WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the April 2015 issue of *CERN Courier*.

Celebration of the International Year of Light and Light-based Technologies (IYL 2015) continues in this issue with a look at the challenges in building a new light source in South East Asia, while Viewpoint asks whether the skills developed for high-energy physics could be used to make the dark side of the universe visible. These skills are already being directed at a large-scale project to investigate further what are arguably the most invisible of the elementary particles – the neutrinos. Celebrations also extend to wishing a happy 90th birthday to *CERN Courier*'s first editor, Roger Anthoine.

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CERNCOURIER

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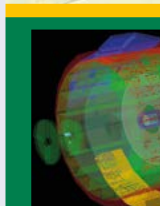
First light for the TPS



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

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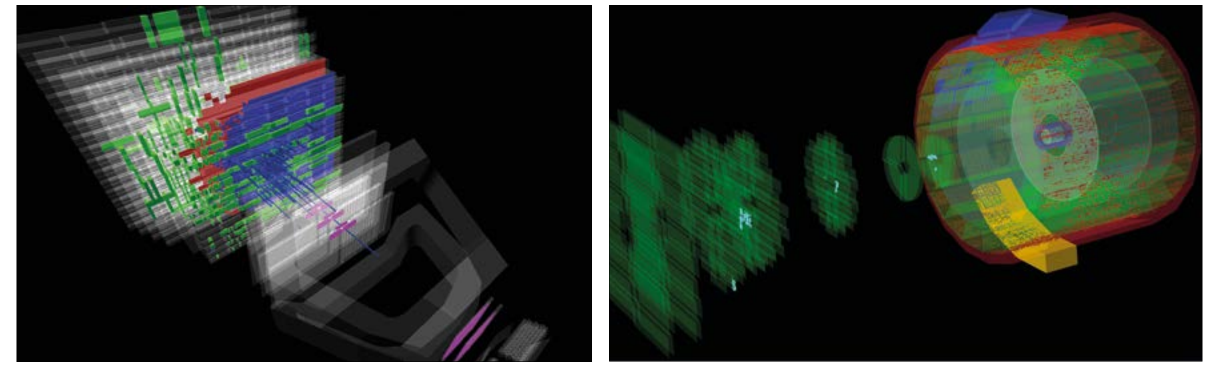
On the cover: The two light sources at the NSRRC, with the TLS (small) and the TPS (big), which has just achieved its first light (p22). (Image credit: NSRRC.)

News

CERN

The LHC: a machine in training



Successful injector tests sent protons through part of the LHC ring in March, creating "splash" events in the LHCb (left) and ALICE experiments. (Image credits: LHCb, left, and ALICE collaborations.)

After the long maintenance and consolidation campaign carried out during the first long shutdown, LS1, the early part of 2015 has been dominated by tests and magnet training to prepare the LHC for a collision energy of 13 TeV. With all of the hardware and software systems to be checked, a total of more than 10,000 test steps needed to be performed and analysed on the LHC's magnet circuits.

The LHC's backbone consists of 1232 superconducting dipole magnets with a field of up to 8.33 T operating in superfluid helium at 1.9 K, together with more than 500 superconducting quadrupole magnets operating at 4.2 K or 1.9 K. Many other superconducting and normal resistive magnets are used to allow the correction of all beam parameters, bringing the total number of magnets to more than 10,000. About 1700 power converters are necessary to feed the superconducting circuits.

The dipole magnets in the first of the LHC's eight sectors were trained successfully to nominal current in December (*CERN Courier* January/February 2015 p5), and training continued throughout the first three months of 2015. Although all of the dipole magnets were tested individually before installation, they had to be trained together in the tunnel up to 10,980 A, the current that corresponds to a beam energy of 6.5 TeV.

Training involves repetitive quenches before a superconducting magnet reaches the target magnetic field. The quenches are caused by the sudden release of electromechanical stresses and a local increase in temperature that triggers a change from the superconductive to the resistive state. The entire coil is then warmed up and cooled down again – for the LHC dipoles, this might take several hours. The magnet protection system is crucial for detecting a quench and safely extracting the energy stored in the circuits – about 1 GJ per dipole circuit at nominal current (*CERN Courier* September 2013 p33).

The typical time needed to commission a dipole circuit fully is in the order of three to five weeks, and all of the interlock and protection systems have to be tested, both before and while ramping-up the current in steps. By mid-February, the dipole circuits in three sectors had been trained to the level equivalent to 6.5 TeV, with the total number of quenches confirming the initial prediction of about 100 quenches for all of the dipoles in the machine. By early March, four sectors were fully trained for 6.5-TeV operation, with a fifth well into its training programme.

On the weekend of 7–8 March, operators performed injection tests with beams of protons being sent part way around the LHC. Beam 1 passed through the ALICE detector up to point 3 of the LHC, where it was dumped on a collimator, and beam 2 went through the LHCb detector up to the beam dump at point 6. The team recorded various parameters, including the timings of the injection kickers and the beam trajectory in the injection lines and LHC beam pipe.

The ALICE and LHCb collaborations prepared their experiments to receive pulses of particles and recorded "splash" events as the particles travelled through their detectors. LHCb used the tests to commission the detector and the data-acquisition system, as well as to perform detector studies and alignments of the different sub-detectors. The ALICE collaboration meanwhile used muons originating from the Super Proton Synchrotron beam dump for timing studies of the trigger and to align the muon spectrometer.

If commissioning remains on schedule, the LHC should restart towards the end of March, with first collisions at 13 TeV in late May/early June.

Sommaire en français

COSMIC RAYS

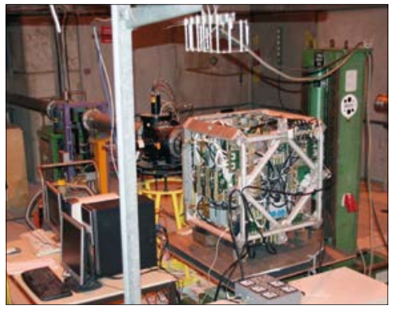
NUCLEON takes its place in space

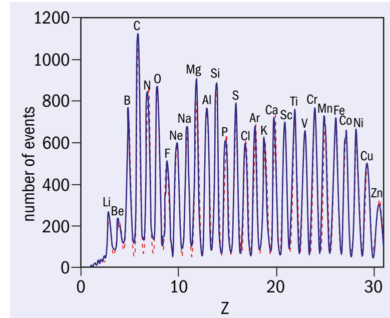
On 13 January, less than three weeks after being launched into space, the NUCLEON satellite experiment was switched on to collect its first cosmic-ray events. Orbiting the Earth on board the RESURS-P No.2 satellite, NUCLEON has been designed to investigate directly the energy spectrum of cosmic-ray nuclei and their chemical composition from 100 GeV to 1000 TeV (10^{11}–10^{15} eV), as well as the cosmic-ray electron spectrum from 20 GeV to 3 TeV. It is well known that the region of the "knee" – 10^{14}–10^{16} eV – is crucial for understanding the origin of cosmic rays, as well as their acceleration and propagation in the Galaxy.

NUCLEON has been produced by a collaboration between the Skobeltsyn Institute of Nuclear Physics of Moscow State University (SINP MSU) as the main partner, together with the Joint Institute for Nuclear Research (JINR) and other Russian scientific and industrial centres. It consists of silicon and scintillator detectors, a carbon target, a tungsten γ-converter and a small electromagnet calorimeter.

The charge-detection system, which consists of four thin detector layers of 1.5 × 1.5 cm silicon pads, is located in front of the carbon target. It is designed for precision measurement of the charge of the primary-particle charge.

A new technique, based on the generalized kinematical method developed for emulsions, is used to measure the cosmic-ray energy. Avoiding the use of heavy absorbers, the Kinematic Lightweight Energy Meter (KLEM) technique gives an energy resolution of 70% or better, according to simulations. Placed just behind the target, this energy-measurement system consists of silicon microstrip layers with tungsten layers to convert secondary γ-rays to electron–positron pairs. This significantly increases the number of secondary particles and therefore improves the accuracy of the energy determination for a primary particle.





Clockwise from top left: Fig. 1. The NUCLEON flight model at the H8 SPS beam line, for combined tests of all of the detector subsystems. (Image credit: JINR.) Fig. 2. Charge measurements of the NUCLEON detector from the SPS 2013 test run. Fig. 3. The launch of the rocket Soyuz-2.1b with the RESURS-P No.2 satellite. (Image credit: Roscosmos.)

The small electromagnet calorimeter (six tungsten/silicon microstrip layers 180 × 180 mm weighing about 60 kg, owing to satellite limitations) has a thickness of 12 radiation lengths, and will measure the primary cosmic-ray energy for some of the events. The effective geometric factor is more than 0.2 m²sr for the full detector and close to 0.1 m²sr for the calorimeter. The NUCLEON device must allow separation of the electromagnetic and hadronic cosmic-ray components at a rejection level of better than 1 in 10^3 for the events in the calorimeter aperture.

The design, production and tests of the trigger system were JINR's responsibility. The system consists of six multistrip scintillator layers to select useful events by measuring the charged-particle multiplicity crossing the trigger planes. The two-level trigger systems have a duplicated structure for reliability, and will provide more than 10^8 events with energy above 10^{11} eV during the planned five years of data taking.

The NUCLEON prototypes were tested many times at CERN's Super Proton Synchrotron (SPS) with high-energy electron, hadron and heavy-ion beams. The last test at CERN, which took place in 2013 at the H2 heavy-ion beam, was dedicated to testing NUCLEON's charge-measurement system. The results showed that it provides a charge resolution better than 0.3 charge units in the region up to atomic number Z = 30 (figure 2). The Z < 5 beam particles were suppressed by the NUCLEON trigger system.

In 2013, NUCLEON was installed on the RESURS-P No. 2 satellite platform for combined tests at the Samara-PROGRESS space-qualification workshop, some 1000 km southeast of Moscow. The complex NUCLEON tests were continued in 2014 at the Baikonur spaceport, in conjunction with the satellite and the Soyuz-2.1b rocket, before the successful launch on 26 December. The satellite is now in a Sun-synchronous orbit with inclination 97.276° and a middle altitude of 475 km. The total weight of the NUCLEON apparatus is 375 kg, with a power consumption of 175 W.

The flight tests of the NUCLEON detector were continued during January and February, and the NUCLEON team hopes to present the preliminary results at the summer conferences this year. The next step after this experiment will be the High-Energy cosmic-Ray Observatory (HERO) to study high-energy primary cosmic-ray radiation from space. The first HERO prototype is to be tested at the SPS in autumn.

LHC EXPERIMENTS

LHCb gets a precise handle on sin 2β

In the first week of March, at Les Rencontres de Physique de la Vallée d'Aoste, La Thuile, the LHCb collaboration announced a precision measurement of CP (charge/parity) violation in decays of neutral B^0 mesons to the $J/\psi\, K^0_S$ final state.

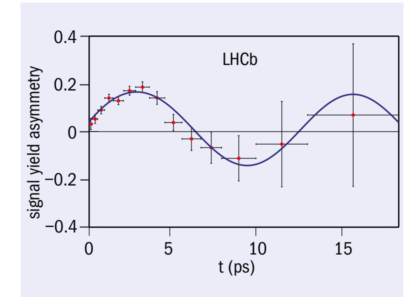
The "golden channel", $B^0 \to J/\psi\, K^0_S$, allows for a clean determination of the angle β of the triangle that represents the unitarity of the Cabibbo–Kobayashi–Maskawa (CKM) quark-mixing matrix. The matrix describes CP violation in the Standard Model as the result of a single irreducible complex phase (*CERN Courier* July/August 2014 p26). Its unitarity relates observables of many different measurements to a small number of parameters, thereby allowing for a stringent test of the electroweak sector of the Standard Model.

The CP violation in $B^0 \to J/\psi\, K^0_S$ arises from the interference of the direct decay and the decay after B^0–$\bar{B}^0$ oscillation. It manifests itself as an asymmetry between the decay rates of B^0 and $\bar{B}^0$ mesons that depends on the decay time, t:

$$A(t) = \frac{N_{\bar{B}^0}(t) - N_{B^0}(t)}{N_{\bar{B}^0}(t) + N_{B^0}(t)} \propto S \sin(\Delta m\, t) - C \cos(\Delta m\, t).$$

Here, S and C are the CP observables, and $\Delta m/2\pi$ is the frequency of the B^0–$\bar{B}^0$ oscillation. Because the decay is dominated by a single decay amplitude, C is expected to vanish and S can be identified as sin 2β.

The LHCb collaboration has now analysed the full data set from Run 1 of the LHC, comprising 114,000 reconstructed and selected $B^0 \to J/\psi\, K^0_S$ decays (LHCb Collaboration 2015). The analysis relies on identifying the initial flavour of the B meson, i.e. whether it was produced as a B^0 or a $\bar{B}^0$ meson. This so-called flavour tagging exploits event properties that are correlated to the production flavour of the B meson. The flavour identification succeeds for 41,560 $B^0 \to J/\psi\, K^0_S$ decays, and is correct in 64% of the cases.



The time-dependent asymmetry between the decay rates of B^0 and $\bar{B}^0$ mesons measured by LHCb.

The LHCb measurement yields $S = 0.731 \pm 0.035\,(\text{stat.}) \pm 0.020\,(\text{syst.})$, and is in good agreement with the value expected from CKM unitarity when excluding direct measurements of sin 2β, $0.771^{+0.017}_{-0.041}$ (Charles *et al.* 2015). Despite the challenges of the hadronic environment of the LHC, the result is at a similar precision to the $B^0 \to J/\psi\, K^0_S$ analyses of the BaBar and Belle experiments at the PEP-II and KEKB B factories.

BaBar and Belle established CP violation in the B^0 meson system by observing it in $B^0 \to J/\psi\, K^0_S$ decays for the first time in 2001 (*CERN Courier* April 2001 p5). They have since contributed with measurements of sin 2β leading to a very precise world-average value of 0.682±0.019 (Heavy Flavor Averaging Group 2014). Although LHCb's new result is not yet as precise, it notably demonstrates that the experimental challenges are met, and that a similar precision will be achievable with the data to be collected in the LHC's Run 2. LHCb will then contribute significantly to our knowledge of this fundamental parameter, and will allow for more stringent tests of CKM unitarity.

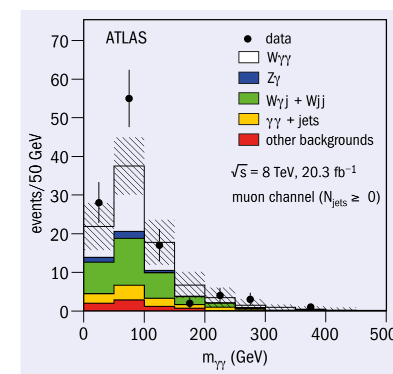
Further reading

J Charles *et al.* 2015 arXiv:1501.05013 [hep-ex].
Heavy Flavor Averaging Group 2014 arXiv:1412.7515 [hep-ex].
LHC Collaboration 2015 LHCb-PAPER-2015-004.

ATLAS sets limits on anomalous quartic-gauge couplings

Experiments at the LHC have been exploring every corner of predictions made by the Standard Model in search of deviations that could point to a more comprehensive description of nature. The LHC detectors have performed superbly, producing measurements that, to date, are consistent with the model in every area tested, the discovery of the Higgs boson with Standard Model properties being a crowning achievement of LHC Run 1 data-taking.

The ATLAS and CMS collaborations are now looking into deeper levels of Standard Model predictions by probing additional ways in which the gauge bosons (W^+, W^-, Z and photon) interact with each other. These self-interactions are at the heart of the model's electroweak sector. The gauge bosons are predicted to interact through point-like triple and quartic couplings. The triple-gauge couplings have been tested both at the LHC and at Fermilab's Tevatron, following on from beautiful studies at the Large Electron–Positron collider that demonstrated the existance of these couplings and measured their properties. A new frontier at the LHC is to explore the quartic coupling of four gauge bosons. This can be done through the two-by-two scattering of the bosons, or more directly through the transition of one of the bosons to a final state with three bosons.



Diphoton invariant-mass distribution for the muon channel in Wγγ. The hashed areas show the total systematic and statistical uncertainty on the background estimate.

The ATLAS experiment has used data collected in 2012 from 8 TeV proton–proton collisions to make a measurement of triple-gauge boson production. The measurement isolates a final state with a W boson decaying to leptonic final states eν or μν plus the production of two photons with transverse energy $E_T > 20$ GeV, and additional kinematic requirements defined by the acceptance of the ATLAS detector and the need to suppress soft photons. This process is sensitive to possible deviations of the quartic-gauge coupling WWγγ from Standard Model predictions.

The rate of WWγγ is six orders of magnitude lower than that of inclusive W production. The isolation of this signal is a challenge, owing to both the small production rate and competition from similar processes containing a W boson with jets and single photons. The measurement relies upon the ability of the ATLAS electromagnetic calorimeter to select isolated, directly produced photons from those embedded in the more prolific production of hadronic jets. The figure shows the m(γγ) mass distribution from the 110 events that pass the final $pp \to W(\mu\nu)\,\gamma\gamma + X$ selection cuts. The data are compared with the sum of backgrounds plus the Wγγ signal expected from the Standard Model.

