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

CERN Courier is distributed worldwide to governments, institutions and laboratories affiliated with CERN, and to their partners. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

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The cover: One of the first few events from the IceCube Neutrino Observatory produced by a neutrino with an energy of about 1 PeV and a 99.999% detection of atmospheric muons (top). Image credit: IceCube Collaboration.
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Theodora Cudmore

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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.)
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**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 achieve this 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 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.

CUORE will be used to search for the rarest and most elusive particles in the universe, namely neutrinos, which are produced in the Sun and in the LHC. CUORE will also be able to sample the cosmic microwave background and the relic density of dark matter.

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

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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.”

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.

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

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 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 successful 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.

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

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... et enquête sur l’atténuation du ψ(2S) ...

L’association bossons W-jets sous la loupe d’ATLAS

L’Als a présenté ses mesures de précision de la masse du quark top

Le cryomodule de type ILC passe le test

Le Global Neutrino Network prend son élan

Le microscope de super–résolution passe au 3D

La source ultra-lumineuse de rayons X est un « simple » pulsar
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 beams were maintaining systems at point 6. Down in the tunnel, sector 5-1 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 7-1 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.)

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 contains about 6% of which are kaons. After almost eight years of design and construction, NA62 was ready for the beam to start-up in October. In early September, the last of the eight sectors of the SPS North Area at CERN’s Prévessin site, had been lowered into position in the experiment. The straw tracker is the first of its kind to be placed directly into the vacuum tank, sits alongside a silicon-pixel detector and a dedicated read-out boards, before beam commissioning began in early October to test the tracker prior to integrating it with the other sub-detectors for data taking.

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, 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://dxs.cern.ch/record/1951890.

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

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 bunch-merged hadron collider. The absolute luminosity at a particle collider is not only an important figure of merit for the machine, it is also a necessary tool for determining the absolute cross-sections for reaction processes. Specifically, the number of interactions, \( N \), measured in an experiment depends on the values of cross-section \( \sigma \) and luminosity \( L \), i.e.

\[
N = \frac{\sigma \cdot L}{\text{beam overlap}}.
\]

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 in the beam overlap using a combination of beam–gas and beam–beam interactions. The results are shown here for a selected colliding bunch pair and a central slice on the longitudinal axis.

A standard method to determine the overlap of the beams is the so-called “ghost” charge – also used by the ALICE, ATLAS and CMS experiments. For proton–proton interactions at 8 TeV, a relative precision of the luminosity calibration of 1.4% was obtained using van der Meer scans and 1.1% using beam–gas imaging, resulting in a combined precision of 1.2%. 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 (BOV), is being developed by a collaboration from CERN, EPFL, and RWTH Aachen. It includes a gas-injection system and a scintillating-fibre tracker telescope, which are expected to be commissioned with beam in 2015. For further reading, see LHCb Collaboration 2014 arXiv:1410.0149 [hep-ex].

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.

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Further reading


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NA62 gets going at the SPS

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NA62’s main aim is to study rare kaon decays, following on from its predecessors NA31 and NA48, which made significant 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 includes 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 straw-tracker chambers had been lowered into position in the experiment. The straw tracker is the first of its kind in terms of 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.

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

LHC beams

How 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 times luminosity L×N×σ, 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 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. 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 1.4% 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 (BOV), is being developed by a collaboration from CERN, EPFL, and RWTH 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


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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–nucleus collisions, primarily driven by the discovery of ridge structures in angular correlations of hadron multiplicities (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 region of low transverse momentum (pT) where the jet 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 (Δφ) and pseudorapidity (Δη) with respect to a trigger particle. The minijets reveal themselves as a peak on the “near” side (Δφ < 0, Δη > 0) and an elongated structure in η on the “away” side (Δφ = 0, Δη > 0) on top of the double ridge. The ridge structures themselves are found on the near and away side to be independent of η and almost symmetric around ±2. The production of the correlations on the away side 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, before and after ridge subtraction (see text for more details), is large, and stronger than for the jet in the away side. 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 exist, qualitative differences emerge in the 10–60% multiplicity class, where strong ridge effects are found. 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 in which the trigger particle yields from incoherent fragmentation of multiple parton–parton scatterings, while the double ridge is not jet related and is additive to the multiplicity class.

Further reading

B. Abelev et al. (ALICE Collaboration) 2014 JHEP 1402 078

The ψ(2S) nuclear modification factor, compared with the corresponding quantity for Z+Y 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 $\sqrt{s_{NN}}=5.02$ TeV in both the proton-going direction (rapidity 2.03 < ycms < 3.53) and the lead-going direction (~4.4 < ycms < ~2.96). The modification of the production yields induced by CNM, with respect to the corresponding proton–proton yield scaled by the number of nuclear–nuclear collisions, is quantified through the nuclear modification factor R_{Pb}, 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 charm 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 ce 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.

News

ATLAS takes a closer look at W+jets

The ATLAS collaboration has updated its measurement of production of W bosons in association with jets ($W+\text{jets}$), 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 of $W+\text{jets}$ 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 calorimeter coverage, which can measure jets at large rapidities. Unlike at previous colliders, where the $p_T$ values for the jets were a few hundreds of GeV-electron volts at most, the transverse momentum of the jets at the LHC can be an order of magnitude larger than the mass of the W boson itself. In these cases, large QCD corrections can be associated with the multiple scales in the event, and these are difficult to predict.
ALICE probes the role of mini-jets 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 high-lying 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 mini-jets – jet-like structures in the region of low transverse momentum (pT) 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 (Δφ) and pseudorapidity (Δη) with respect to a trigger particle. The mini-jets reveal themselves as a peak near the “near side” (Δφ = 0, Δη = 0) and an elongated structure in Δη on the “away side” (Δφ = ±π/n) on top of the double ridge. The ridge structures themselves are found on the near and away side to be independent of Δφ and almost symmetric around ±π/2.

The production of the correlations on Δφ makes it possible to quantify the particle production in semi-hard processes. The number of particles in the mini-jets is given by the integral under the peak 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, before and after ridge subtraction (see text for more details), changes in a region and subtracted from both sides of the correlation function. Non-symmetric components (e.g. cos Δφ) 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 exist, qualitative differences emerge in the 60% highest multiplicity class. 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 mini-jet yield stems from an incoherent fragmentation of multiple parton–parton scatterings, while the double ridge is not jet related and is additive to the near-side rapidity.

Further reading

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Heavy ion collisions...
For the first time, the gradient specification of the International Linear Collider (ILC) design study on 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. The gradient specification is the highest ever achieved on such a cryomodule, and it sets a new standard for future experiments at the ILC. The team at Fermilab used a combination of precise measurements and simulations to achieve this milestone. The results will inform the design and construction of future superconducting radio-frequency (SRF) cavities, which are critical components of the ILC electron-positron collider. The success at Fermilab highlights the combination of theoretical calculations, experimental measurements, and advances in superconducting technology that are needed to build high-performance SRF cavities for future accelerators.
CMS presents precision measurements of the top-quark mass from Run 1

Precise measurements of the top-quark mass 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 (CMS Collaboration 2014a), the dilepton and both jets that were accompanied by a W boson were used to measure the top-quark mass. 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 172.38 ± 0.10 ± 0.65 (value±stat.±syst.) GeV.

