger than the mass of the W boson itself. In these cases, large QCD corrections can be associated to the multiple scales in the event, and these are difficult to predict

▷

by fixed-order calculations. Also, because of the disparity in the scales between the mass of the W boson and the p_T of the jet, electroweak corrections can play a major role. The second advancement is the availability of next-to-leading-order (NLO) predictions in perturbative QCD for events with large numbers of associated jets. These calculations have smaller theoretical uncertainties compared with leading-order predictions.

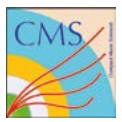
The recent ATLAS measurement of W+jets production focuses on detailed comparisons between the jet and event properties that are observed and several state-of-the-art theory predictions. The figure (p9) highlights the differential cross-section as a function of the p_T of the leading jet, i.e., the highest transverse momentum. The data are compared with leading-order calculations (Alpgen, Sherpa), NLO calculations (Blackhat+Sherpa, MEPS@NLO), and beyond NLO calculations (LoopSim, Blackhat+Sherpa exclusive sums). At large values of the jet's p_T, the higher-order calculations tend to underestimate the data. In these regions of phase space, additional corrections to the cross-sections from electroweak diagrams are expected to be sizable. However, they are also expected to be negative, and therefore cannot account for this trend. The leading-order predictions model this particular distribution better, but in other kinematic observables, such as the jet rapidity, their description of the data is not as good.

This result is based on the measurement of more than 25 different properties of W+jet events. No single theoretical prediction can describe the data accurately for all distributions. These results will help to improve understanding of QCD and motivate more accurate theoretical calculations for future comparisons with data.

Further reading

ATLAS Collaboration 2014 arXiv:1409.8639 [hep-ex], submitted to *Eur. Phys. J. C.*

CMS presents precision measurements of the top-quark mass from Run 1



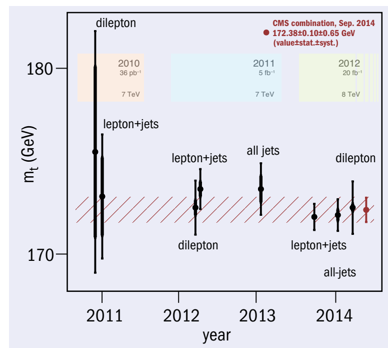
Precise measurements of the mass of the top quark provide key inputs to global electroweak fits and to tests of the internal consistency of the Standard Model. The masses of the Higgs boson and the top quark are the two key parameters that determine whether the vacuum is stable – an issue with broad cosmological implications.

At the LHC, top quarks are predominantly produced in quark–antiquark pairs, and top-quark events are characterized by the decays of the daughter W bosons and bottom quarks, leading to three experimental signatures. In the "lepton+jets" channel, the two bottom-quark jets are accompanied by a single lepton (e or μ) and one undetected neutrino from the decay of one of the W bosons, together with two light-quark jets from the other W. In the dilepton channel, both W bosons decay to leptons, so two leptons (ee, eμ, μμ) and two undetected neutrinos accompany the bottom-quark jets. Last, if the W bosons both decay to quark–antiquark pairs, the signature will include four light-quark jets – the all-jets channel.

At the recent TOP2014 workshop in Cannes, the CMS collaboration presented a new measurement of the mass of the top quark, based on the full LHC data set recorded during 2012. This corresponds to approximately 20 fb^{-1} of integrated luminosity at $\sqrt{s} = 8$ TeV, which is roughly four times the size of the combined data sets at $\sqrt{s} = 7$ TeV from 2010 and 2011. The latest result comes from a new measurement in the dilepton channel (CMS Collaboration 2014a). It complements the results from the lepton+jets and all-jets channels that were announced earlier this year (CMS Collaboration 2014b and 2014c).

The new measurement uses an analytical matrix-weighting technique to determine the most probable solution for missing transverse energy in the events. The top-quark mass is determined from a fit to the combined results, yielding a value of 172.47±0.17 (stat.) ±1.40 (syst.) GeV. In contrast, for the other two analyses, two-dimensional likelihood functions were used to determine simultaneously the top-quark mass and the overall jet-energy scale. The measurements of 172.04±0.11 (stat.) ±0.74 (syst.) GeV and 172.08±0.27 (stat.) ±0.84 (syst.) GeV, together with the new result, complete the initial set of high-precision analyses using the Run 1 data.

At the TOP2014 workshop, CMS also presented a combination of these results with five previous measurements using the 2010 and 2011 data sets (CMS Collaboration 2014d). The figure shows the combination and the evolution of the CMS measurements as a function of time. The combined value for the top-quark mass is found to be 172.38±0.10 (stat.) ±0.65 (syst.) GeV. With a precision of 0.38%, this is the most precise result from any single experiment. Work continues on additional analyses using alternative techniques, and results from these are expected in the coming months.



The evolution of the CMS measurements of the top-quark mass as a function of time and their combination. The latest result completes the set of LHC Run I measurements.

Further reading

CMS Collaboration 2014a CMS-PAS-TOP-14-010.
CMS Collaboration 2014b CMS-PAS-TOP-14-001.
CMS Collaboration 2014c CMS-PAS-TOP-14-002.
CMS Collaboration 2014d CMS-PAS-TOP-14-015.

ACCELERATORS

ILC-type cryomodule makes the grade

For the first time, the gradient specification of the International Linear Collider (ILC) design study of 31.5 MV/m has been achieved on average across an entire ILC-type cryomodule made of ILC-grade cavities. A team at Fermilab reached the milestone in early October. The cryomodule, called CM2, was developed to advance superconducting radio-frequency technology and infrastructure at laboratories in the Americas region, and was assembled and installed at Fermilab after initial vertical testing of the cavities at Jefferson Lab. The milestone – an achievement for scientists at Fermilab, Jefferson Lab, and their domestic and international partners in superconducting radio-frequency (SRF) technologies – has been nearly a decade in the making, from when US scientists started participating in ILC research and development in 2006.

Between 2008 and 2010, all of the eight cavities in CM2, after being electropolished, had been individually pushed to gradients above 35 MV/m at Jefferson Lab in vertical tests. They were subjected to additional horizontal tests at Fermilab. They were among 60 cavities being evaluated globally for the prospect of reaching the ILC gradient. This evaluation was known as the S0 Global Design Effort, and was a build-up to the S1-Global Experiment, which put to the test the possibility of reaching 31.5 MV/m across an entire cryomodule. The final assembly of the S1 cryomodule set-up took place at KEK in Japan between 2010 and 2011. In S1, seven nine-cell 1.3 GHz niobium cavities strung together inside a cryomodule achieved an average gradient of 26 MV/m. An ILC-type cryomodule consists of eight such cavities.

Over the years, teams in the Americas region have acquired significant expertise in SRF technology, including increasing cavity gradients. Cavities manufactured by companies in the US, for example, have improved in quality: three of the eight cavities that make up CM2 were fabricated locally.

The CM2 group at Fermilab will push the gradients higher to determine the limits of the technology and to continue to understand and advance it. They expect to send an actual electron beam through CM2 in 2015, to understand better how the beam and cryomodule respond together. The aim is to use CM2 in the Advanced Superconducting Test Accelerator currently being commissioned at Fermilab. The SRF technology developed for FLASH at DESY, the European XFEL and now CM2 also has applications for the proposed PIP-II at Fermilab and at light sources such as LCLS-II at SLAC.

CM2 in its home at Fermilab's NML building, as part of the future Advanced Superconducting Test Accelerator. (Image credit: Fermilab.)

ASTROPARTICLE PHYSICS

The Global Neutrino Network takes off

On 20–12 September, CERN hosted the fifth annual Mediterranean-Antarctic Neutrino Telescope Symposium (MANTS). For the first time, the meeting was organized under the GNN umbrella.

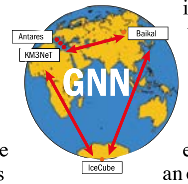
The idea to link more closely the various neutrino telescope projects under both water and ice has been a topic for discussion in the international community of high-energy neutrino astrophysicists for several years. On 15 October 2013, representatives of the ANTARES, BAIKAL, IceCube ▷

News

and KM3NeT collaborations signed a memorandum of understanding for co-operation within a Global Neutrino Network (GNN). GNN aims for extended inter-collaboration exchanges, more coherent strategy planning and exploitation of the resulting synergistic effects.

No doubt, the evidence for extraterrestrial neutrinos recently reported by IceCube at the South Pole (p30 this issue) has given wings to GNN, and is encouraging the KM3NeT (in the Mediterranean Sea) and GVD (Lake Baikal) collaborations in their efforts to achieve appropriate funding to build northern-hemisphere cubic-kilometre detectors. IceCube is also working towards an extension of its present configuration.

One focus of the MANTS meeting was, naturally, on the most recent results from IceCube and ANTARES, and their relevance for future projects. The initial configurations of KM3NeT (with three to four times the sensitivity of ANTARES) and GVD (with sensitivity similar to ANTARES) could provide additional information on the characteristics of the IceCube signals, first because they look at a complementary part of the sky, and second because water has optical properties that are different from ice. Cross-checks with different systematics are of the highest importance for these detectors in natural media. As an example, KM3NeT will measure down-going muons from cosmic-ray interactions in the atmosphere with superb precision. This could help in determining more precisely the flux of atmospheric neutrinos co-generated with those muons, in particular those from the decay of charmed mesons, which are expected to have particularly high energies and therefore could mimic an extraterrestrial signal.



A large part of the meeting was devoted to finding the best "figures of merit" characterizing the physics capabilities of the detectors. These not only allow comparison of the different projects, but also provide an important tool to optimize future detector configurations. The latter also concerns the two sub-projects that aim to determine the neutrino mass hierarchy using atmospheric neutrinos. These are both small, high-density versions of the huge kilometre-scale arrays: PINGU at the South Pole and ORCA in the Mediterranean Sea. In this effort a particularly close co-operation has emerged during the past year, down to technical details.

Combining data from different detectors is another aspect of GNN. A recent common analysis of IceCube and ANTARES sky maps has provided the best sensitivity ever for point sources in certain regions of the sky, and will be published soon. Further goals of GNN include the co-ordination of alert and multimessenger policies, exchange and mutual checks of software, creation of a common software pool, development of standards for data representation, cross-checks of results with different systematics, and the organization of schools and other forums for exchanging expertise and experts. Mutual representation in the experiments' science advisory committees is another way to promote close contact and mutual understanding.

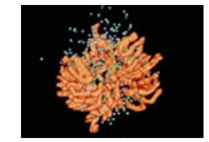
Contingent upon availability of funding, the mid 2020s could see one Global Neutrino Observatory, with instrumented volumes of 5–8 km^3 in each hemisphere. This would, finally, fully raise the curtain just lifted by IceCube, and provide a rich view on the high-energy neutrino sky.

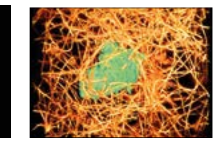
Sciencewatch

Compiled by John Swain, Northeastern University

Super-resolution microscope makes movies

Eric Betzig, of the Janelia Research Campus of the Howard Hughes Medical Institute in Virginia, shared the 2014 Nobel Prize for Chemistry for the invention of super-resolution microscopy. Now, he and his colleagues have taken the technique a step further. They have extended light-sheet microscopy to use utrathin light sheets from 2D optical lattices to scan plane by plane through a specimen to build up a 3D image at up to 1000 frames per second. The reduced illumination also has the advantage of causing minimal specimen damage, so cells and small embryos can be filmed as they go about their lives, as the researchers demonstrate for 20 biological processes covering four orders of magnitude in space and time.





Stills from two of the movies following cell division, left, and cell movement through a matrix.

Further reading

Bi-Chang Chen *et al.* 2014 *Science* **346** 439.

For the movies, visit http://vimeo.com/album/3098015.

Long-range tractor beam

A Star Trek-like tractor beam able to stably push or pull semitransparent gold-coated glass spheres over tens of centimetres has been developed by Vladen Shvedov of the Australian National University in Canberra and colleagues. They use a laser beam with a doughnut-shaped profile (with a hole down the middle) to hold the sphere. Then, by adjusting the polarization of the same beam (azimuthal or radial), they can have energy absorbed mainly on the sphere's front side, heating it so that it ejects warm air and is pushed along the beam, or at the rear side, so that the warm air pushes back and the tractor beam exerts a pull. This is the first working long-range tractor beam that both pushes and pulls.

Further reading

V Shvedov *et al.* 2014 *Nature Photonics* **8** 846.

Hot solar explosions

Just above the surface of the Sun lies the relatively cool photosphere, at around 6000 K, but it turns out to host some remarkably hot explosions. Using the Interface Region Imaging Spectrograph (IRIS), Hardi Peter of the Max Planck Institute for Solar System Research in Göttingen and colleagues report pockets of plasma heated to almost 100,000 K for a few minutes. Presumably from magnetic reconnection, these explosions have 0.1–1% of the energy of a flare, making the brightest ones an order of magnitude more energetic than the microflares known as "Ellerman bombs". This new finding contributes to an ever more complex view of the photosphere.

Further reading

H Peter *et al.* 2014 *Science* **346** 1255726.

Oxygen and the boring billion

In the beginning...the Earth had essentially no free oxygen in its atmosphere. The Great Oxygenation Event came around 2000 million years ago, when cyanobacteria produced enough oxygen for it to accumulate, but only in the past 800 million years did an explosion of multicellular animal life take place. The intervening period of not much happening is often called, rather approximately, "the boring billion". Now, Noah Planavsky of Yale University and colleagues have shown that it coincides with a low atmospheric oxygen content, improving previous upper limits by at least an order of magnitude. Looking at the oxidation of chromium isotopes in ancient sediments, they found that oxygen levels were only 0.1% of those today – while associated with the boring billion, this is not boring at all.

Further reading

N J Planavsky *et al.* 2014 *Science* **345** 635.

Hope for a diabetes cure

For the first time, human stem cells have been converted into insulin-producing pancreatic β cells. Douglas Melton of the Harvard Stem Cell Institute and colleagues report on a complex process that over 35 days produces some 200 million β cells, which would be enough, in theory, to treat a human patient. Transplanted into mice, the β cells work, secreting human insulin and improving hyperglycemia in diabetic mice. In human diabetics, these cells might still be destroyed in the person's immune system, like the original β cells, but recipients of transplanted cadaveric human tissue transplants have been insulin-free for five years – a procedure that is limited owing to the scarcity of suitable donor tissue. While not yet a cure, this is the first example of making functional, transplantable insulin-producing human cells, and of the importance of continuing stem-cell work.

Further reading

F W Pagliuca *et al.* 2014 *Cell* **159** 428.

Genetic tools on paper

The term "on paper" often means "theoretically", but James Collins of Harvard University, Boston University, and the Howard Hughes Medical Institute in Maryland and colleagues have shown that working biological circuits can be printed on paper. They produced cell-free gene networks made from off-the-shelf parts and freeze-dried onto paper. When rehydrated, these worked as diagnostic devices with a colorimetric output, capable of detecting glucose and distinguishing RNA fragments from two related species of the Ebola virus.

Further reading

K Pardee *et al.* 2014 *Cell* **159** 1.

Oxygen – less space is more

An oxygen cylinder holds more gas if filled first with a sponge-like powder. Jared DeCoste of Leidos, Inc. in Maryland and colleagues searched among 10,000 metal-organic frameworks using a Monte Carlo simulation, and found two that increase the capacity of an empty cylinder by 89% and 114% at a pressure of 140 bar. This should allow for smaller, lighter oxygen tanks that require lower pressures, and has implications for divers, fighter pilots, astronauts, and anyone who needs medical oxygen.

Further reading

J B DeCoste 2014 *Angew. Chem. Int. Ed.* **53** 1.

Astrowatch

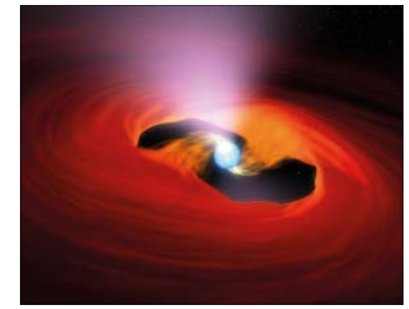
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva, and CHIPP, University of Zurich

Ultra-luminous X-ray source is 'just' a pulsar

Until now, ultra-luminous X-ray sources (ULXs) were thought to be black holes, because their high luminosity implied a mass exceeding by far the maximal mass of a neutron star. The most luminous of them were thought, furthermore, to be of a rare class of intermediate-mass black holes. The surprising discovery of pulsations from one of them now shakes this interpretation, and suggests that at least some neutron stars can become much more luminous than previously thought.

ULXs were discovered in nearby galaxies by the Einstein Observatory in the 1980s. These sources are characterized by X-ray luminosities that are intermediate between normal X-ray binaries and active galactic nuclei (AGN). If luminosity simply scaled with the mass of the accreting compact object, ULXs should be intermediate black holes with masses typically 100 to 10,000 times that of the Sun. This is an unusual mass range for black holes, which are more commonly found either with masses of about 10 solar masses, typical of stars, or with millions of solar masses, as in the case of those powering AGNs at the centres of galaxies.

A simple mass-luminosity relation arises naturally from the equilibrium between the inward gravitational force and the outward radiation pressure acting on matter accretion. Indeed, accretion can only increase as long as the resulting luminosity does not exceed what is known as the Eddington limit, at which the radiation pressure stops accretion and generates an intense outward wind. The Eddington luminosity is linearly proportional to mass and has a value of about 10^{31} W for a solar-mass star, which is about 10,000 times the luminosity of the Sun.



Artist's rendering of a pulsar – a rapidly rotating magnetized neutron star – funnelling plasma from the surrounding accretion disc onto its magnetic poles. (Image credit: NASA/JPL-Caltech.)

Although the Eddington limit holds, strictly, only for isotropic accretion, it serves as an order-of-magnitude upper limit to the luminosity of a source of a given mass. A ULX with a luminosity of 10^{33} W should, therefore, indicate the presence of a black hole at least 100 times the mass of the Sun. This argument is now disproved strongly by the detection of pulsed X-ray emission from a ULX in the nearby galaxy Messier 82 (M82), reported by Matteo Bachetti from the University of Toulouse and colleagues.

This source, M82 X-2, is the second brightest X-ray source in this star-forming galaxy, and can reach a luminosity exceeding 10^{33} W. The clear detection of pulsations with a period of 1.37 s and an orbital modulation of 2.5 days identifies the source as a binary system that is composed of a neutron star accreting gas from a massive companion star. The pulsed emission was observed in the 3–30 keV X-ray range by the Nuclear Spectroscopic Telescope Array, a NASA satellite launched from below an aeroplane on 13 June 2012. Confirmation that the pulsating source is indeed the ULX M82 X-2 came from contemporaneous observations by the Chandra X-ray Observatory and the Swift satellite.

The discovery of pulsations in M82 X-2 was made possible thanks to a long observation campaign in early 2014 of the M82 galaxy triggered by the explosion of the supernova SN 2014J (*CERN Courier* October 2014 p17). It proves that at least some ULXs can be accreting pulsars, rather than massive black holes. Theorists are now left with the challenge of proposing a model to explain how a pulsar can radiate at about 100 times its Eddington luminosity.

● **Further reading**

M Bachetti *et al.* 2014 *Nature* **514** 202.

Picture of the month

This portrait of the Earth and Moon system was taken by the Chinese Chang'e 5-T1 mission. It offers a rare view of the far side of the Moon – which is always hidden as seen from the Earth – with the Earth appearing as a distant blue marble. The Chinese spacecraft was launched on 23 October for a round-trip flight around the Moon before a successful return to Earth on 31 October. Although this was mainly an unmanned engineering test mission, it bears witness to the rapid development of the Chinese space programme. A year ago, China attracted worldwide attention with mutual portraits of a lunar lander and its little rover Yutu ("Jade Rabbit"). India is also making a notable entry into deep-space exploration with its Mars Orbiter Mission, which has been sending back beautiful images of the red planet since its orbital insertion manoeuvre on 23–24 September, following a 10-month journey. (Image credit: Chinese National Space Administration, Xinhuanet.)

CERN Courier Archive: 1971

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

CERN NEWS

Getting colder

[Earlier this year] we reported the bringing into operation of a 45 cm^3 polarized proton target working at 0.55 K. It now looks as if the development can be carried further with the testing of a new refrigerator using a 10 cm^3 sample, which can be maintained at a temperature of less than 0.05 K. This is a step not only towards higher rates of polarization but also towards "frozen spin" targets, which could allow particles emerging from collisions to be detected over almost 4π solid angle.

The refrigerator, built by T O Niinikoski of the Technical University of Helsinki in collaboration with the CERN Polarized Targets Group, is based on the principle of He^3/He^4 dilution. The use of high-speed pumps (250 m^3/h) give a cooling power that is the greatest ever reached for such low temperatures, making it possible to maintain the sample at 0.03 K under normal operating conditions and to sustain temperatures as low as 0.022 K.

The final aim is to perfect 15 cm long targets for the large aperture magnet in the East Hall or the Omega spectrometer. To derive the maximum amount of information from these spectrometers it is desirable to analyse particles leaving the target at any angle. With targets built so far, very homogeneous and intense magnetic fields were necessary, with poles close to the target, reducing the solid angle for observations.

The lower the temperature, the longer the relaxation time for the polarized protons to revert to a completely disorientated state. At very low temperatures, the inertia of spins is such that prolonged polarization can be maintained even if the magnetic field ceases to have the homogeneity and intensity necessary for creating the effect. This is a "frozen spin" target. It is hoped that, in Omega's 1.5 T field, the target will be able to maintain its polarization for several days at a temperature of 0.06 K.

● Compiled from texts on p353.

BATAVIA

15-foot chamber

The major bubble-chamber facility at the National Accelerator Laboratory, a 15-foot chamber, is at an advanced stage of construction in the Neutrino Laboratory at the 200/500 GeV accelerator.

Initially it had been hoped to build a 25-foot chamber but, with no sign of money to construct a chamber of this size, the scale was trimmed down to a 15-foot version. An important factor has been the readiness of the NAL Group under W Fowler to bring in extensive help. Thus the chamber design incorporates ideas from Argonne on the magnet, Stanford on the expansion system, Brookhaven on the vessels, and CERN on the optics, piston and seal.

The volume of liquid is 30,000 litres, contained in an almost spherical vessel with a length along the beam direction of 15 foot. It is designed to operate with hydrogen, deuterium, neon or mixtures. The superconducting magnet will provide a field of 3 T at the centre of the chamber.

The expansion system will operate about once per second, giving the possibility of four expansions per accelerator cycle. The profligate use of six cameras, located at the top of the chamber in two triangular arrays, enables hadron pictures to be taken while neutrino experiments are running. Thus the neutrino beam to the chamber might absorb 70% of the beam early in the flat top, leaving the opportunity for a burst of charged particles at the end.

The project began in summer 1970. Since early this year, the globe of the 7 m diameter vacuum vessel has been a prominent feature of the NAL site. On 25 October the chamber body arrived at the laboratory, and was installed in its final position in the vacuum tank on 30 November. It is hoped that the first cool-down will take place in July 1972, and that the chamber will be ready for experiments by the beginning of 1973.

Left: Aerial view of the neutrino laboratory at NAL. On the right is the globe shape of the bubble-chamber vacuum vessel. Right: Arrival of the chamber body, looking at the top where the six camera ports are located.

● Compiled from texts on pp358–359.

Compiler's Note

Absolute zero, 0 K, thought of as the lowest temperature possible, is taken as –273.15°C. The LHC cryogenic system, the largest in the world, gets to within 1.9 K, making it one of the coldest places on Earth, colder than outer space at 2.7 K. Recently, a cubic metre of copper weighing 400 kg was cooled to 0.006 K (6m K) for the CUORE experiment in Gran Sasso (see p5 this issue). The lowest temperature ever recorded, 0.0000000001 K (100 pK) was reached at the Helsinki University of Technology Low Temperature Lab by nuclear magnetic ordering – bbbrrrrr!

Those venerable bubble chambers surely had charisma, resembling iconic submersibles such as the Bathysphere of William Beebe and Otis Barton, who descended to a record-breaking 920 m in 1934, and the Deepsea Challenger of film director James Cameron, who, in 2012, hit the bottom of the Mariana Trench, the oceans' deepest point, where the temperature is a comfortable 1 to 4°C but the pressure is 1000 times the value at sea level, 11 km above.

RHIC's new gold record

New luminosity records for collisions of gold beams, plus the first-ever head-on collisions of gold with helium-3, marked an exceptional run for Brookhaven's heavy-ion collider in 2014.

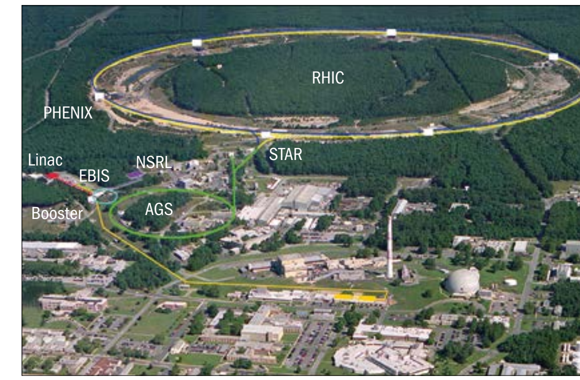


Fig. 1. RHIC and its injectors – the Linac for polarized protons, the EBIS for ions, the Booster and the AGS. (Image credit: Brookhaven National Laboratory.)