These data are used to put limits on deviations of the quartic gauge coupling ▷

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$WW\gamma\gamma$ from Standard Model predictions by introducing models for anomalous (non-Standard Model) contributions to $pp \rightarrow W\gamma\gamma + X$ production. These contributions typically enhance events with large invariant mass of the two photons. The anomalous quartic coupling limits are imposed using a subset of the $pp \rightarrow W\gamma\gamma + X$ events with $m(\gamma\gamma) > 300$ GeV and no central high-energy jets. The resulting limits on various parameters that introduce non-Standard Model quartic couplings show that they are all consistent with zero (ATLAS Collaboration 2015). Once again, the Standard Model survives a measurement that probes a new aspect of its electroweak predictions.

Further reading

ATLAS Collaboration 2015 CERN-PH-EP-2015-009.

CMS prepares to search for heavy top-quark partners in Run 2

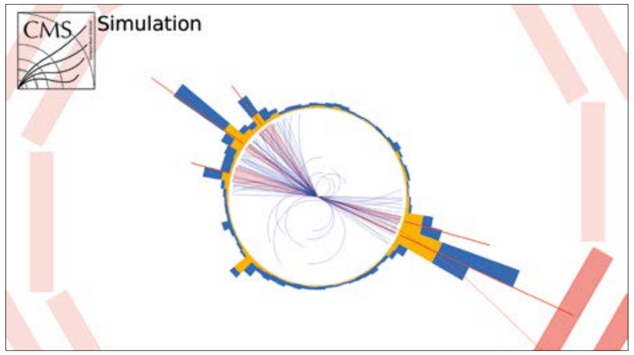
As the experiment collaborations get ready for Run 2 at the LHC, the situation of the searches for new physics is rather different from what it was in 2009, when Run 1 began. Many models have been constrained and many limits have been set. Yet a fundamental question remains: why is the mass of the newly discovered Higgs boson so much below the Planck energy scale? This is the so-called hierarchy problem. Quantum corrections to the mass of the Higgs boson that involve known particles such as the top quark are divergent and tend to push the mass to a very high energy scale. To account for the relatively low mass of the Higgs boson requires fine-tuning, unless some new physics enters the picture to save the situation.

A variety of theories beyond the Standard Model attempt to address the hierarchy problem. Many of these predict new particles whose quantum-mechanical contributions to the mass of the Higgs boson precisely cancel the divergences. In particular, models featuring heavy partners of the top quark with vector-like properties are compelling, because the cancellations are then achieved in a natural way. These models, which often assume an extension of the Standard Model Higgs sector, include the two-Higgs doublet model (2HDM), the composite Higgs model, and the little Higgs model. In addition, theories based on the presence of extra dimensions of space often predict the existence of vector-like quarks.

The discovery of the Higgs boson was a clear and unambiguous target for Run 1. In contrast, there could be many potential discoveries of new particles or sets of particles to hope for in Run 2, but currently no model of new physics is favoured a priori above any other.

One striking feature common to many of these new models is that the couplings with third-generation quarks are enhanced. This results in final states containing b quarks, vector bosons, Higgs bosons and top quarks that can have significant Lorentz boosts, so that their individual decay products often overlap and merge. Such "boosted topologies" can be exploited thanks to dedicated reconstruction algorithms that were developed and became well established in the context of the analyses of Run-1 data (*CERN Courier* November 2014 p8).

Searches for top-quark partners performed by CMS on the data from Run 1 span a large variety of different strategies and selection criteria, to push the mass-sensitivity as high as possible. These searches have now been combined to reach the best exclusion limit from the Run-1 data: heavy top-quark partners with masses below 800 GeV are now excluded at the 95% confidence level. The figure shows a simulated event with a top-quark partner decaying into a top-quark plus a Higgs boson ($T \rightarrow tH$) in a fully hadronic final state.

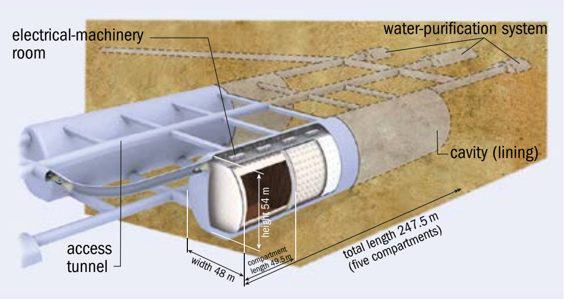


Event display of a simulated $T \rightarrow tH$ decay.

CMS plans to employ these techniques to analyse boosted topologies not only in the analysis framework, but for the very first time also in the trigger system of the experiment when the LHC starts up this year. The new triggers for boosted topologies are expected to open new regions of phase space, which would be out of reach otherwise. Some of these searches are expected to already be very sensitive within the first few months of data-taking in 2015. The higher centre-of-mass energy increases the probability for pair production of these new particles, as well as of single production. The CMS collaboration is now preparing to exploit the early data from Run 2 in the search for top-quark partners produced in 13 TeV proton collisions.

NEUTRINOS

Proto-collaboration formed to promote Hyper-Kamiokande



Left, schematic of the detector proposed for the Hyper-Kamiokande project (Image credit: HK Collaboration.) Right: Participants at the Inaugural Symposium of the Hyper-Kamiokande Proto-Collaboration. (Image credit: ICRR.)

The Inaugural Symposium of the Hyper-Kamiokande Proto-Collaboration, took place in Kashiwa, Japan, on 31 January, attended by more than 100 researchers. The aim was to promote the proto-collaboration and the Hyper-Kamiokande project internationally. In addition, a ceremony to mark the signing of an agreement for the promotion of the project between the Institute for Cosmic Ray Research of the University of Tokyo and KEK took place during the symposium.

The Hyper-Kamiokande project aims both to address the mysteries of the origin and evolution of the universe's matter and to confront theories of elementary-particle unification. To achieve these goals, the project will combine a high-intensity neutrino beam from the Japan Proton Accelerator Research Complex (J-PARC) with a new detector based on precision experimental techniques developed in Japan – a new megaton-class water Cherenkov detector to succeed the highly successful Super-Kamiokande detector.

The Hyper-Kamiokande detector will be about 25 times larger than Super-Kamiokande, the research facility that first found evidence for neutrino mass in 1998. Super-Kamiokande's discoveries that, in comparison to other elementary particles, neutrinos have extremely small masses, and that the three known types of neutrino mix almost maximally in flight, support the ideas of theories that go beyond the Standard Model to unify the elementary particles and forces.

In particular, the Hyper-Kamiokande project aspires not only to discover CP violation in neutrinos, but to close in on theories of elementary-particle unification by discovering proton decay. By expanding solar, atmospheric, and cosmic neutrino observations, as well as advancing neutrino-interaction research and neutrino astronomy, Hyper-Kamiokande will also provide new knowledge in particle and nuclear physics, cosmology and astronomy.

As an international project, researchers from around the world are working to start the Hyper-Kamiokande experiment in 2025.The Hyper-Kamiokande proto-collaboration now includes an international steering committee and an international board of representatives with members from 13 countries: Brazil, Canada, France, Italy, Japan, Korea, Poland, Portugal (observer state), Russia, Spain, Switzerland, the UK and the US.

Sciencewatch

Compiled by John Swain, Northeastern University

Lungfish provide clues on how hearing evolved

Hearing may have evolved from direct perception of vibrations by early vertebrate brains. Christian Christensen of Aarhus University in Denmark and colleagues have found that lungfish – the closest living relatives of the first four-legged animals to come onto land around 350-million years ago – have brains that respond to vibrations in their heads. This is despite their having no middle ear to sense pressure directly.

The researchers studied hearing in the lungfish by measuring neurophysiological recordings to estimate the vibration and pressure sensitivity of African lungfish (*Protopterus annectens*). They found that the lungfish detect underwater sound pressure via pressure-to-particle motion transduction by air volumes in their lungs and, more surprisingly, they also respond to airborne sound (Christensen *et al.* 2015a). The Danish researchers also found that salamanders – including fully juvenile ones, which live in water all of the time – have no middle ear, and that they too can detect sound in air (Christensen *et al.* 2015b).

The lungfish ear is a good model for the ears of the first terrestrial vertebrates. A new study shows that they can detect airborne sound despite not having a tympanic middle ear. (Image credit: Christian Bech Christensen.)

Further reading

C B Christensen *et al.* 2015a *Journal of Experimental Biology* **218** 381.
C B Christensen *et al.* 2015b *Proc. Royal Soc. B* doi: 10.1098/rspb.2014.1943.

Learning to play

A breakthrough in computer learning has been achieved by DeepMind, a Google-owned artificial-intelligence company in London. Volodymyr Mnih and colleagues used a single algorithm based on a deep (meaning several layers between input and output) neural network and reinforcement learning to make what they call a deep Q-network or DQN. Using only pixels and game scores, and no direct information about the rules of the games, it learnt to play 49 classic Atari 2600 games (such as "Space Invaders"), beating all previous algorithms and reaching a level comparable to professional human game testers. This is the first artificial agent able to learn and excel at a diverse range of difficult tasks.

Further reading

V Mnih *et al.* 2015 *Nature* **518** 529.

Safe GMOs

A common concern with genetically modified organisms (GMOs) is that they might escape from the lab into the environment and either grow where not wanted, in their original or mutated forms, or transfer genes horizontally to other organisms. Two groups have now found ways to make organisms that are essentially bioconfined to the lab.

George Church of Harvard Medical School in Boston and colleagues computationally redesigned essential enzymes in a strain of *E. coli* bacteria to depend on non-standard amino acids for their survival (Mandell *et al.* 2015). Farren Isaacs of Yale University in New Haven and colleagues achieved similar results using genes from *Methanocaldococcus jannaschii* to make *E. coli* that are also dependent on synthetic amino acids to live (Rovner *et al.* 2015).

Such organisms with exotic biochemistries are attractive both to study life outside of the normal range of terrestrial biochemistry, and as candidates for clinical, environmental and industrial applications, because they are unlikely to become out of control and have undesired or unpredictable effects on the rest of life on Earth.

Further reading

D J Mandell *et al.* 2015 *Nature* **518** 55.
A J Rovner *et al.* 2015 *Nature* **518** 89.

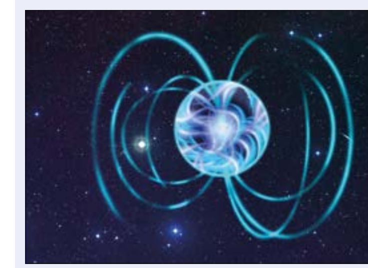
Vocal learning in chimps

Researchers in the UK have found that captive chimpanzees can learn new grunts from neighbours to refer to food, suggesting an analogue of human language-acquisition. Stuart Watson of York University and colleagues compared grunts of seven chimps moved from the Netherlands to join six chimps in a UK zoo. One year after the move, the Dutch chimps used a high-pitched call to refer to apples, quite distinct from the deeper grunts used by the British chimps. After three years, however, the Dutch chimps adopted the grunts of the Brits. While this may not be enough to count as language acquisition, it is the first time that such behaviour has been seen in non-humans, and suggests that social learning of referential words in humans could be older than previously thought.

Further reading

S K Watson *et al.* 2015 *Current Biology* **25** 495.

Magnetars



Artist's impression of the magnetar SGR 0418+5729. (Image credit: ESA.)

Magnetars are neutron stars with huge magnetic fields of around 10^{15}–10^{16} G, but the origin of these fields has remained an open question. Now, Maxim Dvornikov of the University of São Paulo, the Pushkov Institute in Moscow and Tomsk University, and Victor B Semikoz, also at the Pushkov Institute, have shown that the electroweak interaction of ultrarelativistic electrons with nucleons in a neutron star can grow a seed field to the required strength within the 10,000 years or so typical for young magnetars. The required magnetic-field instability comes from electroweak parity-violation in the electron–nucleon interaction, suggesting that these objects are not just the most magnetic in the universe, but among the most striking large-scale demonstrations of parity violation.

Further reading

M Dvornikov and V B Semikoz 2015 *Phys. Rev. D* **91** 061301(R).

Astrowatch

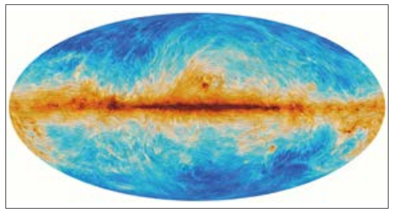
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva, and CHIPP, University of Zurich

Planck reveals no evidence of new physics

The release of the full mission data of ESA's Planck spacecraft is a milestone for cosmology. Despite the high quality of the data – including, for the first time, polarization observations – and the thorough analysis by the Planck collaboration, this event had little impact in the community and in public. Rather than strengthening the case for new physics, it confirms with high accuracy the standard model of cosmology, disfavours the existence of a light sterile neutrino, and turns down the hope for a dark-matter origin of the positron excess in cosmic rays.

Planck is the third generation of missions dedicated to the observation of the cosmic microwave background (CMB). This "first light" – freed 380,000 years after the Big Bang – provides key information on the universe as a whole, its fundamental constituents and its past and future evolution. Planck builds on the detection of the first large-scale CMB anisotropies by the Cosmic Background Explorer (COBE) in the early 1990s, and the much sharper view provided by NASA's Wilkinson Microwave Anisotropy Probe (WMAP) in the following decade (*CERN Courier* May 2006 p12). Planck's strength is that, by extending the wavelength coverage to higher frequencies than measured by WMAP, it is better able to disentangle foreground emission from the Milky Way and other galaxies.

The Planck collaboration – including individuals from more than 100 scientific institutes in Europe, the US and Canada – released the first data of the mission in March 2013, together with 31 scientific papers (*CERN Courier* May 2013 p12). Already then, the results confirmed with higher accuracy the relative abundance of the cosmic ingredients, namely ordinary (baryonic) matter, cold dark matter (CDM) and a cosmological constant (Λ), as derived by WMAP (*CERN Courier* May 2008 p8). The new Planck results confirm that these components sum up to the critical density corresponding to a flat universe with no global curvature, and yield only small changes to the relative abundances in this standard ΛCDM cosmology.



All-sky map of polarized dust emission in the Milky Way (colour coded) with a texture rendering of the magnetic-field lines of the Galaxy. The area observed by BICEP2 is in the lower, blue part of the image, but is still affected by significant dust emission blending with the possible signal from primordial gravitational waves. (Image credit: ESA and the Planck Collaboration.)

The press release from ESA emphasizes the result that the re-ionization of the universe by the first stars took place some 550 million years after the Big Bang, which is some 100 million years later than previously assumed for this end of the "Dark Ages". There are, however, other interesting results on more fundamental physics. Planck further limits the sum of the active neutrino masses to be below 0.194 eV, and constrains the effective number of light, relativistic neutrinos, N_{eff}, to be 3.04±0.33 (both at 95% CL with external constraints). This strongly disfavours the existence of an additional fourth quasi-massless neutrino, which could have been a sterile ("right-handed") one, but it does not exclude the possibility of heavier (> 1–10 eV) sterile neutrinos.

Another interesting result coming from CMB polarization measurements is a constraint on dark-matter annihilation, which could have contributed to the re-ionization of the universe at the beginning of the "Dark Ages". The derived upper limit almost entirely excludes the dark-matter interpretation – a neutralino with a mass of the order of 1 TeV – of the positron excess measured by the Alpha Magnetic Spectrometer (*CERN Courier* November 2014 p6). Finally, the combined analysis of Planck data with the measurements by BICEP2 and the Keck array on the curly B-modes of the CMB polarization confirms that at least most, if not all, of the signal is from galactic dust in the Galaxy (*CERN Courier* November 2014 p15), therefore disproving the claim for primordial gravitational waves from inflation (*CERN Courier* May 2014 p13).

Further reading

Planck 2015 results, submitted to A&A: www.cosmos.esa.int/web/planck/publications.

Picture of the month

The Hubble Space Telescope caught, for the first time, multiple images of a single supernova. The stellar explosion took place in the distant universe, and was split into four images (yellow dots) by the strong gravitational-lensing effect of an intervening galaxy belonging to the cluster MACS J1149+2223 located along the line of sight about five-thousand million light-years away. The gravity of ordinary and dark matter in this galaxy distorts space–time, opening four different routes for light from the remote supernova to Earth – a configuration called an Einstein cross. Owing to the different lengths of these routes, the image reveals the supernova fading at different epochs after ignition of the explosion. In the years to come, a fifth route could even show the explosion in "replay" from the start. (Image credit: NASA, ESA, S Rodney (John Hopkins University) and the FrontierSN team; T Treu (University of California Los Angeles), P Kelly (University of California Berkeley) and the GLASS team; J Lotz (STScI) and the Frontier Fields team; M Postman (STScI) and the CLASH team; and Z Levay (STScI).)

CERN Courier Archive: 1972

A look back to CERN Courier vol. 12, April 1972, compiled by Peggie Rimmer

NAL

First pulses at 200 GeV

The National Accelerator Laboratory came into being in the summer of 1967 with the mandate to build and operate a 200 GeV proton synchrotron. The move to the site, around the former village of Weston, Illinois, was completed in September 1968. On 1 December 1968 ground was broken and construction was under way, aiming to have the accelerator built within a budget of $250 million and operational by 1 July 1972.

On the morning of 1 March 1972 there was a pep talk from Laboratory Director Bob Wilson and from Ernie Malamud reviewing commissioning progress. In the Main Control Room, Frank Cole was leading the new attack on design energy with Jim Griffin at the other end of the intercom in the RF building. Don and Helen Edwards had worked during the night to tidy up the tracking between bending and quadrupole magnets, a possible source of beam instabilities at energies over about 30 GeV.