CMS Collaboration 2014b CMS-PAS-TOP-14-002


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 1 measurements.

CMS Collaboration 2014d

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 M V/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 M V/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 were combined together inside a cryomodule achieved an average gradient of 26 M V/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 for the SRF technology we announced earlier this year (CMS Collaboration 2014b, 2014c). It complements the results from the leptons+jets and all-jets channels that were announced earlier this year (CMS Collaboration 2014b and 2014c).

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The Metrolab PT2026 sets a new standard for precision magnetometers. Leveraging 30 years of expertise building the world’s gold standard magnetometers, it takes magnetic field measurement to new heights, measuring higher fields with better resolution.

The Metrolab PT2026 offers unprecedented flexibility in the choice of parameters, interfacing and probe placement, as well as greatly improved tolerance of inhomogeneous fields. And with Ethernet & USB interfaces and LabVIEW software, it fits perfectly into modern laboratory environments.
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 energetic effects.

No doubt, the evidence for extraterrestrial neutrinos recently reported by IceCube at the South Pole (p25 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 systems 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 charged 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 large 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 physics, 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 km³ 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.

Eric Berzig, 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 ultrathin 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.

Long-range tractor beam

A Star Trek-like tractor beam able to push or pull semitransparent gold-coated glass spheres over tens of centimetres has been developed by Vladimir 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.

Oxygen and the boring billion

In the beginning...the Earth had essentially no free oxygen in its atmosphere. The Great Oxidation Event occurred about 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, Neoh 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 chromite isomorphs 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.

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 insulin and improving hyperglycemia in diabetic mice. In human diabetes, 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 ex vivo production of transferrable insulin-producing human cells, and of the importance of continuing stem-cell work.

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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.
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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), Harder 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 brightened ones an order of magnitude more energetic than the microflares known as “Ehmer bombs”. This new finding contributes to an ever more complex view of the photosphere.

Oxidative stress: more than an oxymoron

The term “on paper” often means “theoretically”, but James Collins of Harvard University, the Sloan Foundation, 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 of 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.

Epileptic seizures treated with genetic tools

Epileptic patients have a greater risk of dying than healthy people, but now two teams of researchers have found a way to implant genetic tools on paper — in this case, in the form of a nanorobot that ingests brain cells and stops them from firing. The nanorobots not only detect epileptic seizures but also prevent them, and could solve a major problem for people with this condition.

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Further reading

N J Planavsky et al. 2014 Science 348 635.

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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 as an order-of-magnitude upper limit to the mass of the accreting compact object, ULXs should be intermediate black holes with masses typically 10 to 10,000 times the mass of the Sun. This is an unusual mass range left with the challenge of proposing a model to explain how a pulsar can radiate at about 10^31 W for a solar-mass star, which is about 10,000 times the luminosity of the Sun.

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 10^31 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 10^37 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, 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 such massive pulsars radiate at about 100 times its Eddington luminosity.

**Picture of the month**

This portrait of the Earth and Moon system was taken by the Chinese Chang’s 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.)

**Further reading**


**Artwork**

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.)
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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 $10^{33}$ W for a solar-mass star, which is about 10,000 times the luminosity of the Sun. 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.

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VERSATILITY IN HIGH VOLTAGE.

Getting colder

[Earlier this year] we reported the bringing into operation of a 45 cm³ 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 cm³ 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 He³/He⁴ dilution. The use of high-speed pumps (250 m³/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 disoriented state. At very low temperatures, the inertia of spins is so large 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 0.006 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 feet. 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 profuse 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.

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 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 (6 m K) for the CUORE experiment in Gran Sasso (see p5 this issue). The lowest temperature ever recorded, 0.0000000001 K (100 µK) reached at the Helsinki University of Technology Low Temperature Lab by nuclear magnetic ordering — brrrrrrrr!

Those venerable bubble chambers surely had charisma, resembling iconic submarines such as the Bathysphere of William Beebe and Otis Barton, who descended to a record-breaking 3800 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.
[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 4\pi 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\(^+\)/He\(^\ast\) 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 disoriented 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 0.006 K.

15-foot chamber

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Today’s “gold standard” for magnetometers, based on Nuclear Magnetic Resonance (NMR), was conceived at the CERN in the late 1970’s. Now on all new NMR magnetometers promises a breakthrough in high precision magnetic field measurement.

A 35-year old design goes into retirement CERN’s 1970’s-era design for an NMR magnetometer turned out to be a huge hit in the (admittedly minuscule) world of high precision magnetic field measurement. Originally conceived for one of the muon g-2 experiments, and perfected by the Geneva-based company Metrolab, it has established itself as the unrivalled magnetic-field reference for standards and research laboratories. It has also become an essential production tool for, for example, MRI system manufacturers. A derivative of the original design is still being sold today, as the Metrolab Precision Teslameter PT2025.

But now its designated successor, the PT2026, is in the starting blocks. This flexible and modern laboratory instrument promises to improve all key performance specifications of NMR magnetometers, by roughly an order of magnitude.

Pushing back the limitations of NMR magnetometers The foremost improvement concerns the measurement range. NMR magnetometers actually measure the NMR resonant frequency of a sample, directly proportional to the surrounding magnetic flux density. The PT2026 measures up to 1 GHz; for hydrogen nuclei, this corresponds to over 23 T, whereas the PT2025’s limit was 2.1 T. The primary limitations are the manufacturers’ experience in the use of ultra high-field superconducting magnets. The PT2026 also improves the measurement resolution. Today’s systems use the Continuous-Wave (CW) technique to detect the NMR resonance: sweep the RF frequency (or equivalently, modulate the field) and detect the absorption peak. The PT2026 also supports the Pulsed-Wave (PW) technique: excite the sample with a broadband pulse and detect the re-emitted frequency. The PW technique is more direct, and, combined with low noise and advanced signal processing, results in a ΔH resolution in stable, homogeneous fields – nearly one part per billion for strong fields; this allows, for example, magnet manufacturers to measure the field decay rate of new superconducting magnets more quickly, providing a clear productivity gain.

If appropriate, this resolution can be traded off against speed, by reducing the measurement integration time. Measurement rates of up to 20 Hz, instead of 1 Hz, now allow capturing short-lived transients. Another key limitation of NMR magnetometers is sensitivity to inhomogeneous fields, which cause a spread of resonant frequencies and make the resonance harder to measure. Side-by-side comparisons show that the PT2026 is 2.5x more tolerant than the PT2025, thus making NMR magnetometers suitable for many new real-world applications. The NMR sample size – on the order of millimeters – limits their use in very small gaps. CW probes also contain modulation coils and electronics close to the sample, which aggravates the situation. PW probes feature a much simpler, smaller probe head that can be several meters removed from the electronics. This is also useful in hostile environments, such as high radiation or low temperatures, which would cause the electronics to fail.