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory completed its 14th physics run in July, during which gold-ion beams were brought into collision at both low (7.3 GeV/nucleon) and high (100 GeV/nucleon) energies. The runs at high energy set new records for instantaneous and average-store luminosities, and the latter now stands at $5 \times 10^{27}\,\text{cm}^{-2}\text{s}^{-1}$, or 25 times the design value. This stellar performance also allowed the introduction of another combination of species to the study of quark–gluon plasma (QGP). For the first time, a collider brought ions of helium-3 – a rare helium isotope with two protons and a single neutron – into collision with gold nuclei.

For the first three weeks of the 2014 run, RHIC delivered gold–gold collisions at 7.3 GeV/nucleon to complete the first phase of a beam-energy scan. The aim of the energy scan is to find a critical point in the QCD phase diagram that marks the end point of a first-order phase transition from cold nuclear matter into QGP. The majority of the scan was done in 2010, with five different collision energies. To date, gold ions have collided with 3.85, 4.6, 5.75, 9.8, 19.5, 27.9, 31.2, 65.2 and 100 GeV/nucleon. A second phase of the beam-energy scan is now planned for energies below the nominal injection energy of 9.8 GeV/nucleon, with a luminosity increase ranging from a factor of three to 10. The large increase in luminosity requires the implementation of electron cooling. Meanwhile, the low-energy part has already allowed the STAR and PHENIX collaborations to test new components in preparation for the high-energy part of the run: the heavy-flavour tracker for STAR and the vertex detector for PHENIX.

The subsequent 18 weeks of the 2014 run with collisions at a beam energy of 100 GeV/nucleon had the goal of delivering as much luminosity as possible, following a luminosity upgrade. This year marked the end of this upgrade period, which began in 2007 and saw the average store luminosity for gold–gold collisions increase by more than a factor of four. The two main elements of the upgrade have been an increase in the bunch intensity from 1.1×10^9 to 1.6×10^9 gold ions, and the implementation of three-dimensional stochastic cooling in both of RHIC's rings (Blaskiewicz *et al.* 2008). The increase in the bunch intensity was achieved through many small upgrades in all of the machines, from the source to RHIC (figure 1), and led to a 2.5-fold increase in the initial luminosity. In addition, stochastic cooling led to a luminosity lifetime that is now determined by "burn-off", with more than 90% of the gold ions lost in collisions with the other beam. Without stochastic cooling, the increased initial luminosity would decay so fast as to be of no use.

Figure 2 (p20) shows the dramatic effect that the upgrades had on the instantaneous and average-store luminosities, where an operating period of 48 h is shown in 2007 and 2014. The 2014 luminosity starts at a much higher value, but still decays for about half an hour before the cooling takes full effect. The cooling then reduces the beam sizes fast enough that the luminosity begins to increase, and typically exceeds the initial value. It then decays with time as more and more ions are lost in the collision process. The 2014 stores ended with luminosity values that are as high as the initial values in 2007.

With the high-luminosity stores and excellent reliability, the integrated luminosity of the 2014 run exceeds the integrated luminosity of all previous gold–gold runs combined. Figure 3 (p20) shows the integrated nucleon-pair luminosity, $L_{NN} = A_1 A_2 L$, where L is the integrated luminosity, and A_1 and A_2 are the number of nucleons of the ions in the two beams, respectively. The use of L_{NN} allows different ion combinations to be compared.

The 2014 stores ended with luminosities as high as the initial values in 2007.

The shutdown period preceding the 2014 run provided the opportunity to upgrade a number of subsystems. Bunch-merging in the Booster and Alternating Gradient Synchrotron (AGS) was improved with a new low-level RF system, leading to an overall increase of about 30% in the maximum extracted beam intensity, ▷

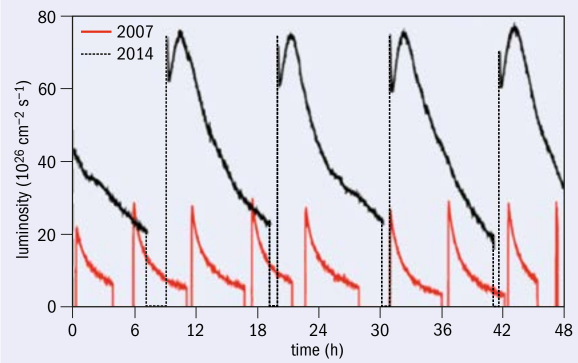


Fig. 2. 48 h operating periods for 2007 and 2014 reveal the effect of the upgrades on the instantaneous and average store luminosities.

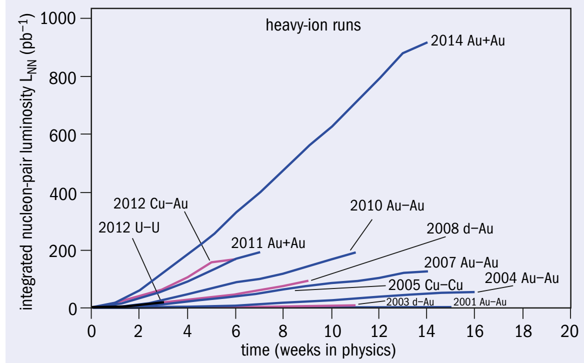


Fig. 3. The integrated nucleon-pair luminosity for a variety of combinations of ions, including the record gold–gold run of 2014.

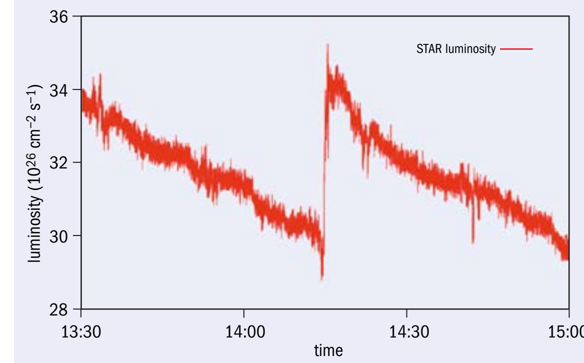


Fig. 4. The luminosity at the STAR detector before, during and after a dynamic β squeeze, 7 h into a physics store in a gold run in 2014.

compared with the 2012 run, the last time that gold ions were used in RHIC. The RHIC stochastic-cooling system, made fully operational in all three planes for the first time for the 2012 uranium run, featured new longitudinal pick-ups and kickers, for better correction of the spread of particles within the bunches (*CERN Courier* October 2012 p17). Additionally, a new 56 MHz passive superconducting RF storage cavity was commissioned, to provide larger RF buckets and reduce longitudinal diffusion caused by intra-beam scattering. The cavity is the first superconducting cavity in RHIC, and it reached 300 kV, which is below the 2 MV design voltage because it was limited by quenches in a higher-order mode damper. With a redesign of the damper and the full voltage of the cavity, the average store luminosity is expected to increase even further in the future, by at least 30%.

To minimize the commissioning time of the collider for the 100 GeV gold–gold run, the decision was taken to use the lattice design for the 2012 uranium run. This provides an increased off-momentum dynamic aperture, compared with previous high-energy heavy-ion runs, of up to 5σ for $\delta p/p = 1.8\times10^{-4}$. The machine performance during the 2012 run with uranium–uranium and copper–gold was such that beam losses were already dominated by burn-off (Luo *et al.* 2014).

Further highlights

One of the highlights of the 2014 run was the implementation of a dynamic β^*-squeeze scheme to increase the integrated luminosity delivered to the STAR and PHENIX experiments. The beam size at any given point in the storage ring is given by $\sqrt{\beta\varepsilon}$, where β is the β function and ε is the emittance. In this scheme, the β function at the interaction point is reduced while the beams are in collision. The scheme takes advantage of the fact that, owing to stochastic cooling, the emittance ε decreases during the store, so that a larger β function can be accommodated in the final focus triplets. With this, the β function at the interaction point (β^*) – and therefore the beam size – is reduced, leading to an increase in luminosity. After about one hour, the transverse emittance ε is reduced by a factor 2.5–3, and eventually to less than 1 μm rms.

The lattice design for this dynamic squeeze relies on the principles of the achromatic telescopic squeeze (ATS) developed at CERN in the context of the LHC upgrade (Fartoukh 2013). The ATS method was adapted for RHIC to match the machine constraints, both in engineering (the magnet power-supplies' wiring scheme) and in beam dynamics (the location of experimental insertions and phase-advance requirements). Once the linear optics had been corrected – reducing the β beat in the machine from 40% to 10% – it was possible to ramp the lattice dynamically into its new set point, sending the β^* from 0.70 m down to 0.50 m. This could only be done reliably with the help of orbit and tune feedbacks. Prior to their operational implementation, each new β^* set point was commissioned during dedicated beam-experiment periods.

Figure 4 shows the luminosity at the STAR detector before, during and after a β squeeze, 7 h into a physics store. The dynamic β squeeze became part of the routine operation in the second half of the 2014 run, and will be the main method to level the luminosity in future. To maximize the physics output, RHIC's detectors might require that the instantaneous luminosity does not exceed a certain value. With cooling and the dynamic β squeeze, ions can be stored and burned off in the collisions in a way that is most useful to the experiments.

With the success of the gold–gold run at 100 GeV/nucleon, the last weeks of the 2014 run were reassigned to allow a new type of collision to be studied: helium-3 on gold ions. Understanding the properties of QGP can be advanced by looking into the emission patterns of the subatomic particles that it generates while cooling down. These patterns are a function of the initial "shape" of the QGP, which is given by the type of collision between the two stored beams. In colliders such as RHIC and the LHC, almost spherical particles (e.g. protons, gold and lead) are sent to collide head on, resulting in showers of subatomic particles that are projected in a circular pattern. The idea behind using helium-3 is that it features a triangular shape, allowing the STAR and PHENIX collaborations to look at different initial forms of QGP.

The biggest challenge for RHIC was to send the helium-3 beam onto the gold-ion beam for head-on collisions. Given the large difference in the charge-to-mass ratio of the two species – 2:3 for helium-3 versus 79:197 for gold – the beam trajectories were such that it became necessary to add crossing angles through the collision points in STAR and PHENIX, and a large horizontal orbit excursion in both interaction regions. The orbit excursions reached 10 mm – for comparison, well-controlled orbits have rms values of 20 μm. In addition, with a circumference of 3833 m, the path length of the helium-3 beam was 10 mm longer than that of the gold-ion beam.

Thanks to a modified bunch-merging mechanism through the RHIC injector chain, the bunch intensity for the helium-3 beam was increased by a factor of four compared with the previous year. With this significant improvement, the successful implementation of the specific beam paths in all of the interaction regions, and a short commissioning time despite the complexity of running with two particle species that are so different, this dedicated run was also a major success, exceeding the luminosity goals for both experiments.

• Further reading

M Blaskiewicz *et al.* 2008 *Phys. Rev. Lett.* **100** 174802.
S Fartoukh 2013 *Phys. Rev. ST Accel. Beams* **16** 111002.
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Résumé

Le nouveau record du RHIC

Le Collisionneur d'ions lourds relativistes (RHIC) du Laboratoire national de Brookhaven a achevé en juillet sa quatorzième période d'exploitation pour la physique, durant laquelle des faisceaux d'ions or ont été amenés à entrer en collision à basse énergie (7,3 GeV/nucléon) comme à haute énergie (100 GeV/nucléon). La période d'exploitation à haute énergie a atteint de nouveaux records en matière de niveaux de luminosité moyenne et instantanée. Cette performance exemplaire a également permis l'introduction d'une autre combinaison d'ions dans l'étude du plasma quark-gluon. Pour la première fois, un collisionneur a amené des ions d'hélium-3, un isotope rare de l'hélium comptant deux protons et un seul neutron, à entrer en collision avec des noyaux d'or.

Guillaume Robert-Demolaize and **Wolfram Fischer**, Brookhaven National Laboratory.

In their own words

Recollections of CERN's early days from the CERN Archives.

CERN appeared a gigantic enterprise to the young people who started to work for the fledgling organization from 1952 onwards, even before its official foundation in 1954. The adventure is traced here via some recollections recorded in interviews carried out by Marilena Streit-Bianchi for the CERN Archives between 1993 and 1997. These edited extracts cover some of the different evolving facets of the organization from the early 1950s to the late 1970s, and pay tribute to some of those who have passed away before the 60th anniversary of the young CERN they describe so vividly. Their enthusiasm and competences brought the organization to the level of excellence that has now become familiar.
● Compiled and edited by Marilena Streit-Bianchi and Christine Sutton.

Résumé
Avec leurs propres mots

Le CERN est apparu comme une gigantesque entreprise aux yeux des jeunes gens qui ont commencé à travailler pour la nouvelle organisation à partir de 1952. Enregistrés entre 1993 et 1997 lors d'entretiens réalisés par Marilena Streit-Bianchi pour les archives du CERN, leurs souvenirs retracent cette aventure. Les extraits couvrent les différentes facettes de l'évolution du Laboratoire du début des années 1950 jusqu'à la fin des années 1970. C'est aussi l'occasion de rendre hommage, 60 ans après, à certains d'entre eux aujourd'hui disparus.

A first recruit and the first machine

Frank Krienen in 1963, with an example of one of his important contributions to particle physics – the wire spark chamber. (Image credit: CERN-GE-6303023.)

I was working at Philips Hilversum where I met Professor Bakker, and I became an assistant at the Zeeman Laboratory in Amsterdam. In 1951 I was asked to join his team, which was working on building CERN. I attended the Copenhagen meeting in 1952, when the alternate gradient principles became known – I believe that it was at this very moment that CERN was born. Although many of us, including myself, did not completely understand it, we immediately believed that an interesting new machine could be built, going from weak focusing to strong focusing. UNESCO provided money for our salaries. It was not much that we earned, but it was a terrific experience to arrive at a place where French and English had to be spoken.

Building the Synchrocyclotron (SC)
The alternating gradient machine was in development, and in the meantime it was decided to build a weak-focusing 600 MeV proton synchrocyclotron. I was asked to look after its set-up. We were a nice small team of 12 people sitting in barracks near the airport, whereas the [Proton Synchrotron] PS team, much larger, was staying at the University of Geneva. The construction of the site started, and it took 3–4 years. The six of us that really built the SC machine were working in a free atmosphere. It could look wild from the outside, but among us [there] was a strong discipline based on trust. We developed the RF system and conceived the tuning fork called the vibrating capacitor, made out of parts of very soft aluminium alloy. I made the design…and it was published in *Nuclear Instruments and Methods*. It worked well. The high-frequency system did not take too much time, whereas the magnet being 3000 tonnes of steel 5 m [in] diameter was not simple. After the war, all of the big countries wanted to contribute to it [France, Germany, Italy, England]. Each of them had some capability but didn't have them all, so there was a choice to be made, and it was decided to make it based on technical and not on political grounds.
● *Frank Krienen 1917–2008.*

Frank Krienen was one of the first recruits for CERN's 600 MeV Synchrocyclotron, in 1952. In the 1960s, he turned to developing particle detectors, in particular wire spark chambers using different types of read-out. Later, he worked on the construction and operation of the electric quadrupoles for the muon storage ring, for the third and last g-2 experiment at CERN in the years 1969–1977, followed by the design and development of the electron-cooling apparatus for CERN's Initial Cooling Experiment ring. (For more, see CERN Courier *July/August 2008 p25.)*

Assisting the birth and growth of CERN

Eliane de Modzelewska, left, with director-general Victor Weisskopf, in 1961. (Image credit: CERN-HI-6104638.)

Le tout début
Lorsque j'ai commencé à travailler pour Edoardo Amaldi, secrétaire général par intérim de l'Organisation, il y avait déjà eu une session du Conseil et la deuxième allait avoir lieu à Amsterdam, juste au moment de mon arrivée à Rome. Nous avons tout de suite eu beaucoup de travail de préparation sur le projet de Convention qui devait être signé au mois de juillet à Paris. En plus de cela, il fallait au même moment régler beaucoup de correspondance. Les procès-verbaux des réunions étaient produits à l'UNESCO, et tous les documents pour les diverses réunions des comités étaient envoyés à l'état de projet au Secrétariat, qui devait les taper, traduire, reproduire et diffuser. Edoardo Amaldi tenait toujours avec lui un petit cahier et avait l'habitude de prendre des notes. Il disait ensuite « on a discuté de ça et ça, il y aura ça et ça à faire » ; il n'y avait aucune perte de temps, car tout était clair et extrêmement bien ordonné. Il y avait quatre groupes du futur CERN en Europe, et, pour les tenir au courant de ce qui se passait ailleurs, on résumait la correspondance et les autres informations que nous recevions du Président du Conseil ; ainsi, tous étaient tenus au courant de ce qui se discutait et du progrès des activités. Bien entendu, à l'époque, il n'y avait pas de service de reproduction, de machines à photocopier ou d'ordinateurs. Une salle à l'Institut de physique de Rome était réservée pour nos activités. Nous avons ainsi fait connaissance là-bas d'ingénieurs et de physiciens dont certains sont venus plus tard au CERN.

Les premières années
Lorsqu'on est passé des baraques au Bâtiment principal, on a senti que c'était quelque chose de définitif, que l'aventure se terminait. Cornelis Jan Bakker n'a pas voulu s'installer au dernier étage ; il est resté au premier parce qu'il voulait aller voir souvent ce qui se passait au SC et il disait que, si l'on doit prendre l'ascenseur pour aller dans les ateliers, on le fera moins souvent. Cela a été un période magnifique car tout le monde se connaissait et nous étions tous solidaires ; nous avions tous été contaminés par le virus CERN. Il n'y avait pas que les scientifiques ou les ingénieurs qui s'emballaient et travaillaient beaucoup, mais aussi les administrateurs, les stagiaires, les gens dans les ateliers. On sentait qu'on faisait quelque chose d'absolument nouveau et qu'il fallait absolument que cela réussisse. Je ne sais pas à combien de réunions j'ai assisté. Je me souviens de Gentner, d'Amaldi, de Bakker, de Bernardini qui répétaient comme si c'était la prière du jour que l'Administration doit être aussi réduite que possible et servir à nous décharger des tâches qui nous prendraient trop de temps précieux pour d'autres choses, mais on ne doit ni l'entendre, ni l'avouer.

Le PS a été achevé dans les temps et selon le budget fixé. C'était la splendide réussite de John Adams, jeune chef de projet, homme tellement brillant et en même temps très précis. Quand le premier faisceau a circulé, il y a eu une explosion de joie. Nous sommes tous allés dans le hall Adams danser.
● *Eliane de Modzelewska 1917–2004.*

Eliane de Modzelewska (née Bertrand) was chosen by Edoardo Amaldi in Rome in 1952–1953 to assist in the early steps that led to CERN. She worked with nine directors-general, from Amaldi, with the provisional Conseil Européen pour la Recherche Nucléaire (1952–1954), to Herwig Schopper. (For more, see CERN Courier *October 2004 p60.)*

Accelerating expertise

Kjell Johnsen, left, shows Willi Jentschke, centre, and Hildred Blewett some of the emerging results at the start-up of the ISR in 1971. (Image credit: CERN-AC-7101182.)

I went to Imperial College where Professor Dennis Gabor was, because I wanted to study beyond what university had given me. He had excellent courses in advanced particle dynamics, statistical physics, etc. It was an extremely important year for me, although [his] lectures were not on accelerators. The work I did for myself was on accelerators, and more specifically on linear accelerators, and the reason is simple. In Norway…a small country with few accelerators…the idea came up that perhaps it was possible to make accelerators in…the low-energy field. But in my stay with Gabor it was more the general knowledge I gained that was very much useful later in life.

The Proton Synchrotron (PS) Group
I was involved already a bit with Odd Dahl in 1951, then I became part of CERN full time from summer 1952. At that time, Dahl was leading the PS Group, as it was called in those days, from Bergen, [where] a group was working on the study of possible accelerators for what was called CERN. We were sitting in the home institute. It was an interesting experience – we ▷

had to communicate by letters and by travelling. There was no computer connection like now. I have never written so much in my life as I did in the first two years, or travelled for meetings as I did during 1952. I must admit that a very good spirit was struck…we were a good group, elected in a very specific way. Senior people like Dahl, [Wolfgang] Gentner, [John] Cockcroft, [Edoardo] Amaldi, etc, selected very good young people among their collaborators and students. We were enthusiastic, and we had the fortunate happening that the [alternating] gradient principle was invented at the beginning of the study. I have ever since admired Dahl for having the courage to switch the whole activity onto this new principle, only weeks after it was, shall we say, invented. It was a tremendous challenge to study if the energy could go to 30 GeV, instead of the 10 GeV we were talking of before.

The Intersecting Storage Rings (ISR)

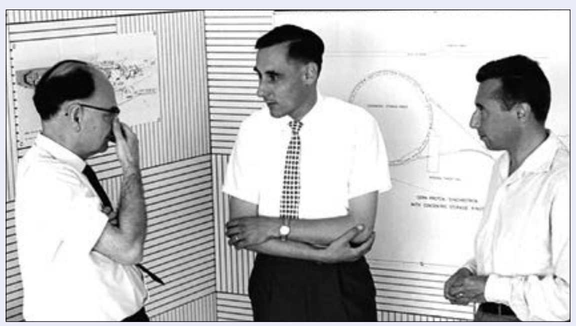
I never thought of becoming the project head. I thought my ability beautifully fit the study-preparation phase, and then what I would have considered a more practical person could take over and lead the project. I hoped that he would ask me as deputy. So it was a surprise when I was asked to become the head of the ISR project.

A difficult thing to achieve technologically for the machine was to have an RF system that could do the job. The next most difficult big problem was the vacuum system, because we realized that it was tremendously important for the lifetime of the beam, an essential element for having efficient operation. The vacuum was improved continuously, far beyond what we first thought was necessary. There were many aspects related to vacuum that had to be solved. Indeed, to achieve the vacuum that we needed, most improvements were done after we put the machine into operation. I think for 10 years the vacuum was gradually improved, and improved and improved.

● *Kjell Johnsen 1921–2007.*

Kjell Johnsen joined CERN in 1952, and became a world-leading accelerator expert through his work on the design of the PS. He went on to lead the ISR project, CERN's first hadron collider and forerunner of the LHC. (For more, see CERN Courier *October 2007 p41.)*

Pioneering at the Proton Synchrotron



Wolfgang Schnell, centre, discusses plans for the future ISR with Lorenzo Resegotti, right, and Arnold Schoch, in 1964. (Image credit: CERN-GE-6407094.)

My diploma thesis was on voltage control of electronically controlled oscillators for the PS accelerator, based on nuclear spin resonance under the direction of Professor Chris Schmelzer. It was directly for CERN. I was listed as CERN staff member and assistant to Schmelzer. We had some instruments we could buy, but I had no pay, of course. So when my diploma was finished, I had the choice to work on my PhD or to come to CERN immediately, in 1954. When I came to CERN I was 25. It was the first time I left my country, the first time I went somewhere they did not speak German. In a sense, the integration was easy, to get a furnished room, to be with other internationals at CERN [and] not so much with the local population. We did not know whether we would succeed, but we were young, 25–26...It was a fantastic time. It was not yet clear if CERN would really happen.

I worked on the RF system of the PS, and then on the control system. The lab was very small, [but] it grew up very quickly, and when we were at the end – the time of PS running – we were almost the size of a small division, about 100 people. In my mind, the PS construction had two phases. The first phase, 1954–1959, looked hopeless. We had no experience, we were almost fooling around in a fantastic team: John Adams, Mervyn Hine, Simon van der Meer – a few people that had experience, and were making sure that it would not fail altogether. A few years later, we were all very professional – magnet, RF, control system – all working on different projects.

The atmosphere, the enthusiasm, the communication was still not very different, to some extent, until LEP, and certainly up to the ISR period. At the beginning we were at the University of Geneva in barracks, going through how to do the purchasing, and only a few had the privilege to have a room in the building. We were physically separated from the theory group until after we built the machine: Pierre Germain, Jack Sharp, Bengt Sagnell, Robert Gabillard, and in the Magnet Group, Bas De Raad, Lorenzo Resegotti among others.

The Large Electron–Positron collider (LEP)

LEP was, in a sense, a very large extension of what had been done before. The problems were not fundamental – it was the size. The relationship with industry was also for LEP still essentially what we always had. We would develop by looking at things we could buy, and even for prototypes we made it work and then went to industry to have it mastered. Of course for LEP…there were not just a few cavities, but 128. It was not 100 magnets, but 1000. The firms were shown what was developed here, left free to make a proposal, even to do it differently – but then they had to do double the work: explain what they wanted to do…why they wanted to do it like that, and then do the production. It was the same type of relationship we had started with the PS. Many things at CERN go back to the PS.