At 11.00 a stable beam was achieved after injection of about 10^{11} protons per pulse at 7.2 GeV from the Booster. By 11.30 the beam was through transition and a steady climb to higher energies began. To simplify the removal of magnets which failed, the magnet water-cooling circuits were not operating and pulse rates had to be kept low to avoid overheating. The cycle sequence was forty pulses at 30 GeV, each taking 1 s, followed by a single pulse to 200 GeV field levels taking 5 s.

At 12.30 the scope trace indicating accelerated beam crept out to 167 GeV. Excitement was growing and the Main Control Room became a crowd scene with a huddle of heads round Ed Gray operating the main control console. At 13.08 the shout went up "There it is"; the trace went all the way out to 200 GeV. Design energy had been achieved several months ahead of the initial schedule and within the forecast construction budget.

● Compiled from texts on pp120–123.

1 March 1972. "There it is". Happy faces cluster around the screen in the NAL Main Control Room. At the scope are (l. to r.) Frank Cole, Jeff Gannon and John Clarke with, immediately behind them, Dick Cassel, Ryuji Yamada, Bruce Strauss and Paul Evan. (Image credit: NAL.)

Bubble chambers

BESSY

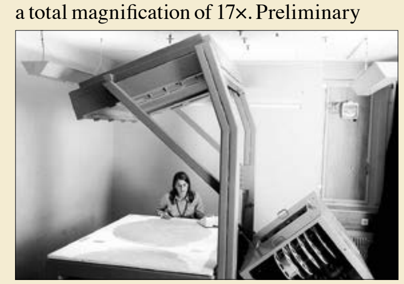
In 1969, when the question of processing of film from the 3.7 m [Big] European hydrogen Bubble Chamber BEBC was tackled, it became clear that to use existing scanning devices, regions containing interesting events would have to be roughly identified in advance. The result is BESSY, the BEBC European Scanning SYstem, a scanning and preliminary measuring table not involving high precision.

BESSY has a mirror fixed to the machine, a projection table 1.3 × 1.6 m² and four projection lenses on a single plate giving a total magnification of 17×. Preliminary measuring can be carried out in the image plane with a precision of ±170 µm (equivalent to ±10 µm in the film plane).

The tricks which helped bring the price down to 41,500 SF, less than half the price of a table produced using conventional methods throughout, concern the film driving motors, lenses, film pressure plates, mirrors, projector and condenser. The driving motors are very sturdy car windscreen wiper motors; there are twelve of them at a price of about 50 SF each.

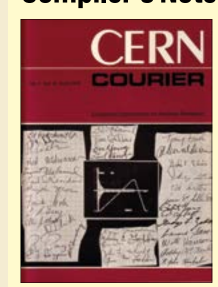
Special lenses were made by Jos. Schneider, Germany, at a price of 1000 SF per unit, to correct distortions caused by the film pressure plates. The mirror has only been polished once; the quality is adequate and the price is less than a fifth that of a high precision mirror. The lamps with incorporated mirror are commercially available units from movie projectors. The condenser is made from a plastic Fresnel lens costing a few tens of Swiss francs.

● Compiled from texts on pp127–128.



A prototype of BESSY, the scanning table designed specifically for use on film from BEBC, delivered to CERN in December 1971. (Image credit: CERN-EX-7204071.)

Compiler's Note



Mechanical and electro-mechanical devices have long brought out the whimsical and wonderful in inventors, as evidenced in some of the machines for scanning and measuring bubble-chamber film. Even Nobel laureate Ernest Rutherford sanctioned this approach to building apparatus in his apocryphal declaration "If you can't do it with string and sealing wax on a lab bench, it probably isn't worth doing at all".

During the Second World War, semi-automatic analysis machines, invented to help decrypt secret messages of the Axis Powers, were operated by "girls", namely "Wrens" from the Women's Royal Naval Service (WRNS) at the UK Government Code and Cypher School in Bletchley Park. The Wrens found the devices so comical that they christened them "Heath Robinsons" in honour of the renowned British cartoonist whose speciality was drawing ridiculously complicated gadgets to solve simple problems. Heath Robinsons were the predecessors of Colossus, the world's first programmable digital electronic computer, and the Wren operators might well be regarded as the predecessors of particle physics' scanning girls (was there ever a scanning boy?).

HEPTech: where academia meets industry

Eleonora Getsova explains how the HEPTech network gives a European dimension to innovative approaches and technology-transfer opportunities in high-energy physics.

Representatives of HEPTech member organizations and the network's Co-ordination Committee at the HEPTech Board Meeting, which took place at CERN in December 2014. (Image credit: CERN-PHOTO-201412-257-2.)

Technologies developed for fundamental research in particle, astro-particle and nuclear physics have an enormous impact on everyday lives. To push back scientific frontiers in these fields requires innovation: new ways to detect one signal in a wealth of data, new techniques to sense the faintest signals, new detectors that operate in hostile environments, new engineering solutions that strive to improve on the best – and many others.

The scientific techniques and high-tech solutions developed by high-energy physics can help to address a broad range of challenges faced by industry and society – from developing more effective medical imaging and cancer diagnosis through positron-emission tomography techniques, to developing the next generation of solar panels using ultra-high vacuum technologies. However, it is difficult and costly not only for many organizations to carry out the R&D needed to develop new applications, products and processes, but also for scientists and engineers to turn their technologies into commercial opportunities.

The aim of the high-energy physics technology-transfer network – HEPTech – is to bring together leading European high-energy physics research institutions so as to provide academics and industry with a single point of access to the skills, capabilities, technologies and R&D opportunities of the high-energy physics community in a highly collaborative open-science environment. As a source of technology excellence and innovation, the network bridges the gap between researchers and industry, and accelerates the industrial process for the benefit of the global economy and wider society.

HEPTech is made up of major research institutions active in particle, astroparticle and nuclear physics. It has a membership of 23 institutions across 16 countries, including most of the CERN member states (see table on page x). Detailed information about HEPTech member organizations and an overview of the network's activities are published annually in the *HEPTech Yearbook* and are also available on the network's website.

So, how was the network born? Jean-Marie Le Goff, the first co-ordinator and present chairman of HEPTech, explains: "Particle physics is a highly co-operative environment. The idea was to spread that spirit over to the Technology Transfer Offices." So in 2008 a proposal was made to the CERN Council to establish a network of Technology Transfer Offices (TTOs) in the field of particle physics. The same year, Council approved the network for a pilot phase of three years, reporting annually to the European Strategy Session of Council. In the light of the positive results obtained over those three years, Council approved the continuation of the network's activities and its full operation. "Since then it has grown – both in expanding the number of members and in facilitating bodies across Europe that can bring innovation from high-energy physics faster to industrial exploitation", says Le Goff.

The primary objective of the HEPTech network is to enhance technology transfer (TT) from fundamental research in physics to society. Therefore, the focus is on furthering knowledge transfer (KT) from high-energy physics to other disciplines, industry and society, as well as on enhancing TT from fundamental research in physics to industry for the benefit of society. The network also aims to disseminate intellectual property, knowledge, skills and technologies across organizations and industry, and to foster collaborations between scientists, engineers and business. Another important task is to enable the sharing of best practices in KT and TT.

HEPTech's activities are fully in line with its objectives. To foster the contacts with industry at the European level, the network organizes regular academia–industry matching events (AIMEs). These are technology-themed events that provide matchmaking between industrial capabilities and the needs of particle physics and other research disciplines. They are HEPTech's core offering to its members and the wider community, and the network has an active programme in this respect. Resulting from joint efforts by the network and its members, the AIMEs usually attract about 100 participants from more than 10 countries (figures from 2014). Last year, the ▷

HEPTech members

Institution	Country
Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	France
European Organization for Nuclear Research (CERN)	Switzerland
Centre National de la Recherche Scientifique (CNRS/IN2P3)	France
Centro Nacional de Fisica de Particulas Astroparticulas y Nuclear (CPAN)	Spain
University of Belgrade (Center for Technology Transfer and Institute of Physics)	Serbia
Demokritos National Centre for Scientific Research (NCSR)	Greece
Deutsches Elektronen-Synchrotron (DESY)	Germany
ELI ALPS	Hungary
ELI Beamlines, Institute of Physics of the Academy of Sciences	Czech Republic
Ecole Polytechnique Fédérale de Lausanne (EPFL)	Switzerland
European Spallation Source (ESS)	Sweden/Denmark
Helmholtzzentrum für Schwerionenforschung (GSI)	Germany
Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)	Romania
Istituto Nazionale di Fisica Nucleare (INFN)	Italy
Inovacentrum- Czech Technical University	Czech Republic
Jožef Stefan Institute (JSI)	Slovenia
Knowledge Transfer Network (KTN)	UK
Laboratório de Instrumentação e Física Experimental de Partículas (LIP)	Portugal
National Technical University of Athens (NTUA)	Greece
Sofia University St. Kliment Ohridski	Bulgaria
Science and Technology Facilities Council (STFC)	UK
Weizmann Institute of Science	Israel
Wigner Research Centre for Physics	Hungary

topics ranged from the dissemination of micropattern-gas-detector technologies beyond fundamental physics, through potential applications in the technology of controls, to fostering academia–industry collaboration for manufacturing large-area detectors for the next generation of particle-physics experiments, and future applications of laser technologies.

"The topics of the events are driven on the one hand by the technologies we have – it's very much a push model. On the other hand, they are the results of the mutual effort between the network and its members, where the members have the biggest say because they put in a lot of effort", says Ian Tracey, the current HEPTech co-ordinator. He believes that a single meeting between the right people from academia and industry is only the first step in the long process of initiating co-operation. To establish a project fully, the network should provide an environment for regular repetitive contact for similar people. To address this need, HEPTech looks at increasing the number of AIMEs from initially four up to eight events per year.

"The benefit of having HEPTech as a co-organizer of the AIMEs is clearly the European perspective", says Katja Kroschewski, head of TT at DESY. "Having speakers from various countries enlarges the horizon of the events and allows coverage of the subject field across Europe. It is different from doing a local event – for instance, having companies only from Hamburg or just with the focus on Germany. As the research work concerned has an international scope, it absolutely makes sense to organize such events. It is good to have the input of HEPTech in shaping the programme of the event and to have the network's support within the organizing committee as well."

HEPTech has teamed up with the work package on relations with industry of the Advanced European Infrastructures for Detectors at Accelerators (AIDA) project (which was co-funded by the European Commission under FP7 in 2011–2014), to organize AIMEs on detectors, with a view to fostering collaboration with industry during the pre-procurement phase. A total of seven AIMEs were organized in collaboration with AIDA and the RD51 collaboration at CERN, covering most of the technology fields of importance for detectors at accelerators. HEPTech financed four of them. A total of 101 companies attended the events, giving an average of 14 companies per event. For technology topics where Europe could meet the needs of academia, the percentage of EU industry was about 90% or above, going down to 70% when the leading industry for a technology topic was in the US and/or Asia.

To help event organizers find pertinent academic and industrial players in the hundreds, sometimes thousands, of organizations active in a particular technology, CERN used graph-analysis techniques to develop a tool called "Collaboration spotting". The tool automatically processes scientific publications, patents and data from various sources, selects pertinent information and populates a database that is later used to automatically generate interactive sociograms representing the activity occurring in individual technology fields. Organizations and their collaborations are displayed in a graph that makes the tool valuable for monitoring and assessing the AIMEs.

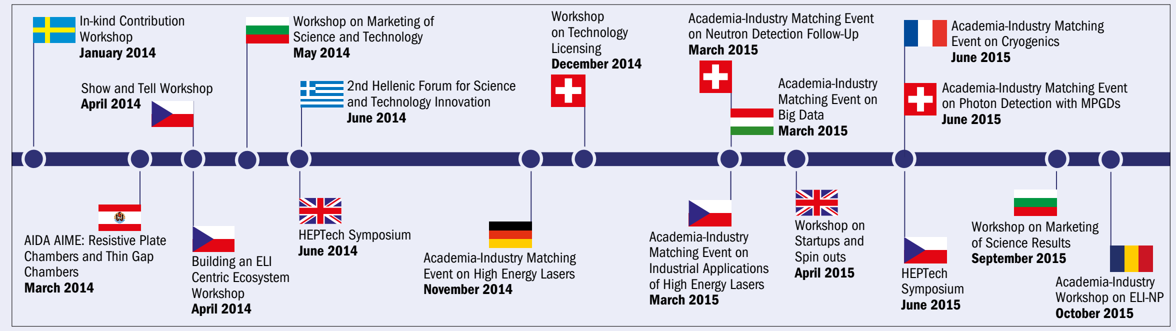
However, the findings from AIDA show that it is difficult to conduct an assessment of the impact on industry of an AIME. "To keep a competitive advantage, companies entering a partnership agreement with academia tend to restrict the circulation of this news as much as possible, at least until the results of the collaboration become commercially exploitable," explains Le Goff. "Although it tends to take some years before becoming visible, an increase in the number of co-publications and co-patents among attendees is a good indicator of collaboration. Clearly some of them could have been initiated at preceding events or under other circumstances, but in any case, the AIME has contributed to fostering or consolidating these collaborations."

Learning and sharing

Another area of activity is the HEPTech Symposium, which is dedicated to the support of young researchers in developing entrepreneurial skills and in networking. This annual event brings together researchers at an early stage in their careers who are working on potentially impactful technologies in fields related to astro-, nuclear and particle physics. For one week, HEPTech welcomes these Early Stage Researchers from around Europe, providing an opportunity for networking with commercially experienced professionals and TT experts and for developing their entrepreneurial potential.

The first HEPTech Symposium took place in June 2014 in Cardiff. The young researcher whose project attracted the greatest interest was awarded an expenses-paid trip around the UK to look for funding for his project. The 2015 symposium will be held in Prague on 31 May–6 June and will be hosted by Inovacentrum from the Czech Technical University in collaboration with ELI Beamlines and the Institute of Physics of the Academy of Sciences. HEPTech has established a competitive procedure for members that would like to host the event in future. Those interested have to demonstrate their capacity for organizing both a quality training programme and the entertainment of the participants.

A timeline of HEPTech events



Providing opportunities for capacity-building and sharing best practice among its members is of paramount importance to HEPTech. The network is highly active in investigating and implementing novel approaches to TT. A dedicated workgroup on sharing best practices responds to requests from members that are organizing events on a number of subjects relevant to the institutions and their TT process. These include, for instance, workshops presenting cases on technology licensing, the marketing of science and technology ond others. Through workshops, the network is able to upscale the skills of its member institutions and provide capacity-building by sharing techniques and different approaches to the challenges faced within TT. These events – an average of four per year – are driven by the members' enthusiasm to explore advanced techniques in KT and TT, and help to create a collaborative spirit within the network. The members provide significant assistance to the implementation of these events, including lecturers and workshop organization.

Bojil Dobrev, co-convener of the workgroup on best practices provides a recent example of best-practice transfer within the network, in which intellectual property (IP) regulations elaborated by a HEPTech workgroup were successfully used as a basis for development of IP regulations at Sofia University, Bulgaria. In 2013-2014, a survey focusing on the needs and skills of HEPTech members was conducted within the remit of this workgroup. The objectives were to identify the skills and potential of the HEPTech members and their requirement for support through the network, focusing mainly on the early stage (established recently) TTOs. The survey covered all aspects of a TTO's operation – from organization and financing, through IP activities, start-ups, licensing and contacts with industry, to marketing and promotion. "The survey was used as a tool to investigate the demand of the TTOs. Its outcomes helped us to map HEPTech's long-term strategy and to elaborate our annual work plan, particularly in relation to training and best-practice sharing", explains Dobrev.

Taking into consideration the overall achievements of HEPTech and based on the annual reports of the network co-ordinator, CERN Council encouraged HEPTech to continue its activities and amplify its efforts in the update of the European Strategy for Particle Physics in May 2013. The following year, in September, the Council president gave strong support and feedback for HEPTech's work.

HEPTech's collaborative efforts with the European Extreme Light Infrastructure (ELI) project resulted in network membership of all three pillars of the project. Moreover, at the Annual Forum of the EU Strategy for the Danube Region, representatives of governments in the Danube countries acknowledged HEPTech's role as a key project partner in the Scientific Support to the Danube Strategy initiative.

With its stated vision to become "the innovation access-point for accelerator- and detector-driven research infrastructures" within the next three years, HEPTech is looking to expand – indeed, three new members joined the network in December 2014. It also aims to take part in more European-funded projects and is seeking closer collaboration with other large-scale science networks, such as the European TTO Circle – an initiative of the Joint Research Centre of the European Commission, which aims to connect the TTOs of large European public research organizations.

Résumé

HEPTech : un pont entre la recherche et l'industrie

Le réseau de transfert de technologies en physique des hautes énergies (HEPTech) a pour but de rassembler les grands instituts de recherche européens de physique des hautes énergies afin d'offrir aux chercheurs et aux entreprises un point d'accès aux connaissances, compétences, technologies et possibilités de R&D de la communauté de physique des hautes énergies dans un environnement fondé sur le principe de la science ouverte et de la collaboration. Source d'excellence et d'innovation en matière technologique, le réseau représente un pont entre les chercheurs et les entreprises et accélère le processus industriel au service de l'économie mondiale et de la société dans son ensemble.

Eleonora Getsova, HEPTech Communication Officer, CERN.

Long-distance neutrinos

The international community plans to use high-energy neutrinos from Fermilab in a high-precision 1000-km baseline experiment.