Ease of use through systems improvements In addition to pushing back physical limits, a modernized and improved system design improves the ease of use. A frustrating aspect of using an NMR magnetometer is that before starting to measure, the instrument has to painstakingly sweep through its entire frequency range to seek out the NMR resonant frequency. This process typically takes ten seconds – and may never terminate if something is wrong. The PT2026 dramatically reduces the time required, using a built-in 3-axis Hall sensor that reduces the search range by two orders of magnitude. A feature of the original CERN design is the close coupling of the RF generator with the probes. Feedback loops keep the RF generator tuned to the NMR resonance detected by the probe, and each step of a frequency divider corresponds to a probe with a different range. In the PT2026, the RF generator is freely programmable and decoupled from the probes, thus allowing customized probe ranges. Other examples of the many systems-level improvements include modern interface standards, full software support, input and output triggers, and the possibility of eliminating the need for calibration by using an external reference clock.

Wanted: challenging applications The PT2026 is a breakthrough in precision magnetic field measurement. Metrolab is especially excited to present this instrument to the high energy physics community, where it has its roots and where it will certainly find some of its most challenging and innovative uses.

Contact Claude Thabuis Sales and Production Manager www.metrolab.com
New heights in magnetic field measurement

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Contact
Claude Thabuis
Sales and Production Manager
www.metrolab.com

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.

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 collisions with 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 x 10^34 cm^2/s, 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 energy part of the run: the heavy-flavour tracker for STAR and the vertex detector for PHENIX.

This year marked the end of this upgrade period, which began much luminosity as possible, following a luminosity upgrade. 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, LNN = A1A2L, where L is the integrated luminosity, and A1 and A2 are the number of nucleons of the ions in the two beams, respectively. The use of LNN allows different ion combinations to be compared.

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.

Metalab

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

Heavy ions
Heavy ions 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. 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 maximize 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 $0.8 < \beta^* < 3 \times 10^{-8}$. 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 $\beta^*$-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 $\beta^*$, where $\beta$ is the function and $\epsilon$ is the emittance. In this scheme, the $\beta$ 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 $\epsilon$ decreases during the store, so that a larger $\beta$ function can be accommodated in the final focus triplets. With this, the $\beta$ function at the interaction point ($\beta^*$) – and therefore the beam size – is reduced, leading to an increase in luminosity. After about one hour, the transverse emittance $\epsilon$ is reduced by a factor 2.5–3, and eventually to less than 1 mm$^3$.

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 characteristics, 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 $\beta$ beat in the machine from 40% to 10% – it was possible to ramp the lattice dynamically into its new set point, sending the $\beta^*$ 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 $\beta^*$ set point was commissioned during dedicated beam-experiment periods.

Figure 4 shows the luminosity at the STAR detector before, during and after a $\beta^*$ squeeze, 7 h into a physics store in a gold run in 2014. The scheme takes advantage of the fact that, owing to stochastic cooling and the dynamic $\beta^*$-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 and the dynamic $\beta^*$ squeeze, ions can be stored and burned off in the collisions in a way that is most useful to the experiments.

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, there was 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-bunching 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


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 ont été amenés à entrer en collision à basse énergie (7,3 GeV/nucleon) comme à haute énergie (100 GeV/nucleon). 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 et Wolfram Fischer, Brookhaven National Laboratory.
Heavy ions

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

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 maximize 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 σp = 1.8 × 10^{-4}. The machine performance during the 2012 run with uranium–uranium and copper–gold was such that beam losses were already dominated by burn-offs (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 σβ, where β is the function and r 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 r 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 (βf) – and therefore the beam size – is reduced, leading to an increase in luminosity. After about one hour, the transverse emittance r 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-suppliers’ 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 function in the machine from 40% to 10% – it was possible to ramp the lattice dynamically into its new set point, sending the βf from 0.7 m down to 0.5 m. This could only be done reliably with the help of orbit and tune feedbacks. Prior to their operational implementation, each new βf set point was commissioned during dedicated beam-experiment periods.

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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 organisation 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


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-650032.)

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.

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 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.

The Proton Synchrotron (PS) Group

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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-701182.)

The Proton Synchrotron (PS) Group

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 useful later in life.

The years 1954–1959

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
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Assisting the birth and growth of CERN

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

Les premières années

Lorsqu’on est passé des baraquements 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 ce qui se passait au SC et il disait que, si l’on doit prendre l’ascenseur pour aller dans les ateliers, on le ferait 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’embellissaient et travaillaient beaucoup, mais aussi les administrateurs, les stagiaires, les gens dans les ateliers. On sentait qu’il 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, d’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 nos déchargeurs des tâches qui nous prenaient trop de temps précieux pour d’autres choses, mais on ne doi ni l’entendre, ni l’accepter.

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 séance du Conseil et la deuxième avait alors lieu à Amsterdam, juste au moment de mon arrivée à Rome. Nous avions tout de suite au beau temps de travail de préparation sur le projet de la 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 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 qu’ils 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 avions ainsi fait connaître le bas d’ingénieurs et de physiciens dont certains sont venus plus tard au CERN.

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-70182.)

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 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 Dahi, [Wolfgang] Gentner, [John] Cockcroft, [Edoardo] Amaldi, etc, selected very 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 Dahi 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 fitted the study-preparation phase, and then what I would have considered a more practical person could take over and lead the project.

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

The atmosphere, the enthusiasm, the communication was still 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, Bao De-Rao, Lorenzo Rescegti 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 build, 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 joined the PS construction team in 1954. In 1958, he developed the phase-lock feedback system that solved the problem of beam losses during the start-up. He later contributed significantly to the QR 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+p collider. (For more, see CERN Courier December 2006 p36.)

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 IF 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 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 bremsstrahlung of the LHC. (For more, see CERN Courier October 2007 p41.)

From the PS to computing

The PS and Mont Citron

The initial work on the experimental facilities of the PS had been under [Wolfgang] Gentner, together with Asenio 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 hall that was called Mont Citron, which was built 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 Varena 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

Mervyn Hine, left, and Ben Segal, with the 3 m antenna for the STELLA satellite project – conceived by Hine – which interconnected six European labs. (For more, see CERN Courier May 1955 p11.)

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, Pasiol Zanaleti 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… 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”.


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 Harlow twins”. With the PS commission, Hine became director for applied physics in 1960, first under Adams as director-general and then under Victor P. Weisskopf. Hine contributed to every aspect of particle physics, in particular to medium-term planning for the whole laboratory. (For more, see CERN Courier June 2004 p47 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 a search on neutrinos 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 even 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, Jülich…

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60 years of CERN
Pioneering at the Proton Synchrotron

Wolfgang Schnell, centre, discusses plans for the future ISR with Lorenzo Resegotti, right, and Arnold Schoin, in 1964. (Image credit: CERN-GE-64/070/F.)