● *Wolfgang Schnell 1929–2006.*

Wolfgang Schnell joined the PS construction team in 1954. In 1959, he developed the phase-lock feedback system that solved the problem of beam losses during the start-up. He later contributed significantly to the ISR and discovered the longitudinal and transverse Schottky signals, the latter leading to the verification of stochastic cooling, proposed by Simon van der Meer, which was critical for the conversion of the Super Proton Synchrotron to a $p\bar{p}$ collider. (For more, see CERN Courier *December 2006 p36.)*

From the PS to computing

Mervyn Hine, left, and Ben Segal, with the 3 m antenna for the STELLA satellite project – conceived by Hine – which interconnected six European labs at the then-radical wide-area speed of 1 Mbit/s. (Image credit: CERN-PHOTO-8001439-1.)

The PS and Mont Citron

The initial work on the experimental facilities of the PS had been under [Wolfgang] Gentner, together with Anselm Citron. They were basing themselves quite a lot on cosmic-ray results that had been obtained for things like particle yields, as this was the information available at the time. Citron, I think, had done calculations on the shielding necessary, and when we made the layout for the PS South hall and the main experimental area where the main beams – that was high-energy beam – would go, it was felt necessary to make a set-up for the experimental beams at the end, outside the experimental hall, so that whatever particles would not get into the neighbouring countryside. It was decided then to make the hill that was called Mont Citron, which was built up at the end of the PS experimental hall [now the site of Linac 4]. That was an area where Citron was working.

At the meeting in Varenna in which all business of the PS was discussed – Fermi was also there just before he died – I gave a talk on a paper written with Citron, where we put down what kind of particles could come out from a 25 GeV collision in a target, in terms of the supposed intensity coming from the PS, and therefore what kind of yields [there] could be. Quite a lot of the calculation had been done by Citron, and had been done without really considering the layout we were talking about. I wrote the paper, Citron approved it and I gave the talk. This was in 1954 and published in 1955 [CERN 55-23]. The machine at this stage was still on paper…

Data-handling Division (DD)

When [Bernard] Gregory took over [as director-general, 1966] he wanted to make the directors be more actively responsible – to work with the divisions not as staff members but as executive managers. The DD came to me as director of applied physics, so I had the DD under me when I stepped down from the directorate in 1972...[In 1976, Paolo] Zanella took over the DD. He managed it extremely well within the given limitations. With people complaining about computing taking away resources from the physics programme, a great educational programme was done, and I remember that during this period we educated five directors of physics to know something about computing. Some of them became quite good. [Volker] Soergel was very good and made good use of it when he went to DESY. It was hard work, and I know that van Hove and others had laborious discussions to bring the directors on board and…to make them aware of the fact that if the accelerator was off for three weeks, nobody would notice, but if computing was off for three days everybody would be "murderers".

● *Mervyn Hine 1920–2004.*

After carrying out pioneering work on accelerators in the UK, Mervyn Hine came to CERN with John Adams to work on the PS in 1953 – they were often referred to as "the Harwell twins". With the PS commissioned, Hine became director for applied physics in 1960, first under Adams as director-general and then under Victor Weisskopf. Hine's role expanded later well beyond applied physics, in particular to medium-term planning for the whole laboratory. (For more, see CERN Courier *June 2004 p17 and July/August 2004 p39.)*

A woman in the world of particles

I had in high school a teacher in mathematics and physics that I liked very much…so I enrolled at the university [of Milan] in a course of mathematics and physics. There, physics was taught by Professor Polvani, who was very inspiring, and I decided to do physics. When I had to choose my thesis, Giuseppe Cocconi, who had just come back from Rome, had decided to start research in cosmic rays, and I joined him to do my thesis on a search for neutrons in the cosmic radiation. The work was done up in the mountains below the Matterhorn on the Italian side at 2000 m. The methods were primitive and the data obtained marginal. Cocconi, my future husband, was the supervisor of my thesis work. We worked together for two years on cosmic-ray research. After the end of the work with cosmic rays we never worked together again, neither at Cornell nor at CERN…but he always supported me.

Bubble-chamber work at CERN

We started with three laboratories, the ABC collaboration [for Aachen–Bologna–CERN], and ended with a collaboration of 13 institutes – very large, and at times it was very heavy to co-ordinate institutes from different countries. With several Institutes from Eastern [European] countries, it was difficult having people coming from or going there. People would mainly work from home and later try to come and discuss together the results produced. The philosophy of the group was to aim for the highest available energy and highest workable production. After 1977 with the neutrino beam, it was neutrino physics in the last years of my work at CERN and there again with more universities, Oxford, Athens, Julich…

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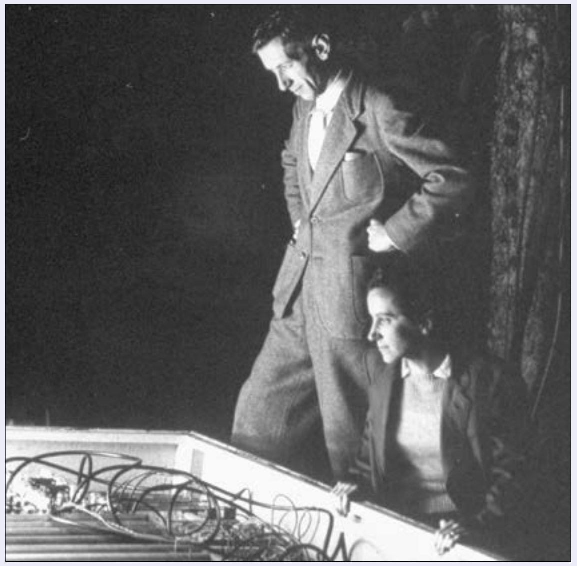


Giuseppe and Vanna check cosmic-ray detectors in this photograph from 1948. (Image credit: Time&Life/Getty Images.)

Combining professional life and children

I had the usual difficulties [that women have]. My solution was to work half time, so all the time at Cornell and at CERN I worked half time. Of course for this there are no general rules: each woman has to find her solution. This was a good solution for me, but of course limiting for work...I never found myself discriminated against as a woman, neither at Cornell nor at CERN, absolutely not. Of course some problems came from the fact [that] I did not work full time. I did some work at home, but that was not as much as if I would have worked full time, but this was my decision.

● *Vanna Cocconi-Tongiorgi 1917–1997.*

After her thesis work in Italy, Vanna Cocconi-Tongiorgi moved with Giuseppe Cocconi to Cornell University in 1947, and stayed for 15 years. At Cornell, she continued her work on cosmic rays, and was the first to observe neutron spallation. Back in Europe, she worked at CERN on the SC and the PS in the years 1959–1960, before becoming a member of the personnel in 1963, and the "heart'" of the European bubble-chamber collaboration. (For more, see CERN Courier *November 1997 p30.)*

A link with other countries

Owen Lock, right, with Willibald Jentschke, director-general of Lab I, in 1975. (Image credit: CERN-PHOTO-7511297-1.)

CERN schools

I attended all of the CERN schools until I retired, which makes in the order of 30 schools. You ask me if I remember any particular lecture, any particular school. One real outstanding lecture was from Lev Okun from the Institute of Theoretical and Experimental Physics in Moscow. I remember when I visited there in 1965–1966, I was walking with him in the gardens of the institute…and I called the place the "Institute of Experimental and Theoretical Physics". He stopped me and said "Lock, this is the Institute of Theoretical and Experimental Physics." He gave a lecture in Hungary [Dobogoko 1979] where he did not use an overhead projector or notes, but with a bit of chalk he simply developed the argument with [the students]. It is not that I am against the use of transparencies, but it is so easy to show them and not explain all of the steps one has to do. Perhaps the best school as such, just because of the whole atmosphere, I would point out the school in Alushta in 1975. It was so very nice, the people and all the rest.

Non-member states

I started very early with non-member states such as the Soviet Union and then later, when China opened up in 1973…everything to do with non-member states in a sense came my way, especially when I started to work for [Herwig] Schopper in 1981 when[John] Adams's mandate came to its end. One of the first things I did with Schopper was to go to China with him to negotiate a memorandum of understanding. During my time as his personal assistant I dealt with almost all problems that came up. So when a letter came from Mongolia, it was my job to think about and consult people in the Theory Division and in the Experimental Physics Division as to what sort of reply we should get to the Mongolians. I was never formally responsible, let's say, for Mongolia, Turkey or India, but because of personal contact I dealt with these things. The only countries for which I was officially the linkman were the Soviet Union, for which I was quite often the scientific secretary in scientific committees; China, where I was formally the linkman for the exchange programme they had; and Finland, which dated back from the time I was head of the Fellows and Visitors Service.

● *Owen Lock 1927–2010.*

After a PhD with Cecil Powell's group in Bristol and work on emulsion experiments at Birmingham, Owen Lock joined the CERN staff in 1960 to lead the Nuclear Emulsion Group. He organized and initiated in 1962 the Easter School for Emulsion Physicists, which became the CERN School of Physics, and was responsible subsequently for the school becoming a joint venture with JINR, Dubna. He later became involved with relations with non-member states under several directors-general. (For more, see CERN Courier *June 2010 p31.)*

ISOLDE: a northern attraction

Gregers Hansen, left, with Helge Ravn at ISOLDE in 1979. (Image credit: CERN-PHOTO-7912213-1.)

The early ISOLDE

My real acquaintance with CERN began in 1964, when some of my colleagues in Sweden, Norway, Denmark, France and Germany proposed what then came to be known as the ISOLDE Collaboration. In the early 1950s, the idea of a small machine had existed, and in the early 1960s Karl Ove Nielsen and Otto Kofoed-Hansen [worked] at the synchrotron of the Niels Bohr Institute [in Copenhagen]. But the lifetime was limited for this small machine, and in 1964 it was realized that the CERN Synchrocyclotron (SC) would be a fantastic machine for this purpose, with the backing of the countries I mentioned. After the proposal to build an isotope separator on the SC was presented to Professor Weisskopf, all went fast. Already in December of the same year, a committee was set up for checking and approval, and it was rapidly decided to start construction. I was interested in participating, and I came the year after in 1965 for my first physics stay at CERN to do an experiment at the SC simply to get used to the environment, [and] to use some of the equipment we were planning to use at ISOLDE. Then came the construction period, which was again something that went very fast: approval December 1964, the first beam in October 1967. The whole construction involved making a new underground area, the same still in use up to 1990. [Giorgio] Brianti paid an important role – he was the head of the SC when I began to work there, and his support was essential in reaching the level of performance we had.

One of the important points was when it became clear that the radiation level would prevent putting the beam facility above ground. Calculations were done both on the Route de Meyrin and on the gas station across the road. It showed that one could easily reach levels that one could not tolerate in public areas, so the idea came to put the facility underground…Brianti checked the safety requirements, and found out that an accidental spill along the beam line would exceed the committed doses in the underground area, so we had extra shielding added.

The new ISOLDE

I think the new ISOLDE at the Booster would not have existed without [Carlo] Rubbia's enthusiasm. He was the first that did not start with the money. He asked what can we do for this physics? What can we do to function better? He was the one that said look at the Booster. Actually I had looked at the Booster earlier, but at that time…the intensity would have been too weak, the conditions would have been difficult. But Rubbia was aware that the Booster had developed, and actually what it could offer was extremely attractive. We just thought of [what] we had longed to discover in 1972 and could be done there. The new installation was really working very well. He was pleased when we all decided for [it] and the credit goes to Rubbia.

● *Gregers Hansen 1933–2005.*

Gregers Hansen studied at the Technical University of Denmark. He was then employed at the Niels Bohr Institute and Risø National Lab , before becoming professor at Aarhus University in 1966. He spent a large part of his scientific life connected to CERN and ISOLDE – he was ISOLDE group leader in the years 1970–1978, and deputy division leader in the Experimental Physics Division in the years 1974–1977. (For more, see CERN Courier *November 2005 p49.)*

A prolific advocate for particle physics

I was 15 when I got interested in physics. My curiosity was the universe, and also the fact that physics was something useful. My father was teaching physics, we were living in Lyon and at 18 I went to Paris…within two years I was at the École Normale. It was the time when we were discovering a new world, quantum mechanics in particular, which was not taught at the university at that time.

Public talks and time

Quite often I am asked to do popular talks and then you have to find a subject that would interest them. Of course what we do here – why particle physics? – is very important, but the main topic has to be more general and the flow of time is one [possibility]…At a music festival in Perouse, this small medieval village in France, the organizer decided to have a physics component, so they asked me to give a talk. The lecture was about one hour, and then there were two hours afterwards with many people asking questions. What I said about time…is nothing very original. I just showed what time is, at least in physics, which essentially goes to motion. Time is driven by motion. What would be time without motion?…Then of course you have the flow of time, which for standard physics contains causality, the question of reversible and irreversible phenomena, time in thermodynamics. With all that you can debate.

The promotion of physics education

How to motivate people to study physics? Firstly, try to improve the teaching of physics at university level and also at high-school level. The European Physical Society [EPS] got involved in that because it is a society ▷

Maurice Jacob, left, with Jacques Prentki, in the Theory Secretariat in 1983. (Image credit: CERN-PHOTO-8311678-1.)

of the societies. You have typically a physics society, which is essentially academic, university based, and there is a society of physics teachers. These two societies are in contact but are separate, so EPS was asked to look both at high-school level and at university level. We set up a division on education, which had three pillars. One was on teaching, with discussions involving teachers from different countries, [the second with] different university communities, both at graduate and undergraduate level, and thirdly helping with exchange programmes with the European Union.

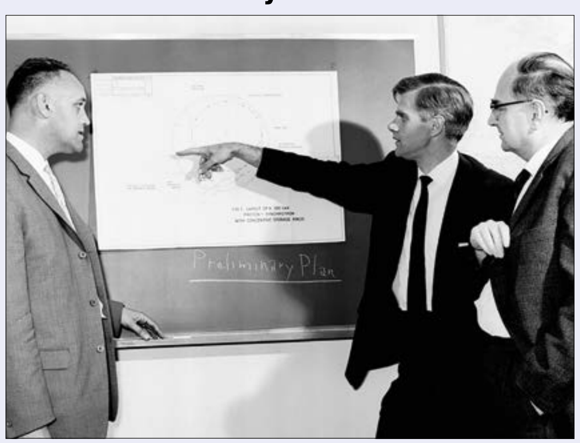
CERN Courier

I was asked to chair the first [advisory] committee of *CERN Courier* in the late 1970s, at the time with certain uneasiness. Some people on the CERN management complained that [it] was not giving CERN the share that a magazine called *CERN Courier* should give, and it should have more on CERN-related events and less on other communities of particle physics. One has to realize that *CERN Courier* is not serving CERN only but the world community of particle physics. This was an agreement that was reached I think in 1974 by the directors of the major laboratories – that it would be a unique journal serving the whole community…As a committee we… conveyed to the management that [it] was not a purely CERN magazine, but was actually serving the whole community, and [the cover] should read, next to the title, "International Journal of Particle Physics".

● *Maurice Jacob 1933–2007.*

After starting his research career in Saclay, with time at Brookhaven and Caltech, Maurice Jacob joined CERN in 1967. A theoretical physicist, he brought theorists and experimentalists together to debate new measurements and results. He also played an important role in the French and European Physical Societies, and was a prolific speaker and writer about particle physics. (For more, see CERN Courier *July/August 2007 p39 and October 2003 p54.)*

A director in the early 1970s



Kees Zilverschoon, left, Kjell Johnsen and Arnold Schoch discuss the layout for a 300 GeV proton synchrotron surrounded by a pair of storage rings for colliding-beam experiments, in 1963. (Image credit: CERN-GE-6305027.)

Directors and divisions at CERN (1970–1975)

The division-leader role was simple: to make sure that the division worked, to make the teams work, to ensure that decisions that were made were developed and maintained. The director had the double task to see that the division leaders did a good job [at the time there were at most three divisions under a director]. The director was of course closer to the director-general, because he was responsible to the director-general for the divisions. It was [the director's] task to see that they did the work, and that was done through a proper delegation of [responsibility and] power: the division leader had his power. The director had, as a second task, to take part in the directorate meetings – called at that time the Board of the Directors – where they discussed the matter of CERN as a whole, but always having in mind their own divisions [and] that if they were [forming] a conclusion in the Board of Directors, they would have to implement it in their own divisions. This was not the case in the structure that was set up by John Adams, because there the directors – the members of the directorate, as they were called at that time – were made more [like] assistants to the director-general.

The major achievement on the [Proton Synchrotron] PS when I was the director [of the PS Department in the years 1970–1975] was the construction of the new linac [the 50 MeV Linac 2], which was an important thing at the time. It was certainly proposed by the linac people at that moment in the Machine PS Division [with a study report in 1973], and I had to get it through the directorate.

It was [Kjell] Johnsen who suggested that if the ISR was made, then the PS machine should be used as an injector. We studied it in the MPS Division – they had to convert a number of things in the machine for the injection. We always had the feeling that technical things could always be solved.

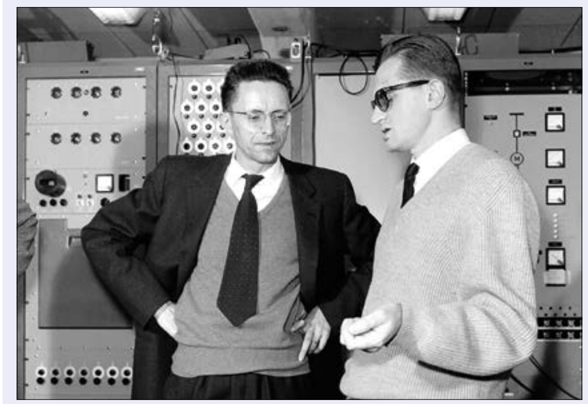
Two laboratories (1971–1975)

The transition [to two laboratories] with Adams went smoothly, but what didn't go smoothly was collaboration between the two – the so-called Laboratory I in Meyrin and Laboratory II in Prévessin. Lab I had been hit very badly. The budget was reduced, the number of staff was reduced, and nevertheless we had to keep it going. There were frictions at moments, and that was why a co-ordination meeting was set up with the two directors-general – Jentschke and Adams – Hans-Otto Wüster, George Hampton and Lévy-Mandel and me. We were having meetings once a week and discussed the problems.

● *Cornelis "Kees" Zilverschoon 1923–2102.*

Kees Zilverschoon joined CERN in May 1954 as an applied physicist to work on the construction project for the PS, led by John Adams. He contributed to many of CERN's accelerator projects for more than 30 years, up to and including the Large Electron–Positron collider. He was director of the PS Department in the years 1970–1975. (For more, see CERN Courier *July/August 2012 p42.)*

A bridge between accelerators and experiments



Franco Bonaudi, right, with Pierre Germain, in the PS control room in 1960. (Image credit: CERN-GE-6002983.)

The $p\bar{p}$ project

There was a certain amount of risk. I can comment on a few things, for instance when the idea was already pushed very strongly at a stage when it was not clear yet if one should use electron cooling or stochastic cooling. Both options were mentioned as possibilities in the very first report that was written down – we tried to keep all possibilities open. The Initial Cooling Experiment ring was pushed very strongly, and there I would like to mention the name of Guido Petrucci who was in charge, and did an excellent job on that machine thanks to the team of [Simon] van der Meer, Wolfgang Schnell and many others. It showed how stochastic cooling worked, so that was the moment of making that choice. It was also the moment of no return. We announced in the Council that it was working and there was no longer any obstacle.

There were also some other worries. One of them was the rate of production of antiprotons. People were not sure within more than a factor of two how antiprotons would really be produced by a target with that kind of primary proton beam with that solid angle. It was proposed by Paul Falk-Variant and some other people – and I supported the idea – that measurements should be done in the SPS [Super Proton Synchrotron]. After all, we had the beams available and it could be done easily and quickly. We talked with van der Meer to get his support, but he was very much against. He said it was too late, and in any case whatever we measured we had to go ahead anyway. I think he was right in a way. Nobody really knew what the real production rate would be, and a factor of two was not making all that difference in the success of the project.

I think that the $p\bar{p}$ project also helped CERN in defending the regular level of budget, because it was clear that for that kind of project, money was needed. They wanted to do it quickly, and there were ambitious set-ups, especially the UA1 experiment, on top of the machine. In the absence of $p\bar{p}$ we might have had a strong erosion of the CERN budget.

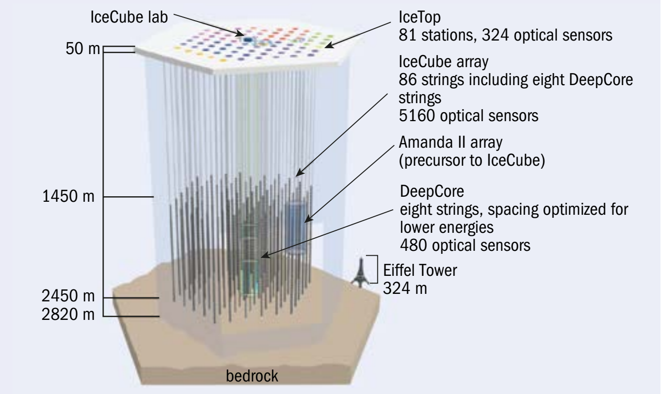
The UA2 experiment

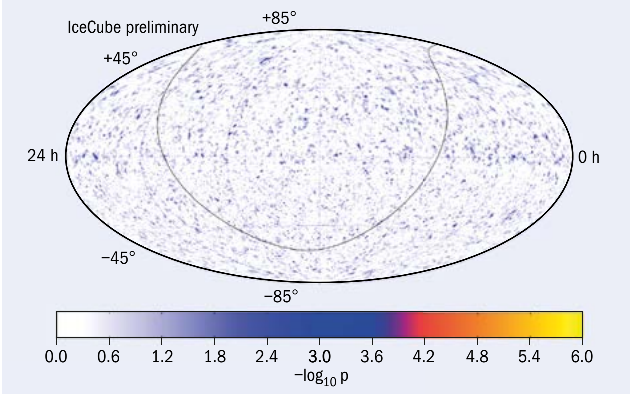
I was at the end of my mandate of three years as director of accelerators and I wanted to take part in one of the $p\bar{p}$ experiments. I thought it was more correct for me to take part if they accepted me in the second experiment. Therefore I watched with great interest in one of the open sessions of the SPS [Experiments Committee]. There were two proposals, one from Sam Ting and the other from Pierre Darriulat. I remember very vividly the beautiful presentation by Luigi Di Lella, which was a masterful presentation of an experiment. After the experiment of Darriulat was approved, they very kindly accepted me. Pierre told me afterwards that they had some reluctance: "Who is this guy that was in the directorate and now wants to work with us?" The difficulties were soon dissipated and we worked beautifully together.

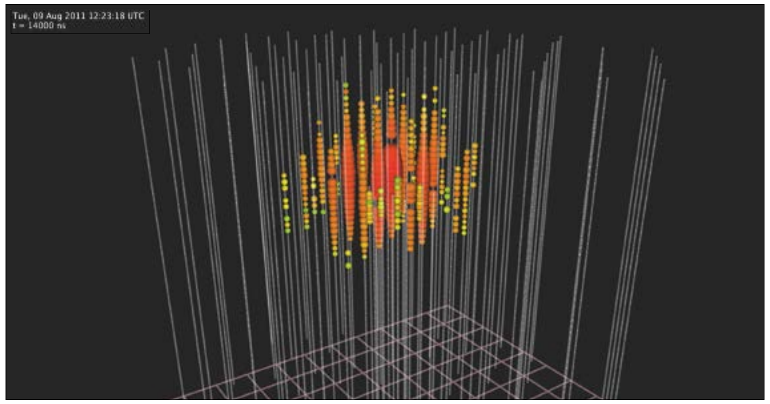
● *Franco Bonaudi 1928–2008.*

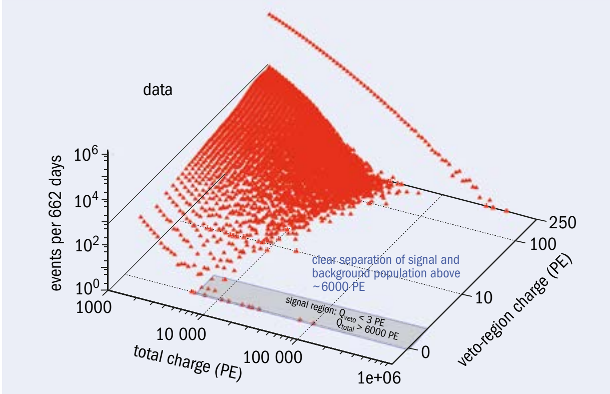
As early as 1952, Franco Bonaudi went to Liverpool at Edoardo Amaldi's request, to learn about synchrocyclotrons and join the study group led by Cornelius Bakker for CERN's 600 MeV Synchrocyclotron (SC). He went on to oversee construction of the SC, and to lead the design of experiment infrastructures at the Interacting Storage Rings, the Super Proton Synchrotron and the Large Electron–Positron collider. (For more, see CERN Courier *April 2009 p19.)*

CERN Courier December 2014
Astroparticle physics









From left to right: Fig. 1. Schematic of IceCube including DeepCore. The IceTop surface array consists of 162 tanks in 81 stations that observe cosmic-ray air showers. (Image credit: IceCube.) Fig. 2. IceCube sky map, in equatorial coordinates, made with four years of data. The northern-hemisphere data are mostly from neutrinos, and contain 177,544 events. The grey line shows the galactic plane. (Image credit: IceCube.) Fig. 3. The interaction of a neutrino of energy of about 1 PeV in IceCube. The light pool of roughly 100,000 photons extends across more than 500 m. The reconstructed visible energy is 1.04 PeV, which represents a lower limit on the energy of the neutrino that initiated the particle shower. The vertical lines of white dots show the IceCube digital optical modules (DOMs). The 300 coloured dots are the DOMs that observed a signal. The colour indicates the arrival time, from red (early) to purple (late), while the size of the dots indicates the number of photons detected. (Image credit: IceCube.) Fig. 4. One year of IceCube data as a function of the total number of photons and the number present in the veto region. The signal region requires more than 6000 photoelectrons, with fewer than three of the first 250 photoelectrons in the veto region of the detector. The signal, including nine events with reconstructed neutrino energy in excess of 100 TeV, is clearly separated from the background.