Participants at the Neutrino Summit held in September at Fermilab. (Image credit: Fermilab.)

The neutrino is the most abundant matter-particle in the universe and the lightest, most weakly interacting of the fundamental fermions. The way in which a neutrino's flavour changes (oscillates) as it propagates through space implies that there are at least three different neutrino masses, and that mixing of the different mass states produces the three known neutrino flavours. The consequences of these observations are far reaching because they imply that the Standard Model is incomplete; that neutrinos may make a substantial contribution to the dark matter known to exist in the universe; and that the neutrino may be responsible for the matter-dominated flat universe in which we live.

This wealth of scientific impact justifies an energetic programme to measure the properties of the neutrino, interpret these properties theoretically, and understand their impact on particle physics, astrophysics and cosmology. The scale of investment required to implement such a programme requires a coherent, international approach. In July 2013, the International Committee for Future Accelerators (ICFA) established its Neutrino Panel for the purpose of promoting both international co-operation in the development of the accelerator-based neutrino-oscillation programme and international collaboration in the development of a neutrino factory as a future intense source of neutrinos for particle-physics experiments. The Neutrino Panel's initial report, presented in May 2014, provides a blueprint for the international approach (Cao *et al*. 2014).

The accelerator-based contributions to this programme must be capable both of determining the neutrino mass-hierarchy and of seeking for the violation of the CP symmetry in neutrino oscillations. The complexity of the oscillation patterns is sufficient to justify two complementary approaches that differ in the nature of the neutrino beam and the neutrino-detection technique (Cao *et al*. 2015). In one approach, which is adopted by the Hyper-K collaboration, a neutrino beam of comparatively low energy and narrow energy spread (a narrow-band beam) is used to illuminate a "far" detector at a distance of approximately 300 km from the source (see p9). In a second approach, a neutrino beam with a higher energy and a broad spectrum (a wide-band beam) travels more than 1000 km through the Earth before being detected.

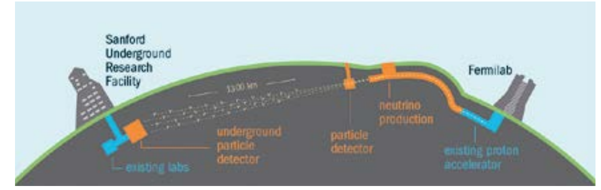
Since summer 2014, a global neutrino collaboration has come together to pursue the second approach, using Fermilab as the source of a wide-band neutrino beam directed at a far detector located deep underground in South Dakota. In addition to measuring the neutrinos in the beam, the experiment will study neutrino astrophysics and nucleon decay. This experiment will be of an unprecedented scale and dramatically improve the understanding of neutrinos and the nature of the universe.

This new collaboration – currently dubbed ELBNF for Experiment at the Long-Baseline Neutrino Facility – has an ambitious plan to build a modular liquid-argon time-projection chamber (LAr-TPC) with a fiducial mass of approximately 40 kt as the far detector and a high-resolution "near" detector. The collaboration is leveraging the work of several independent efforts from around the world that have been developed through many years of detailed studies. These groups have now converged around the opportunity provided by the megawatt neutrino-beam facility that is planned at Fermilab and by the newly planned expansion with improved access of the Sanford Underground Research Facility in South Dakota, 1300 km from Fermilab. To give a sense of scale, to house this detector some 1.5 km underground requires a hole that is approximately 120,000 m^3 in size – nearly equivalent to the volume of Wimbledon's centre-court stadium.

The principal goals of ELBNF are to carry out a comprehensive investigation of neutrino oscillations, to search for CP-invariance violation in the lepton sector, to determine the ordering of the neutrino masses and to test the three-neutrino paradigm. In addition, with a near detector on the Fermilab site, the ELBNF collaboration will perform a broad set of neutrino-scattering measurements. The large volume and exquisite resolution of the LAr-TPC in its deep underground location will be exploited for non-accelerator physics topics, including atmospheric-neutrino measurements, searches for nucleon decay, and measurement of astrophysical neutrinos (especially those from a core-collapse supernova).

The new international team has the necessary expertise, technical knowledge and critical mass to design and implement this exciting "discovery experiment" in a relatively short time frame. The goal is

Future experiments



Layout of the proposed long-baseline neutrino experiment.

the deployment of a first detector with 10 kt fiducial mass by 2021, followed by implementation of the full detector mass as soon as possible. The accelerator upgrade of the Proton Improvement Plan-II at Fermilab will provide 1.2 MW of power by 2024 to drive a new neutrino beam line at the laboratory. There is also a plan that could further upgrade the Fermilab accelerator complex to enable it to provide up to 2.4 MW of beam power by 2030 – an increase of nearly a factor of seven on what is available today. With the possibility of space for expansion at the Sanford Underground Research Facility, the new international collaboration will develop the necessary framework to design, build and operate a world-class deep-underground neutrino and nucleon-decay observatory. This plan is aligned with both the updated European Strategy for Particle Physics (*CERN Courier* July/August 2013 p9) and the report of the Particle Physics Project Prioritization Panel (P5) written for the High Energy Physics Advisory Panel in the US (*CERN Courier* July/August 2014 p12).

A letter of intent (LoI) was developed during autumn 2014, and the first collaboration meeting was held in mid January at Fermilab. Sergio Bertolucci, CERN's director for research and computing, and interim chair of the institutional board, ran the meeting. More than 200 participants from around the world attended, and close to 600 physicists from 140 institutions and 20 countries have signed the LoI, to date. The collaboration has chosen its new spokespersons – Mark Thompson of Cambridge University and André Rubbia of ETH Zurich – and will begin the process of securing the early funding needed to excavate the cavern in a timely fashion so that detector installation can begin in the early 2020s.

Mounting such a significant experiment on such a compressed time frame will require all three world regions – Asia, the Americas and Europe – to work in concert. The pioneering work on the liquid-argon technique was carried out at CERN and implemented in the ICARUS detector, which ran for many years at Gran Sasso. To deliver the ELBNF far detector requires that the LAr-TPC technology be scaled up to an industrial scale. To deliver the programme required to produce the large LAr-TPC, neutrino platforms are being constructed at Fermilab and at CERN. A team led by Marzio Nessi is working hard to make this resource available at CERN and to complete in the next few years the R&D needed for both the single- and dual-phase liquid-argon technologies that are being proposed on a large scale (see box).

The steps taken by the neutrino community during the nine months or so since summer 2014 have put the particle-physics community on the road towards an exciting and vibrant programme that will culminate in exquisitely precise measurements of neutrino oscillation. It will also establish in the US one of the flagships of the international accelerator-based neutrino programme called for by the ICFA Neutrino Panel. In addition, ELBNF will be a world-leading facility for the study of neutrino astrophysics and cosmology.

With such a broad and exciting programme, ELBNF will be at the forefront of the field for several decades. The remarkable success of the LHC programme has demonstrated that a facility of this scale can deliver exceptional science. The aim is that ELBNF will provide a second example of how the world's high-energy-physics community can come together to deliver an amazing scientific programme. New collaborators are still welcome to join in the pursuit.

ICARUS and WA105

The ICARUS experiment, led by Carlo Rubbia, employs the world's largest (to date) liquid-argon detector, which was built for studies of neutrinos from the CNGS beam at CERN (*CERN Courier* July/August 2011 p30). The ICARUS detector with its 600 tonnes of liquid argon took data from 2010 to 2012 at the underground Gran Sasso National Laboratory. ICARUS demonstrated that the liquid-argon detector has excellent spatial and calorimetric resolution, making for perfect visualization of the tracks of charged particles. The detector has since been removed and taken to CERN to be upgraded prior to sending it to Fermilab, where it will begin a new scientific programme.

For more than a decade, the neutrino community has been interested in mounting a truly giant liquid-argon detector with some tens-of-kilotonnes active mass for next-generation long-baseline experiments, neutrino astrophysics and proton-decay searches – and, in particular, for searches for CP violation in the neutrino sector. WA105, an R&D effort located at CERN and led by André Rubbia of ETH Zurich, should be the "last step" of detector R&D before the underground deployment of detectors on the tens-of-kilotonne scale. The WA105 demonstrator is a novel dual-phase liquid-argon time-projection chamber that is 6 m on a side. It is already being built, and should be ready for test beam by 2017 in the extension of CERN's North Area that is currently under construction.

Further reading

For the ELBNF LoI, see indico.fnal.gov/getFile.py/access?resId=0&materialId=0&confId=9214.
Cao *et al*. 2014 arXiv:1405.7052.
Cao *et al*. 2015 arXiv:1501.03918.

Résumé
Neutrinos sur une longue distance

À l'été 2014, une collaboration mondiale sur les neutrinos a vu le jour. Objectif : utiliser un faisceau de neutrinos large bande du Fermilab dirigé vers un détecteur souterrain dans le Dakota-du-Sud. En plus de mesurer les neutrinos dans le faisceau, l'expérience étudiera l'astrophysique des neutrinos et la désintégration des nucléons. D'une ampleur sans précédent, elle améliorera considérablement notre compréhension des neutrinos et de la nature de l'Univers. Plus de 200 participants du monde entier étaient présents à la première réunion de la collaboration, et près de 600 physiciens de 20 pays ont signé à ce jour la lettre d'intention.

Ken Long, Imperial College London and STFC, and **Rob Roser**, Fermilab.

CERN Courier April 2015
Accelerators

The TPS begins to shine

Creative solutions to a series of challenges were key to the successful start of a new light source in South-East Asia.

INTERNATIONAL YEAR OF LIGHT 2015

On 31 December, commissioning of the Taiwan Photon Source (TPS) at the National Synchrotron Radiation Research Center (NSRRC) brought 2014 to a close on a highly successful note as a 3 GeV electron beam circulated in the new storage ring for the first time. A month later, the TPS was inaugurated in a ceremony that officially marked the end of the 10-year journey since the project was proposed in 2004, the past five years being dedicated to the design, development, construction and installation of the storage ring.

The new photon source is based on a 3 GeV electron accelerator consisting of a low-emittance synchrotron storage ring 518.4 m in circumference and a booster ring (*CERN Courier* June 2010 p16). The two rings are designed in a concentric fashion and housed in a doughnut-shaped building next to a smaller circular building where the Taiwan Light Source (TLS), the first NSRRC accelerator, sits (see cover). The TLS and the new TPS will together serve scientists worldwide whose experiments require photons ranging from infrared radiation to hard X-rays with energies above 10 keV.

Clockwise from top left: The big ring of the TPS nestles behind the administration building at the NSRRC, located in the Hsinchu Science Park; the first synchrotron light from the TPS storage ring, delivered on 31 December 2014; the TPS storage ring (left) and booster ring (right) inside the tunnel. (Image credits: NSRRC.)

Four-stage commissioning

The task of commissioning the TPS comprised four major stages involving: the linac system plus the transportation of the electron beam from the linac to the booster ring; the booster ring; the transportation of the electron beam from the booster ring to the storage ring; and, finally, the storage ring. Following the commissioning of the linac system in May 2011, the acceptance tests of key TPS subsystems progressed one after the other over the next three years. The 700 W liquid-helium cryogenic system, beam-position monitor electronics, power supplies for quadrupole and sextupole magnets, and two sets of 2 m-long in-vacuum undulators completed their acceptance tests in 2012. Two modules of superconducting cavities passed their 300 kW high-power tests. The welding, assembly and baking of the 14 m-long vacuum chambers designed and manufactured by in-house engineers were completed in 2013. Then, once the installation of piping and cable trays had begun, the power supply and other utilities were brought in, and set-up could start on the booster ring and subsystems in the storage ring.

The installation schedule was also determined by the availability of magnets. By April 2014, 80% of the 800 magnets had been installed in the TPS tunnel, allowing completion of the accelerator installation in July (bottom right). Following the final alignment of each component, preparation for the integration tests of the complete TPS system in the pre-commissioning phase was then fully under way by autumn.

The performance tests and system integration of the 14 subsystems in the pre-commissioning stage started in August. By 12 December, the TPS team had begun commissioning the booster ring. The electron beam was accelerated to 3 GeV on 16 December and the booster's efficiency reached more than 60% a day later. Commissioning of the storage ring began on 29 December. On the next day, the team injected the electrons for the first time and the beam completed one cycle. The 3 GeV electron beam with a stored current of 1 mA was then achieved and the first synchrotron light was observed in the early afternoon on 31 December (far right). The stored current reached 5 mA a few hours later, just before the shut down for the New Year holiday. As of the second week of February 2015, the TPS stored beam current had increased to 50 mA.

Stringent project requirements left little room for even small deviations from the delivery timetable.

The US$230 million project (excluding the NSRRC staff wages) involved more than 145 full-time staff members in design and construction. Like any other multi-million-dollar, large-scale project, reaching "first light" required ingenious problem solving and use of resources. Following the groundbreaking ceremony in February 2010, the TPS project was on a fast track, after six months of preparing the land for construction. Pressures came from the worldwide financial crisis, devaluation of the domestic currency, reduction of the initial approved funding, attrition of young engineers who were recruited by high-tech industries once they had been trained with special skills, and bargaining with vendors. In addition, the stringent project requirements left little room for even small deviations from the delivery timetable or system specifications, which could have allowed budget re-adjustments.

To meet its mandate on time, the project placed reliance and pressure on experienced staff members. Indeed, more than half of the TPS team and the supporting advisors had participated in the construction of the TLS in 1980s. During construction of the TPS, alongside the in-house team were advisers from all over the world whose expertise played an important role in problem solving. In addition, seven intensive review meetings took place, conducted by the Machine Advisory Committee.

From the land preparation in 2010 onwards, the civil-construction team faced daily challenges. For example, at the heart of the Hsinchu Science Park, the TPS site is surrounded by heavy traffic, 24 hours a day, all year round. To eliminate the impact of vibration from all possible sources, the 20 m wide concrete floor of the accelerator tunnel is 1.6 m thick. Indeed, the building overall can resist an earthquake acceleration of 0.45 g, which is higher than the Safe Shutdown Earthquake criteria for US nuclear power plants required by the US Nuclear Regulatory Commission.

The civil engineering took an unexpected turn at the very start when a deep trench of soft soil, garbage and rotting plants was uncovered 14 m under the foundations. The 100 m long trench was estimated to be 10 m wide and nearly 10 m thick. The solution was to fill the trench with a customized lightweight concrete with the hardness and geological characteristics of the neighbouring foundations. The delay in construction caused by clearing out the soft soil led to installation of the first accelerator components inside the TPS shielding walls in a dusty, unfinished building with no air conditioning. The harsh working environment in summer, with temperatures sometimes reaching 38 °C, made the technological challenges seem almost easy.

Technology transfer

The ultra-high-vacuum system was designed and manufactured by NSRRC scientists and engineers, who also trained local manufacturers in the special technique of welding, the clean-room setup, and processing in an oil-free environment. This transfer of technology is helping the factories to undertake work involving the extensive use of lightweight aluminum alloy in the aviation industry. During the integration tests, the magnetic permeability of the vacuum system in the booster ring, perfectly tailored for the TPS, proved not to meet the required standard. The elliptical chambers were removed immediately to undergo demagnetization heat-treatment in a furnace heated to 1050 °C. For the 2 m long components this annealing took place in a local factory, while shorter components were treated at the NSRRC. The whole system was back online after only three weeks – with an unexpected benefit. After the annealing process, the relative magnetic permeability of the stainless vacuum steel chambers reached 1.002, lower than the specification of 1.01 currently adopted at light-source facilities worldwide.

The power supplies of the booster dipole magnets were produced abroad and had several problems. These included protection ▷

Left: NSRRC staff celebrating the successful TPS commissioning, including front row, from right, Gwo-Huei Luo, executive director TPS project and NSRRC deputy-director, Shangjr Gwo, NSRRC director, Shih-Lin Chang, former NSRRC director, Lih-Juann Chen, chair of the NSRRC Board of Trustees, Yuen-Chung Liu, former NSRRC director, and Chien-Te Chen, director-general TPS project and former NSRRC director. (Image credit: NSRRC.) Right: President Ying-Jeou Ma, centre, touring the TPS storage ring with Chien-Te Chen, left, and Shangjr Gwo, during the official inauguration on 25 January. (Image credit: Office of the President.)

circuits that overheated to the extent that a fire broke out, causing the system to shut down during initial integration tests in August. As the vendor could not schedule a support engineer to arrive on site before late November, the NSRRC engineers instead quickly implemented a reliable solution themselves and resumed the integration process in about a week. The power supplies for the quadrupole and sextupole magnets of the storage ring were co-produced by the NSRRC and a domestic manufacturer, and deliver a current of 250 A, stable to less than 2.5 mA. Technology transfer from the NSRRC to the manufacturer on the design and production of this precise power supply is another byproduct of the TPS project.

24-hour shifts

Ahead of completion of the TPS booster ring, the linac was commissioned at a full-scale test site built as an addition to the original civil-construction plan (*CERN Courier* July/August 2011 p11). The task of disassembling and moving the linac to the TPS booster ring, re-assembling it and testing it again was not part of the initial plan in 2009. The relocation process nearly doubled the effort and work time. As a result, the four-member NSRRC linac team had to work 24-hour shifts to keep to the schedule and budget – saving US$700,000 of disassembly and re-assembly fees had this been carried out by the original manufacturer. After the linac had been relocated, the offsite test facility was transformed into a test site for the High-Brightness Injector Group.