The atmosphere, the enthusiasm, the communication was still 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 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 1958, he developed the phase-lock feedback system that solved the problem of beam losses during the start-up. He later contributed significantly to the QF 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+p collider. (For more, see CERN Courier December 2006 p46.)

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At the meeting in Varese 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 the PS, considering the PS focusing system. (Image credit: CERN-PHOTO-8001439-1.)

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A link with other countries

Giuseppe and Vanna check cosmic-ray detectors in this photograph from 1949. (Image credit: Time&Life/Getty Images.)

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

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

ISOLED: a northern attraction

The early ISOLED

Gregers Hansen

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 ISOLED 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 Wessellkopf, 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 [also] 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 played 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 ISOLED

I think the new ISOLED at the Booster would not have existed without [Carl] 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 1964. He spent a large part of his scientific life connected to CERN and ISOLED – he was ISOLED group leader in the years 1970–1975, and deputy division leader in the Experimental Physics Division in the years 1974–1977. (For more, see CERN Courier November 2005 p48.)

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 will interest them. Of course what do we 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 Perusio, 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 stated what time is, at least in physics, which essentially goes to motion. Time is given 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? First, try to improve the teaching of physics at university level and also at school level. The European Physical Society (EPS) get involved in that because it is a society...
A link with other countries

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

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.

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

ISOLDE: a northern attraction

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Gregers Hansen, right, with Willibald Jentschke, director-general of Luh, in 1975.
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 universities, [the second with] different university communities, both at graduate and undergraduate level, and thirdly helping with exchange programmes with the European Union.

A director in the early 1970s

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

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 [I] was not giving CERN the share that a journal 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 realise that CERN Courier is not serving CERN only but the world community of particle physics. This arrangement was that agreed in 1974 by the directors of the major laboratories – that it would be a unique journal serving the whole community. ...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”.

After starting his research career in Saclay, with time at Brookhaven and CERN, Maurice Jacob joined CERN in 1967. A theoretical physicist, he brought theorists and experimentalists together to develop 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 p31 and October 2003 p4.)

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 close 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 also 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] Johnson 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 Geneva. Lab 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.

A director in the early 1970s

Kees Zilversoons, left, Kjell Johnson and Arnold Souch 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-6303027.)

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A bridge between accelerators and experiments

Kees Zilversoons joined CERN in May 1954 as an applied physicist to work on the construction project for the PS, and by John Adams. He contributed to many of CERN’s accelerators projects for more than 30 years, up to 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.)

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

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 p̅p 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 p̅p we might have had a strong erosion of the CERN budget.

The IUA 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 p̅p 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 Darrilat. I remember very vividly the beautiful presentation by Luigi Di Leila, which was a masterful presentation of an experiment. After the experiment of Darrilat was approved, we 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.


As early as 1962, Franco Bonnardi went to Liverpool at Edoardo Amaldi’s request, to learn about synchrocyclotrons and join the study group led by Cornelis Bakker for CERN’s 500 MeV Synchrocyclotron (SC). He went on to oversee construction of the SC, and to lead the effort 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.)

A bridge between accelerators and experiments

The p̅p 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 [Simone] 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 of how many antiprotons would really be produced by a target with that kind of primary proton beam with that solid angle. It was proposed by Paul Fink- 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.

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60 years of CERN
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.

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

The division leader had his power. The director had, as a second task, to direct-general, because he was responsible to the director-general for developing and maintained. The director had the double task to see that the division worked, thirdly helping with exchange programmes with the European Union.

The division-leader role was simple: to make sure that the division worked, to get it through 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] Johnson 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 Provence. Lab 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 coordination meeting was set up with the two directors-general – Jenssche and Adams – Hans-Otto Walter, George Hampton and Lévy-Mandeld and me. We were having meetings once a week and discussed the problems.

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 close 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 [making] 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.

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Two laboratories (1971–1975)
The transition [to two laboratories] with Adams went smoothly, but what didn’t
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” 5

The signal region requires more than 6000 photoelectrons, with fewer than three of the first 250 photoelectrons in the signal. The colour indicates the arrival time, from red (early) to purple (late), while the size of the dots indicates the number of photoelectrons detected. (Image credit: IceCube.) Fig. 4. One year of IceCube data as a function of the total number of photons present in the veto region.

The IceCube lab

The 177,544 events in the northern-hemisphere sample are mostly downgoing muons. 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 × 1019 eV) interact with photons of around 10–4 eV in the cosmic-microwave background, exciting them to a Δ resonance.

νμ
ντ
and
νe
– each leave
signature – one shower when the ν 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, 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 high-energy muons, which are less likely to be of atmospheric origin. The 177,544 events in the northern-hemisphere sample are mostly from ν. 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.

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Δ→πν
Δ→νπ
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Δ→νK

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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 have different signatures in the detector. Charged-current ν_μ produce high-energy muons, which leave long tracks. All ν_μ interactions, and all neutral-current interactions, produce hadronic or electromagnetic showers. High-energy ν_μ produce a characteristic “double-bang” signature – one shower when the ν_μ 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 as far as required. The “live” times are also impressive – in the range of 95%.

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Some might originate in the Galaxy, but there is no compelling evidence for that. Many explanations have been proposed for the IceCube observation. Dark matter can be gravitationally captured by the Earth, the Sun, or the dwarf galaxy satellites of the Milky Way. The latter hypothesis is strongly supported by the fact that dark-matter particles with masses of 100 GeV–600 GeV are expected to interact via elastic and inelastic scattering with neutralinos. The signal observed by IceCube is consistent with the hypothesis that dark-matter particles with a mass of 100 GeV–600 GeV are being absorbed by the Earth. The IceCube collaboration has also reported the detection of a signal from the next supernova in the Galaxy. These explosions produce a burst of neutrinos, which are emitted by the explosion of a star and decay of the iron core. The neutrino signal observed by IceCube is consistent with the hypothesis that a supernova explosion occurred in the Galaxy within the last few million years. The IceCube collaboration has also reported the detection of a signal from a high-luminosity gamma-ray burst. The gamma-ray burst is likely to be associated with the explosion of a neutron star. The IceCube collaboration has also reported the detection of a signal from a high-luminosity gamma-ray burst. The gamma-ray burst is likely to be associated with the explosion of a neutron star. The IceCube collaboration has also reported the detection of a signal from a high-luminosity gamma-ray burst. The gamma-ray burst is likely to be associated with the explosion of a neutron star.
Astroparticle physics

A neutrino with a typical energy of $10^{18}$ eV (1 EeV). The search for new events had an energy near 1 PeV, the analysis produced evidence that a neutrino with such energy, isolated downgoing neutrino is highly likely to be cosmic.

Going 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 that these high-energy neutrinos were protons. The collaboration added a third year of data, pushing the significance above the “magic” 5 $\sigma$ level (Aartsen et al. 2014a). One of the new events is an atmospheric neutrino above 2 PeV, making it the most energetic neutrino ever seen.