Cosmic neutrinos and more: IceCube's first three years

The coldest region of the Earth might seem a strange place to study the hottest places in the universe, but this is just what the IceCube detector does.

For the past four years, the IceCube Neutrino Observatory, located at the South Pole, has been collecting data on some of the most violent collisions in the universe. Fulfilling its pre-construction aspirations, the detector has observed astrophysical neutrinos with energies above 60 TeV, at the "magic" 5σ significance. The most energetic neutrino observed had an energy of about 2 PeV (2×10^{15} eV) – 250 times higher than the beam energy of the LHC.

These neutrinos are just one highlight of IceCube's broad physics programme, which encompasses searches for astrophysical neutrinos, searches for neutrinos from dark matter, studies of neutrino oscillations, cosmic-ray physics, and searches for supernovae and a variety of exotica. All of these studies take advantage of a unique detector at a unique location: the South Pole.

IceCube observes the Cherenkov light emitted by charged particles produced in neutrino interactions in 1 km^3 of transparent Antarctic ice. The detector is the ice itself, and is read out by 5160 optical sensors. Figure 1 shows how the optical sensors are distributed throughout the 1 km^3 of ice, 1.5 km beneath the geographic South Pole. They are deployed 17 m apart, on 86 vertical cables or "strings". Seventy-eight of the strings are spaced horizontally, 125 m apart in a grid of equilateral triangles forming a hexagonal array across an area of a square kilometre. The remaining eight strings form a more densely instrumented sub-array called DeepCore. In DeepCore, most of the sensors are concentrated in the lower 350 m of the detector.

Each sensor, or digital optical module (DOM), is like a miniature satellite made up of a 10 inch (25 cm) photomultiplier tube together with data-acquisition and control electronics. These include a custom 300 megasample/s waveform digitizer with 14 bits of dynamic range, plus light sources for calibrations, all consuming a power of less than 5 W. The hardware is protected by a centimetre-thick pressure vessel.

The ice in IceCube formed from compacted snow that fell on Antarctica 100,000 years ago. Its properties vary with depth, with layers reflecting the atmospheric conditions when the snow first fell. Measuring the optical properties of this ice has been one of the major challenges of IceCube, involving custom "dust loggers", studies with LED "flashers" and cosmic-ray muons. During the past decade, the collaboration has found that the ice is layered, that the layers are not perfectly flat and, most recently, that the light scattering is somewhat anisotropic. Each insight has led to a better understanding of the detector and to smaller systematic uncertainties. Fortunately, advances in computing technology have allowed IceCube's simulations to keep up, more or less, with the increasingly complex models of light propagation in the ice.

The distributed sensors give IceCube strong pattern-recognition capabilities. The three neutrino flavours – ν_e, ν_μ and ν_τ – each leave different signatures in the detector. Charged-current ν_μ produce high-energy muons, which leave long tracks. All ν_e interactions, and all neutral-current interactions, produce hadronic or electromagnetic showers. High-energy ν_τ produce a characteristic "double-bang" signature – one shower when the ν_τ interacts and a second when the τ decays. More complex topologies have also been studied, including tracks that start in the detector as well as pairs of parallel tracks.

Despite past doubts, IceCube works and works well. More than 98% of the sensors are fully operational, and another 1% are usable – most of the failures occurred during deployment. The post-deployment attrition rate is a few DOMs per year, so IceCube will be able to operate for as long as required. The "live" times are also impressive – in the range of 99%.

IceCube has excellent reconstruction capabilities. For kilometre-long muon tracks, the angular resolution is better than 0.4°, verified by studying the shadow of the Moon cast by cosmic rays. For high-energy contained events, the angular resolution can reach 15°, and at high energies the visible energy can be determined to better than 15%.

Cosmic neutrinos

The detector's dynamic range covers from 10 GeV to infinity. The higher energy the neutrino, the easier it is to detect. Every six minutes, IceCube records an atmospheric neutrino, from the decay of pions, kaons and heavier particles produced in cosmic-ray air showers. These 100,000 neutrinos collected every year are interesting in their own right, but they are also the background to any search for cosmic neutrinos. On top of this, the detector records about 3000 atmospheric muons every second. This is a painful background for neutrino searches, but a gold mine for cosmic-ray physics.

Although IceCube has an extremely rich physics programme, the centrepiece is clearly the search for cosmic neutrinos. Many signatures have been proposed for these neutrinos: point source searches, a high-energy diffuse flux, identified ν_τ, and others. IceCube has looked for all of these.

Point-source searches are the simplest strategy conceptually – just create a sky map showing the arrival directions of all of the detected neutrinos. Figure 2 shows the IceCube sky map containing 400,000 events gathered across four years (Aartsen *et al.* 2014c). In the southern hemisphere, the large background of downgoing muons is only partially counteracted by selecting higher-energy muons, which are less likely to be of atmospheric origin. The 177,544 events in the northern-hemisphere sample are mostly from ν_μ. So far, there is no statistically significant evidence for any hot spots, even in searches for spatially extended sources. IceCube has also looked for variable sources, whether episodic or periodic, with similar results. These limits constrain theoretical models, especially those involving gamma-ray bursts.

If there are enough weak sources in the cosmos, they should be visible as an aggregate, diffuse flux. This diffuse flux is expected to have a harder energy spectrum than do atmospheric neutrinos. Calculations have indicated that IceCube would be more sensitive to this diffuse flux than to point sources, which is indeed the case. Several early searches, using the partially completed detector, turned up intriguing hints of an excess over the expected atmospheric neutrino flux. Then the search diverged from the anticipated script.

One of the first searches for diffuse neutrinos with the complete detector looked for ultra-high-energy cosmogenic neutrinos – neutrinos produced when ultra-high-energy cosmic-ray protons ($E>4\times10^{19}$ eV) interact with photons of around 10^{-4} eV in the cosmic-microwave background, exciting them to a Δ^+ resonance. The decay products of the pion produced in the Δ's decay include ▷

a neutrino with a typical energy of 10^{18} eV (1 EeV). The search found two spectacular events, one of which is shown in figure 3 (p31). Both events were well contained within the detector – clearly neutrinos. Both had energies around 1 PeV – spectacular, but too low to be produced by cosmic rays interacting with CMB photons. Such events were completely unexpected.

Inspired by these events, the IceCube collaboration instigated a follow-up search that used two powerful techniques (Aartsen *et al.* 2013). The first was a filter to identify neutrino interactions that originate inside the detector, as distinct from events originating outside it. The filter divides the instrumented volume into an outer-veto shield and a 420 megatonne inner active volume. Figure 4 (p31) shows how this veto works: by rejecting events with significant in-time energy deposition in the veto region, neutrino interactions within the detector's fiducial volume can be separated from backgrounds. For neutrinos that are contained within the instrumented volume of ice, the detector functions as a total absorption calorimeter, measuring energy with 15% resolution. It is flavour-blind, equally sensitive to hadronic or electromagnetic showers and to muon tracks. This veto analysis also used a "tagging" approach to estimate the atmospheric-muon background using the data, rather than relying on simulations. Because of the veto, the analysis could observe neutrinos from all directions in the sky.

The second innovation was to take advantage of the fact that downgoing atmospheric neutrinos should be accompanied by a cosmic-ray air shower depositing one or more muons inside IceCube. In contrast, cosmic neutrinos should be unaccompanied. A very high-energy, isolated downgoing neutrino is highly likely to be cosmic.

The follow-up search found 26 additional events. Although no new events had an energy near 1 PeV, the analysis produced evidence for cosmic neutrinos at the 4σ level. To clinch the case, the collaboration added a third year of data, pushing the significance above the "magic" 5σ level (Aartsen *et al.* 2014a). One of the new events had an energy above 2 PeV, making it the most energetic neutrino ever seen.

The observation of a flux of cosmic neutrinos was soon confirmed by the independent and more traditional analysis recording the diffuse flux of muon neutrinos penetrating the Earth. Both observations are consistent with a diffuse flux composed equally of the three neutrino flavours. No statistically significant hot spots were seen. The observed flux is consistent with that expected from cosmic accelerators producing equal energies in gamma rays, neutrinos and, possibly, cosmic rays.

Newer studies are shedding more light on these events, extending contained-event studies down to lower energies and adding flavour identification. At energies above 10 TeV, the astrophysical neutrino flux can be fit by a single power-law spectrum that is significantly harder than the background cosmic-ray muon spectrum: $\phi_\nu = 2.06^{+0.4}_{-0.3} \times 10^{-18} \left(\frac{E_\nu}{100\,\mathrm{TeV}}\right)^{-2.46\pm0.12}$ GeV^{-1} cm^{-2} sr^{-1} s (Aartsen *et al.* 2014d).

Within the limited statistics, the flux appears isotropic and consistent with the ν_e:ν_μ:ν_τ ratio of 1:1:1 that is expected for cosmic neutrinos. The majority of the events appear to be extragalactic. Some might originate in the Galaxy, but there is no compelling statistical evidence for that at this point.

Many explanations have been proposed for the IceCube observations, ranging from the relativistic particle jets emitted by active galactic nuclei to gamma-ray bursts, to starburst galaxies to magnetars. IceCube's dedicated searches do, however, disfavour gamma-ray bursts as the source. A spectral index of –2 ($dN_\nu/dE \sim E^{-2}$), predicted by Fermi shock-acceleration models, is also disfavoured, but many other scenarios are possible. Of course, the answer is clear: more data are needed.

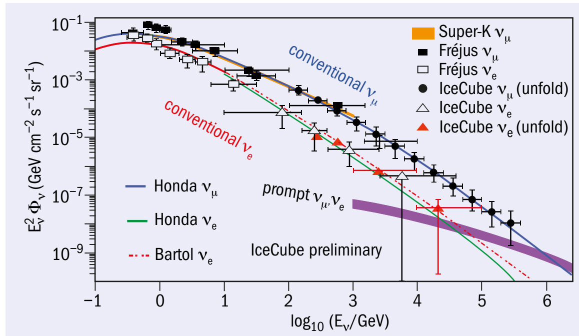


Fig. 5. The flux of atmospheric ν_μ and ν_e, compared with several models and results from other experiments. The models have been updated to account for the measured cosmic-ray "knee" and current understanding of cosmic-ray composition. The prompt-ν bands show the estimated ν flux from the production and decay of charmed particles.

Other physics

The 100,000 neutrinos and 85×10^9 cosmic-ray events recorded each year provide ample opportunities to search for dark matter and to study cosmic rays as well as neutrinos themselves. IceCube has measured the cosmic-ray spectrum and composition and observed anisotropies in the spectrum at the 10^{-4} level that have thus far defied explanation. It has also studied atypical events, such as muon-free showers expected from photons with peta-electronvolt energies, produced in the Galaxy, and investigated isolated muons produced in air showers. The latter have separations that shift from an exponential decrease to a power-law separation spectrum, as predicted by perturbative QCD.

IceCube observes atmospheric neutrinos across an energy range from 10 GeV to 100 TeV – at higher energies, the atmospheric flux is swamped by the flux of cosmic neutrinos. As figure 5 shows, the flux is consistent with expectations across a large energy range. Lower-energy neutrinos are of particular interest because they are sensitive to neutrino oscillations. For neutrinos passing vertically through the Earth, the ν_μ flux develops a first minimum at 28 GeV.

Figure 6 (opposite) shows the observed ν_μ flux, seen in one year of data, using well-reconstructed events contained within DeepCore. The change in flux with distance travelled/energy (L/E) is consistent with neutrino oscillations and inconsistent with a no-oscillation scenario. IceCube constraints on the mixing angle θ_{23} and $|\Delta m^2_{32}|$ are comparable to constraints from other experiments.

IceCube also searched for neutrinos from dark-matter annihilation. Dark matter can be gravitationally captured by the Earth, the Sun, or in the centre or halo of the Galaxy. It then accumulates and the dark-matter particles annihilate, producing neutrinos. IceCube has searched for signatures of this annihilation, and has set limits.

The Sun is a particularly interesting option, producing a characteristic dark-matter signature that cannot be explained by any astrophysical scenario. It is also mostly protons, allowing IceCube to set the world's best limits on the spin-dependent cross-section for the interaction of dark-matter particles with ordinary matter.

The collaboration has also looked for even more exotic signatures, such as magnetic monopoles and pairs of upgoing particles. One particularly spectacular and interesting signature could come from the next supernova in the Galaxy. These explosions produce a blast of neutrinos with 10–50 MeV energy. This energy level is far too low to trigger IceCube directly, but the neutrinos would be visible as a collective increase in the singles rate in the buried IceCube photomultipliers. Moreover, IceCube has a huge effective area, which will allow measurements of the time structure of the supernova-neutrino pulse with millisecond precision.

IceCube is still a novel instrument unlikely to have exhausted its discovery potential. However, at high energies, it might not be big enough. Doing neutrino astronomy could require samples of 1000 or more, high-energy neutrino events. In addition, some key physics questions require a detector with a lower energy threshold. These two considerations are driving two different upgrade projects.

DeepCore has demonstrated that IceCube is capable of making precise measurements of neutrino-oscillation parameters. If precision studies can be extended to neutrino energies below 10 GeV, it will be possible to determine the neutrino-mass hierarchy. Neutrinos passing through the Earth interact coherently with matter electrons, modifying the oscillation pattern in a way that differs for normal and inverted hierarchies. In addition to a threshold of a few giga-electron-volts, this measurement requires improved control of systematic uncertainties. An expanded collaboration has come together to pursue the construction of a high-density infill array called Precision In Ice Next-Generation Upgrade, or PINGU (Aartsen *et al.* 2014b). The present design consists of 40 additional high-sensitivity strings equipped with improved calibration devices. PINGU should be able to determine the mass hierarchy with 3σ significance within about three years, independent of the value of the CP-violation phase.

The IceCube high-energy extension (IceCube-gen2) aims for a detector with a 10-times-larger instrumented volume, albeit with a higher energy threshold. It will explore the observed cosmic neutrino flux and pin down its origin. With a sample of more than 100 cosmic neutrinos per year, it will be possible to observe multiple neutrinos from the same sources, and so do astronomy. The instrument will also have an improved sensitivity to study the ultra-high-energy neutrinos produced in the interactions of cosmic rays with microwave photons.

Of course, IceCube is not the only collaboration studying high-energy neutrinos. Projects on the cubic-kilometre scale are also being prepared in the Mediterranean Sea (KM3NeT) and in Lake Baikal (GVD), with a field of view complementary to that of IceCube. Within KM3NeT, ORCA, a proposed low-threshold detector, would pursue the same physics as PINGU. And the radio-detection experiments ANITA, ARA, GNO and ARIANNA are beginning to explore the neutrino sky at energies above 10^{17} eV.

After a decade of construction, the completed IceCube detector came on line in December 2010. It has achieved the outstanding goal of observing cosmic neutrinos and has produced important results in diverse areas: cosmic-ray physics, dark-matter searches and neutrino oscillations, not to mention its contributions to glaciology and solar physics. The observation of cosmic neutrinos at the peta-electron-volt energy scale has attracted enormous attention, with many suggestions about the location of the requisite cosmic accelerators.

Looking ahead, IceCube anticipates two important extensions: PINGU, which will determine the neutrino-mass hierarchy, and IceCube-gen2, which will expand a discovery instrument into an astronomical telescope.

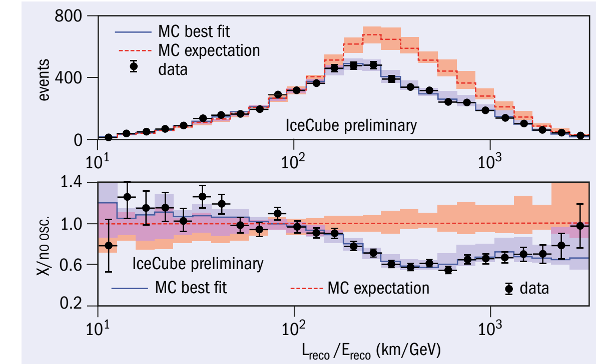


Fig. 6. The top panel shows L/E and the results of a fit to models with (blue) and without (red) oscillations, for a sample of low-energy atmospheric neutrinos. The bottom panel shows the ratio of the data to the no-oscillation expectation. The no-oscillation scenario is ruled out (Aartsen et al. *2014e).*

Further reading

M G Aartsen *et al.* IceCube Collaboration 2013 *Science* **342** 1242856.
M G Aartsen *et al.* IceCube Collaboration 2014a *Phys. Rev. Lett.* **113** 101101.
M G Aartsen *et al.* IceCube–PINGU Collaboration 2014b arXiv:1401.2046.
M G Aartsen *et al.* IceCube Collaboration 2014c arXiv:1406.6757.
M G Aartsen *et al.* IceCube Collaboration 2014d arXiv:1410.1749.
M G Aartsen *et al.* IceCube Collaboration 2014e arXiv:1410.7227.

Résumé

Neutrinos cosmiques, et autres : les trois premières années d'IceCube

Depuis quatre ans, l'Observatoire de neutrinos IceCube, situé au pôle Sud, récolte des données issues des collisions les plus violentes de l'Univers. Répondant aux attentes, le détecteur a observé des neutrinos provenant d'au-delà du Système solaire à des énergies dépassant 60 TeV, avec les 5 σ magiques permettant de valider un résultat. Ces neutrinos ne sont qu'un aspect du vaste programme de physique d'IceCube, qui inclut la détection de neutrinos astrophysiques, de ceux issus de la matière noire, l'étude des oscillations de neutrinos, la physique des rayons cosmiques et la recherche de supernovas. Toutes ces études reposent sur un détecteur d'exception situé à un endroit d'exception : le pôle Sud.

Francis Halzen, University of Wisconsin, Madison, and **Spencer Klein**, Lawrence Berkeley National Laboratory and the University of California, Berkeley.

Heavy-ion collisions: where size matters

Results from ALICE provide insight into the size of the final state at "freeze-out" – and a window on collective behaviour.

Recent observations made by the LHC experiments in proton–lead and high-multiplicity proton–proton events are reminiscent of the collective hydrodynamic-like behaviour observed in lead–lead collisions. However, the results have not been conclusive, and can also be explained in terms of the formation of another state of matter in the initial state – the colour glass condensate. Measuring the space–time extent of the final hadronic state created at "freeze-out" in nuclear collisions – when the majority of particles cease interacting – yields unique information about the initial state and its dynamical evolution. This, in turn, offers an additional constraint on the interpretation of the observed collective-like features. In particular, if the collision proceeds with a hydrodynamic-like expansion, then the final hadronic state should extend to a size significantly larger than that of the initial collision system.

The characteristic length scale of freeze-out is femtoscopic (10^{-15} m) and cannot be measured directly. However, sizes on this scale can instead be measured indirectly through the quantum interference of identical bosons or fermions. These measurements employ the technique of intensity interferometry that was invented by Robert Hanbury Brown and Richard Twiss in 1956, using the relative arrival time of photons from a distant star. In high-energy particle collisions, instead of the relative arrival time, experiments measure the relative momentum of the emitted particles to learn about the size and structure of the source.

Often, the correlation of two identical charged pions is measured as a function of their relative momentum. In hadron and ion collisions, Bose–Einstein statistics lead to enhanced production of bosons that are close together in phase space, and therefore to an excess of pairs – in this case pions – at low relative momentum. The width of the resulting Bose–Einstein peak at low relative momentum is inversely proportional to the characteristic radius of the source at freeze-out.

In high-multiplicity events such as those produced in lead–lead collisions, all background contributions (i.e. mini jets) to the correlation function are diluted to a negligible amount. However, in events with lower multiplicity, such as those produced in proton–proton and proton-lead collisions, sizable backgrounds exist, and these can significantly bias the extracted radii. One way to overcome the problem is to consider cumulants of higher-order Bose–Einstein correlations. Three-pion Bose–Einstein cumulant correlations are advantageous here in two ways. First, the construction of the three-pion cumulant explicitly removes all of the two-pion background correlations. Second, the genuine three-pion Bose–Einstein signal is twice as large as the two-pion signal, owing to the increased symmetrization possibilities.

The ALICE collaboration has measured three-pion Bose–Einstein correlations in proton–proton ($\sqrt{s}$ = 7 TeV), proton–lead ($\sqrt{s_{NN}}$ = 5.02 TeV), and lead–lead ($\sqrt{s_{NN}}$ = 2.76 TeV) collisions at the LHC. The correlation functions were constructed from three types of measured triplet momentum (p) distributions. The first distribution, $N_3(p_1,p_2,p_3)$, is measured by sampling all three pions from the same event. The second distribution, $N_2(p_1,p_2)\,N_1(p_3)$, is measured by taking two pions from the same event and the third from a different event. Finally, the third distribution, $N_1(p_1)\,N_1(p_2)\,N_1(p_3)$, is measured by taking all three pions from different events.

From the measured distributions, the full three-pion correlation function (C_3) can be formed and projected onto the relative ▷

From stars to hadrons

"Correlations between identical particles emitted simultaneously in hadron collisions can be used to determine the dimensions of the region where the [particles] are produced. The method is similar to that used by radio-astronomers to measure the angular dimensions of sources." So begins a paper by Giuseppe Cocconi at CERN, published in 1974. Twenty years earlier, Hanbury Brown and Twiss in the UK had developed a new type of interferometer that used correlations in the intensities of radio signals to measure the angular sizes of sources. They extended this later to visible light and stars. In particle physics, around the same time, Gerson Goldhaber and colleagues in the US found correlations in identical pions produced in proton–antiproton annihilations. Subsequent work showed that indeed there are similarities between the statistics in the detection of photons (bosons) and those of the detection of pions (also bosons) in hadron collisions. The energetic collision can be likened to a thermal light source, with correlated pion momenta offering a window on the size of the source.

Further reading

G Cocconi 1974 *Phys. Lett.* **49b** 459.
R Hanbury Brown and R Q Twiss 1956 *Nature* **177** 27.
G Goldhaber *et al.* 1960 *Phys. Rev.* **120** 300.

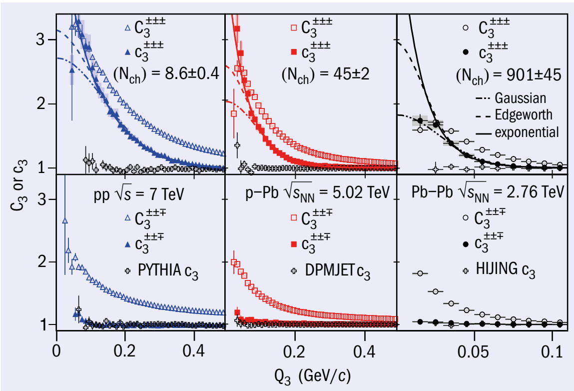


Fig. 1. Three-pion correlation functions versus $Q_3 = \sqrt{(q_{12}^2 + q_{31}^2 + q_{23}^2)}$ in three multiplicity intervals for proton–proton, proton–lead and lead–lead collision data compared, respectively, with PYTHIA, DPMJET and HIJING generator-level calculations. The top panels are for same-charge triplets, while the bottom panels are for mixed-charge triplets (see main text).