Initially, the TPS design included four superconducting radio-frequency (SRF) modules based on the 500 MHz modules designed and manufactured at KEK in Japan for the KEKB storage ring. However, after the worldwide financial crisis in 2008 caused the cost of materials to soar nearly 30%, the number of SRF modules was reduced to three and the specification for the stored electron beam was reduced from 400 mA to 300 mA. But collaboration and technology transfer on a higher-order mode-damped SRF cavity for high-intensity storage rings from KEK has allowed the team at NSRRC to modify the TPS cavity to produce higher operational power and enable a stored electron beam of up to 500 mA – better, that is, than the original specification. (Meanwhile, the first phase of commissioning in December used three conventional five-cell cavities from the former PETRA collider at DESY – one for the booster and two for the storage ring – which had been purchased from DESY and refurbished by the NSRRC SRF team.)

The TPS accelerator uses more than 800 magnets designed by the NSRRC magnet group, which were contracted to manufacturers in New Zealand and Denmark for mass production. To control the electron beam's orbit as defined by the specification, the magnetic pole surfaces must be machined to an accuracy of less than 0.01 mm. At the time, the New Zealand factory was also producing complicated and highly accurate magnets for the NSLS-II accelerator at Brookhaven National Laboratory. To prevent delays in delivering the TPS magnets – a possible result of limited factory resources being shared by two large accelerator projects – the NSRRC assigned staff members to stay at the overseas factory to perform on-site inspection and testing at the production line. Any product that failed to meet the specification was returned to the production line immediately. The manufacturer in New Zealand also constructed a laboratory that simulated the indoor environment of the TPS with a constant ambient temperature. Once the magnets reached an equilibrium temperature corresponding to a room temperature of 25°C in the controlled laboratory, various tests were conducted.

Leadership played a critical role in the success of completing the TPS construction to budget and on schedule.

Like the linac, the TPS cryogenic system was commissioned at a separate, specially constructed test site. The helium cryogenic plant was dissembled and reinstalled inside the TPS storage ring in March 2014, followed by two months of function tests. With the liquid nitrogen tanks situated at the northeast corner, outside and above the TPS building, feeding the TPS cooling system – which stretches more than several hundred metres – is a complex operation. It needs to maintain a smooth transport and a long-lasting fluid momentum, without triggering any part of the system to shut down because of fluctuations in the coolant temperature or pressure. The cold test and the heat-load test of the liquid helium transfer-line is scheduled to finish by the end of March 2015 so that the liquid helium supply will be ready for the SRF cavities early in April.

Since both the civil engineering and the construction of the accelerator itself proceeded in parallel, the TPS team needed to conduct acceptance tests of most subsystems off-site, owing to the compact and limited space in the NSRRC campus. When all of the components began to arrive at the yet-to-be completed storage ring, the installation schedule was planned mainly according to the availability of magnets. This led to a two-step installation plan. In the first half of the ring, bare girders were set up first, followed by the installation of the magnets as they were delivered and then the vacuum chambers. For the second half of the ring, girders with pre-mounted magnets were installed, followed by the vacuum chambers. This allowed error-sorting with the beam-dynamics model to take place before finalizing the layout of the magnets for the minimum impact on the beam orbit. Afterwards, the final alignment of each component and tests of the integrated hardware were carried out in readiness for the commissioning phase.

Like other large-scale projects, leadership played a critical role in the success of completing the TPS construction to budget and on schedule. Given the government budget mechanism and the political atmosphere created by the worldwide economic turmoil over the past decade, leaders of the TPS project were frequently second-guessed on every major decision. Only by having the knowledge of a top physicist, the mindset of a peacemaker, the sharp sense of an investment banker and the quality of a versatile politician, were the project leaders able to guide the team to focus unwaveringly on the ultimate goal and turn each crisis into an opportunity.

● Further reading

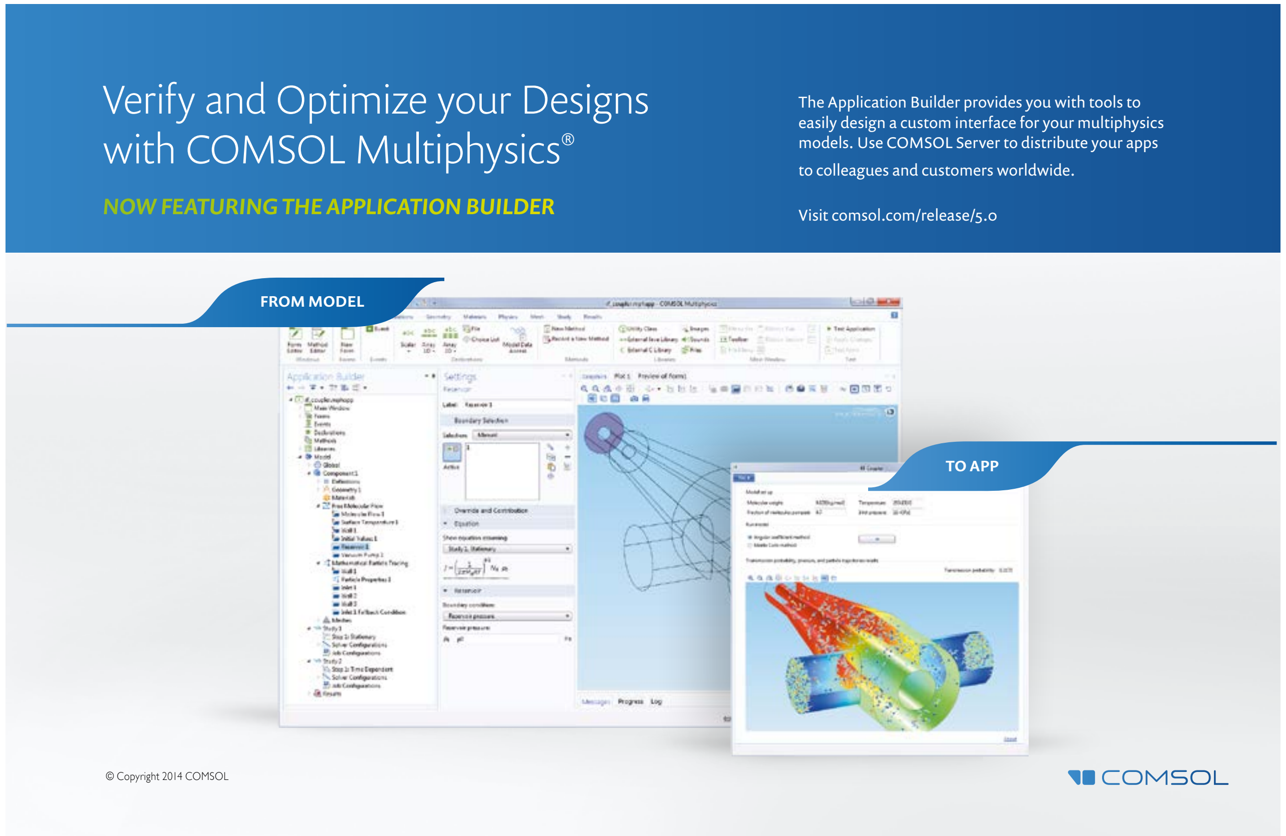
For more details, see http://www.nsrrc.org.tw/english/index.aspx.

Résumé

La TPS commence à briller

L'année 2014 s'est terminée en beauté pour la Source de photons de Taïwan (TPS) au Centre de recherche national sur le rayonnement synchrotron : le 31 décembre, un faisceau d'électrons de 3 GeV a pu circuler pour la première fois dans le nouvel aimant de stockage. Un mois plus tard, la TPS a été inaugurée lors d'une cérémonie qui a officiellement marqué la fin de dix années de préparation depuis que le projet a été proposé en 2004, les cinq dernières années ayant été consacrées à la conception, au développement, à la construction et à l'installation de l'anneau de stockage.

Diana Lin, National Synchrotron Radiation Research Center.



Working with quarkonium

Almost 200 experts met at CERN in November to discuss the latest developments in quarkonium physics at the 10th meeting organized by the Quarkonium Working Group.


QWG activity since 2002: 10 workshops, one school, two reports. (Image credit: A Vairo.)

Quarkonium lies at the very foundation of quantum chromodynamics (QCD). In the 1970s, following the discovery of the J/ψ in 1974, the narrow width (and later the hyperfine splittings) of quarkonium states corroborated spectacularly asymptotic freedom as predicted by QCD in 1973 and served to establish it as the theory of the strong interaction (*CERN Courier* January/February 2013 p24). Further progress in explaining quarkonium physics in terms of QCD turned out, however, to be slow in coming and relied for a long time on models. The reason for these difficulties is that non-relativistic bound states, such as quarkonia, are multiscale systems. While some processes, such as annihilations, happen at the heavy-quark mass scale and, as a consequence of asymptotic freedom, are well described by perturbative QCD, all quarkonium observables are also affected by low-energy scales. If these scales are low enough for perturbative QCD to break down, then they call for a nonperturbative treatment.

In the 1990s, the development of non-relativistic effective field theories such as non-relativistic QCD (1986, 1995) and potential non-relativistic QCD (1997, 1999) led to a systematic factorization of high-energy effects from low-energy effects in quarkonia. Progress in lattice QCD allowed an accurate computation of the latter. Hence, the theory of quarkonium physics became fully connected to QCD. The founding of the Quarkonium Working Group (QWG) in 2002 was driven mostly by this theoretical progress and the urgency and enthusiasm to transmit the new paradigm. Electron–positron collider experiments (BaBar, Belle, BES, CLEO) and experiments at Fermilab's Tevatron were yielding quarkonium data with unprecedented precision, and QCD was in a position to take full advantage of these data.

The QWG gathered together experimentalists and theorists to establish a common language, highlight unsolved problems, set future research directions, discuss the latest data, and suggest new analyses in quarkonium physics. Its first meeting took place at CERN in November 2002 (*CERN Courier* March 2003 p6), where the urgency and enthusiasm of 2002 animated long evening sessions that eventually led to the first QWG document in 2005 (Quarkonium Working Group Collaboration 2005). This document reflects the original intent of the QWG: to rewrite quarkonium physics in the language of effective field theories, emphasizing its potential for systematic and precise QCD studies. But surprises were around the corner.

In 2003 the first observation of the X(3872) by Belle – which with more than 1000 citations is the most quoted result of the B-factories – opened an era of new spectroscopy studies sometimes called the "charmonium renaissance" (*CERN Courier* January/February 2004 p8). From 2003 onwards, several new states were found in the charmonium and bottomonium regions of the spectrum, and they were unlikely to be standard quarkonia. Some of them – the many charged states named $Z_c^{\pm}$ and $Z_b^{\pm}$ – surely were not. Suddenly quarkonium became again a tool for discoveries, not necessarily of new theories, but of new phenomena in the complex realm of low-energy QCD. The second QWG document in 2011 captured this overwhelming flow of new data and the surrounding excitement (Quarkonium Working Group Collaboration 2011). But more excitement and more new data were still to come.

The original intent of the QWG was to rewrite quarkonium physics in the language of effective field theories.

Almost exactly 12 years after the first meeting organized by the QWG, quarkonium experts converged again on CERN for the group's 10th meeting on 10–14 November 2014. Sponsored by the QWG, the 2014 meeting was organized ▷

locally by CERN affiliates and staff members, and supported by the LHC Physics Centre at CERN. The meeting began with several sessions devoted to spectroscopy, with the focus on the new spectroscopy. The ATLAS, Belle, BESIII, CMS and LHCb collaborations all presented new analyses and data. One surprise was BESIII's observation of an $e^+e^- \to \gamma X(3872)$ signal at $s > 4$ GeV, perhaps via Y(4260) $\to \gamma X(3872)$. If confirmed it would relate two of the best known new states in the charmonium region and challenge the popular interpretation of the Y(4260) as a charmonium hybrid.

In view of the many new states, theoretical effort has concentrated on finding a common framework that could describe them. Molecular interpretations, tetraquarks and threshold cusp-effects were among the possibilities discussed at the meeting. A novelty was the proposal to use lattice data to build hybrid and tetraquark multiplets within the Born–Oppenheimer approximation. Two lively round-table discussions debated the new states further. In a special discussion panel, the Particle Data Group members of the QWG asked for input in establishing a naming scheme for these states. The suggestion that eventually came from the QWG was to call the new states in the charmonium region X_{cJ} if $J^{PC} = J^{++}$, Y_{cJ} if $J^{PC} = J^{--}$, P_{cJ} if $J^{PC} = J^{-+}$ and Z_{cJ} if $J^{PC} = J^{+-}$, and to follow a similar scheme in the bottomonium region.

Presenting new results

Non-relativistic effective field theories, perturbative QCD and lattice calculations played a major role in the sessions that were devoted to precise determinations of the heavy-quark masses, the strong coupling constant and other short-range quantities. Typical results required calculations with three-loop or higher accuracies. New results were presented on the leptonic width of the $\Upsilon(1S)$, the quarkonium spectrum, the heavy-quark masses, heavy-quark pair production at threshold and α_s. Lattice QCD provided a valuable input in some of these determinations (figure 1) or an alternative derivation with comparable precision. On the experimental side, the KEDR collaboration highlighted some of its most recent precision measurements in the charmonium region below or close to threshold. Quarkonium observables may serve not only to constrain precisely Standard Model parameters in the QCD sector, but also to determine some otherwise difficult-to-access electroweak parameters. In particular, there was a report on the possibility of measuring the $Hc\bar{c}$ coupling in the radiative decay of the Higgs boson to J/ψ.

The last two days of the workshop were devoted to quarkonium production at heavy-ion and hadron colliders. Measurements of quarkonium production cross-sections in heavy-ion and proton–heavy-ion collisions were presented by the LHC collaborations ALICE, CMS and LHCb, and by PHENIX and STAR at Brookhaven's Relativistic Heavy-Ion Collider (RHIC). It has been known since 1986 that quarkonium dissociation – induced by the medium that is produced in heavy-ion collisions – may serve as a probe of the properties of the medium, possibly revealing the presence of a new state of matter.

To isolate the relevant signal, it is important that the effects of cold nuclear matter are properly accounted for. This is the motivation behind measurements of proton–heavy-ion collisions, and the many theoretical studies that were presented

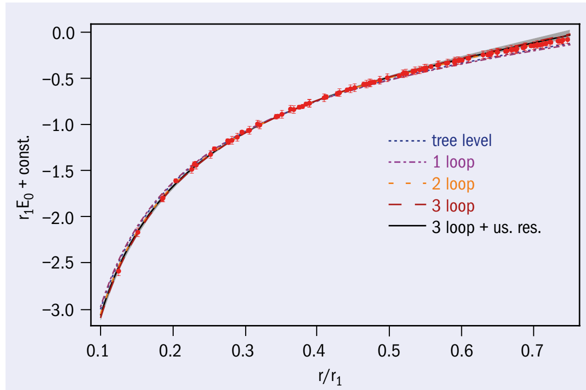


Fig. 1. Comparison of 2+1-flavour lattice QCD data for the static energy E_0 in units of $r_1 = 0.3106(17)$ fm with perturbative expressions at different orders of accuracy. (From the talk of X Garcia i Tormo.)

at the workshop. It is important to account for recombination effects and to look at tightly bound states that are less sensitive to nonperturbative contributions (bottomonium). It is also important to consider the dynamics of thermalization – a key ingredient to link spectral studies to actual data. Finally, it is important to have a controlled way to compute the underlying dissociation processes. This is where major progress was made in recent years with the development of non-relativistic effective field theories for quarkonium in a thermal bath. The main result has been a change in the understanding of quarkonium dissociation. Until recently, dissociation was mostly understood as a consequence of the screening that is induced by the medium, but, nowadays, additional mechanisms of dissociation have been identified, which under some circumstances may be more important than screening. Several speakers reported on the present theoretical situation, as well as lattice calculations in an effective-field-theory framework.

Quarkonium production mechanisms in hadron colliders are at the core of the modern understanding of quarkonium physics. The successful theoretical description of production data from the Tevatron through the so-called colour-octet mechanism helped to establish non-relativistic QCD as a suitable effective field theory for quarkonia in the 1990s. Predictions of non-relativistic QCD continue to be challenged by the enormous amount of data that has been provided over the past years by the experiments at DESY's HERA collider and at the Tevatron and, most recently, by the LHC experiments. ALICE, ATLAS, CMS and LHCb all presented data on regions of large transverse-momentum that were, up to now, unexplored. The meeting discussed theoretical issues that arise in trying to describe these data, and emphasized the crucial role that experiments must play in resolving these issues. One such issue is that different determinations of the nonperturbative matrix elements of non-relativistic QCD, which rely on fitting to the data in different transverse-momentum regions and/or on different sets of observables, lead to different results. Some of these determinations fail to yield definite predictions for quarkonium polarizations, while others lead to polarization predictions that are in contradiction with polarization data (figure 2).

Quarkonium's multiscale nature allows for systematic studies of QCD across a range of energy scales.

An important related issue is to establish clearly the transverse-momentum region in which non-relativistic QCD factorization holds. This issue is best addressed by having the greatest possible amount of cross-section and polarization data at high and low transverse-momenta for both charmonium and bottomonium states, including the P-wave χ_c and χ_b states. Some speakers pointed out that measurements of additional production processes may further constrain the non-relativistic QCD matrix elements. Finally, others suggested that a resolution of the theoretical issues may not be far away.