The observation of a flux of cosmic neutrinos was 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 a background flux of 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: $\phi = 2.06 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$ (Aartsen et al. 2014d).

Within the limited statistics, the flux varies isotropically and is consistent with the $\nu_\mu: \nu_\tau$ ratio of 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 of the events selected for the IceCube observations, ranging from the relativistic particle jets emitted by active galactic nuclei to gamma-ray bursts, to starburst galaxies to magnets. IceCube’s dedicated searches do, however, disfavour gamma-ray bursts as the source. A spectral index of $\beta = 2$ ($\nu E \propto E^{-\beta}$), 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.

**Other physics**

The 100,000 neutrinos and $85 \times 10^5$ cosmic-ray events recorded each year provide ample opportunities to search for dark matter and 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 $\sigma$ level that have not been observed previously. It has also studied transverse energy events, such as muon-free showers expected from photons with peta-electron-volt energy, produced in the Galaxy, and investigated isolated muons produced in air showers. The latter have separations that shift from a power-law 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 $\nu_e$ flux develops a first minimum at 28 GeV.

Figure 6 (opposite) shows the observed $\nu_e$ flux, seen in one year of data, using well-reconstructed events contained within DeepCore. In the change in flux with distance travelled (energy) ($E$) is consistent with $\nu_e$ oscillations and consistent with a no-oscillation scenario. IceCube constraints on the mixing angle $\theta_{13}$ and the mass hierarchy are also improving, as shown in figure 7.

IceCube also searched for neutrinos from dark-matter annihilation. Dark matter can be gravitationally captured by the Earth, the Sun, or in the core of the Galaxy. Then the accumulated dark-matter particles annihilate, producing 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 a neutron source, allowing IceCube to see the Sun’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 very first weak interactions in the Galaxy. These explanations may explain 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.

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 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. Neutrinoless double-beta decay would be a smoking gun for the existence of Majorana neutrinos, electrons, modifying the oscillation pattern in a way that differs for normal and inverted hierarchies. In addition to a threshold of a few gigaelectron-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 Ice Neutrino Next-Generation Upgrade, or PINGU (Aartsen et al. 2014b). The design consists of 40 additional high-sensitivity strings equipped with improved calibration devices. PINGU should be able to determine the mass hierarchy with 3 $\sigma$ significance within about three years, independent of the value of the CP-violation phase.

IceCube’s high-energy extension (IceCube-gen2) will expand a detector with a 10-times-larger instrumented volume, albeit with a higher energy threshold. It will explore the cosmic-ray physics and cosmogenic neutrinos from beyond 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 neutrino 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 performed in the Mediterranean Sea (KME3NeT) 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. Sun, or in the case of construction, the completed IceCube collaboration came on line in December 2010. It has achieved the outstanding goal of observing cosmic neutrinos and has produced important results in various 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 suspicions 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.

**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 des plus violentes des jets dans le CERN. Le détecteur a observé des neutrinos provenant d’au-delà du Système solaire à des énergies dépassant 60 TeV, avec les 3 neutrinos 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 supernebres. 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 collisions at √sNN = 5.02 TeV, proton–lead collisions (√sNN = 5.02 TeV), and lead–lead (√sNN = 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(p, p, p), is measured by sampling all three pions from the same event. The second distribution, N(p, p, N(p)), is measured by taking two pions from the same event and the third from a different event. Finally, the third distribution, N(p, N(p), N(p)), is measured by taking all three pions from different events.

From the measured distributions, the full three-pion correlation function C(p) can be formed and projected onto the relative size.
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.

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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 correlation can be likened to a thermal light source, with correlated pion moments offering a window on the size of the source.

Further reading
G Cocconi 1974 Phys. Lett. 44b 659
R Hanbury Brown and R Q Twiss 1956 Nature 177 27
G Goldhaber et al. 1960 Phys. Rev. 120 300

CERN Courier December 2014
momentum variable \( Q^3 = \sqrt{q_{12}^2 + q_{23}^2 + q_{31}^2} \), as shown in figure 1, where the invariant relative momentum of a pair is defined as \( q_{ij} = \sqrt{-\mathbf{p}_i \cdot \mathbf{p}_j} \). The figure shows the cumulant correlation function \( c_i \), 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 (see main text).

The regions of overlapping multiplicity for the lead–lead, proton–proton overlap zone suggests that the proton–lead system is only 5–15% larger than the proton–proton system at similar multiplicity. In the proton–lead overlap zone, the proton–lead system is only 5–15% larger than the proton–proton system at similar multiplicity. 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**


**Résumé**

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


Dhevan Raja Gangadharan and Constantinos Loizides, Lawrence Berkeley Laboratory.

![Image 1](https://example.com/image1.png)

As ICTP reaches its first half-century, the 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. “Theorists are 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 computing.

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.

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

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momentum variable \( Q = \sqrt{q_1^2 + q_2^2 + q_3^2} \), as shown in figure 1, where the invariant relative momentum of a pair is defined as \( q_i = (p_i - p_j) \). The figure shows the cumulant correlation function \( \langle c_3 \rangle \), 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 (see main text).

Bose–Einstein correlations occur only for same-charge pions, while Coulomb and 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 contaminations). 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

\[
Q_3 = \sqrt{q_1^2 + q_2^2 + q_3^2},
\]

in proton–lead and proton–proton collisions. The proton–proton–proton–lead overlap zone suggests that the proton–lead system is only 5–15% larger than the proton–proton system at similar multiplicity.

The systematic uncertainties are dominated by fit-range variations, and are shown by bounding lines and shaded boxes for two- and three-pion correlations, respectively.

Further reading


Résumé

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In June 1960, the Department of Physics at the University of Trieste organized a seminar on elementary particle physics in the Castelforte 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.

ICTP’s 50th anniversary

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*For the whole programme of events with photos and videos, visit [www.ictp-itc50-anniversary.aspx](http://www.ictp-itc50-anniversary.aspx).*

Interview

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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 technologies. 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, understanding the universe and its functioning should be recognized right from everyone. “I come from Guatemala and have the same rights as Americans and Europeans to address the big questions,” confi rms 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 scientifi c projects is the scientist.”

ICTP has the specifi c 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 fi rst 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 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 [https://indico.cern.ch/event/331449/](https://indico.cern.ch/event/331449/).

Résumé

Le CPT : des théoriciens dans les pays en développement

A peine 10 ans plus jeune que le CERN, le Centre international de physique théorique Abdus Salam (CIPT) a célébré son 50e 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

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Astroparticle physics

CERN Courier December 2014

Cosmic particles meet the LHC at ISVHECRI

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 Patterson, 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 × 1018 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 hadron-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 cancel the LHC data rather well, some tuning 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.

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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.”

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Many talks at the symposium illustrated the importance of multimessenger observations in astroparticle physics, for under-
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 10^17–10^19 eV range, mainly in oxygen, with high energy flux. The astrophysical signal is seen mainly in neutrinos from the southern sky (downgoing). The limited acceptance acceptance in the forward direction at the LHC, QCD calculations and models are still of central importance for understanding high-energy 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/.