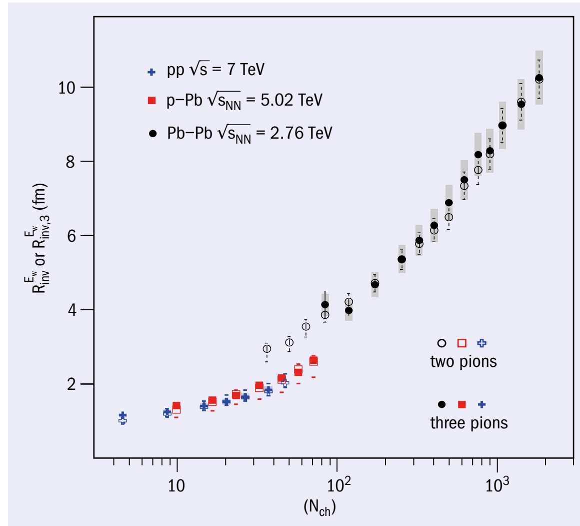


Fig. 2. Radii from Edgeworth fits for two- and three-pion cumulants versus charged-particle multiplicity, N_{ch}. The systematic uncertainties are dominated by fit-range variations, and are shown by bounding lines and shaded boxes for two- and three-pion parameters, respectively.

momentum variable $Q_3 = \sqrt{(q_{12}^2 + q_{31}^2 + q_{23}^2)}$, as shown in figure 1, where the invariant relative momentum of a pair is defined as $q_{ij} = \sqrt{(-(p_i - p_j)^\mu (p_i - p_j)_\mu)}$. The figure shows the cumulant correlation function (c_3), which subtracts the second distribution as described above, to remove two-pion correlations. The top panels are for same-charge triplets, while the bottom panels are for mixed-charge triplets.

Bose–Einstein correlations occur only for same-charge pions, while Coulomb and strong final-state interactions occur for both same- and mixed-charge combinations. The cumulant correlation functions are corrected for these final-state interactions as well as for the dilution from long-lived emitters (resonance decays and secondary contamination). For same-charge triplets, the three-pion cumulant Bose–Einstein correlation is clearly visible, while for mixed-charge triplets the same cumulant correlation function is consistent with unity, as expected when final-state interactions are removed. In addition, for each of the systems measured, the figure shows model calculations that do not take quantum and final-state interactions into account, demonstrating the power of the three-pion cumulants in removing backgrounds.

The extraction of the source radius at freeze-out is done by means of Gaussian, Edgeworth, as well as exponential fits to the same-charge three-pion cumulant correlations. The Edgeworth fit represents a Hermite polynomial expansion of a Gaussian function, and provides generally a good description of the correlation functions. Figure 2 shows the resulting radii from the Edgeworth fits, as a function of charged-particle multiplicity for each of the three collision systems. For comparison, the radius fit parameters from two-pion correlation functions are shown with hollow points.

The regions of overlapping multiplicity for the lead–lead, proton–lead and proton–proton results provide an interesting comparison of system sizes: the lead–lead radii are 35–55% larger than those in proton–lead at similar multiplicity. This observation points to the importance of the initial state as the number of participating nucleons, and the initial size in a lead–lead collision, is clearly different from that in proton–lead and proton–proton collisions. The proton–proton and proton–lead overlap zone suggests that the proton–lead system is only 5–15% larger than the proton–proton system at similar multiplicity.

These quantitative observations in the zones of overlapping multiplicity are well described with initial conditions alone, without the additional expansion from a phase of hydrodynamics. However, the measurements do not rule out the presence of hydrodynamics simultaneously in all three collision systems.

Further reading

ALICE Collaboration 2014 arXiv:1404.1194 [nucl-ex], *Phys. Lett. B* **739**. in press, doi:10.1016/j.physletb.2014.10.034.

Résumé

Collisions d'ions lourds : de l'importance de la taille

Des observations récentes, faites par les expériences du LHC lors d'événements proton–plomb et d'événements proton–proton de haute multiplicité, rappellent le comportement collectif, de type hydrodynamique, observé lors de collisions plomb–plomb. Cependant, les résultats ne sont pas probants. Une étude récente menée par l'expérience ALICE explique un tel comportement collectif par une meilleure compréhension de la taille de l'état final, lorsque les hadrons cessent d'interagir. Les mesures, qui examinent les corrélations entre les pions, reposent sur une technique inventée par Robert Hanbury Brown et Richard Twiss en 1956 pour mesurer les dimensions angulaires des étoiles.

Dhevan Raja Gangadharan and **Constantinos Loizides**, Lawrence Berkeley Laboratory.

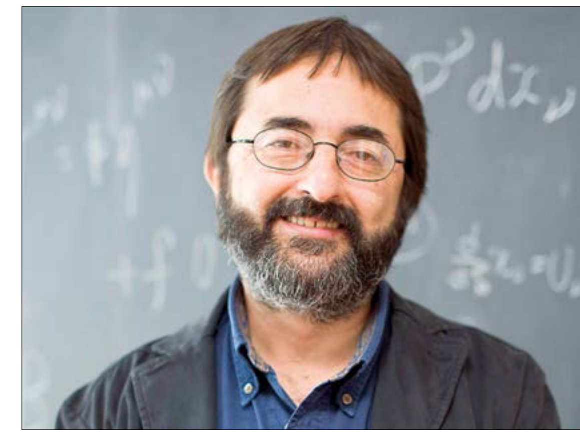
ICTP: theorists in the developing world

As ICTP reaches its first half-century, the current director talks about the contribution that theorists make to society.

Only 10 years younger than CERN, the Abdus Salam International Centre for Theoretical Physics, ICTP, celebrated its 50th anniversary at the beginning of October. The internationally renowned centre was founded by the Nobel laureate and Pakistani physicist, Abdus Salam, in 1964, to promote scientific expertise in developing countries. Today, the centre is recognized as a driving force that supports scientists in their home countries to stem the scientific brain drain from the developing world.

Fernando Quevedo, director of ICTP since 2009, came to CERN in September to take part in the colloquium "From physics to daily life", organized for the launch of two books of the same name, to which he is one of the contributors. His participation in such an initiative is not just a fortunate coincidence, but testimony of his willingness to explain the prominent role that theoretical and fundamental physics have in human development. "Theory is the driving force behind the creation of a culture of science, and this is of paramount importance to developing societies," he explains. "Abdus Salam founded the ICTP because he believed in this strong potential, which comes at a very low cost to the countries that cannot afford expensive experimental infrastructures."

Unfortunately, theorists are not usually credited properly for their contributions to the development of society. "The reason is that a lot of time separates the theoretical advancement from the practical application," says Quevedo. "People and policy makers at some point stop seeing the link, and do not see the primary origin of it anymore." However, although these links are often lost in the complicated ripples of history, it is often the case that when people are asked to recall names of famous scientists, most likely they are theorists. Examples include Albert Einstein, Richard Feynmann, James Clerk Maxwell and, of course, Stephen Hawking. More importantly, theories such as quantum mechanics or relativity have changed not just the way that scientists understand the universe but also, years later, everyday life, with applications that range from lasers and global-positioning systems to quantum computation. For Quevedo, "The example I like best is Dirac's story. He was a purist. He wanted to see the beauty in the mathematical equations.



Fernando Quevedo – addressing big questions. (Image credit: ICTP Photo Archives.)

He predicted the existence of antimatter because it came out of his equations. Today, we use positrons – the first antimatter particle predicted by Dirac – in PET scanners, but people never go back to remember his contribution."

Theorists often have an impact that is difficult to predict, even by their fellow colleagues. "When I was a student in Texas," recalls Quevedo, "we were studying supersymmetry and string theory for high-energy physics, and we saw that some colleagues were working on even more theoretical subjects. At that time, we thought that they were not on the right track because they were trying to develop a new interpretation of quantum mechanics. Two decades later, some of those people had become the leaders of quantum-information theory and had given birth to quantum computing. Today, this field is booming!" Perhaps surprisingly, there is also an extremely practical "application" of string theory: the arXiv project. This online repository of electronic preprints of scientific papers was invented by string theorist Paul Ginsparg. Perhaps this will be the only practical application of string theory.

Theory is the driving force behind the creation of a culture of science.

While Quevedo considers it important to credit the role of the theorists in the development of society and in creating the ▷

ICTP's 50th anniversary

In June 1960, the Department of Physics at the University of Trieste organized a seminar on elementary particle physics in the Castelletto in Miramare Park. The notion of creating an institute of theoretical physics open to scientists from around the world was discussed at that meeting. That proposal became a reality in Trieste in 1964. Pakistani-born physicist Abdus Salam, who spearheaded the drive for the creation of ICTP by working through the International Atomic Energy Agency, became the centre's director, and Paolo Budinich, who worked tirelessly to bring the centre to Trieste, became ICTP's deputy director.

From 6 to 9 October this year, ICTP celebrated its 50 years of success in international scientific co-operation, and the promotion of scientific excellence in the developing world. More than 250 distinguished scientists, ministers and others attended the anniversary celebration. In parallel, the programme included exhibitions, lectures and special initiatives for schools and the general public.

- For the whole programme of events with photos and videos, visit www.ictp.it/ictp-50th-anniversary.aspx.

culture of science, at the same time, he recognizes an equivalent need for the theorists to open their research horizon and accept the challenge of the present time to tackle more applied topics. "Theorists are very versatile scientists," he says. "They are trained to be problem solvers, and their skills can be applied to a variety of fields, not just physics." This year, ICTP is launching a new Master's course in high-performance computing, which will use a new cluster of computers. In line with Quevedo's thinking, during the first year, the students will be trained in general matters related to computing techniques. Then, during the second year, they will have the opportunity to specialize not only in physics but also in other subjects, including climate change, astrophysics, renewable energy and mathematical modelling.

All of these arguments should not be seen as justifications for the need to support theoretical physics. Rather, wondering about the universe and its functioning should be a recognized right for anyone. "I come from Guatemala and have the same rights as Americans and Europeans to address the big questions," confirms Quevedo. "If you are from a poor country, why should you be limited to do agriculture, health, etc? As human beings, we have the right to dream about becoming scientists and understanding the world around us. We have the right to be curious. After all, politicians decide where to put the money, but the person who is spending his/her life on scientific projects is the scientist."

ICTP has the specific mandate to focus on supporting scientists from developing countries. Across its long history, the institute has proudly welcomed visitors from 188 countries – that is, almost the entire planet. While CERN's activities are concentrated mainly in developed countries, the activity map of ICTP spreads across all continents more uniformly, including Africa and the whole of Latin America. "Some countries do not have the right level of development for science to get involved in CERN yet. ICTP can play the role of being an intermediate point to attract the participation of scientists from the least developed countries to then get involved with CERN's projects," Quevedo comments.

Quevedo's relationship with CERN goes beyond his role as ICTP's director. CERN was his first employer when he was a young postdoc, coming from the University of Texas. He still comes to CERN every year, and thinks of it not only as a model but, more importantly, as a "home away from home" for any scientist. Like two friends, CERN and ICTP have a variety of projects that they are developing together. "CERN's director-general, Rolf Heuer, and myself recently signed a new memorandum of understanding," he explains. "ICTP scientists collaborate directly in the ATLAS computing working groups. With CERN we are also involved in the EPLANET project (*CERN Courier* June 2014 p58), and in the organization of the African School of Physics (*CERN Courier* November 2014 p37). More recently, we are developing new collaborations in teacher training and the field of medical physics."

Does Quevedo have a dream about the future of CERN? "Yes, I would like to see more Africans, Asians and Latin Americans here," he says. "Imagine a more coloured cafeteria, with people really coming from all corners of the planet. This could be the CERN of the future."

Further reading

For more on the colloquium "From physics to daily life", including Fernando Quevedo's talk on "Theory for development", visit http://indico.cern.ch/event/331449/.

Résumé

Le CIPT : des théoriciens dans les pays en développement

À peine 10 ans plus jeune que le CERN, le Centre international de physique théorique Abdus Salam (CIPT) a célébré son 50^{e} anniversaire au début du mois d'octobre. Aujourd'hui, le centre est reconnu comme la force vive qui soutient les scientifiques de la région pour lutter contre l'exode des cerveaux des pays en développement. Au cours de cet entretien, le directeur actuel parle des contributions des théoriciens à la société et explique pourquoi il faut les soutenir : « La théorie est à l'origine de toute culture scientifique, qui est cruciale pour les sociétés en développement. »

Antonella Del Rosso, CERN.

Cosmic particles meet the LHC at ISVHECRI

More than 120 physicists from across the world met at CERN to discuss questions related to hadron production in cosmic-ray interactions and at accelerator experiments.

ISVHECRI 2014 attracted more than 120 physicists from around the world. (Image credit: Michael Hoch/CMS.)

In August this year, CERN hosted the International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI), the 18th meeting in the series that started in 1980 in Nakhodka, Russia, and is supported by the International Union for Pure and Applied Physics. In the early years, the symposia focused mainly on studying hadronic interactions of cosmic rays in the atmosphere and in emulsion chambers, which were the main cosmic-ray detectors at the time. The scope of the series has since widened, and it has become a frontier for scientists from both the cosmic-ray and high-energy physics communities to discuss hadronic interactions as a common research subject of the two fields.

At this year's symposium, which was organized jointly by high-energy and cosmic-ray physicists – Albert de Roeck, Michelangelo Mangano and Bryan Pattison, of CERN, and David Berge of NIKHEF – the participants focused on the latest data on hadron production from CERN's LHC, and the implications for interpreting cosmic-ray measurements. The LHC is the first collider to provide data at an equivalent proton–nucleon energy that exceeds that of the so-called "knee" – the observed change in cosmic-ray flux at 3×10^{15} eV, which is still to be explained. A series of review talks provided a comprehensive, cross-experiment overview of the latest LHC data, ranging from dedicated measurements of hadron production in the forward direction to a multitude of minimum-bias measurements in proton–proton and heavy-ion collisions. In addition, presentations showed how the forward measurements made at the HERA electron–proton collider at DESY have proved to be very useful for cosmic-ray studies. These reviews were complemented by an evening lecture on Higgs physics by John Ellis of Kings College London.

Tanguy Pierog of Karlsruhe Institute of Technology (KIT) and CERN's Peter Skands reviewed the different approaches chosen for developing hadronic-interaction models for applications in cosmic-ray and high-energy physics. Even though the predictions of such models that were developed for cosmic-ray interactions turned out to cover the first LHC data rather well, some retuning was necessary, both to improve the description of the measurements at the LHC and to obtain more reliable high-energy extrapolations. The predictions of the models show an increasing convergence after such tuning, and lead to a more consistent description of air-shower data.

However, even the latest generation of interaction models does not solve the discrepancies found for the production of muons in extensive air showers at very high energy. A discrepancy in the number of muons at giga-electron-volt energies is seen, for example, in the data from the Pierre Auger Observatory on inclined showers whose electromagnetic component is absorbed in the atmosphere before reaching the detectors at the Earth's surface (figure 1, p40). Furthermore, data from the KASCADE-Grande experiment presented by Juan Carlos Arteaga of Universidad Michoacana, Morelia, indicate a much weaker attenuation of the muonic-shower component than expected from simulations. KIT's Ralf Ulrich pointed out that, in contrast to the electromagnetic-shower profile, which depends on neutral-pion production in high-energy interactions only, both high- and low-energy interactions are important for understanding the production of muons in air showers. Therefore, measurements from fixed-target experiments such as NA61/SHINE at CERN and the Main Injector Particle Production experiment at Fermilab, which Boris Popov of JINR reviewed, are also important for obtaining a better understanding of muon production in air showers. Alternative scenarios for enhancing this muon production, involving extensions of the Standard Model, were discussed by Glennys Farrar of New York University.

Many talks at the symposium illustrated the importance of multimessenger observations in astroparticle physics, for under- ▷

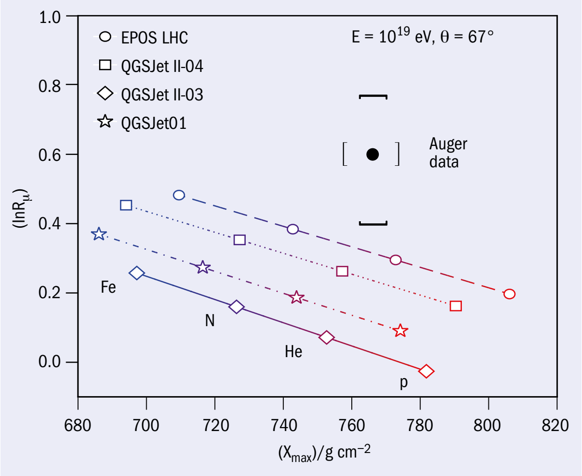


Fig. 1. The mean depth of shower maximum, X_{max}, and the relative average logarithmic muon content $lnR_μ$ in air showers (R being the muon number relative to 1.45×10^7), as measured at the Pierre Auger Observatory, compared with predictions calculated with different hadronic-interaction models. (Image credit: Aab et al. *2014.)*

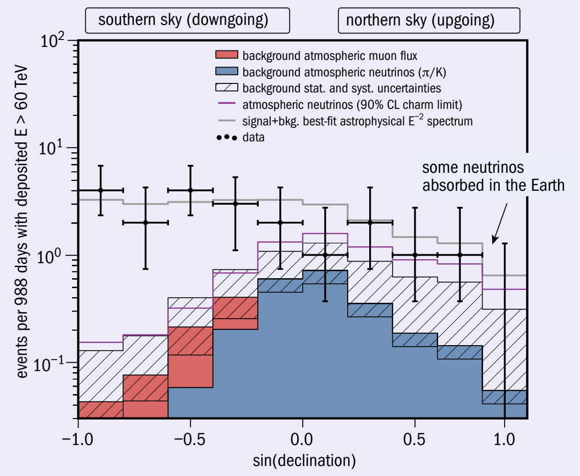


Fig. 2. Zenith-angle distribution of high-energy neutrinos detected by IceCube. The northern sky (upgoing neutrinos) is dominated by atmospheric neutrinos, the prediction of which matches the observations well. The astrophysical signal is seen mainly in neutrinos from the southern sky (downgoing). (Image credit: Aartson et al. *2014.)*

standing not only the sources and the mass composition of cosmic rays but also a plethora of astrophysical phenomena. Examples are the review by Eli Waxman of the Weizmann Institute on different cosmic-particle accelerators and discussion of the propagation of ultra-high-energy cosmic rays by Andrew Taylor of the Dublin Institute for Advances Studies.

One highlight of the meeting was the discussion of high-energy neutrinos from astrophysical sources recently detected by IceCube (figure 2 and p30). Kota Murase of the Institute for Advanced Study, Princeton, reviewed different theoretical scenarios for the production of neutrinos in the tera- to peta-electron-volt energy range (10^{12} – 10^{15} eV). Tom Gaisser of the University of Delaware summarized the knowledge on neutrinos produced in interactions of cosmic rays in the atmosphere, which constitute the dominant background of non-astrophysical origin in the IceCube data. At peta-electron-volt and higher neutrino energies, the atmospheric lepton flux is dominated by the decay of charm particles, and LHC measurements on the production of heavy flavours are the only experimental data that reach the equivalent relevant energies. Given the limited acceptance in the forward direction at the LHC, QCD calculations and models are still of central importance for understanding high-energy neutrino production, as Victor Gonzalez of Universidade Federal de Pelotas and others discussed. Similarly, as Ina Sarcevic of the University of Arizona pointed out, calculating the interaction cross-section of neutrinos of energies up to 10^{19} eV is a challenge in perturbative QCD because of the need for parton densities at very low x. Anna Stasto of Penn State presented different theoretical approaches to understand low-x QCD phenomena, concluding that there is no multipurpose framework of general applicability.

The remaining uncertainties in predicting hadron production in high-energy interactions were one of the central questions discussed at the meeting, and highlighted by Paolo Lipari of INFN/Roma in his concluding remarks. There was general agreement that, in addition to ongoing theoretical and experimental efforts, the measurement of particle production in LHC collisions of protons with light nuclei, for example oxygen, would be the next step needed to reduce the uncertainties further.

Further reading

For more information about ISVHECRI 2014, visit https://indico.cern.ch/event/287474/.

A Aab *et al.* Pierre Auger Collaboration 2014 arXiv:1408.1421 [astro-ph.HE], submitted to *Phys. Rev. D.*

M G Aartson *et al.* IceCube Collaboration 2014 *Phys. Rev. Lett.* **113** 101101.

Résumé

ISVEHCRI : des particules cosmiques rencontrent le LHC

Le dix-huitième Symposium international sur les interactions des rayons cosmiques à très hautes énergies (ISVHECRI) a eu lieu au CERN au mois d'août. Des physiciens du monde entier s'y sont réunis pour discuter de questions relatives aux hadrons produits par les interactions des rayons cosmiques et par les expériences de l'accélérateur. Les participants se sont intéressés particulièrement aux nouveaux résultats concernant les hadrons produits au LHC du CERN et leurs répercussions sur l'interprétation des mesures des rayons cosmiques. Des exposés de synthèse ont examiné en détail les données du LHC les plus récentes, les modèles d'interaction hadronique et les connaissances actuelles sur les rayons cosmiques d'ultra-haute énergie.

Ralph Engel, Karlsruhe Institute of Technology.

Faces & Places

FACILITIES

ESS lays new foundations for science

Several hundred members of the European scientific community gathered at the construction site of the European Spallation Source (ESS) in Lund, for the Foundation Stone Ceremony on 9 October. The event was held to lay the foundation not only of the new facility, but also for a new generation of science in Europe.

The ESS is a consortium of European nations co-operating in the design and construction of one of Europe's largest active infrastructure projects, which has evolved to meet the scientific demand for facilities that are beyond the capability of individual nations or institutions in scope and complexity (*CERN Courier* June 2014 p27). Following two decades of increasingly sophisticated technical design work, scientists, engineers, project managers and builders have now embarked on the construction of the most powerful neutron source in the world. The facility will provide the tools to enable discoveries in nanotechnology, life sciences, pharmaceuticals, materials engineering and experimental physics. Both the research to come and the establishment of the facility itself will serve as an economic driver for all of Europe.

The foundation-stone event follows the ESS ground-breaking held in early September, when the host countries, Sweden and Denmark, recognized their successful establishment of the pan-European political and economic partnership for ESS. First neutrons are expected by 2019 and the first experiments are scheduled to begin in 2023.

Top: Representatives of the countries involved in the ESS at the Foundation Stone Ceremony. The stone itself was in the form of a puzzle, with different representatives laying the pieces, from the first, bottom left, to the last, bottom right. (Image credits: ESS.)

EXHIBITION

Italian industry and culture come to CERN

Maurizio Serra, centre, with CERN's director-general, Rolf Heuer, right. (Image credit: CERN-PHOTO-201410-201 – 34.)

At the fifth Italy at CERN, held on 8–10 October, 30 Italian companies presented their products and services. The exhibitors came from a range of technical fields, including superconducting technologies and engineering components. Maurizio Serra, Italian ambassador to the United Nations Office and other international organizations in Geneva, visited the stands after inaugurating the exhibition together with CERN's director-general, Rolf Heuer.

Accompanying the industrial stands was an exhibition of a different kind, with paintings by Alberto Di Fabio. In addition, each evening featured Italian musicians in CERN's main auditorium, with performances by the Associazione Musicale Progetto Bel Canto and Duo Poem.

CERN60

UN and CERN celebrate 60 years of science for peace and development

At the UN headquarters in New York, the special event to celebrate 60 years of science for peace and development included speakers Carlo Rubbia, left, Kofi Annan, centre, and Hitoshi Murayama. (Image credits: UN Photo/Evan Schneider.)

At a special event at the United Nations headquarters in New York on 20 October, CERN and the United Nations Economic and Social Council (ECOSOC) celebrated science for peace and development, a culmination of events to mark CERN's 60th anniversary. Under the chairmanship of the ECOSOC president, Martin Sajdik, the event included a series of speeches from eminent scientists and world leaders, who underlined the role that science has played in peaceful collaboration, innovation and development.

Following Sajdik's opening speech, introductions were given by the president of the 69th UN General Assembly, Sam Kutesa, and UN secretary-general, Ban Ki-moon. Addresses by the permanent representatives for Switzerland, Paul Seger, and France, François Delattre, preceded a speech by CERN's director-general, Rolf Heuer, who stressed the importance of effective dialogue between science and international affairs.

The keynote speeches began with Carlo Rubbia, Nobel laureate in physics and former director-general of CERN, followed by Kofi Annan, Nobel-peace-prize laureate and former UN secretary-general. Both spoke about the role that science has played in the past decades to bring people together. Hitoshi Murayama, director of the Kavli Institute for the Physics and Mathematics of the Universe, University of Tokyo, and Naledi Pandor, minister for science and technology of the Republic of South Africa, then spoke on what science can do to contribute to pressing global issues.

Invited representatives of the world of politics, diplomacy and science took part in an interactive discussion, introduced by CERN's Fabiola Gianotti, who is a member of the Scientific Advisory Board to the UN secretary-general. Concluding remarks came from Sebastiano Cardi, chair of the Second Committee of the UN General Assembly, and a video message from Irina Bokova, director-general of UNESCO, as well as from Heuer and Sajdik.

The UN is supportive of science and its role in society, and this event follows on from when CERN was granted observer status to the UN General Assembly in 2012 (*CERN Courier* January/February 2013 p5).

● For a recording of the webcast, visit http://webtv.un.org/watch/cern-sixty-years-of-science-for-peace-and-development/3849462291001.

AWARDS

French Physical Society honours Guillaume Unal

Guillaume Unal, of CERN, has been awarded the Jean Ricard Prize by the French Physical Society (SFP). He was presented with the award by Alain Fontaine, president of the SFP, in a ceremony at the Musée du quai Branly in Paris on 21 October, after a presentation by Livio Mapelli, head of CERN's physics department. Unal has worked on the CDF experiment at Fermilab and on UA2, NA48 and ATLAS at CERN, where he was a key contributor to the understanding of the liquid-argon electromagnetic calorimeter, and the discovery of the Brout–Englert–Higgs boson in the $\gamma\gamma$ channel.