A celebration of quarkonium

Embedded in the workshop, Chris Quigg's seminar in the CERN Physics Department's series celebrated the first 40 years of quarkonium in the presence of many of the heroes of quarkonium physics. The talk, rich in anecdotes and insights, but also with many highlights on current directions, served as a delightful pause in the packed schedule of the workshop. It also served to put the workshop, whose discussion items focused on the advances of the past year and a half, on a broader, more historical perspective.

Quarkonium is a special system. Its multiscale nature with at least one large energy scale allows for systematic studies of QCD across a range of energy scales. Its clean experimental signatures have led over the years to a significant experimental programme, which is pursued today by, among others, the Belle and BES experiments as well as those at RHIC and at the LHC. Quarkonium has proved to be a competitive, sometimes unique, source for precise determinations of the parameters of the Standard Model (the strong-coupling constant, masses, Higgs-coupling to heavy quarks), a valuable probe for emergent QCD phenomena in vacuum (such as exotic bound states: hybrids, tetraquarks, molecules; or the colour-octet mechanism in quarkonium production and decay) and in medium (such as the state of matter formed in heavy-ion collisions); and, possibly, a probe for new physics. The QWG has provided during the past 12 years an organization in which the advance of quarkonium physics could be shared in a coherent framework among a wide community of physicists. The CERN workshop in 2014 was also a celebration of this achievement.

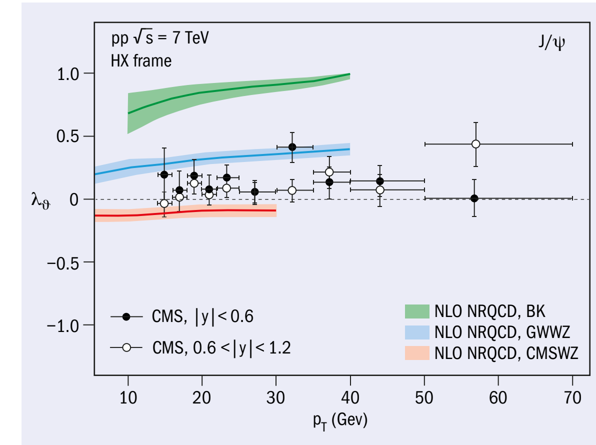


Fig. 2. The quarkonium polarization puzzle: J/ψ polarization for three different sets of non-relativistic QCD matrix elements vs CMS data. (From the talks of G Bodwin and C Lourenço.)

Further reading

For all of the speakers and their presentations, see http://indico.cern.ch/event/278195/.

Quarkonium Working Group Collaboration (N Brambilla *et al.*) 2005 FERMILAB-FN-0779, CERN-2005-005, arXiv:hep-ph/0412158.
Quarkonium Working Group Collaboration (N Brambilla *et al.*) 2011 *Eur. Phys. J.* **C71** 1534, arXiv:1010.5827 [hep-ph].

Résumé

Travailler avec le quarkonium

La découverte, dans les années 1970, des états étroits du quarkonium corrobora de façon remarquable la liberté asymptotique prédite par la chromodynamique quantique, et permit d'ériger celle-ci en théorie des interactions fortes. Toutefois, il aura fallu attendre les années 1990 pour que la physique du quarkonium puisse être expliquée plus finement sur le plan théorique. En 2002, le groupe de travail sur le quarkonium a été constitué afin qu'expérimentateurs et théoriciens fassent le point sur les problèmes irrésolus, examinent les dernières données disponibles et proposent de nouvelles analyses dans le domaine de la physique du quarkonium. En novembre 2014, près de 200 experts se sont réunis au CERN à l'occasion de la dixième réunion du groupe.

Nora Brambilla and **Antonio Vairo**, TU Munich for the Quarkonium Working Group.

Faces & Places

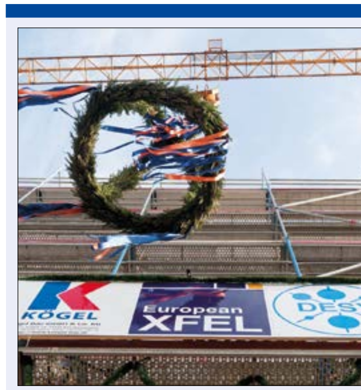
FACILITIES

NSLS-II dedicated at Brookhaven

In a ceremony on 6 February, Ernest Moniz, the US secretary of energy, dedicated the National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory (BNL). The new facility continues the 32-year legacy of research at Brookhaven's first light source, NSLS, which led directly to the awarding of two Nobel prizes and contributed to a third. The planning, design and construction of NSLS-II spanned 10 years before it delivered its "first light" in October 2014. It provides beams 10,000 times brighter than NSLS, and when the 30 beamlines are all completed it will be able to support thousands of scientific users each year.

NSLS-II is a $912-million user facility of the US Department of Energy's Office of Science, which produces extremely bright beams of X-ray, ultraviolet and infrared light. With $150 million in funding through the American Recovery and Reinvestment Act of 2009, it has come online on time and under budget.

At the ceremony, Department of Energy secretary Ernest Moniz, centre, recognized Brookhaven site office manager, Frank Crescenzo, left, and NSLS-II project director, Steve Dierker, for their leadership on the project. (Image credit: BNL.)



A topping-out ceremony for the headquarters building of the European XFEL took place in Schenefeld in the German federal state of Schleswig-Holstein on 18 February. The event marked a milestone in the construction of the X-ray free-electron laser. The symbolic "tree" made its way to the roof by crane, as the ceremony began with the traditional toast given by the foreman of the site in honour of the construction workers. (Image credit: European XFEL.)

APPOINTMENT

Ratoff takes over at the Cockcroft Institute

The Cockcroft Institute at Daresbury Laboratory has appointed Peter Ratoff as its new director from 1 March. A founding member of the institute when it was established in 2004, he has been acting director since Swapan Chattopadhyay took up a new appointment in the US in July 2014 (*CERN Courier* September 2014 p32).

As professor of experimental particle physics and head of the Physics Department at Lancaster University, Ratoff's research has focused on the design and construction of particle detectors and experiments at particle accelerators and colliders, in particular for testing the Standard Model in both strong and electroweak sectors. He takes over at a time when the institute's portfolio contains challenging new research projects, ranging from upgrades of the LHC at CERN to a ground-breaking R&D programme in light sources at Daresbury.

The Cockcroft Institute is a joint venture in accelerator science and technology involving the Universities of Liverpool and Manchester, Lancaster University and the Science and Technology Facilities Council. Dedicated to the design and optimization of new accelerator technologies at the LHC, as well as at other accelerator laboratories around the world, the institute enables UK scientists and engineers to play a major role in accelerator design, construction and operation.

Peter Ratoff, left, at the farewell for Swapan Chattopadhyay, right, in July 2014. (Image credit: DL Media Services.)

AWARD

Lahri to receive the Hevesy Medal

Susanta Lahiri of the Saha Institute of Nuclear Physics, Kolkaka, is one of two awardees for the 2015 Hevesy Medal, "for his outstanding and sustained contribution in heavy-ion-induced radioisotope production, tracer packet technique, converter targets, and green chemistry". The 2015 award goes also to Kattesh Katti of the University of Missouri-Colombia.

Lahiri is recognized for a rich career during which he has developed and maintained active international collaborations with leading physics and chemistry institutes, including CERN, notably for the development of high-power targets in the EURISOL Design Study and the LIEBE test project at ISOLDE, and in research on radiopharmaceuticals and superheavy elements. In a long list of achievements, Lahiri launched the conference series on Application of RadiotraCers and Energetic Beams in Sciences (ARCEBS). He will receive the award at the 10th International Conference on Methods and Applications of Radioanalytical Chemistry (MARC X), another major conference in the field.

The medal is named after George de Hevesy, who received the Nobel Prize in Chemistry in 1943 for his work on the use of isotopes as tracers in the study of chemical processes. The Hevesy Medal was established 25 years later as the premier international award of excellence in radioanalytical and nuclear chemistry.

Susanta Lahiri. (Image credit: S Lahiri.)

OUTREACH

New exhibition on CERN opens in Egypt

The Bibliotheca Alexandrina in Egypt is one of the most culturally inspiring, yet unexpected, places to find an exhibition about CERN and particle physics. "The Alphabet of the Universe: from CERN to North Africa and the Middle East" was inaugurated on 19 January in the Planetarium Science Centre (PSC), one of the main attractions in the modern library in Alexandria. In an area of 400 square metres, the exhibition covers four main themes: what we know, open issues, accelerators and detectors, computing and applications.

The 40 exhibits, designed by CERN and the PSC, were handmade in Egypt. Some were inspired by and based on existing CERN exhibitions but most were created from scratch. The Higgs field is explained using pistons that can be pushed to feel the difference in resistance, and therefore mass. Mesons and hadrons are explained with black and white magnetic pieces that can be put together only according to the allowed combinations. The exhibition also includes a presentation of CERN as the world's largest particle-physics laboratory, where different cultures work together on cutting-edge science.

The exhibition will remain in Alexandria until the end of the year.

"The Alphabet of the Universe" exhibition in Egypt. (Image credit: Bibliotheca Alexandrina.)

*John Bell, the theoretician from CERN who is deservedly best known for his ground-breaking theorem, has been honoured in his native Belfast with the naming of a new street after his work. "Bell's Theorem Crescent" celebrates the famous 1964 paper that laid the basis for emerging new technologies such as quantum computing (*CERN Courier *September 2014 p34). The unveiling of the new street name – which marked the start of the first-ever Northern Ireland Science Festival – was attended by Belfast lord mayor, Nichola Mallon, relatives of John Bell (Ruby McConkey, centre left, and Robert Bell, centre right), and representatives from Northern Ireland's science community. (Image credit: Stakeholder.)*

CONFERENCE

Poland looks at participation in future accelerators

Participants at the round table: left, from left to right, Agnieszka Zalewska, Ewa Rondio, Andrzej Siemko, Roman Pöschl, Alain Blondel, Tadeusz Lesiak, Roy Alexan; right, from left to right, Manfred Kramer, Robert Zwaska, Max Klein, Lucie Linssen, Marek Jeżabek. (Image credit: Epiphany Conference organizing committee.)

Around 110 particle physicists gathered together on 8–10 January for the Cracow Epiphany Conference on Future High Energy Colliders. The meeting took place at the headquarters of the Polish Academy of Arts and Sciences, in the heart of the city.

Rather than the three biblical Magi searching for the baby Jesus – traditionally celebrated at Epiphany – the conference brought together physicists in search of a strategy for future European participation in new accelerator projects. To guide them, several world-class experts provided the participants with 24 illuminating talks. All of the relevant proposed accelerator schemes, both linear (ILC in Japan and CLIC at CERN) and circular (CEPC/SppS in China and FCC at CERN) came under scrutiny, with special attention paid to accelerator issues as well as the physics potential and detector prerequisites. The LHC upgrade together with CERN's R&D studies of future superconducting magnets were also discussed. Separate talks were devoted to the AWAKE project of plasma acceleration at CERN, and to Fermilab's programme of intense proton beams aimed at neutrino physics.

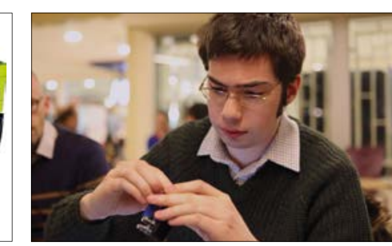
The conference concluded with an excellent overview by Agnieszka Zalewska, the president of CERN Council, which was followed by a round-table discussion. Led by Marek Jeżabek, the general director of Cracow's Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), the discussion concentrated on options for European contributions to future projects for particle physics.

Following its two-decades-long tradition, the Epiphany meeting provided a useful platform for young researchers to present their scientific achievements, with 17 interesting talks. The inspiring and friendly atmosphere of the conference, with lively discussions after the talks and during coffee, was particularly motivating for the young attendees.

● For more about the Epiphany conference, visit epiphany.ifj.edu.pl/current. The proceedings will be published as the July 2015 issue of *Acta Physica Polonica B*.

OUTREACH

Build your own Lego LHC



Left: A computer simulation of the miniature Lego LHC. (Image credit: N Readioff.) Right: Nathan Readioff tests his designs. (Image credit: Kate Shaw.)

A PhD student working on the ATLAS experiment has created a replica of the LHC using Lego bricks. Nathan Readioff, from the University of Liverpool, has submitted his design to Lego Ideas, and now awaits the 10,000 votes needed for it to qualify for the Lego Review, which decides if projects become new Lego products.

Readioff's design is a stylized model of the LHC, showcasing the four main experiments ALICE, ATLAS, CMS and LHCb, but on a micro scale. Each detector is small enough to fit into the palm of the hand, yet the details of the internal systems are intricate and revealed by cutaway walls. Every major sub-detector is represented by a Lego piece. The models are not strictly in scale with one another – for example, the LHC diploes are oversize – but they use the same size of base to maximize the detail that can be included, and give a more uniform look to the set.

While working on the Lego LHC, Readioff learnt a surprising amount about CERN and the various detectors. He also learnt how to assemble a robust Lego model, and questions the designs recommended by computer simulation. His replica has parts that hold together well, to help the builder assemble each detector within minutes.

To build your own miniature LHC, download the complete instruction manuals and parts lists at https://build-your-own-particle-detector.org. To vote for Readioff's Lego LHC design, register with Lego Ideas and click the "Support" button on the Lego LHC page https://ideas.lego.com/projects/94885.

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Faces & Places

Visits

The Nepalese minister for health and population, **Khaga Raj Adhikari**, right, visited CERN on 29 January. Following a general introduction to the laboratory's activities by CERN's head of international relations, **Rüdiger Voss**, he was presented with a temperature-sensitive mug depicting the history of the universe. Later, the minister visited the CMS experiment and the Antiproton Decelerator. (Image credit: CERN-PHOTO-201501-018 – 10.)

On 30 January, **Carlos Moedas**, the European commissioner for research, science and innovation, visited the CMS underground experimental cavern, with CERN's director for research and computing, **Sergio Bertolucci**, left. The visit also included the Computing Centre and the area where magnets for the SESAME light source in Jordan are being tested. (Image credit: CERN-PHOTO-201501-019 – 2.)

During his visit to CERN on 17 February, the Lithuanian minister of education and science, **Dainius Pavalkis**, third row, right, met teachers taking part in the Lithuanian Teachers' Programme – one of many national programmes organized by CERN. He also heard about the LHC Computing Grid project and saw the CMS underground area. (Image credit: CERN-PHOTO-201502-033 – 5.)

Meetings

The **25th International Workshop on Weak Interactions and Neutrinos**, WIN2015, will be held at the Max-Planck-Institut für Kernphysik in Heidelberg on 8–13 June. The workshop offers a significant opportunity to assess the experimental and theoretical status of the field, and initiate collaborative efforts to address current physics questions. The programme includes plenary and parallel sessions on electroweak theory and Higgs physics, neutrino physics, astroparticle physics and flavour physics, as well as highlight talks on topics with significant developments. For further details and registration (deadline 3 May), see www.mpi-hd.mpg.de/WIN2015/.

POETIC6, the 6th edition of the **International Conference on the Physics Opportunities at an ElecTron-Ion Collider**, will take place at Ecole Polytechnique in Palaiseau, France, on 7–11 September. While the central theme will be the physics of a future electron–ion collider, the workshop will also cover related physics in the CEBAF, RHIC and LHC experimental programmes. The conference will primarily cover developments on the theory/phenomenology side, but accelerator and experimental developments of interest will also be discussed. The aim is to foster exchanges between theory, phenomenology and experiment. For more information, visit poetic6.sciencesconf.org.

Faces & Places

Obituary

Charles Townes 1915–2015

The inventor of the laser, Charles Hard Townes, passed away on 27 January at the age of 99. He made significant contributions in many areas of physics and remained active until his last year, when declining health intervened.

Townes was born in 1915 in Greenville, South Carolina. Following undergraduate work at Furman University, he did graduate work at Duke University and then Caltech, where he received his PhD in 1939. He then moved to Bell Labs in New Jersey, where he remained throughout the Second World War, designing radar-based bombing systems.

After the war, he became interested in using shorter, microwave wavelengths for molecular spectroscopy. The challenge was to generate sufficiently intense beams. He conceived the idea of putting the gas in a resonant cavity – by absorbing an incident photon, the gas would be stimulated to emit a coherent burst. In 1954, he and his students built such a device: an ammonia maser.

By 1958, he was interested in shorter, visible wavelengths. He and his brother-in-law, Arthur Schawlow, conceived the idea of a laser, using mirrors in a gas tube to produce a cavity. For this work, Townes shared the 1964 Nobel Prize in physics. Today, lasers are used in household items from laser printers to DVD readers. In research, they are even being used for particle acceleration – the BELLA facility at Berkeley recently accelerated electrons to 4.2 GeV, in a 9-cm-long accelerator (*CERN Courier* January/February 2015 p9).

Charles Townes. (Image credit: Lawrence Berkeley National Laboratory.)

In 1967, Townes moved to Berkeley, where he acquired an interest in astronomy. One of his first activities was to build a maser amplifier and microwave spectrometer, to search for radiation from the vibrational modes of complex molecules. By 1968, he and Jack Welch had observed ammonia and water signatures from the core of the Milky Way, confounding many astronomers who did not believe that molecules could survive in space. They went on to discover water masers operating in space. These observations initiated a new area of astronomical research.