Résumé
ISVHECRI : des particules cosmiques rencontrent le LHC

Ralph Engel, Karlsruhe Institute of Technology.
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The remaining uncertainties in predicting hadron production 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.

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Résumé
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Ralph Engel, Karlsruhe Institute of Technology.

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 neutrino 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 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.

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, Roel Heuer.

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

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

Guillaume Unal, of CERN, has been awarded the Jean Ricard Prize by the French Physical Society (FPS). He was presented with the award by Alain Fontaine, president of the FPS, in a ceremony at the Musée du quai Branly on 21 October. At a presentation by Livio Mapelli, head of CERN’s physics department, Unal

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. Hiroshi 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.

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 in a series 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.

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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 Alain Blondel and Daniel Fournier. (Image credit: Louis Fayard.)

Awards

French Physical Society honours Guillaume Unal

Guillaume Unal, of CERN, has been awarded the Jean Ricard Prize by the French Physical Society (FPS). He was presented with the award by Alain Fontaine, president of the FPS, in a ceremony at the Musée du quai Branly on 21 October. At a presentation by Livio Mapelli, head of CERN’s physics department, Unal

had a 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 y 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 physics are Georges Charpak, Patrice Mussat, Marcel Banner, Yves Decrais, Alain Blondel and Daniel Fournier.

On 25 June, Evangelenos Palms 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 Descloux, director of the institute, who also cited the work of Gazis in the development in Greece of medical applications of particle physics, such as proton therapy. (Image credit: Institut Français de Grèce.)

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 particle physics, condensed matter and string models. Keldysh received the award for outstanding results in solid-state physics, including the theory of tunneling 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.

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. Utilising 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 the international community. The JAI 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 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 been a focus of accelerator research in the UK significantly, gaining international leadership in this vital scientific area, and they have contributed strongly to the 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.
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.)

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Unal, a presentation by Livio Mapelli, head 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

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CERN 60

Faces & Places
CERN Courier December 2014

Faces & Places

Vi S i t s

Tom Kibble visited LHIC experiments for the first time on 10 and 11 November, on his way to Trieste, where he had participated in the 50th anniversary celebrations of the Abdus Salam International Centre for Theoretical Physics (p38). After visiting the ATLAS and CMS Detector Control Centres, he delivered a colloquium on the generation of electroweak unification and the Englert–Higgs mechanism. The following day, he went underground to see CMS, seen here, before returning to the UK. (Image credit: CERN-Photo/CH-2014-009-8.)

M e e t i n g

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 unidirectional technology and free-electron laser science. The national and international free-electron laser community is being called to thematic 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://db065.uchicago.edu/www/Indore_FEL_workshop_2014_a.pdf.

C o r r e c t i o n

Which was the first cross-border accelerator? The October issue of CERN Courier (p9 and 24) asserted that it was the Super Proton Synchrotron, which started 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).

O b i t u a r i e s

Walter Thirring 1927–2014

Walter Thirring, one of the most important theoreticians in Austria since 1945, passed away in Vienna 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 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 1945, he returned to Europe as a lecturer at the University of Bern, and also held positions in Rhodes and Oxford (UK). 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. In 1953, Walter moved to CERN and started collaboration with Rudolf 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 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 mechanics 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’s European Laboratory for Particle Physics (p38), from 1998 to 2014. As a member of the directorate, Walter participated in the decision to install a new 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 physicists 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.

Bruno Righini 1931–2014

Bruno Righini, who for 32 years was responsible for the Electronic Test and Measurement 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 modern theoretical physics, 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 impetus 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 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 the equipment. He also coordinated the main section of the CERN reporting system for electronics, which included more than 100 laboratories. In all these respects, Bruno contributed considerably to improving the electronics of experiments at CERN and in Vienna.
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 (AICTP). After visiting the ATLAS and CMS areas of CERN, 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-R.)

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He was open minded and liked to listen, in opinions ever becoming a point of importance. For many of us, he was not only a colleague but also a dear friend, to the extent that we feel the sadness of being treated with due consideration. We will always remember Bruno, his natural wisdom, his quiet wit and his deep understanding of our human society at CERN. He will be missed by all who knew him.

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.

Kadyshevsky was born on 5 May 1937 in Moscow. He studied at the Savoio Military School 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 postgraduate researcher at the JINR in Dubna.

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.

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In 1964, Kadyshevsky published a series of papers dedicated to the covariant 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. Application to the problem of constructing the effective 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 formulation. This approach allows the transfer of research methods, intuition and experience accumulated in the theory 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.

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Staff members of JINR.

In December 2010, a coating on CERN’s Globe of Science and 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-1021235-01, top, CERN-GE-630205, right, CERN-GE-1021315-04, below

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 regular status. Applicants should have a PhD 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 exposed to research at CERN.

Application should be made via the portal located at http://indiana.postdocadmin.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.

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 Stanford, Washington and Livingston, Louisianna. 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.

More information about LIGO available at www.ligo.caltech.edu

For more information about Ligo, please visit the website at http://ligo.caltech.edu.

Leung Center for Cosmology and Particle Astrophysics

The Leung Center for Cosmology and Particle Astrophysics (LeCoPa) of National Taiwan University is pleased to announce the availability of several Post-Doctoral Fellow or Assistant Professor 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 LeCoPa Distinguished Junior Fellows with competitive salary. LeCoPa 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 ORB telescope UFFO that can slew to the event within 1sec. These positions are available on August 1, 2015. Interested applicant should email letter of application with curriculum vitae, research statement, publication list and three letters of recommendation before December 1, 2014 to Ms. Van-Ling Lee at reinsteg@ntu.edu.tw.

For more information about LeCoPa, please visit the website at http://lecopa.astronomy.nthu.edu.tw.

Leung Center for Cosmology and Particle Astrophysics
National Taiwan University

NATIONAL TAIWAN UNIVERSITY
Leung Center for Cosmology and Particle Astrophysics

Distinguished Junior Fellowship

LeCoPa 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 ORB telescope UFFO that can slew to the event within 1sec. These positions are available on August 1, 2015. Interested applicant should email letter of application with curriculum vitae, research statement, publication list and three letters of recommendation before December 1, 2014 to LeCoPa Distinguished Junior Fellowship.

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National Taiwan University

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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 capacity as the institute’s scientific leader, he contributed greatly to the development of JINR’s cooperation at JINR.

He undertook a range of scientific and organizational activities. He was member of the President 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 Societies of Russia and a member of the board of directors of the International Union of Pure and Applied Physics. His scientific achievements brought a number of prizes, and he was an honorary or foreign member of various academies. Vladimir Kadyshhevsky 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.
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. The Director interacts with ESS’s scientific instrumentation, scientific support facilities, 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, possessing strategic direction and shaping the implementation of technical solutions and best practices that address ESS’s priorities. The Director advises the Director General on all 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 the implementation and operational phases.