The Jean Ricard Prize is the SFP's most prestigious award, and has been awarded to an experimental high-energy physicist only a few times since its creation in 1970. The former recipients in experimental high-energy physics are Georges Charpak, Paul Musset, Marcel Banner, Yves Declais, Alain Blondel and Daniel Fournier.

Left to right: Livio Mapelli, Guillaume Unal and Alain Fontaine. (Image credit: Louis Fayard.)

ITEP presents the 2014 Pomeranchuk Prize

Alexander Zamolodchikov of Rutgers University and Leonid Keldysh of the P N Lebedev Physical Institute, Moscow, received the 2014 Pomeranchuk Prize in a ceremony at the Institute for Theoretical and Experimental Physics (ITEP) on 18 September. The prize – established by ITEP in 1998 in memory of Isaak Pomeranchuk – is awarded annually to one foreign and one Russian theoretician, for outstanding achievements in the field.

Zamolodchikov was honoured for outstanding results in mathematical physics, including exact S-matrices in the theory of integrable systems, the construction of two-dimensional conformal field theories, and exact results in renormalization group dynamics. His work has found many applications in the theory of elementary particles, condensed matter and string models. Keldysh received the award for outstanding results in solid-state physics, including the theory of tunnelling phenomena in semiconductors, a diagram technique for non-equilibrium quantum systems, and the prediction of exciton condensation. They are used in many areas, for example quantum field theory and quantum cosmology.

Leonid Keldysh, left, and Alexander Zamolodchikov, recipients of the 2014 Pomeranchuk Prize. (Image credit: E Demidova/ITEP.)

On 25 June, Evangelos Gazis of the National Technical University of Athens (NTUA) was honoured by the French Ministry of National Education with the insignia of Officer of the Order of Academic Palms for his work at CERN's LHC, bringing together Greek and French communities in the field of physics. Presented to distinguished academics and figures in the world of culture and education, the decoration was originally founded by Napoleon I to honour eminent members of the University of Paris. The ceremony was held at the Institut Français de Grèce, where the insignia was presented by Olivier Descotes, director of the institute, who also cited the work of Gazios in the development in Greece of medical applications of particle physics, such as proton therapy. (Image credit: Institut Français de Grèce.)

ANNIVERSARY

The John Adams Institute: 10 years strong

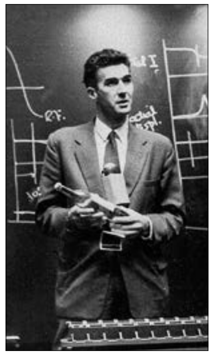
John Adams, the great pioneer of CERN's accelerator complex, received his education at evening classes, and mastered his skills not at university but via practical work, first in research at Siemens and then in a UK government radar laboratory. Now, times are better, and graduate students receive education in accelerator science at university, but the necessity of practical research and hands-on experience remains the universal formula for training the next generation of scientists. This formula is the underlying principle of the UK's John Adams Institute for Accelerator Science (JAI).

Established in 2004, initially as a joint venture between the University of Oxford and Royal Holloway, University of London, the JAI has become an internationally recognized centre for accelerator science. It has earned an international reputation for training the next generation of accelerator scientists, a significant number graduating each year with world-class PhDs to take up posts in industry and at national laboratories.

JAI academics, researchers and students have together developed a strong research programme at the forefront of accelerator science. Spanning national and international facilities and projects, the programme aims at developing novel accelerators for fundamental science simultaneously with systems for medical, biological and industrial applications. Since its foundation, the JAI has developed – and continues to enhance – its connections with industry and its outreach programme. The institute works closely with industrial companies to bring scientific ideas closer to practical applications. Its inspiring and innovative outreach is increasing the desire of younger generations to aspire to technical and scientific careers.

This year, the JAI celebrates its 10th anniversary. At its inauguration ceremony on 25 October 2004, Brian Foster announced that the joint Royal Holloway and Oxford accelerator centre had been renamed the John Adams Institute for Accelerator Science. The JAI and its twin, the Cockcroft Institute of Accelerator Science and Technology, have boosted accelerator research in the UK significantly, regaining international leadership in this vital scientific area, and they have contributed strongly to world-class research and training, of which Adams would be proud.

● The JAI is a joint venture between the University of Oxford, Royal Holloway, University of London, and (since 2011) Imperial College London. For more information, see www.adams-institute.ac.uk/.



John Adams, leader of the Proton Synchrotron construction team at CERN, when he announced the successful acceleration of protons to 24 GeV on 24 November 1959. (Image credit: CERN-HI -5901881-1.)

Visits

Tom Kibble visited LHC experiments for the first time on 10 and 11 October, on his way from Trieste, where he had participated in the 50th anniversary celebrations of the Abdus Salam International Centre for Theoretical Physics (p38). After visiting the ATLAS detector, he delivered a colloquium on the genesis of electroweak unification and the Brout–Englert–Higgs mechanism. The following day, he went underground to see CMS, seen here, before returning to the UK. (Image credit: CMS-PHO-PUBLIC-2014-009 – 8.)

The president of Bulgaria, **Rosen Plevneliev**, seated, visited CERN on 14 October. He signed the CMS guestbook during his underground visit to the CMS experimental cavern, accompanied by spokesperson **Tiziano Camporesi**, before visiting the LHC tunnel and meeting with Bulgarians at CERN (Image credit: CERN-PHOTO-201410-205 – 34.)

Meeting

An international workshop on the **Science and Technology of the Free-Electron Laser** is being held at the School of Physics, Devi Ahilya University, Indore, on 4–6 December. The theme of the workshop is undulator technology and free-electron laser science. The national and international free-electron-laser facilities will be discussed, with focus on the design issues of laser-plasma accelerators for free-electron lasers. The event is being held as part of the celebrations of the university's 50th anniversary. For further information, see http://sbfel3.ucsb.edu/www/Indore_FEL_workshop_2014_a.pdf.

Correction

Which was the first cross-border accelerator? The October issue of *CERN Courier* (pp19 and 24) asserted that it was the Super Proton Synchrotron, which started up in 1976 in its 7 km tunnel that straddles the Franco-Swiss border. However, the Proton Synchrotron (PS) Booster, which accelerated its first protons on 26 May 1972, correctly lays claim to this accolade. On the Meyrin site, Route Rutherford follows the border, straight across the middle of the circular Booster. Its four rings currently take protons at 50 MeV from Linac 1 and accelerate them to 800 MeV for injection to the PS (*CERN Courier* September 2012 p33).

New products

Keithley Instruments has announced the Model 2460 SourceMeter, the company's latest benchtop Source Measure Unit (SMU) instrument with a capacitive touchscreen graphical user interface. Model 2460 offers users higher power sourcing (up to 105 V, 7 A DC/7 A pulse, 100 W max.) with 0.012% basic measurement accuracy and 6½-digit resolution, making it useful for high-power, high-precision I–V characterization of modern materials and high-power devices. For more details, tel +49 89 84 93 0740, e-mail info@keithley.de or visit www.keithley.com.

Murata has announced the addition of the OKD series of non-isolated point-of-load (PoL) DC/DC converters from Murata Power Solutions. Available in three different package formats – through-hole, single-in-line, and surface mount – the OKDx-T/40 is a 40 A, 132 W digital DC/DC converter. These highly efficient (typically 97.2%), fully regulated converters offer a high power density and measure just 30.85 × 20.0 × 8.2 mm. For more information, tel +44 1252 811666, e-mail atonooka@murata.co.uk or visit www.murata.eu.

Model 307 from **Resolve Optics Ltd** is a high-performance, 40 mm focal length, infrared (IR) lens designed specifically for thermal-imaging applications in the 8–14 μm waveband. Manufactured from germanium, Model 307 lenses come with antireflective coatings that ensure high performance throughout the IR waveband, and operate over 0–40 °C without refocusing. For more details, tel +44 1494 777100, e-mail sales@resolveoptics.com or visit www.resolveoptics.com/.

VadaTech has announced a 2U Hybrid Chassis that provides MicroTCA.4-compliant slots along with MicroTCA.0 standard slots. The VT812 2U Chassis Platforms feature four mid-size MTCA.0 and four mid-size MTCA.4 slots, including corresponding MicroRTMs (Rear Transition Modules for MicroTCA). The MicroTCA.4 architecture is designed primarily for high-energy physics applications, but is an excellent fit for many other applications. The chassis offers dual MicroTCA Carrier Hubs (MCHs), dual redundant power supplies, a JTAG Switch Module (JSM) and a Telco Alarm. For more information, visit www.VadaTech.com.

Wind River has introduced its latest version of Wind River Linux, which users can now access as binary code, in addition to source-code format. The new version is also updated with the current Linux kernel, toolchain, and user space based on the upcoming Yocto Project release. Developed from the Yocto Project open-source development infrastructure, Wind River Linux uses the latest Linux kernel as its upstream source to ensure access to the latest from the open-source community. For more details, tel +33 164 866 664, e-mail isabelle.denis@windriver.com or visit http://tinyurl.com/wrlinux7.

Obituaries

Walter Thirring 1927–2014

Walter Thirring, one of the most important theoreticians in Austria since 1945, passed away on 19 August, after a long battle with illness.

Walter's grandfather as well as his father, Hans, were physicists too – the latter is well known for his important contributions to general relativity. The family suffered a great deal during the Second World War: Walter's father was dismissed by the Nazis and his brother lost his life. Walter was saved because he was wounded during an exercise in the German army. In line with family tradition, he then succeeded with a picture-perfect career in mathematical physics, after earning his PhD from the University of Vienna in 1949 with distinction, his thesis dealing with aspects of the Dirac equation.

After completion of his thesis, Walter left to visit Erwin Schrödinger in Dublin, Werner Heisenberg in Göttingen, Wolfgang Pauli in Zürich, Albert Einstein in Princeton, and others. In 1954, he returned to Europe as a lecturer at the University of Bern, and also held visiting positions in the US. During this time, he established himself as a pioneer in the newly emerging quantum field theory, and wrote an important paper on renormalization and a paper with Stanley Deser, Marvin Goldberger and Murray Gell-Mann on dispersion relations in particle physics. He also formulated a model for strong interactions based on SU(3), which influenced the work of Gell-Mann that led to the quark model. After a fruitful decade on the road, he finally settled in 1959 as professor at the Institute of Theoretical Physics of the University of Vienna, where he stayed until his retirement in 1995.

Scientifically, Walter was probably best

Walter Thirring. (Image credit: Austrian Central Library for Physics.)

known for what is now called the Thirring model, which is an exactly solvable model in two dimensions with quartic fermionic interactions. Another milestone was the proof of the stability of matter, with Elliott Lieb. He was also widely known for his excellent textbooks in theoretical physics, mainly on quantum electrodynamics and quantum field theory. His particular concern was to put his lectures on a solid mathematical foundation, which led to the four-volume work on mathematical physics. His scientific legacy also comprises famous students and collaborators, such as Julius Wess.

During his travelling years, Walter learned to appreciate the international character of modern science and became aware of its all-importance. When he returned to his home country, his insight and interest in these matters were crucial in re-establishing Austria in the scientific landscape. In particular, he was instrumental in facilitating Austria's membership of CERN in 1959, which paved the way for research on a truly international basis. His special ties with CERN culminated in membership of the directorate of CERN as head of the Theory Division, from 1968 to 1971. As a member of the directorate, Walter participated in the decision to build the Super Proton Synchrotron on the CERN site – a decision that proved to be crucial for the future of CERN and of particle physics.

Walter always stressed that international collaboration and combined effort is of utmost importance for smaller countries such as Austria, which by themselves could not afford large-scale science such as particle physics. In line with this, he spent much effort in fostering European collaboration, especially in view of the dominant US and Russian activities in science. One of his most visible achievements is the Erwin-Schrödinger-Institut für Mathematische Physik in Vienna, which has become a renowned international centre of research in mathematical physics. Given its location, it became an important meeting point for scientists from both Eastern and Western Europe. Moreover, the Walter Thirring Institute for Mathematical Physics, Astrophysics and Nuclear Investigations, in the Ukraine, founded in 1996, as well as the collaboration with the Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, serve an important role in the peaceful interaction between scientists of the East and West.

Walter's death is a great loss for science and international collaboration, and we will keep his memory alive at CERN.

● *Harald Grosse, Wolfgang Lerche and André Martin, on behalf of Walter's friends at CERN and in Vienna.*

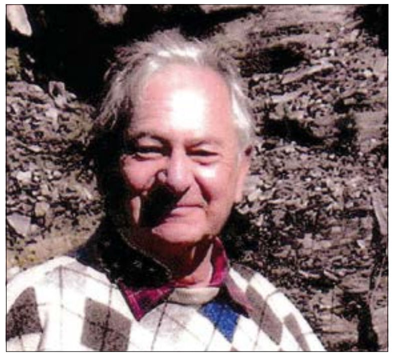
Bruno Righini 1931–2014

Bruno Righini, who for 32 years was responsible for the Electronic Test and Maintenance Group of the Experimental Physics (EP) Division at CERN, passed away recently after a sudden and cruel illness.

A physicist at the University of Bologna who had written textbooks on general and transient electronics, Bruno arrived at CERN in 1964. He oriented the still small group towards experimental physics, which at the time was moving from photographic bubble-chamber detectors to counters and electronic recording. This development gave an extraordinary impulse to the creation of new sections for digital electronics and data acquisition, both being fields where Bruno's competence was outstanding. Sections in charge of instruments, of their design and of the study of the corresponding specifications and standards were duly extended. In short, the group became responsible for the evaluation, selection and procurement of the electronic equipment used in the experiments and stored in a central pool.

Bruno solved the delicate function of selection by establishing an objective system of tests that were transparent and open to all. The suppliers, if they wished, could participate in tests at CERN, therefore removing any possible doubt about receiving fair treatment. This, and other solutions, were widely appreciated by the experimental physicists, and contributed to making the group close-knit and united in its purpose, as well as to giving proper credit to the people concerned.

Bruno always kept in close contact with the physics teams and understood their needs well. He dealt with people in a simple, unassuming and intelligent way, which gave everybody the feeling of being treated with due consideration. For many of us, he was not only a colleague but also a dear friend, to the extent that we could debate at length, without different opinions ever becoming a point of importance. He was open minded and liked to listen, in



Bruno Righini. (Image credit: Mrs B Rhigini.)

search of a clear definition of a problem or a better solution. His keen sense of justice made discussions interesting, purposeful and constructive. The group and the Electronics Pool became gradually an essential and indispensable feature of the EP Division, and were recognized as such by the internal staff as well as by external visiting teams.

We all feel the sadness of his premature passing away, and wish to express our sympathy and deepest condolences to his family in these difficult circumstances. We will always remember Bruno, his natural wisdom, his quiet wit and his deep understanding of our human society at CERN.

● *His colleagues and friends.*

Alan Astbury 1934–2014

Alan Astbury, a distinguished experimental particle physicist and emeritus professor at the University of Victoria, passed away on 21 July in Victoria, after a brief illness. He was renowned for his leading role in the discovery of the W and Z bosons at CERN in 1983, for his tenure as director of TRIUMF (1994–2001), and for his lasting contributions to particle physics in Canada.

Born in Crewe, England, Alan obtained his BSc and PhD at the University of Liverpool. Following postdoctoral research at the Lawrence Radiation Laboratory, Berkeley, he returned to the UK to the Rutherford Laboratory in 1964, where he remained for 19 years. There, with others, he rapidly devised an experiment at the laboratory's 7 GeV proton synchrotron, Nimrod, which verified the 1964 discovery of CP violation in neutral kaon decays. He went on to conduct further experiments, both at Nimrod and at CERN's 25 GeV Proton Synchrotron, where in the years 1970–1973 he led a UK collaboration in a programme using an antiproton beam. These experiments found new states in hadron spectroscopy – work that contributed to the experimental foundations of the quark model. He chaired CERN's Electronic Experiments (1975–1976) and Proton Synchrotron (1976–1978) committees, and also served as *ex-officio* member of the Scientific Policy Committee.

In 1977, Alan joined Carlo Rubbia in an ambitious project at CERN's Super Proton Synchrotron that aimed at colliding counter-rotating proton and antiproton beams at the highest energies ever achieved to produce the W and Z bosons of the weak force. A year later, Rubbia invited

Alan Astbury. (Image credit: TRIUMF.)

Alan to become co-spokesperson for the UA1 experiment, and in 1983 both the UA1 and UA2 experiments announced the discoveries of the W and Z bosons – an achievement that led to the awarding of the Nobel Prize in Physics to Rubbia and Simon van der Meer in 1984.

From 1976 to 1983, Alan served on the Experiments Evaluation Committee for the TRIUMF laboratory, where the University of Victoria (UVic) played a large role as a founding member, through the work of Michael Pearce and other faculty members. Apparently, something caught Alan's attention about Victoria, and in the summer of 1983 he took up the university's inaugural R M Pearce Chair of Physics.

Once at UVic, Alan started a world-class programme in particle physics, with initial efforts spent on the UA1 experiment. He became a member of the Stanford Linear Accelerator Centre Scientific Policy Committee, and a year later, in 1985, UVic became a member of the SLAC Large Detector collaboration. Alan's expertise quickly benefited the Canadian subatomic community and its long-term planning.

In 1990, it became clear that the Large Electron–Positron collider (LEP) in CERN was rapidly reaching its design specifications, and Alan brought his research group at UVic into OPAL, one of the four large experiments. He was director of the Institute of Particle Physics of Canada from 1991 to 1995, and his support was critical in establishing the ATLAS Canada collaboration in 1992. He attracted a number of outstanding young Canadian particle physicists to UVic, and several graduate students from his group were awarded Canada Research Chairs, while many others went on to faculty positions in Canada and abroad.

In 1988, the consortium of universities that created and ran TRIUMF proposed that the accelerator complex be expanded to produce very high intensity and much higher energy beams that could be used for many experiments, including neutrino physics. Alan was made the leader of what was called the Project Definition Study for the TRIUMF Kaon Factory, producing a report in 1990. The Canadian government rejected the project – although a similar project was built eventually in Japan – and for a while it looked as though TRIUMF was coming to an end.

Alan took over as director of TRIUMF in 1994, and created a new vision for the laboratory and a new accelerator project to create rare nuclei – the Isotope Separator and ACcelerator (ISAC). By the time that he retired as director in 2001, TRIUMF had an international reputation as a world leader in nuclear astrophysics and nuclear-structure physics. At the same time, Alan and TRIUMF played crucial advisory roles on the early design of the ATLAS experiment. As TRIUMF's director, he oversaw and facilitated important Canadian contributions to both the LHC and the ATLAS detector. Canada's proud role in the recent discovery of the Higgs boson owes much to his remarkable foresight.

On the international front, Alan was appointed to the Physics Research Committee (1987–1993) that advised the directors of DESY. Along the way, he was recognized for his accomplishments with the 1986 Rutherford Medal from the UK's Institute of Physics, was made a fellow of the Royal Society of Canada in 1988, and elected fellow of The Royal Society of London in 1993.

He was awarded many honours after he stepped down as director of TRIUMF in 2001. These included the British Columbia Science Council Career Achievement Award, the Canadian Association of Physics Medal for Lifetime Achievement in Physics, and the UVic Craigdarroch Gold Medal for Career Achievement, as well as honorary degrees from the University of Liverpool, UVic and Simon Fraser University. He was president of the International Union of Pure and Applied Physics from 2005 to 2008, and during this time recruited new members and instituted a new award for young scientists.

It was hard to remember that Alan was an emeritus professor. He came into UVic every day. His door was always open, and he continued to give advice and regale us with amusing anecdotes. He had a lifelong passion for football (soccer) and traditional jazz, and would often talk about the latest game result in the British Premier League or the World Cup. He was very interested in the welfare of the students and postdoctoral fellows, and also followed the career of some young jazz pianists closely. Alan was an exceptional man who inspired his peers with his courage, wisdom, humour and humanity.

A devoted husband and father, he is survived by his wife Kathy and his daughters Elizabeth and Gillian.

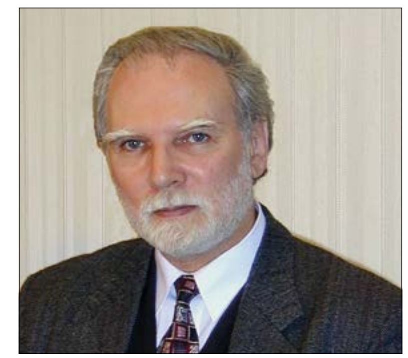
● *Richard Keeler and Michel Lefebvre, University of Victoria.*

Vladimir Georgievich Kadyshevsky 1938–2014

On 24 September, the scientific leader of JINR, Vladimir Georgievich Kadyshevsky, died suddenly. A prominent scientist in elementary-particle theory and high-energy physics, he had an unfailing interest in the most challenging and principle issues in physics, creative approaches in research, and a rich intuition.

Kadyshevsky was born on 5 May 1937 in Moscow. He studied at the Suvorov Military School in Sverdlovsk from 1946 to 1954, before entering the physics department of the Lomonosov Moscow State University (MSU). He immediately expressed an interest in theoretical physics. In 1959 his diploma thesis "On Mass Spectrum and Fundamental Length in Field Theory" won first prize and was awarded the medal of the USSR Ministry of Education at the All-Union Olympiad for students' theses. He graduated in 1960 and continued his studies as a postgraduate under Nikolai Bogoliubov. He successfully defended his PhD thesis in 1962, before starting work at the Laboratory of Theoretical Physics of JINR.

From 1964, Kadyshevsky published a series of papers dedicated to the covariant Hamiltonian formulation of quantum field theory. He worked out a unique diagram technique that, unlike the well-known Feynman technique, operates on amplitudes on a mass surface. Its application to the problem of the interaction of two relativistic particles allowed him to reduce the number of variables and establish the 3D integral equation for the relativistic scattering amplitude that is now known as the Kadyshevsky equation. His approach allows the transfer of research methods, intuition and experience accumulated in the theory



Vladimir Kadyshevsky. (Image credit: JINR.)

of analogous non-relativistic systems – for example, few-nucleon atomic nuclei – to the sphere of elementary-particle physics. The Kadyshevsky equation is today used for practical calculations of hadron–hadron interactions and for the description of the quark structure of hadrons.

His name is also connected with the relativistic formulation of quantum field theory in quantized space–time that satisfies the unitarity requirements and the generalized causality condition. His internationally acknowledged work in this field foreshadowed research in non-commutative geometry in the 1990s that is now the focus of theoreticians' attention. In the theory of internal symmetry, Kadyshevsky postulated a number of correlations for effective cross-sections and the masses and magnetic moments of hadrons that have been proved experimentally. Even before the Standard Model of electroweak interactions was constructed, he studied lepton–hadron symmetries that are revealed in weak processes.

Kadyshevsky became professor at MSU in 1970 and for many years was head of the Elementary Particle Physics Chair. Many of his students have become successful, well-known scientists, working in scientific centres in Russia and abroad. On numerous occasions he guided the work of schools for young scientists, international symposia and conferences. On his initiative a new university – the International University of Nature, Society and Man – was opened in Dubna in 1994, and a year later he became its president.

After being head of a group of Soviet physicists working at Fermilab in the years 1977–1978, Kadyshevsky later led JINR's activities for the DELPHI experiment at CERN's Large Electron–Positron collider in the years 1983–1985, in particular guiding related theoretical research. Then, at the suggestion of Bogoliubov, he was elected to be director of the Laboratory of Theoretical Physics of JINR in 1987. In this position, he made an important contribution to promotion of the scientific traditions of the Dubna theoretical school, and to the development of broad international co-operation.

In 1992, Kadyshevsky became head of JINR, a position he held until 2005. During these difficult years, he and his colleagues managed not only to maintain the institute but also to enhance its position considerably. In this period, experiments on Russia's first superconducting accelerator of relativistic nuclei – the Nuclotron – began; the research reactor IBR-2 was upgraded to provide neutron beams with record parameters; the synthesis of new superheavy elements was

Faces & Places

carried out; and there was much progress in the development of programmes in particle physics at JINR and at other large scientific centres around the world. From 2005, in his position as the institute's scientific leader, he contributed greatly to the development of the main scientific trends and international co-operation at JINR.

He undertook a range of scientific organizational activities. He was member of the Presidium of the Russian Academy of Sciences, and of the Expert Advisory Board under the chairman of the Russian Federation Accounts Chamber. For a number of years he was president of the Union of Scientific Societies of Russia and a member of the board on particles and fields of the International Union of Pure and Applied Physics. His scientific achievements brought a number of prizes, and he was an honorary doctor of several foreign universities, as well as an honorary or foreign member of various academies.