Townes then grew interested in other aspects of infrared astronomy, searching for heat sources in outer space, and pursuing precision infrared spectrometry. In 1985, he and Reinhard Genzel observed swirling gas clouds orbiting a massive object now known to be a black hole. Townes developed high-resolution interferometric arrays, using them to study the dust that surrounds old stars and even to search for signals from extra-terrestrial civilizations.

Throughout his life, Townes maintained an interest in the intersection of science and religion. His seminal 1966 article "The Convergence of Science and Religion" established him as a leading voice – among scientists, in particular – seeking commonality between the two disciplines. For this work, he received the 2005 Templeton Prize.

Townes is survived by his wife of 74 years, Frances Hildreth Townes (née Brown), four daughters, six grandchildren and two great grandchildren.

● *Based – with permission – on the obituary by Robert Sanders published on the UC BerkeleyNews Center website, http://newscenter.berkeley.edu/2015/01/27/nobel-laureate-and-laser-inventor-charles-townes-dies-at-99/.*

New products

AMS Technologies provide high-power laser diodes up to 150 mW with a wavelength range from 650 nm to 1120 nm in different packaging options. Single-frequency laser radiation, precisely balanced in narrow linewidth and tunability, will excite, detect or manipulate atoms such as rubidium or caesium. A variety of AR-coated diodes are available for external-cavity set-ups, which can cover wide wavelength ranges. For further information, visit www.amstechnologies.com/products/optical-technologies/components/lasers-light-sources/lasers/diode-lasers/view/dfb-dbr-lasers/.

Goodfellow has expanded its offering to include custom manufacturing and finishing of components to customers' precise specifications. Services include, but are not limited to, precision machining, cutting, turning, rolling, drilling, grinding, and milling; forming, bending, and shaping; coating with almost any metal or polymer to a defined thickness; and surface treatment, mechanical polishing and chemical polishing. Contact Goodfellow at info@goodfellow.com.

Intersil Corporation has introduced the ISL8203M, a dual 3A/single 6A step-down DC/DC power module that simplifies power-supply design for FPGAs, ASICs, microprocessors, DSPs and other point-of-load conversions in communications, test and measurement systems. The module's compact 9.0 × 6.5 × 1.83 mm footprint combined with 95 % efficiency provides power-system designers with a high performance, easy-to-use solution for low-power, low-voltage applications. The encapsulated module includes a PWM controller, synchronous switching MOSFETs, inductors and passive components to build a power supply supporting an input voltage range of 2.85 V to 6 V. For more information, visit www.intersil.com/products/ISL8203M.

ULVAC Technologies, Inc., has introduced the HELIOT 900 helium leak detector, which features a fast pumping speed to detect small leaks quickly, and a simple tablet-style interface. Fast response time, fast background clean-up and a 7" Android touch-screen display/controller make the system highly productive. The pumping speed of 5 l/s shortens the time for the helium background to drop. The device can detect helium or hydrogen, and several programmable configurations help to automate leak-test operations. The HELIOT 900 series features a multiple valve design for the highest sensitivity: 10^{-12} torr-l/s. For more information, contact Evan Sohm, e-mail esohm@us.ulvac.com, or visit www.ulvac.com.

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Please contact us for information about rates, colour options, publication dates and deadlines.

Fermilab

People Fellowship at Fermilab

The Peoples Fellowship at Fermilab seeks applications from newly minted Ph.Ds. (degree conferred within the past three years) in the following disciplines: Accelerator Physics; Accelerator-Related Technology; Particle Physics and Cosmology or related field. Post-doctoral experience is not required but may be advantageous for candidates applying from the field of particle physics and cosmology or a related field.

The Fellowship is awarded on a competitive basis and is designed to attract outstanding entry-level accelerator physicists, specialists in accelerator technologies, and high energy physics post-doctoral researchers with demonstrated leadership potential who wish to embark on a new career in accelerator physics or technology.

This exciting opportunity offers extraordinary latitude in research activities selection. Current areas of research that are of interest at FNAL include (but are not limited to): single particle and collective nonlinear dynamics of intense beams, microwave/optical stochastic and electron cooling of phase-space, high intensity proton beams, high intensity neutrino sources, high-field superconducting magnets, superconducting radio-frequency science and technology, high luminosity and high energy 1-100 TeV class future colliders for leptons and hadrons, novel accelerator concepts, accelerator controls and feedback, and computational physics, simulations and modeling.

The Peoples Fellowship provides an attractive salary and benefits package competitive with a university assistant professorship. The appointment term for candidates with less than two years post-doc experience is an initial four year appointment eligible to be considered for a second three-year term. For candidates with two or more years of post-doc experience, the term is an initial three year appointment, eligible to be considered for a second two-year term.

Qualifications and Essential Job Functions

- Ph.D. within the last three years in accelerator physics or accelerator-related technology or particle physics and cosmology or a related field
- Demonstrated ability to carry out independent research
- Demonstrated leadership potential
- Excellent oral and written communication skills as demonstrated by presentations at conferences and a strong record of publications in professional journals

Respect, understand and value the individual differences that embody the principles of diversity.

Abide by all environmental, safety and health regulations.

Physical Activity and Work Requirements

Human Factors: Prolonged Computer Work, Visually Demanding, Tight Work Schedules, Confined Spaces

- Ability to travel by automobile and/or commercial air carrier both domestically and internationally may be required
- Ability and a willingness to work in underground experimental areas may be required

To be considered for this exceptional opportunity, candidates must submit a cover letter with statement of interest, an online CV, three (3) letters of reference, and a list of publications.

The application deadline is June 30, 2015.

Questions may be submitted via email to peoplesfellowship@fnal.gov and/or **swapan@fnal.gov. Attention: Prof. Swapan Chattopadhyay, Chair, Peoples Fellowship Committee**

There is no legal requirement that Fermilab sponsor an employee for U.S. permanent residence. As a result, Fermilab will make the decision to sponsor an employee on a case-by-case basis. Fermilab will consider the following factors, among others, when determining whether to sponsor an employee for U.S. permanent residence: performance, length of service, long-term need for the position, and cost.

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IceCube WinterOver Experiments Operator

WIPAC is a research center at the UW-Madison responsible for the IceCube Neutrino Observatory at the South Pole.

Working as a team with one additional IceCube winter-over personnel, this position will be responsible for all winter-over operations of this state-of-the-art neutrino observatory.

This position is located at the Amundsen-Scott South Pole Station and reports to the Winter-over Manager in Madison, WI.

Training for two candidates is anticipated to begin in Madison, WI at the beginning of August. Deployment to the South Pole is expected to be in early October for 12-13 months with no possibility of leaving during the winter months from mid-February to mid-October.

Successful candidates will attend the NSF contractor orientation program and will be expected to pass physical and psychological evaluations to work at polar and high altitude sites for one year, as required by the National Science Foundation (NSF) Office of Polar Programs.

M.S. in Computer Science, Physics, Electrical Engineering or related field is required. B.S. in Computer Science, Electrical Engineering, or related field and substantial (equivalent to a Masters degree) experience will be considered.

For instructions to apply http://www.ohr.wisc.edu/WebListing/Unclassified/PVLSummary.aspx?pvl_num=81771

To ensure consideration, application materials must be received by April 11, 2015.

RUHR UNIVERSITÄT BOCHUM RUB 50 Jahre

The Ruhr-Universität Bochum (RUB) is one of Germany's leading **research universities**. The University draws its strengths from both the diversity and the proximity of scientific and engineering disciplines on a single, coherent campus. This highly **dynamic setting** enables students and researchers to work across traditional boundaries of academic subjects and faculties. The RUB is a **vital institution** in the Ruhr area, which has been selected as European Capital of Culture for the year 2010.

PROFESSOR (W2) IN EXPERIMENTAL PHYSICS IN THE FIELD OF HADRONS AND NUCLEI

The **Ruhr-Universität Bochum – faculty of Physics and Astronomy** invites applications for the position of a Professor (W2) in Experimental Physics in the field of hadrons and nuclei to start as soon as possible.

The future holder of the post will represent the subject in research and teaching.

The applicant should further demonstrate the ability to develop a productive and vigorous externally-funded research program in the field of experimental hadron physics as well as the enthusiasm and drive to teach and mentor both undergraduate and graduate students. The new professorship should complement existing activities in the field of meson spectroscopy and the successful candidate should take part in the planning and construction of experiments and detectors at the future FAIR facility in Germany. Modern detector technology is also used in medicine and the faculty has just opened a new field of studies in Medical Physics so a willingness to build up a working group in this is also desirable.

The teaching obligations are for Experimental Physics within all of the courses of study offered by the Department. The successful candidate should also participate actively in the newly created Medical Physics course of study.

Positive evaluation as a junior professor or equivalent academic achievement (e.g. habilitation) and evidence of special aptitude are just as much required as the willingness to participate in the self-governing bodies of the RUB and to generally get involved in university processes according to RUB's mission statement.

We expect further more:

- high commitment in teaching
- readiness to participate in interdisciplinary academic work
- willingness and ability to attract external funding

The Ruhr-Universität Bochum is an equal opportunity employer.

Complete applications with cover letter, full CV, statements of teaching philosophy and teaching records, publication list and a research plan should be sent to the **Dean of the faculty of Physics and Astronomy of the Ruhr-Universität Bochum, 44780 Bochum, Germany** no later than **April 2, 2015**. Further information is available at **www.physik.rub.de**.

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Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association
DESY

PARTICLE PHYSICS.

DESY, Hamburg location, is seeking:
Scientist (m/f)

DESY

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

The particle physics programme of DESY consists of strong contributions to the LHC experiments ATLAS and CMS and to the preparation of a future linear collider. The experimental programme is enhanced by collaboration with a strong theory group. DESY is searching an experienced high energy experimental physicist, who will take a leading role in the reconstruction of charged particles in ATLAS and contribute actively to physics data analysis.

The position

- Active role in the ATLAS experiment
- Leading role in the reconstruction of charged particles and in the analysis of ATLAS data
- Participation in the supervision of students and postdocs

Requirements

- PhD in experimental High Energy Physics
- Extensive knowledge in tracking algorithms
- Experience in HEP data analysis preferentially at hadron colliders
- Outstanding teamwork abilities
- Excellent communication skills and knowledge of English

For further Information please contact Klaus Moenig +49-33762-7-7271, klaus.moenig@desy.de or Ingrid-Maria Gregor +49-40-8998-3032, ingrid.gregor@desy.de.

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

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Deadline for applications: 15 May 2015
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CERNCOURIER
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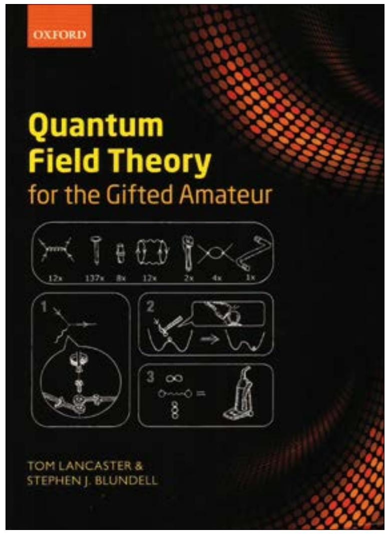
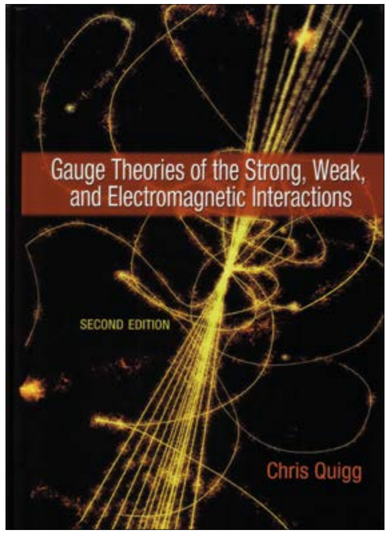
Bookshelf

Quantum Field Theory for the Gifted Amateur
By Tom Lancaster and Stephen J Blundell
Oxford University Press
Hardback: £65 $110
Paperback: £29.99 $49.95
Also available as an e-book, and at the CERN bookshop

Gauge Theories of the Strong, Weak, and Electromagnetic Interactions (2nd edition)
By Chris Quigg
Princeton University Press
Hardback: £52.00 $75.00
Also available as an e-book, and at the CERN bookshop





Many readers of *CERN Courier* will already have several introductions to quantum field theory (QFT) on their shelves. Indeed, it might seem that another book on this topic has missed its century – but that is not quite true. Tom Lancaster and Stephen Blundell offer a response to a frequently posed question: What should I read and study to learn QFT? Before this text it was impossible to name a contemporary book suitable for self-study, where there is regular interaction with an adviser but not classroom-style. Now, in this book I find a treasury of contemporary material presented concisely and lucidly in a format that I can recommend for independent study.

Quantum Field Theory for the Gifted Amateur is in my opinion a good investment, although of course one cannot squeeze all of QFT into 500 pages. Specifically, this is not a book about strong interactions; QCD is not in the book, not a word. Reading page 308 at the end of subsection 34.4 one might expect that some aspects of quarks and asymptotic freedom would appear late in chapter 46, but they do not. I found the word "quark" once – on page 308 – but as far as I can tell, "gluon" did not make its way at all into the part on "Some applications from the world of particle physics."

If you are a curious amateur and hear about, for example, "Majorana" (p444ff) or perhaps "vacuum instability" (p457ff, done nicely) or "chiral symmetry" (p322ff), you can start self-study of these topics by reading these pages. However, it's a little odd that although important current content is set up, it is not always followed with a full explanation. In these examples, oscillation into a different flavour is given just one phrase, on p449.

Some interesting topics – such as "coherent states" – are described in depth, but others central to QFT merit more words. For example, figure 41.6 is presented in the margin to explain how QED vacuum polarization works, illustrating equations 41.18-20. The figure gives the impression that the QED vacuum-polarization effect decreases the Coulomb–Maxwell potential strength, while the equations and subsequent discussion correctly show that the observed vacuum-polarization effect in atoms adds attraction to electron binding. The reader should be given an explanation of the subtle point that reconciles the intuitive impression from the figure with the equations.

Despite these issues, I believe that this volume offers an attractive, new "rock and roll" approach, filling a large void in the spectrum of QFT books, so my strong positive recommendation stands. The question that the reader of these lines will now have in mind is how to mitigate the absence of some material.

The answer lies in the second edition of Chris Quigg's *Gauge Theories of the Strong, Weak, and Electromagnetic Interactions*. By a remarkable coincidence, this essentially revised volume fills in much of what the "gifted amateur" wants to know about how QFT is applied in traditional particle physics. It is hard to find words to describe Quigg's clean, high-quality work; as an author he is a virtuoso performer. He takes the reader through the Standard Model of particle physics to the first steps beyond it, showing the most important insights, describing open questions and proposing original literature and further reading. He has designed or collected many insightful figures that illustrate beautifully the intriguing properties of the Standard Model.

However, it's hard for me personally to end the review on this high note since the research in the field of gauge theories of strong interactions does not end with the perturbative processes. Over the past 30 years, a vast new area has opened up with many fundamental insights. These connect to the QCD vacuum structure, the Hagedorn temperature and colour deconfinement as encapsulated in the new buzzword – quark–gluon plasma, the strongly-interacting colour-charged many-body state of quarks and gluons. Moreover, there is a wealth of numerical lattice results that accompany these developments.

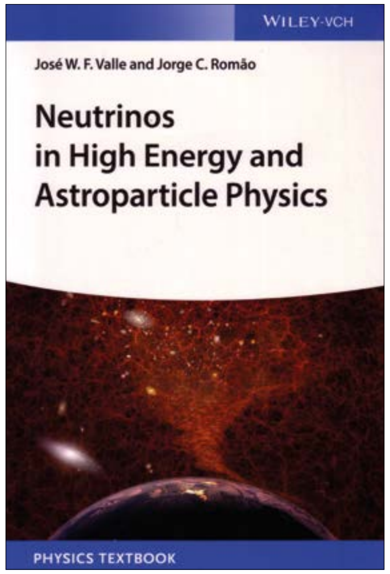
I find no key word for this in the index of Quigg's book, although there is mention of "confinement" (p336ff). On page 340, a phrase-long summary mentions the temperature of a chiral-symmetry-restoring transition (from what to what is not stated) that characterizes the lattice QCD results seen in figure 8.47 on p342. This one-phrase entry is all that describes in my estimate 20% of the experimental work at CERN of the past 25 years, and the majority of particle physics at Brookhaven for the past 15 years. In this section I also read how vacuum dielectric properties relate to confinement. I know this argument from Kenneth Wilson, as refined and elaborated on by TD Lee, and the lattice-QCD work initiated by Michael Creutz at Brookhaven, yet Quigg attributes this to an Abelian-interaction model that I did not think functioned.

Bookshelf

The author, renowned for his work addressing two-particle interactions, represents in his book the traditional particle-physics programme as continued today at Fermilab, where the novel area of QCD many-body physics is not on the research menu, though it has come of age at CERN and Brookhaven. One can argue that this new science is not "particle physics" – but it is definitively part of "gauge theories of strong interactions", words embedded in the title of Quigg's book. Thus, quark–gluon plasma, vacuum structure and confinement glare brightly by their absence in this volume.

Looking again at both books it is remarkable how complementary they are for a *CERN Courier* reader. These are two excellent texts and together they cover most of modern QFT and its application in particle physics in 1000 pages at an affordable cost. I strongly recommend both, individually or as a set. As noted, however, the reader who purchases these two volumes may need a third one covering the new physics of deconfinement, QCD vacuum and thermal quarks and gluons – the quark–gluon plasma.