Responsibilities:

- Develops and directs the ESS’s Neutron Scattering program to assure the effective delivery of the ESS’s neutron scattering programs to in-kind deliverables.
- Coordinates and manages the planning and implementation of the scientific instruments, scientific support facilities and the Data Management and Software Center.
- Provides leadership and professional direction to the staff within the Directorates.
- Leads efforts to secure the ESS’s success during the implementation and operational phases.
- Conducts activities to identify and manage risks.
- Manages and coordinates the relationship with partner institutions.
- Leads activities to ensure that the ESS remains internationally competitive.
- Provides direction on cross-Directorates’ matters.
- Oversees the appointment of the Director of the Institute for Neutron Scattering, with the approval of the Director General.
- Provides oversight of the activities of the ESS’s External Advisory Board.

The successful candidate is an experienced leader in neutron science, with a background in related technical fields. The successful candidate will have a track record of success in the development and operation of neutron instruments and scientific programs, particularly with a focus on the delivery of neutron scattering facilities.

Requirements:

- PhD in Physics, Neutron Science, or a related field.
- Demonstrated experience in neutron science and neutron scattering facilities.
- Excellent communication skills and ability to interact effectively with both internal and external partners.
- Strong ability to lead and manage a team.
- Strong ability to develop and maintain partnerships with other institutions.
- Strong ability to communicate complex ideas to a wide audience.
- Strong ability to work in a fast-paced environment.

Successful candidates will be part of the ESS’s Executive Management Team, which will be responsible for the overall management of the ESS’s scientific program.

This position is intended either for an engineer or for a physicist. A good understanding of neutron science and neutron scattering facilities is required.

We thank all applicants in advance.

Virginia Tech

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 [http://www.phys.vt.edu/jobs/cmt/]. Candidates should apply at [http://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).

The Helmholtz Association is Germany’s largest scientific organization. [www.helmholtz.de]
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Reach an international audience
brightrecruits.com
NIU-Fermilab ACCELERATOR RESEARCH CLUSTER

A new joint initiative between Northern Illinois University (NIU) and Fermi National Accelerator Laboratory (Fermilab) envisages developing a collaborative program with targeted and matched mutual investments to create a cluster of research excellence in advanced accelerator science and technology. The research cluster will enable “discovery-class” science driven by charged particle beams and associated advanced techniques and technologies of superconducting cavity electromagnetics, high-field magnets, lasers and nonlinear dynamical control of particle, atomic and molecular beams. The R&D will be directed towards developments in particle physics and related disciplines of cosmology, material and life sciences and their applications to societal grand challenges of energy, environment, health and security.

Opportunities exist to contribute to large scale national and international accelerator activities such as the development of the long baseline neutrino facility at Fermilab and TeV-scale collider developments worldwide as well as cutting edge innovative research in laboratory - scale experiments to investigate the “dark” sector of the vacuum and other precision experiments e.g. “g-2” and “mu-to-e”.

Working seamlessly with the outstanding accelerator research staff at Fermilab, NIU physics and engineering departments and its Northern Illinois Centre for Accelerator and Detector Development (NICADD) and the consortium of mid-western universities and laboratories, with access to advanced accelerator test facilities at Fermilab, ANL and other international laboratories such as CERN (Switzerland), DESY (Germany), ESS (Sweden), John Adams Institute and Cockcroft Institute (UK), the cluster will offer unique collaborative research opportunities. Details of specific opportunities and recruitment will be announced in near future. Prospective Masters- and PhD-level students, postdoctoral fellows, research scientists and aspiring academic faculty members should contact Professor Swapan Chattopadhyay (scchat@niu.edu or swapan@fnal.gov) for further details and send early expressions of interest and professional background information in advance.

The Review of Particle Physics

Particle physics and cosmology are complex and extensive areas of research; they are constantly being explored with reports of new discoveries being published all the time. The Review of Particle Physics summarises and collates most of this research, bringing together the data to create a comprehensive report on the current state of the field.

The 2014 edition of the Review of Particle Physics will be published for the Particle Data Group as an article 090001 in Volume 38, No. 9 of Chinese Physics C and will include:

- Data from previous editions as well as the latest papers
- 3283 new measurements from 899 papers
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- All of the particle properties and search limits listed in summary tables
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- New and heavily revised reviews

Published in partnership with:

- Institute of High Energy Physics of the Chinese Academy of Sciences
- Institute of Modern Physics of the Chinese Academy of Sciences

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 

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 David Marion
Prometheus Books
Hardback: $22.95
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 irreducible 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, before 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 last chapter is devoted to 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 replaid that the gravitational lines of force could “weave a web across the sky” and “guide the stars in their courses”.

With the discovery of the 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.

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In an artistic interpretation of a plot of the constraints of various CKM elements. See the review for more interesting short annotations from interesting short annotations from

IOP Publishing | science first

Festive Bookshelf

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Prometheus Books

Hardback: $29.95

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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.

- Maximo Giovanini, CERN and INFN
- Milan-Bicocca
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 scaffold 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 reject them or make them very light.”

The book is an excellent guide to anyone interested in witnessing that important step in the progress of fundamental physics.

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**Time in Powers of Ten: Natural Phenomena and Their Timescales**

By Gerald H. Joffe and Stefan VandenHeuvel (translated by Stanislaw Srbik and Victor Hooft)

W. H. Freeman

Hardback: £31
Paperback: £16
E-book: £12

Also available at the CERN bookshop

Publishing and the Advancement of Science: From Selfish Genes to Galileo’s Finger

By Michael Rodgers

World Scientific

Hardback: £50

Paperback: £16

E-book: £9.95

Also available at the CERN bookshop

In Publishing and the Advancement of Science, retired science editor Michael Rodgers takes us on an autobiographical tour of the world of science publishing, taking in textbooks, trade publications 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 go with writing 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 revolution that is going on today, greater authors or brilliant typographers 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 some popular science books work and others fail, in a nagging 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— started 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 world 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 was 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— alterations 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 popular science books work and others fail, his short shrift of telling us what makes them great.

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**The Perfect Wave: With Neutrinos at the Boundary of Space and Time**

By Heinrich Päs

Harvard University Press

Hardback: £19.95

Paperback: £16

E-book: £12

Also available at the CERN bookshop

The Perfect Wave begins with an entertaining introduction that links the Ancient Greeks and atomism to the effects of psychedelic drugs (and nowadays) particle physics. The book then 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 mass 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.

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 supergeometry, 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, these biographical anecdotes always take 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 described).

All in all, this book is much more detailed in its description of particle-physics theories (present 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 book to pick up.