Vladimir Kadyshevsky was an active advocate of values of fundamental science. He strived to increase the public prestige of Russian science and the Russian Academy of Sciences. He had a strong sense of responsibility, devotion to science, ambition and an extraordinary commitment to work. These features combined in his character with a natural refinement, amiability and kind attitude towards people. His friends, students and colleagues will always remember him in their hearts.
● *Staff members of JINR.*

In December 2010, a coating on CERN's Globe of Science of Innovation, above, gave the iconic structure an appropriately seasonal look for those who have a taste for traditional Christmas pudding.

Snow is often a feature of winter at CERN, but the winter of 1962–1963 was one of the coldest in northern Europe, with extreme conditions from the frozen river Rhine in Germany to frozen sea on the UK's coast. CERN also froze, as is evident from the black-and-white picture taken in January 1963 of the barracks that were still being used as labs and offices.

Nearly 50 years later, harsh conditions arrived again in Europe, from around 22 November in 2010. Heavy snow arrived in Switzerland on 26 November, followed by a week of cold weather. In the photo taken below at CERN on 2 December 2010, the sun may have been shining on the Jura mountains in the background, but the low temperatures ensured that there was not much call for the use of CERN bicycles. (Image credits: CERN-GE-1012315-01, top, CERN-GE-6301205, right, CERN-GE-1012315-04, below.)

Recruitment

Postdoctoral Research Positions
LIGO Laboratory

California Institute of Technology (Caltech)
Massachusetts Institute of Technology (MIT)

The Laser Interferometer Gravitational-Wave Observatory (LIGO) has as its goal the development of gravitational wave physics and astronomy. The LIGO Laboratory is managed by Caltech and MIT, and is funded by the National Science Foundation. It operates observatory sites equipped with laser interferometric detectors at Hanford, Washington and Livingston, Louisiana. The initial LIGO detectors performed better than their design sensitivity and data sets spanning over three years of coincident operation have been collected. Analysis is ongoing, with extensive participation by the LIGO Scientific Collaboration (LSC). A major upgrade (Advanced LIGO) is almost complete which will increase the sensitivity of the detectors by tenfold once commissioned. In addition, an R&D program supports the development of enhancements to the detectors as well as future capabilities.

The LIGO Laboratory anticipates having one or possibly more postdoctoral research positions at one or more of the LIGO sites – Caltech, MIT and at the two LIGO observatories – beginning in Fall 2015. Hires will be made based on the availability of funding. Successful applicants will be involved in the operation of LIGO itself, analysis of data, both for diagnostic purposes and astrophysics searches, as well as the R&D program for future detector improvements. We seek candidates across a broad range of disciplines. Expertise related to astrophysics, modeling, data analysis, electronics, laser and quantum optics, vibration isolation and control systems is desirable. Most importantly, candidates should be broadly trained physicists, willing to learn new experimental and analytical techniques, and ready to share in the excitement of building, operating and observing with a gravitational-wave observatory. Appointments at the post-doctoral level will initially be for one-year with the possibility of renewal for up to two subsequent years.

Applications for post-doctoral research positions with LIGO Laboratory should indicate which LIGO site (Caltech, MIT, Hanford, or Livingston) is preferred by the applicant. Applications should be sent to **HR@ligo.caltech.edu** (Electronic Portable Document Format (PDF) submittals are preferred). Caltech and MIT are Affirmative Action/Equal Opportunity employers. Women, minorities, veterans, and disabled persons are encouraged to apply.

Applications should include curriculum vitae, list of publications (with refereed articles noted), and the names, addresses, email addresses and telephone numbers of three or more references. Applicants should request that three or more letters of recommendations be sent directly to HR@ligo.caltech.edu (Electronic Portable Document Format (PDF) submittals are preferred). Consideration of applications will begin December 1, 2014 and will continue until all positions have been filled.

Caltech and MIT are Affirmative Action/Equal Opportunity Employers
Women, Minorities, Veterans and Disabled Persons are encouraged to apply
More information about LIGO available at www.ligo.caltech.edu

INDIANA UNIVERSITY

ATLAS Postdoctoral Position with Indiana University

The Indiana University High Energy group on the ATLAS experiment at the Large Hadron Collider seeks an outstanding applicant for a postdoctoral associate position, beginning at a negotiated date. Applicants should have a Ph.D. in High Energy Particle Physics, and demonstrated experience in physics analysis, preferably on a colliding beam experiment. Experience with detector hardware, electronics or computing is also valuable. The successful applicant will be expected to reside at CERN.

Application should be made via the portal located at **http://indiana.peopleadmin.com/postings/926** that also provides application requirements and details, including descriptions of the group and our research interests and directions.

Indiana University is an equal employment and affirmative action employer and a provider of ADA services. All qualified applicants will receive consideration for employment without regard to age, ethnicity, color, race, religion, sex, sexual orientation or identity, national origin, disability status or protected veteran status.

NATIONAL TAIWAN UNIVERSITY
Leung Center for Cosmology and Particle Astrophysics

Distinguished Junior Fellowship

The Leung Center for Cosmology and Particle Astrophysics (LeCosPA) of National Taiwan University is pleased to announce the availability of several Post-Doctoral Fellow or Assistant Fellow positions in theoretical and experimental cosmology and particle astrophysics, depending on the seniority and qualification of the candidate. Candidates with exceeding qualification will be further offered as LeCosPA Distinguished Junior Fellows with competitive salary. LeCosPA was founded in 2007 with the aspiration of contributing to cosmology and particle astrophysics in Asia and the world. Its theoretical studies include inflation, dark energy, dark matter, large-scale structure, cosmic neutrinos, and classical and quantum gravity. The experimental investigations include the balloon-borne ANITA project in Antarctica, the ground-based ARA Observatory at South Pole, and the TAROGE Observatory in the east coast of Taiwan in search of GZK neutrinos, and a satellite GRB telescope UFFO that can slew to the burst event within 1sec. These positions are available on August 1, 2015. Interested applicant should email his/her application with curriculum vitae, research statement, publication list and three letters of recommendation before December 1, 2014 to **Ms. Yen-Ling Lee** ntulecospa@ntu.edu.tw
For more information about LeCosPA, please visit its website at http://lecospa.ntu.edu.tw/

Three letters of recommendation should be addressed to
Prof. Pisin Chen, Director
Leung Center for Cosmology and Particle Astrophysics
National Taiwan University

CERN Courier December 2014

EUROPEAN SPALLATION SOURCE

The European Spallation Source (ESS) in Lund, Sweden, invites applications for Director for Neutron Scattering Facilities.

GET INVOLVED

We are looking for a highly qualified:

ESS Director for Neutron Scattering Facilities

Description of position

Reporting to the Director General, the Director for Neutron Scattering Facilities provides leadership and professional direction to the staff within the Directorate, and manages the planning and implementation of the Directorate's scope of responsibilities. This scope includes ESS's scientific instrumentation, scientific support facilities and the Data Management and Software Center located in Copenhagen, Denmark. The Director for Neutron Scattering Facilities ensures that the ESS facility is constructed and commissioned successfully and will meet its scientific objectives.

The Director for Neutron Scattering Facilities is an experienced leader, proving strategic direction and inspiring the implementation of technical solutions and best practices that address ESS's priorities. The Director advises the Director General on matters relating to neutron science instrumentation, scientific support facilities, the Data Management and Software Center.

Main responsibilities

The Director for Neutron Scattering Facilities will be a member of the Executive Management Team that will secure the success of ESS during construction, commissioning, and into operations. He/she will be responsible for performance goals, scope, cost, schedule, and deliverables of the Neutron Scattering Facilities Directorate and, together with the Director General and the other Directors, for the entire ESS.

Qualifications

The successful candidate has an advanced university degree in physics or relevant discipline, in combination with substantial knowledge of large science projects and construction management of neutron instruments and related areas. Knowledge of principles and practices of scientific research laboratories is a prerequisite. Experience working in collaboration with partner institutions to realise in-kind deliverables is highly desirable. The position requires a leader who works to enable the success of others, makes clear and prompt decisions, and takes responsibility for actions, projects and people. The ability to provide clear direction, delegate work appropriately, empower others and uphold ethics and values will also be of great importance. Excellent networking and interpersonal skills required, as well as demonstrated financial awareness and ability to add value through creative solutions to complex problems. Seeking opportunities for organisational improvement and working strategically to realise organisational goals is also a key success factor.

For further information about the position please visit ESS webpage or use QR code for direction. Last application date is the 17th of January 2015.

http://europeanspallationsource.se/vacancies

Elettra Sincrotrone Trieste

Elettra-Sincrotrone Trieste is an international multidisciplinary research center operated as a user facility, featuring a 2.0/2.4 GeV, third-generation synchrotron light source and a variety of support laboratories. The extremely high quality of the machine and beamlines has set new performance records and has been producing results of great scientific interest. See http://www.elettra.eu for more information. A free-electron laser (FEL) based, fourth generation source - FERMI@Elettra – is currently under commissioning. See http://www.elettra.eu/FERMI/ or more information.

We are seeking the following candidates:

- E/13/09 TwinMic PostDoc Research Associate at Elettra
- E/13/10 Spectromicroscopy Research Staff Scientist at Elettra
- E/13/18 BaDElPh Research Staff Scientist at Elettra
- E/14/05 X-Ray Fluorescence Research Associate at Elettra

For any further details please see our web site:

http://www.elettra.eu/about/careers/careers.html

We thank all applicants in advance.

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eLISA/LISAPathfinder:
Data Analysis/instrumentation engineer at APC (Paris)

APC, AstroParticle and Cosmology laboratory in Paris, is offering a 3 year (CNRS) contract in order to work on the data analysis of the LISAPathfinder (LPF) mission and its link to the incoming eLISA system engineering study. LPF (due to be launched mid-2015) is a technology mission aimed at validating some of the concepts that will be used for the detection of gravitational waves in space by eLISA. The mission will last of the order of 6 months and will imply travelling to Darmstadt (Germany) and Madrid (Spain) for periods of 1-2 weeks. The applicant will require some experience of data analysis, if possible related to instrumental activities. A practice of Matlab is recommended. The position is intended either for an engineer or for a physicist. A good english level is necessary as the applicant will interact with the European community of LISAPathfinder.

In parallel with this LPF activity, the applicant will be involved in the eLISA system engineering study needed for the preparation of the future the AIT/AIV phase, under French responsibility. A permanent position at the end of the contract could be considered.

The deadline for applications is 15 January 2015. The application can be sent to eric.plagnol@apc.univ-paris7.fr and julien.brossard@apc.univ-paris7.fr.

Further information about APC can be found at www.apc.univ-paris7.fr/APC_CS/

Faculty Position
Department of Nuclear Science and Engineering

The Department of Nuclear Science and Engineering at the Massachusetts Institute of Technology (MIT), Cambridge, MA, invites applications for faculty positions starting September 2015 or thereafter. Appointment will be at the assistant or untenured associate professor level. In special cases, a senior faculty appointment may be possible.

The Department is a world leader in the generation, control and application of nuclear reactions and radiation for the benefit of society and the environment. Its faculty teach and conduct research in fields from fundamental nuclear science to practical applications of nuclear technology in energy, security and other fields. The highest priority area of research, for current candidates, is **theoretical and computational plasma physics for fusion applications**. However, we will consider truly exceptional candidates across the full range of the Department's fields of research and education. These include advanced modeling, simulation, theory, experimentation, and design for nuclear fission systems; the nuclear fuel cycle; plasma physics and fusion engineering; materials for extreme environments; quantum engineering and control; and radiation science and technology. [See http://web.mit.edu/nse/].

Applicants must have a doctorate in a relevant engineering or scientific field by the beginning of employment, and must have demonstrated excellence in research and scholarship in a relevant technical field. We welcome applications from a wide range of related disciplines, including physics, chemistry, materials science, mechanical engineering, computational science and engineering, and environmental engineering. However, a commitment to excel in teaching in one of the core fields of nuclear science and engineering is essential. Faculty duties will include teaching at the graduate and undergraduate levels, research, and supervision of graduate students.

Applications are being accepted electronically at http://nse-search.mit.edu/. Each application must include: a curriculum vitae, the names and addresses of three or more references, a two-page strategic statement of research interests, a one-page statement of teaching interests, and electronic copies of no more than three representative publications. Each candidate must also arrange for three or more reference letters to be uploaded electronically.

Recognizing MIT's strong commitment to diversity in education, research and practice, minorities and women are especially encouraged to apply.

Applications received before 1/31/2015, will be given priority.

MIT is an equal opportunity/ affirmative action employer.

Massachusetts Institute of Technology

VirginiaTech
Invent the Future

Assistant Professor, Department of Physics, Virginia Tech

The **Department of Physics at Virginia Tech** invites applications for a tenure-track faculty position in the area of hard condensed matter theory. Appointment at the Assistant Professor level is anticipated but exceptional senior candidates will also be considered. Successful candidates will complement and extend the department's experimental and theoretical strengths in quantum materials, mesoscopic physics, transport, strongly correlated systems, and quantum information.

The complete posting is available at www.phys.vt.edu/jobs/cmtheory.html. Candidates should apply at www.jobs.vt.edu to posting TR0140120. Review of applications will begin on December 19, 2014, and will continue until the position is filled.

Virginia Tech is committed to diversity and seeks a broad spectrum of candidates including women, minorities, and people with disabilities. Virginia Tech is a recipient of the National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers (www.advance.vt.edu).

Accelerators | Photon Science | Particle Physics

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

DESY

PARTICLE PHYSICS.

DESY, Hamburg location, is seeking:
Scientists (f/m) - Tenure Track

DESY

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

The particle physics programme of DESY consists of strong contributions to the LHC experiments ATLAS and CMS and to the preparation of a future linear collider. The experimental programme is enhanced by collaboration with a strong theory group. DESY is searching two experienced high energy experimental physicists, who will take leading roles in the LHC physics data analysis and the experiments upgrade program in the frame of CMS.

The position

- Active role in the CMS experiment
- Leading role either in the Higgs data analysis or in the Standard Model data analysis and proton structure function measurements
- Detector operations and developments for the CMS High Luminosity program
- Participation in the supervision of students and postdocs

Requirements

- PhD in experimental High Energy Physics
- Extensive knowledge and experience with experiments in HEP
- Experience in HEP detector development and operations
- Outstanding teamwork abilities and excellent communication skills and knowledge of English

For further information please contact Dr. Matthias Kasemann +49 40 8998 4588 or Prof. Dr. Elisabetta Gallo, elisabetta.gallo@desy.de

Depending on qualification the position is permanent or limited to 5 years and becomes permanent after a positive evaluation by a tenure track committee after three years.

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.

Please send your application quoting the reference code, also by E-Mail to:
Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: EM165/2014
Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-3392 |
E-Mail: recruitment@desy.de
Deadline for applications: 31 December 2014
www.desy.de

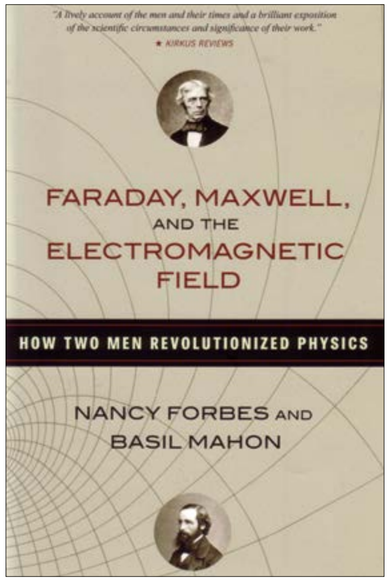
The Helmholtz Association is Germany's largest scientific organisation.
www.helmholtz.de

HELMHOLTZ | ASSOCIATION

Bookshelf

Festive Bookshelf

Once again, it will soon be time for many of us to take a well-earned break with friends and family, probably after a few hectic hours searching for presents in this festive season. To help with the shopping – whether for others or for yourself – this end-of-year Bookshelf presents some suggestions for more relaxed reading.



Faraday, Maxwell, and the Electromagnetic Field: How Two Men Revolutionized Physics

By Nancy Forbes and Basil Mahon
Prometheus Books
Hardback: $25.92

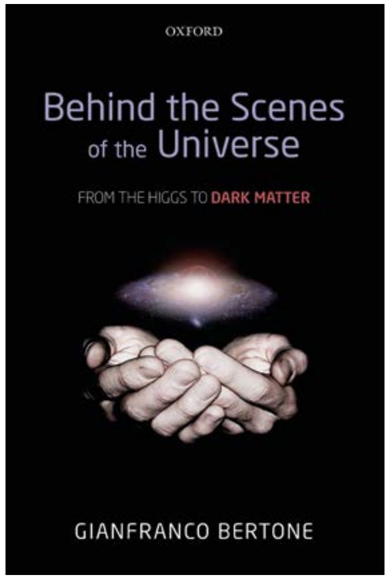
The birth of modern physics coincides with the lifespans of Michael Faraday (1791–1867) and James Clerk Maxwell (1831–1879). During these years, electric, magnetic and optical phenomena were unified in a single description by introducing the concept of the field – a word coined by Faraday himself while vividly summarizing an amazing series of observations in his *Experimental Researches in Electricity*. Faraday – a mathematical illiterate – was the first to intuit that, thanks to the field concept, the foundations of the physical world are imperceptible to our senses. All that we know about these foundations – Maxwell would add – are their mathematical relationships to things that we can feel and touch.

Today, the field concept – both classically and quantum mechanically – is unavoidable, and this recent book by Nancy Forbes and Basil Mahon sheds fresh light on the origins of electromagnetism by scrutinizing the mutual interactions of Victorian scientists living through a period characterized by great social and scientific mobility. Faraday started as a chemist, became an experimental physicist, then later a businessman and even an inspector of lighthouses – an important job at that time. Maxwell began his career as a mathematician, became what we would call today a theoretical physicist, and then founded the Cavendish Laboratory while holding the chair of experimental physics at the University of Cambridge.

The first seven chapters focus on Faraday's contributions, while the remainder are more directly related to Maxwell and his scientific descendants or, as the authors like to say, the Maxwellians. The reader encounters not only the ideas and original texts of Faraday and Maxwell, but also a series of amazing scientists, such as the chemist Humphry Davy (Faraday's mentor), as well as an assorted bunch of mathematicians and physicists including David Forbes (Maxwell's teacher), John Tyndall, Peter Tait, George Airy, William Thomson (Lord Kelvin) and Oliver Heaviside. All of these names are engraved in the memories of students for contributions sometimes not directly related to electromagnetism, and it is therefore interesting to read the opinions of these leading scientists on the newly born field theory.

The historical account might at first seem a little biased, but it is nonetheless undeniable that the field concept took shape essentially between England and Scotland. The first hints for the unification of magnetic and electric phenomena can be traced back to William Gilbert, who in 1600 described electric and magnetic phenomena in a single treatise called *De Magnete*. More than 200 years later, the Maxwell equations (together with the Hertz experiment) finally laid to rest the theory of "action at a distance" of André-Marie Ampère and Charles-Augustin de Coulomb.

The last speculative paper written by Faraday (and sent to Maxwell for advice) dealt with the gravitational field itself. Maxwell replied that the gravitational lines of force could "weave a web across the sky" and "guide the stars in their courses". General relativity was on the doorstep.
● *Massimo Giovannini, CERN and INFN Milan-Bicocca.*



Behind the Scenes of the Universe: From the Higgs to Dark Matter

By Gianfranco Bertone
Oxford University Press
Hardback: £19.99
Also available as an e-book, and at the CERN bookshop

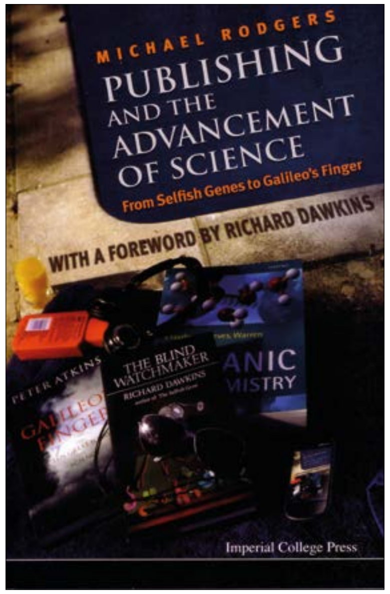
With the discovery of *a* Higgs boson by the ATLAS and CMS experiments, the concept of mass has changed from an intrinsic property of each particle to the result of an interaction between the particles and the omnipresent Higgs field: the stronger that interaction is, the more it slows down the particle, which effectively behaves as if it is massive. This experimental validation of a theoretical idea born 50 years ago is a major achievement in elementary particle physics, and confirms the Standard Model as *the* cornerstone in our understanding of the universe. However, as is often the case in science, there is more to mass than meets the eye: most of the mass of the universe is currently believed to exist in a form that has, so far, remained hidden from our best detectors.

Gianfranco Bertone seems to have been travelling through the dark side of the universe for quite a while, and I am glad that he has taken the time to write this beautiful account of his journey. The book is easy to read, the scientific observations, puzzles and discussions being interspersed with interesting short annotations from history, art, poetry, etc. Readers should enjoy the non-technical tour through general relativity, gravitational lensing, cosmology, particle physics, etc. In particular, one learns that space–time bends light rays travelling through the universe, and that we can deduce the properties of a lens by studying the images it distorts. At the end of this learning curve we reach the conclusion that "we have a problem": no matter where we look, and how we look, we always infer the existence of much more mass than we can see. Bertone expresses it poetically: "The cosmic scaffolding that grew the galaxies we live in and keeps them together is made of a form of matter that is unknown to us, and far more abundant in the universe than any form of matter we have touched, seen, or experienced in any way."

The second half of the book wanders through the efforts devised to indentify the nature of dark matter, through the direct or indirect detection of dark-matter particles, with the LHC experiments, deep underground detectors, or detectors orbiting the Earth. As more data are collected and interpreted, more regions of parameters defining the properties of the dark-matter particles are excluded. In a few years, the data accumulated at the LHC and in astroparticle experiments will be such that, for many dark-matter candidates, "we must either discover them or rule them out". The book is an excellent guide to anyone interested in witnessing that important step in the progress of fundamental physics.

● *Carlos Lourenço, CERN.*

Publishing and the Advancement of Science: From Selfish Genes to Galileo's Finger
By Michael Rodgers
World Scientific
Hardback: £50
Paperback: £25
E-book: £19



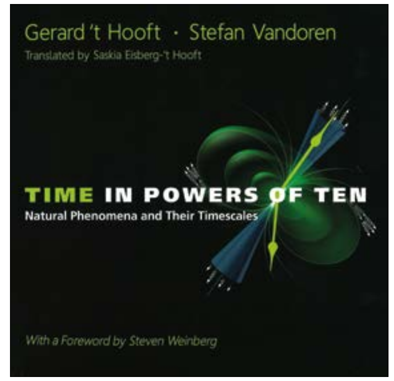
In *Publishing and the Advancement of Science*, retired science editor Michael Rodgers take us on an autobiographical tour of the world of science publishing, taking in textbooks, trade paperbacks and popular science books along the way. The narrative is detailed and chronological: a blow-by-blow account of Rodgers' career at various publishing houses, with the challenges, differences of opinion and downright arguments that it takes to get a science book to press.

Rodgers was part of the revolution in popular-science publishing that started in the 1970s, and he conveys with palpable excitement the experience of discovering great authors or reading brilliant typescripts for the first time. Readers with an interest in science will recognize such titles as Richard Dawkins' *The Selfish Gene* or Peter Atkins' *Physical Chemistry*, both of which Rodgers worked on. Frustratingly, he falls short of providing real insight into what makes a popular-science book great. There is a niggling sense of "I know one when I see one", but a lack of analysis of the writing.

Rodgers' first job in publishing – as "field editor" for Oxford University Press (OUP), starting in 1969 – had him visiting universities around the UK, commissioning academics to write books. Anecdotes about the inner workings of OUP at the time take the reader back to a charming, pre-web way of working: telephone calls and letters rather than e-mails and attachments, and responding to authors in days rather than minutes. The culture of publishing at the time is conveyed with wry humour. OUP sent memos about the proper use of the semicolon, and had a puzzlingly arcane filing system, which added to the sense of mustiness.

A section on the development of Dawkins' seminal *The Selfish Gene* threw up interesting tidbits – altercations about the nature of the gene, and a discussion about what makes a good title – but I was less interested in the analysis of the US market for chemistry textbooks, or such tips as "The best time to publish a mainstream coursebook is in January, to allow maximum time for promotion."

At times, the level of autobiographical detail dilutes Rodgers' sense of intellectual excitement about the scientific ideas in his books. The measure of a book's success



in terms of copies sold and years in print makes publishing a commercial rather than intellectual exercise, which to some extent left me disappointed. And although Rodgers worked part time, freelance or was made redundant at various points in his career, apart from a brief section in the epilogue, he seems rather blind to the changes sweeping the publishing industry, with the advent of free online content.