● *Johann Rafelski, University of Arizona.*



Neutrinos in High Energy and Astroparticle Physics
By José W F Valle and Jorge C Romão
Wiley-VCH
Paperback: £75 €90
Also available at the CERN bookshop

Neutrinos have kept particle physicists excited for at least the past 20 years. After they were finally proved to be massive, two mass-squared differences and all three mixing angles have now been determined, the final remaining angle, θ_{13}, in 2012 by the three reactor experiments: Daya Bay, RENO and Double Chooz. As neutrino masses are expected to be linked intimately to physics beyond the Standard Model that can be probed at the LHC, and as neutrinos are about to start a "second career" as astrophysical probes, it seems a perfect time to publish a new textbook on the elusive particle. The authors Jose Vallé and Jorge Romão are leading protagonists in the field who have devoted most of their careers to the puzzling neutrino. In this new book they share their experience of many years at the forefront of research.

They begin with a brief historical introduction, before reviewing the Standard Model and its problems and discussing the quantization of massive neutral leptons. The next three chapters deal with neutrino oscillations and absolute neutrino masses – the mass being one of the fundamental properties of neutrinos that is still unknown. Here the authors give a detailed discussion of the lepton-mixing matrix – the basic tool to describe oscillations – and seesaw models of various types. An interesting aspect is the thorough discussion of what could be called "Majorananess" and its relation to neutrino masses, lepton-number violation and neutrinoless double beta decay – for example, in the paragraphs dealing with the Majorana–Dirac confusion and black-box theorems, a point that is rarely covered in text books and often results in confusion.

Next, the book discusses how neutrino masses are implemented in the Standard Model's SU(2) × U(1) gauge theory and the relationship to Higgs physics. This is followed by a detailed treatment of neutrinos and physics beyond the Standard Model (supersymmetry, unification and the flavour problem), which constitutes almost half of the entire book. Here the text exhibits its particular strength – also in comparison to the competing books by Carlo Giunti and Chung Kim, and by Vernon Barger, Danny Marfatia and Kerry Whisnant, both of which concentrate more on neutrino oscillation phenomenology – by discussing exhaustively how neutrino physics is linked to physics beyond Standard Model phenomenology, such as lepton-flavour violation or collider processes. The inclusion of a detailed discussion of these topics is a good choice and it makes the book valuable as a textbook, although it does make this part rather long and encyclopedic. Another strong point is the focus on model building. For example, the book discusses in detail the challenges in flavour-symmetry model building to accommodate a non-zero θ_{13}, and the deviation of the lepton-mixing matrix from the simple tri-bi-maximal form.

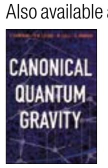
The authors end with a brief chapter on cosmology, concentrating mainly on dark matter and its connection to neutrinos. While this chapter obviously cannot replace a dedicated introduction to cosmology, a few more details such as an introduction of the Friedmann equation could have been helpful here. In general, the treatment of astroparticle physics is shorter than expected from the title of the book. For example, the detection of extragalactic neutrinos at IceCube is not covered – indeed, IceCube is only mentioned in passing as an experiment that is sensitive to the indirect detection of dark matter. Also leptogenesis and supernova neutrinos are mentioned only briefly.

The book mainly serves as a detailed and concise, thorough and pedagogical introduction to the relationship of neutrinos to physics beyond the Standard Model, and in particular the related particle-physics phenomenology. This subject is highly topical and will be more so in the years to come. As such, *Neutrinos in High Energy and Astroparticle Physics* does an excellent job and belongs on the bookshelf of every graduate student and researcher who is seriously interested in this interdisciplinary and increasingly important topic.

● *Heinrich Päs, TU Dortmund, and Sandip Pakvasa, University of Hawaii.*

Books received

Canonical Quantum Gravity: Fundamentals and Recent Developments
By Francesco Cianfrani et al
World Scientific
Hardback: £84
E-book: £63
Also available at the CERN bookshop



This book aims to present a pedagogical and self-consistent treatment of the canonical approach to quantum gravity, starting from its original formulation to the most recent developments in the field. It begins with an introduction to the formalism and concepts of general relativity, the standard cosmological model and the inflationary mechanism. After presenting the Lagrangian approach to the Einsteinian theory, the basic concepts of the canonical approach to quantum mechanics are provided, focusing on the formulations relevant for canonical quantum gravity. Different formulations are then compared, leading to a consistent picture of canonical quantum cosmology.

Inside Story

Roger Anthoine: A man of many parts

Celebrating the 90th birthday of *CERN Courier*'s first editor.

A special small edition of CERN Courier *wished the magazine's first editor "Bonne anninversaire" for his 90th birthday.*

I must have first met Roger Anthoine in 1979, when I was physical-sciences editor of *New Scientist*, he was in charge of public relations at CERN, and the organization was celebrating its 25th anniversary. Now, as he celebrates his 90th birthday, I realize what a privilege it is to have come to know him a little better during my time as editor of *CERN Courier*.

Back in 1979, Brian Southworth led the editorial team of *CERN Courier*, which also included Gordon Fraser and Henri-Luc Felder. Little did I realize then that like much of public relations at CERN, the *Courier* – a source of information that I valued highly in my role at *New Scientist* – had begun with Roger. He had been hired by CERN 20 years previously, expressly to start an internal publication for what in those early days was fewer than 900 staff. The publication was the vision of the then director-general, Cornelis Bakker. Roger, a Belgian with degrees in engineering and journalism, was in many ways the ideal person for the task. With no knowledge of the arcane world of particle physics, he could put himself in the position of the non-physicist staff members who wanted to find out in the simplest terms what their laboratory was doing.

He had to begin from square one, securing funding, deciding on the format, frequency and distribution, finding a printer and, last but not least, choosing a name – *CERN Courier* in English, *Courrier CERN* in French. The name, and much else of the magazine today, still bears Roger's imprint. The budget allocated was sufficiently low from the start to oblige him to seek additional support from advertising – an unusual strategy for a "house" magazine. The content, he recalled in the article he wrote at the time of the *Courier*'s 50th anniversary, was perhaps the easiest issue to decide upon (CERN Courier July/August 2009 p23). There was plenty happening at the laboratory, with its first small accelerator, the Synchrocyclotron, already running, and the Proton Synchrotron (PS) – the flagship of the era – about to start up. It was an appropriate time for the monthly magazine to start, with the first issue appearing in August 1959.

Unfortunately, Roger soon had his hands full for rather tragic reasons. John MacCabe, head of CERN's small Public Information Office, died suddenly in April 1960 at the age of 45, and Roger immediately found himself in charge of other public-relations activities, including VIP visits and the press office. It was difficult to edit the magazine, even if only 12 pages long, as well as do his former superior's job. So, the *Courier* went into "hibernation" before re-emerging with a new-style cover under a new editor – Alec Hester – in January 1962.

Roger was to spend the next 25 years working in public relations in its widest sense. During this time he introduced much of what was to become familiar at CERN: the first in-house guides to explain the wonders of the organization to visitors, then mainly on Saturdays; the comic strips by Georges Boixader first published in the *Tribune de Genève* in 1978; the naming of CERN's streets; the production of films at CERN… He also had the opportunity to meet many of the iconic figures in both particle physics and politics – including, perhaps most surprisingly, Che Guevara, who in 1964 visited CERN as Cuba's minister of industry.

After 27 years at CERN, Roger retired in 1986. He had served under seven directors-general, from Bakker who first employed him, up to Herwig Schopper, who thanked him at his retirement ceremony. Now at the age of 90, he has been retired for longer than he was at CERN, but he has kept up his contact with the press in the region, returning to his roots as a journalist by writing for local newspapers about CERN's activities. He has also been able to spend more time on his first love – aviation. A pilot since 1944, it is only recently that he lost the right to fly solo, for health reasons. His flying provided CERN with some historic aerial photos. In January 1963, after a three-day blizzard, Roger took to the skies above the laboratory at the controls of a Piper Super Cub, in temperatures of around –25 °C, to take pictures of the snow-covered landscape, with one ungloved hand on his Rolleiflex 6 × 6 cm camera (*CERN Courier* October 2004 p55.) During retirement, with time to apply his writing talents to his interest in historical aspects of aviation, he has published books in French and in English. After I eventually stepped into his shoes in 2003, our conversations often turned to the British Royal Air Force, in which my father served during the Second World War.

Roger started *CERN Courier* with an initial print run of 1000, and by the time he had to put it on hold, little more than a year later, the number had already risen to 3000. Now, some 21,000 copies are printed 10 times a year. From the start it had excited interest beyond CERN, and today serves a worldwide community, having been rebranded in 1974 with the subtitle "International Journal of High-Energy Physics" (*CERN Courier* December 2014 p28).

Much of what Roger introduced remains reflected in the magazine today. So, reader, as you enjoy this issue (as indeed I hope you do), join with me, and all of those who worked with Roger at CERN, in wishing him "Bonne anniversaire et une superbe 91ème année".

● *Christine Sutton, CERN.*

Viewpoint

In search of hidden light

Could the skills developed for the energy frontier also be focused on the cosmic frontier?

In my journey as a migrant scientist, crossing continents and oceans to serve physics, institutions and nations wherever and whenever I am needed and called upon, CERN has always been the focal point of illumination. It has been a second home to whichever institution and country I have been functioning from, particularly at times of major personal and professional transition. Today, at the completion of yet another major transition across the seas, I am beginning to connect to the community from my current home at Fermilab and Northern Illinois University. Eight years ago, I wrote in this column on "Amazing particles and light" (*CERN Courier* March 2007 p50) and, serendipitously, I am drawn by CERN's role in shaping developments in particle physics to comment again in this International Year of Light, 2015.

"For the rest of my life I want to reflect on what light is!", Albert Einstein exclaimed in 1916. A little later, in the early 1920s, S N Bose proposed a new behaviour for discrete quanta of light in aggregate and explained Planck's law of "black-body radiation" transparently, leading to a major classification of particles according to quantum statistics. The "photon statistics" eventually became known as the Bose–Einstein statistics, predicting a class of particles known as "bosons". Sixty years later, in 1983, CERN discovered the W and Z boson at its Super Proton Synchrotron collider, at what was then the energy frontier. In another 30 years, a first glimpse of a Higgs boson appeared in 2012 at today's high-energy frontier at the LHC, again at CERN.

Today, CERN's highest-priority particle-physics project for the future is the High-Luminosity LHC upgrade (*CERN Courier* March 2015 p28). However, the organization has also taken the lead in exploring for the long-term future the scientific, technological and fiscal limits of the highest energy scales achievable in laboratory based particle colliders, via the recently launched Future Circular Collider (FCC) design effort, to be completed by 2018. In this bold initiative, in line with its past tradition, CERN has again taken the progressive approach of basing such colliders on technological innovation, pushing the frontier of high-field superconducting dipole magnets beyond the 16 T range. The ambitious strategy inspires societal aspirations, and has the promise of returning commensurate value to global creativity and collaboration. It also leaves room for a luminous electron–positron collider as a Higgs factory at the energy frontier, either as an intermediate stage in the FCC itself or as a possibility elsewhere in the world, and is complementary to the development of emerging experimental opportunities with neutrino beams at the intensity frontier in North America and Asia.

Einstein, top, and Bose shared an affinity for strings: Einstein played the violin from childhood and Bose was a master on the Indian string instrument, the esraj. (Image credits: top, E O Hoppe/LIFE; below, Birla Industrial and Technological Museum.)

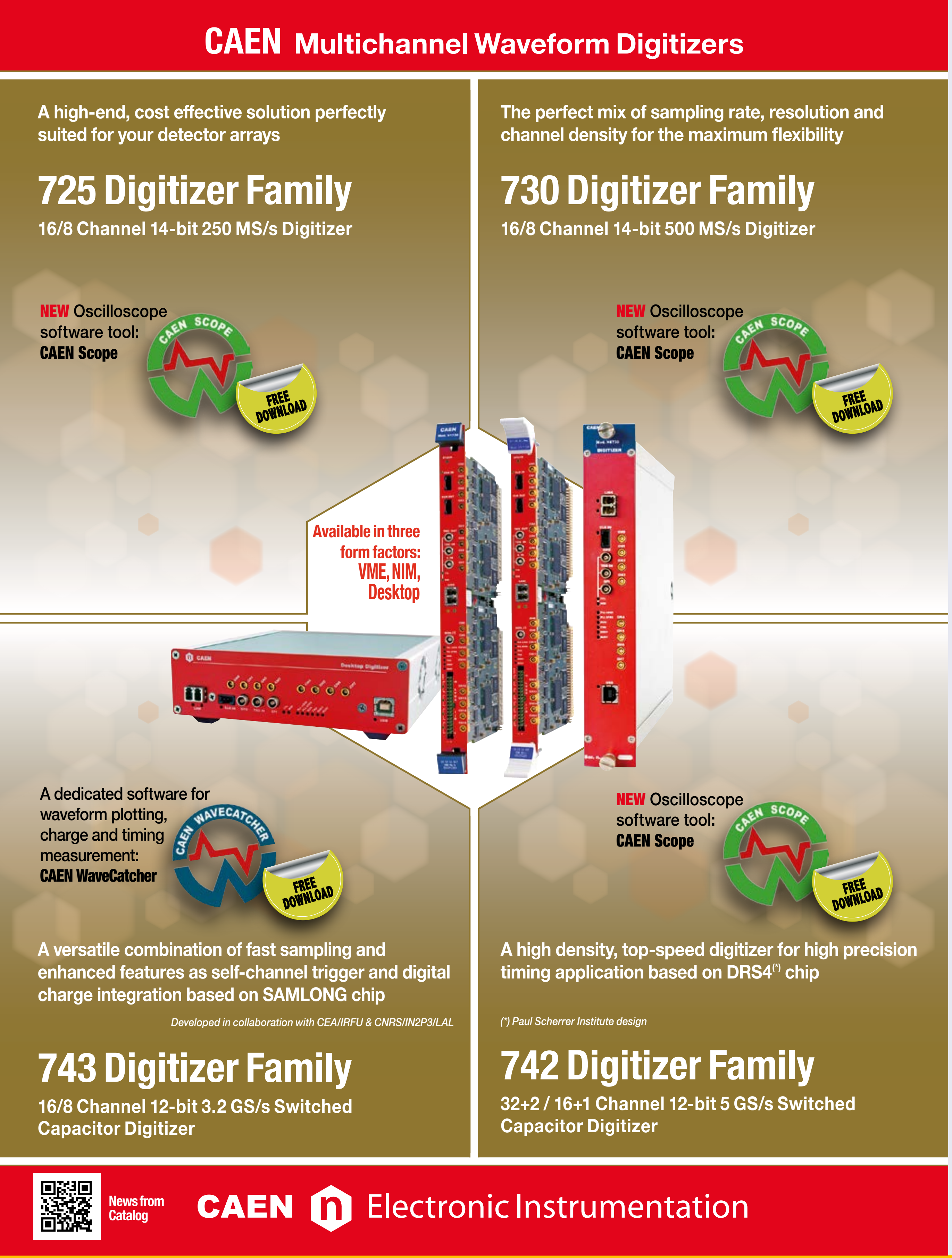
What a marvellous pursuit it is to reach ever higher energies via brute-force particle colliders in an earth-based laboratory. Much of the physics at the energy frontier, however, is hidden in the so-called "dark sector" of the vacuum. Lucio Rossi wrote in this column last month how light is the most important means to see, helping us to bridge reality with the mind (*CERN Courier* March 2015 p54). Yet even light could have a dark side and be invisible – "hidden-sector photons" could have a role to play in the world of dark matter, along with the likes of axions. And dark energy – is it real, what carries it?

All general considerations for the laboratory detection of dark matter and dark energy lead to the requirement of spectacular signal sensitivities with the discrimination of one part in 10^{25}, and an audacious ability to detect possible dark-energy "zero-point" fluctuation signals at the level of 10^{-15} *g*. Already today, the electrodynamics of microwave superconducting cavities offers a resonant selectivity of one part in 10^{22} in the dual "transmitter–receiver" mode. Vacuum, laser and particle/atomic beam techniques promise gravimeters at 10^{-12} *g* levels. Can we stretch our imagination to consider eavesdropping on the spontaneous disappearance of the "visible" into the "dark", and back again? Or of sensing directly in a laboratory setting the zero-point fluctuations of the dark-energy density, complementing the increasingly precise refinement of the nonzero value of the cosmological constant via cosmological observations?

The comprehensive skills base in accelerator, detector and information technologies accumulated across decades at CERN and elsewhere could inspire non-traditional laboratory searches for the "hidden sector" of the vacuum at the cosmic frontier, complementing the traditional collider-based energy frontier.

Like the synergy between harmony and melody in music – as in the notes of the harmonic minor chord of Vivaldi's *Four Seasons* played on the violin, and the same notes played melodiously in ascending and descending order in the universal Indian raga *Kirwani* (a favourite of Bose, played on the esraj) – the energy frontier and the cosmic frontier are tied together intimately in the echoes of the Big Bang, from the laboratory to outer space.

● *Swapan Chattopadhyay is with the Fermilab senior leadership team and its accelerator division in a joint appointment with Northern Illinois University, where he is professor and director of accelerator research. Until recently, he served as the inaugural director of the Cockcroft Institute, UK (2007–2014).*



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