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**CERN: How We Found the Higgs Boson**

By Michael Krause

World Scientific

Hardback: £38

Paperback: £16

E-book: £14

Also available at the CERN bookshop

AsJets: We Menschen und Teilchen aufeinandertreffen: Begegnungen am CERN

Wiley-VCH

Hardback: £22.50

Paperback: £14.90

E-book: £14

Also available at the CERN bookshop

There have been quite a few books recently published about Fermi’s theory of neutrino interactions which are aimed at— might I say, 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 at 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 supergeometry, which postulates the existence of an entire zoo of other particles.
Time in Powers of Ten: Natural Phenomena and Their Timescales

By Gerald H. Huth and Stefan Vandenbosch (translated by Stanislaw Przybylak)

World Scientific

Hardback: £31
Paperback: £16
E-book: £12

Also available at the CERN bookshop

Leaping in powers of 10, the book races through the phenomena of the universe, be it the esoteric or the more mundane. The book reveals the extraordinary complexity of our universe — it is a fascinating journey.

Also available at the CERN bookshop

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 book describes the development of the neutrino in the history of quantum mechanics, the Standard Model of particle physics, and the implications for the Standard Model, and even delves a little into supersymmetry as a natural extension. 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 not be the case.

The text discusses the importance of understanding the fundamental forces of nature, and how they are interconnected through the Standard Model. It also explores the role of neutrinos in the early universe, and how they could potentially explain the existence of dark matter. The book delves into the latest research on neutrino oscillations and the search for neutrinoless double-beta decay, highlighting the role of CERN’s experiments in these fields.

The text also emphasizes the importance of experimental physics in advancing our understanding of the universe. It highlights the role of collaborations between experimental and theoretical physicists, and the need for continued support for basic research.

In conclusion, this book provides a fascinating insight into the world of neutrino physics, and the role of experiments at CERN in advancing our understanding of the universe. It is a must-read for anyone interested in the latest developments in this field of physics.
Faithful to Science: The Role of Science in Religion
By Andrew Steane
Oxford University Press
Hardback: 07.19.15
Also available as an e-book
The interface between science and religious faith represents one of the most important ways in which people engage with the world. The book develops a view of human endeavour that includes religious faith and science. I hope that it inspires people to see one another as 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.

Faithful to Science: The Role of Science in Religion

Andrew Steane

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 indubitably that the most general worldview of human life embraces both science and theistic belief naturally, and that there is no conflict between the two. CERN is also reflecting on these themes in the 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 how 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 mindset of a world view of human endeavor that includes religious faith and science. I hope that it inspires people to see one another as 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.

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 highest 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 it is today the renowned ‘Hagedorn paper’. The Hagedorn temperature and the SBM were officially born (CERN Courier September 2001) already.

It is relevant to recapitulate what the dates on the CERN-TH preprints mean. In those days, a handwritten manuscript was handed to Tania Fabergé, the Theory Division (TH) secretary. I received a sequential TH preprint number and the 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 Pretkki.

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 seminars in the winter of 1973/74, I see a blackboard full of clean, exact equations — and his sign not to clean the board, because he knew we would resume the early morning.

But how did Hagedorn, with his uncanny physics instinct, by way of what and what motivation at what time and at what temperature 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 atmosphere at which the colliding QCD vacuum structure dissolves, and the structure of matter changes from hadrons to quark–gluon degrees of freedom. The exponential growth in the understanding of these degrees of freedom started as the result of the quest for 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 on the path leading to the expansion of the SBM towards a quark–gluon plasma. To achieve this goal, we introduced the conserved baryon quantum number, and a reaction volume concept that we named a “multiparticle hadron state”. The outcome was that under enough pressure, the Hagedorn clusters dissolve into quark–gluon plasma.

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 at 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 “unlisted conference reports”. Other events are also being planned to emphasize the importance of this anniversary.
about CERN and its latest “biggest” discovery – the Higgs boson. According to the referee, 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 their experience, and to examine how and if they learn how they feel about working in such a “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 I was interested in the explanations, 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 interviews. It was hard to regain the conversation one or two pages later.

Nevertheless, you do get to know some hard-core scientists at their personal level. Their answers give the reader a glimpse of the grand enthusiasm that is CERN, and they also hint that the adventure is far from over – even after the Higgs discovery. And with all the backgrounds, it is evident that many of these do not have a physics degree to gain a basic understanding of the science.

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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, it is a very personal way of seeing the world.

In conclusion, the book should appeal to anyone who has an interest in the understanding of the world view of human endeavour that includes religious faith and science. I hope that it inspires people to open their eyes 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.

Emanuel Tenenbaum, CERN

Books received
What Makes a Champion? Over Fifty Extraordinary Individuals Share Their Insights
By Allan Snyder (ed.)
World Scientific
Paperback: £19.95
E-book: £9.95

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 well-known names, such as Nelson Mandela, Edmund Hillary and Carson Dugan. The book is therefore timely.

Interviews with a dozen scientists working at CERN

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 complete the mass spectrum. This led me to recognize that not even exponential mass spectrum produces limiting temperature. Thus within two weeks I completed 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. 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 shape and the highest 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”.

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But how did Hagedorn, with his uncanny physics instinct, by way and what motivation did he achieve the statistical bootstrap model? He laid 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 limiting temperature transformed into what today is the temperature at which the confining QCD vacuum structure dissolves, and the structure of matter changes from hadrons to quark–gluon degrees of freedom. The exponential growth in the understanding of hadrons is 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 on the path leading to the expansion of the SBM towards a theory of deconfined quark–gluon degrees of freedom. The exponential growth in the understanding of hadrons is the result of the quark content of hadrons.

Faithful to Science

The interplay 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 influencing forces of human life and experience, and to examine how and if they link together.

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 in 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 “unlisted conference reports”. Other events are also being planned to emphasize the importance of this anniversary.

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 1954 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 keyway 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 p6).

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 of European States 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 restricted 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, embodied 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 horizon. Moreover, not all states that are obvious candidates for a closer scientific and technical partnership might share today the values of a governance framework 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 for cooperation 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.

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 framework 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 for cooperation 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.

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The MCS-CT3 is a new multi-channel scaler/counter-timer from ET Enterprises Ltd which can be interfaced with a PC or Laptop via a USB port to operate as a cost-effective, high performance pulse counting instrument. When used with a compatible amplifier/discriminator, such as the ET Enterprises AD8, and a suitable detector, it becomes a wide-dynamic-range photon counting system.

It is a compact electronics module which records pulse counts as a function of time and stores them in channels, each of which has a user-selectable time window, or ‘dwell-time’. Operation and data retrieval are controlled by a PC using Windows XP, or later, operating systems and the open-source software supplied with the MCS-CT3. A LabVIEW virtual instrument program option is also supplied.

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CERN: a forward look

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

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Department of International Relations

The future.

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CERN’s new membership policy 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. In 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 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 66-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.

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supplied with open-source software which can be customised
compact and cost effective
pmt HV control output for use with programmable HV supplies
automatic plateau plotting (when using pmt HV control output)
can be supplied as a complete photon counting system

And, of course, we have a wide range of photomultipliers and photon detector modules for your application, whether photon counting or analogue, together with associated hardware such as HV supplies and light-tight housings.

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N605
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  - 743: Digitizer Family
    - 8/16 Channel 12-bit 3.2 GS/s Switched Capacitor Digitizer

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Gianni Di Maio
CAEN Maintenance Division Manager

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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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