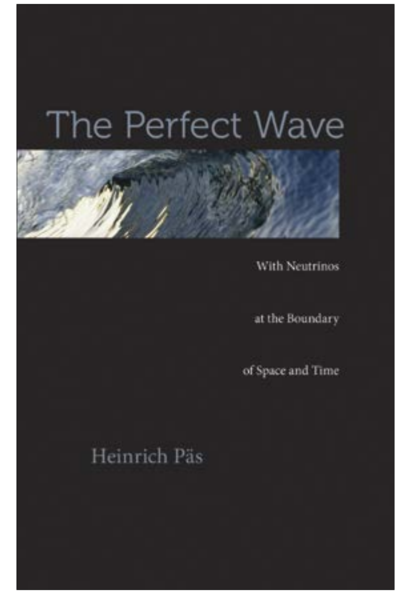
Those interested in the world of publishing, with a special interest in science, will find much to like about this book. But although Rodgers provides quirky tidbits about how some famous books came to be, it falls short of telling us what makes them great.

● *Cian O'Luanaigh, CERN.*

Time in Powers of Ten: Natural Phenomena and Their Timescales
By Gerard 't Hooft and Stefan Vandoren (translated by Saskia Eisberg-'t Hooft)
World Scientific
Hardback: £31
Paperback: £16
E-book: £12
Also available at the CERN bookshop

With powers of 10, one cannot fail to think of the iconic 1970s film made by Charles and Ray Eames – a journey through the universe departing from a picnic blanket somewhere in Chicago. However, this book is not about distance scales, rather time. And the universe it reveals is one of constant turmoil and evolution. No vast empty wastelands here, where nothing changes across many powers of 10. Journeying across the time scales, we discover a universe teeming with activity at every stage – processing, ticking, cycling, continuously moving, changing, surprising.

Every page brims with the authors' evident enthusiasm for the workings of the universe, be it the esoteric or the more mundane. I would never have expected to read a book where cosmic microwave



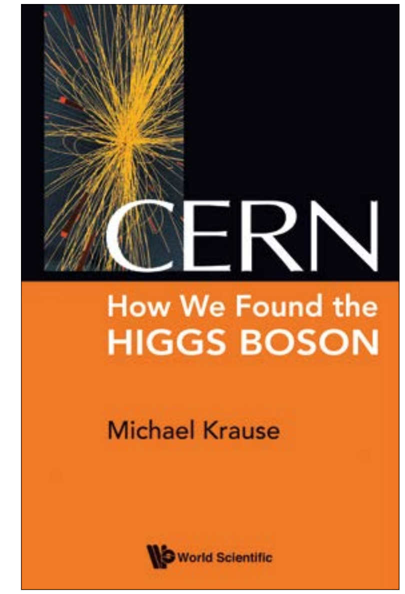
background radiation sits side by side with the problems of traffic congestion in the US (time = 10 trillion seconds).

Leaping in powers of 10, the book races through stories of life, the Earth and the solar system, and on to physical processes quadrillions of times the age of the universe itself. The largest and smallest of time scales transport the reader to the strange and fascinating. Just as with distance scales, the very small and the very large are intimately entwined.

There is a gap between the more anecdotal and the more scientific. Record sprint times (time = 10 seconds) and the rhythm of our biological clock (time = 100,000 seconds) are light interludes in contrast with the decay modes of the η_c meson (time = 10 yoctoseconds) and the Lamb shift (time = 1 nanosecond). While this eclecticism is part of the book's charm, some scientific baggage is required to enjoy the contents fully.

Where the book fails, is in the design. Visually, it is a little dull. With disparate styles of graphic illustrations, many taken from Wikipedia, the image quality is not up to that of the text. A clever design could take readers on a visual voyage, adding to the impact of the writing. The story warrants this effort.

It is striking that mysteries exist at every time scale, not only at the extremes – be it the high magnetic field of pulsars (time = 1 second), the explanation of high-temperature superconductors (time = 10 million seconds) or the origin of water on Earth (time = 100 quadrillion



seconds). The book reveals the extraordinary complexity of our universe – it is a fascinating journey.

● *Emma Sanders, CERN, author of* The Large Hadron Collider Pop-Up Book: Voyage to the Heart of Matter *(Papadakis 2013).*

The Perfect Wave: With Neutrinos at the Boundary of Space and Time
By Heinrich Päs
Harvard University Press
Hardback: £19.95 €24.50 $26.95

The Perfect Wave begins with an entertaining introduction that links the Ancient Greeks and atomism to the effects of psychedelic drugs and (naturally?) particle physics. The book then describes a few key moments in the history of quantum mechanics, the Standard Model of particle physics, the importance of symmetries in the Standard Model, and even delves a little into supersymmetry as a natural extension. Eventually, it moves on to present a brief history of experimental signatures of neutrinos and their masses and mixing, followed by a discussion of the links between neutrino mass and the implications for the evolution of the universe as we know it. The book's concluding chapters describe links between neutrino physics and string theory, which is the author's current area of research.

The fact that neutrinos were postulated to exist about 30 years before they were seen directly, inspires Päs to postulate some other crazy ideas in this book. He hopes that the reader might agree with his assumption that what currently seems "too remote from reality to be of interest" – as Fermi's theory of neutrino interactions was once described – might, one day, be the daily bread of experimentalists, and eventually provide the clues to how the universe can exist at all. One of those crazy ideas, which inspires both the title of the book and about 25% of its pages, is the possibility that neutrinos could be the most likely particle to be capable of travelling backwards in time or faster than the speed of light by going through extra dimensions. Another idea that might be almost as crazy, but is practically assumed to be true and "about to be confirmed at the LHC", is that of supersymmetry, which postulates the existence of an entire zoo of other particles.

The book could be a little too technical for the general public to appreciate, although the readers of *CERN Courier* might feel at home in its pages. There are several novel analogies with everyday phenomena – such as moisture condensing on a beer bottle – that any reader would appreciate, and many references to famous works of art that would also draw in a general audience. Päs also describes the political context and personalities of some of the most important characters in the history of quantum mechanics and particle physics, which helps bring the physics he is describing to life. Unfortunately, however, towards the end of the book he lists several names without any additional character development, which tends to distract from the physics being described (unless of course you are related to the person being named).

In all, this book is much more detailed in its description of particle-physics theories (proven or otherwise) than of the experiments that have brought us to the current state of understanding. But for a fun journey through the intersection of particle-physics history, speculation and literature, this would be the right book to purchase.

● *Deborah Harris, Fermilab.*

CERN: How We Found the Higgs Boson
By Michael Krause
World Scientific
Hardback: £38
Paperback: £19
E-book: £14
Also available at the CERN bookshop

Also published as
Wo Menschen und Teilchen aufeinanderstoßen: Begegnungen am CERN
Wiley-VCH
Hardback: £22.50 €24.90
E-book: £18.99 €21.99
Also available at the CERN bookshop

There have been quite a few books recently

Bookshelf

about CERN and its latest "biggest" discovery – the Higgs boson. According to the preface, this one sets out to tell the story from a different perspective, by putting at its centre the modern scientists who are exploring this *terra incognita*. Interviews with a dozen scientists working at CERN, ranging from the director-general, Rolf Heuer, to physicists working on the experiments, form the main part of the book. These interviews are interspersed with explanatory texts, and there are also a number of factual chapters about the history of physics and especially particle physics, from Galileo to Einstein.

Does the book achieve what it sets out to do, namely to give basic research a human face? Yes and no.

When I first opened the book, I was curious to get to know some of the physicists, to understand what motivates them and to learn how they feel about working in such a huge "laboratory" with thousands of people. But the first chapter (and a long one at that) is about the history of CERN. While this is interesting in itself – CERN was founded after two devastating world wars, as a place where people from many different cultures could work together peacefully – I was not interested in facts and figures.

So I skipped ahead to the interviews – but again they were interspersed with explanatory texts, which I found quite distracting. Although some of these contain interesting and useful information, I found them too long, taking my mind away from the interview, so it was hard to rejoin the conversation one or two pages later.

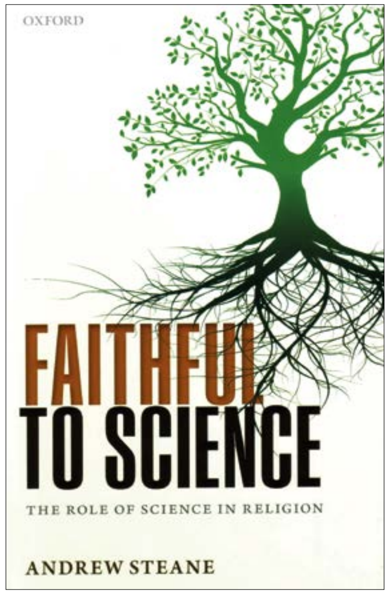
Nevertheless, you do get to know some hardcore scientists at a personal level. Their answers give the reader a glimpse of the great endeavour that is CERN, and they also hint that the adventure is far from over – even after the Higgs discovery. And with all the background information, you do not have to have a physics degree to gain a basic understanding of the science.

● *Hannelore Hämmerle, Max Planck Institute for Astrophysics.*

Faithful to Science: The Role of Science in Religion

By Andrew Steane
Oxford University Press
Hardback: £19.99
Also available as an e-book

The interface between science and religious faith represents one of the most important areas in human conversation, where the aim is to bring together these two central and influential forces of human life and experience, and to examine how and if they link together.



This book sets out to validate the premise that modern science is an integral part of the ordinary and mainstream theistic belief. The author makes an excellent case of demonstrating that science and religious faith have much in common, and that they relate in a fruitful, inspiring and productive manner. In fact, the author concludes indisputably that the most general world view of human life encompasses both science and theistic belief naturally, and that there is no conflict between the two.

CERN is also reflecting on these themes in terms of the origins of the universe with the Big Bang. In partnership with Wilton Park, two conferences have been held with experts to examine the various world views of science, philosophy and theology, and to consider what they share in terms of common understanding. The first conference in 2012 focused on reaching a common language among the world views, while the second conference in 2014 considered the common understanding of the truth. Andrew Steane's book is therefore timely.

Faithful to Science is instructive, well laid out and easy to read. It is written clearly and covers many aspects of the conversation, making arguments clear without being technical. As both a scientist and a believer that reality is deeply personal, the author communicates the excitement and wonders of science and scientific discovery with clarity, particularly within the framework of a larger world view and human understanding that includes religious faith.

In conclusion, the book should appeal to anyone who has an interest in understanding the broader world view of human endeavour that includes religious faith and science. I hope that it inspires people to take a more open and wide-ranging view of human life. *Faithful to Science* should be on the bookshelf of anyone who is interested to explore this more comprehensive human experience.

● *Emmanuel Tsesmelis, CERN.*

Books received

What Makes a Champion! Over Fifty Extraordinary Individuals Share Their Insights
By Allan Snyder (ed.)
World Scientific
Paperback: £18
E-book: £14

What drives great and successful individuals — be they athletes, artists, or scientists — and businesses to achieve the extraordinary? The focus is Australian, but the more than 50 champions come from all walks of life. Contributing authors include some well-known names, such as Nelson Mandela, Edmund Hillary and Corazon Aquino.

Magazines

Cent ans de particules... Où va la physique ?
Dossier *Pour la Science* n° 85 – Octobre-décembre 2014
Edition numérique : 5,49 €
Edition imprimée : 6,95 €
Also available at the CERN bookshop

À l'occasion des 60 ans du CERN, le magazine *Pour la Science* consacre un numéro spécial à la physique des particules. Le dossier commence avec une introduction du physicien Etienne Klein, qui rappelle les conquêtes de cette discipline, et de l'ancien Président du Conseil du CERN, Michel Spiro, qui revient sur l'histoire du grand laboratoire européen. Des articles de scientifiques de renom sont ensuite répartis en trois chapitres. Le premier est consacré au bestiaire des particules et à la découverte du boson de Higgs, avec notamment une interview du prix Nobel François Englert. Le deuxième chapitre porte sur le futur de la discipline, tandis que le troisième s'intéresse à l'impact de la physique des particules sur la société, avec un panorama complet des technologies d'accélérateurs et un article sur l'avenir du web écrit par Nigel Shadbolt et l'inventeur du web, Tim Berners-Lee.

Inside Story

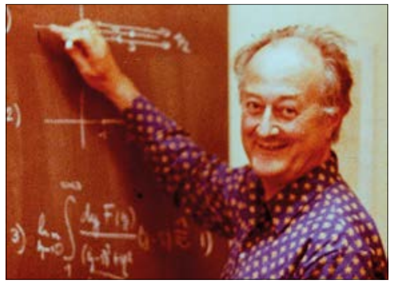
Birth of the Hagedorn temperature

The statistical bootstrap model and the discovery of quark–gluon plasma.

On 3 February 1978, Rolf Hagedorn handed me a copy of his secret, unpublished manuscript on "Thermodynamics of distinguishable particles: a key to high-energy strong interactions?" – CERN preprint TH 483, dated 12 October 1964. The original had a big red mark, showing that it was the original, not to be lost, with the number "0" meaning less than "1" (see below). Hagedorn kept just one red-marked copy, and mentioned that another was in the CERN archives. He told me that I was never to give a copy to anyone – a promise I can now break, having found the document on the CERN Document Server (CDS). This was the initial paper proposing an exponential hadron mass spectrum and the limiting (Hagedorn) temperature.

Hagedorn recollected: "After Léon van Hove read the paper, he asked me to compute requirements for the hadron mass spectrum. This led me to recognize that not every, even exponential, mass spectrum produces limiting temperature. Thus within two weeks I concluded this result was too model dependent to publish, and I withdrew this paper, placing an explanation in CERN archives." I saw Hagedorn did not like this ad-hoc fine tuning, even 13 years after the fact.

The beginning, as always, hung on a fine thread: what would Hagedorn do after withdrawing the limiting temperature paper? He was convinced that his idea that the appearance of a large number of different hadronic states allows the energy content to increase without a rise in temperature was right. Within a span of only 90 days between the withdrawal and the date of a new CERN-TH preprint, he formulated the statistical bootstrap model (SBM), where the salient feature is that the exponential mass spectrum arises from the principle that hadrons are clusters comprising lighter (already clustered) hadrons.



Rolf Hagedorn at the blackboard in 1978. (Image credit: Jan Rafelski.)

In the SBM, the exponential mass spectrum required for limiting temperature arose naturally *ab initio*, as did the close relation between the limiting temperature, the exponential mass-spectrum slope and the lightest hadron mass. The CERN-TH 520 preprint dated 24 January 1965, "Statistical thermodynamics of strong interactions at high energies" – marked with a big "1" in the Hagedorn collection, a manuscript that I was allowed to copy and give to anyone – was published (1965 *Nuovo Cim.Suppl.* **3** 147) and is today the renowned "Hagedorn paper". The Hagedorn temperature and the SBM were officially born (*CERN Courier* September 2003 p30).

It is relevant to recollect what the dates on the CERN-TH preprints meant. In those days, a handwritten manuscript was handed to Tania Fabergé, the Theory Divison (TH) secretary. It received a sequential TH-preprint number and the day's date, as recorded in the TH log book. The paper then sat in the typing queue until it reappeared with date and number clearly visible on the front page. Somewhere along the line, a senior member of TH would look at the work. This was a mild internal refereeing that also helped a young fellow like me to meet senior division members. I made many friends in the Theory Division that way, such as John Bell, Léon van Hove, Maurice Jacob and Jacques Prentki.

However, I had met Hagedorn before, when he came to give a colloquium at the University of Frankfurt, presenting a fascinating description of thermal multiparticle physics. After his talk, he found a way to answer all questions, even though I, for one, lacked an understanding of thermal physics – not unusual in the particle and nuclear context in the early 1970s. He remembered our discussions in Frankfurt a few years later, resuming my education at CERN as if we had never been interrupted. Looking back to those long sessions in the winter of 1977/1978, I see a blackboard full of clean, exact equations – and his sign not to clean the board, because he knew we would resume early the next morning.

But how did Hagedorn, with his uncanny physics instinct, by way of limiting temperature and the statistical bootstrap, lay foundations for a new interdisciplinary field of physics – relativistic heavy-ion collisions and the study of quark–gluon plasma – now a vibrant research programme not only at CERN, but also for example, at Brookhaven, GSI and Dubna? The idea of a limiting temperature transformed into what today is the temperature at which the confining QCD vacuum structure dissolves, and the structure of matter changes from hadronic to quark–gluon degrees of freedom. The exponential growth of the mass spectrum is understood as the result of the quark content of hadrons. The statistical bootstrap idea amounts to an effective model of how the quark structure enters the hadron mass spectrum. The final step to quark matter was made when I embarked with Hagedorn in 1977 on the path leading to the expansion of the SBM towards a theory of hot nuclear matter. To achieve this goal, we introduced the conserved baryon quantum number, and a reaction volume comprising the internal degrees of freedom. The outcome was that under enough pressure, the Hagedorn clusters dissolve into a single quark–gluon drop.

Looking back 50 years later to the events in autumn 1964, I can say that they marked the beginning of the path to the quark–gluon plasma discovery, which CERN announced as a "new state of matter" in February 2000 (*CERN Courier* June 2000 p25). With the support of CERN and Springer publishers, I am currently preparing a book on the first 20 of these 50 years, including eyewitness accounts and "withdrawn" work, "unpublished notes" and "unfiled conference reports". Other events are also being planned to emphasize the importance of this anniversary.

● *Johann Rafelski, Arizona.*

Viewpoint

CERN: a forward look

Why CERN's geographical enlargement is important for the future.

On 1 July, the cycle of events celebrating CERN's 60th anniversary opened in Paris with an event commemorating the anniversary of the CERN Convention, which was signed at the UNESCO headquarters in 1953 by representatives of the founding members. These 12 signatures are indeed worth commemorating. For more than half a century, the convention has stood the test of time as a masterpiece of simple and minimalistic legal language that focuses wisely on the essential cornerstones of CERN's institutional basis and governance. At the same time, it provides for the leeway that is necessary to adapt the organization to a changing political environment, and to new scientific and technological challenges. The convention is a testimony to the wisdom and foresight of CERN's founding fathers, on a par with their vision of rebuilding peace in Europe by establishing a unique focal point that would foster scientific collaboration on an unprecedented scale, between nations that had fought a war against each other only a few years earlier. On the basis of this convention, CERN has served as a model for other successful European science organizations, and most recently for the SESAME synchrotron light source in the Middle East (*CERN Courier* September 2014 p46).

Some of the most intriguing aspects of the CERN Convention are in the provisions for membership in the organization. Whereas Article II stipulates that "the Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character…", nowhere is it stated explicitly that membership in CERN is *restricted* to European states. This ambiguity is by no means fortuitous. It reflects the fact that already in the early 1950s, a possible enlargement of membership beyond Europe was a hotly debated issue on which the provisional council could not reach agreement. It agreed, however, on a carefully crafted compromise that left a door open to shaping the membership policy of CERN at a later stage, and to adapting it to an evolving scientific and political landscape.

Indeed, Council has debated a widening of membership on several occasions, and confirmed repeatedly a restrictive interpretation of Article II, whereby membership remained reserved for European countries. Only in 2010 did Council approve the most radical shift of paradigm of CERN's membership policy to date, embedded in a policy of "geographical enlargement" and opening full membership to non-European states, irrespective of their geographical location. At the same time, Council introduced the new instrument of associate membership to facilitate the accession of new members, including emerging countries outside Europe, which might not command sufficient resources to sustain full membership in the foreseeable future.

CERN's new membership policy follows a twofold rationale. It reflects the globalization of particle physics, which in turn has become a prominent paradigm for the globalization of science at large, and it prepares CERN for its long-term future. Since 2004, the community of CERN "users" has grown from just above 6000 to almost 11,000 scientists and engineers. This dramatic growth has been driven by non-member states more than by the member states. Whereas the numbers are dominated by North America, in recent years the most important growth rates have been observed in communities from Asia and Latin America, where new players emerge on the field of international science. Particle physics has a strong tradition of defying political and geographical boundaries. CERN's new membership policy underpins, in part, the global migration of the particle-physics community, which reflects the scientific attractiveness and success of the LHC.

More important, geographical enlargement is a first step in preparing CERN's membership and governance for the post-LHC future. Whereas the LHC experiments today are truly global operations, the LHC machine was built as a predominantly European project, with a technically and politically important contribution of about 10% from outside Europe, mostly provided in kind. This model is not likely to work for a large next-generation facility in Europe. With the CLIC and FCC studies, CERN is exploring two different, challenging avenues to prepare its future, and the future of the field, after the LHC. No cost estimate exists yet for the various options, but it seems inconceivable that any of them could be approved and built within the same membership, governance and funding structures that worked 20 years ago – successfully, but under great labour pains – for the LHC.

With 10 applications for membership or associate membership received from countries of varying size, and from inside and outside Europe (Brazil, Croatia, Cyprus, Israel, Pakistan, Russia, Serbia, Slovenia, Turkey and Ukraine), during the past four years, the enlargement process has made a promising start. Some of the accession procedures have been completed (Israel has become CERN's 21st member state), Serbia is an associate member in the pre-stage to membership, and other accession procedures are expected to conclude in the near future. (Romania, which applied for membership before the introduction of the new policy in 2010, has been integrated *a posteriori* in the same accession procedure as the other, more recent applicant states.) Other countries that would seem natural candidates acknowledge the promise and potential of a continued scientific and technological partnership, but have remained absent so far, or are hesitant on political or financial grounds.

More work, stamina, and patience will be needed to enlarge the membership of CERN to a size that is commensurate with its future ambitions in quantity and quality. Moreover, not all states that are obvious candidates for a closer scientific and technical partnership might share today the values of a governance that is excellence driven and consensus oriented, and that has prevailed most of the time in CERN's 60-year history. In the long term, broadening the institutional base without sacrificing the traditional values of European co-operation that have been a key ingredient in CERN's past successes is likely to emerge as the true challenge of the enlargement process.

● *Rüdiger Voss and Emmanuel Tsesmelis are CERN's head and deputy head of international relations, respectively.*

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Digital MCA PMT Base for Gamma Spectroscopy
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DT5780
Dual Desktop Digital MCA with HV Power Supply
DT5781
Dual/Quad Desktop Digital MCA
N6781
Dual/Quad NIM Digital MCA
N1068
16 Ch Programmable Spectroscopy Amplifier & CFD
N605
4 Channel Fast Constant Fraction Discriminator
743 Digitizer Family
8/16 Channel 12-bit 3.2 GS/s Switched Capacitor Digitizer
R14xxET
4/8 Channel 19" Rack-mount HV Power Supply Module with Ethernet & Touchscreen
DT14xxET
4 Channel Desktop HV Power Supply Module with Ethernet & Touchscreen
DT5470
USB High Voltage Power Supply
A750x
PCB High Voltage Power Supply
A251x
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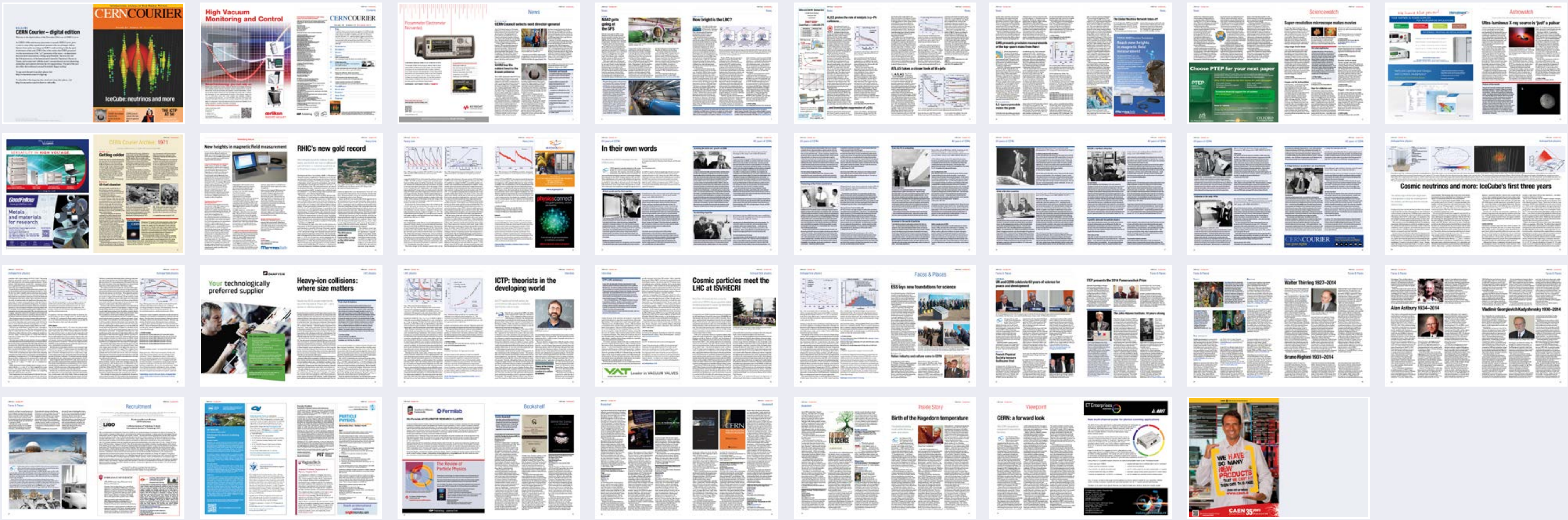

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