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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CERN Courrier electrically meets scientists, engineers, and scientists affiliated with CERN, and to their perimeters. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

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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.)
Diamond-XBPM

NEW: Diamond XBPM – our novel X-Ray Beam Position Monitor is made of single crystal CVD diamond for precision beam position measurements.

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Electrical/mechanical 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 kJ 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 protons 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 moons originating from the Super Proton Synchrontron beam dump for timing studies of the trigger and to align the moon 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.

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On 13 January, less than three weeks after being launched to 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 1 TeV ($10^9–10^{12}$ eV), as well as the cosmic-ray electron spectrum from 2 GeV to 3 TeV. It is well known that the region of the “knee” – $10^{12}–10^{13}$ 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-y-converter and a small electromagnetic calorimeter. The charge-decision 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. The system consists of six multistrip scintillator layers to select useful events by measuring the electromagnetic and hadronic cosmic-ray components at a rejection level better than 1 in 104 for the events in the calorimeter aperture. The design, production and tests of the trigger system were performed by JINR. The system consists of silicon and scintillator layers with tungsten layers to convert secondary y-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.

The “golden channel”, $B^-\rightarrow J/\psi K_s$, allows for a clean determination of the angle 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 one irreducible complex phase (CERN Courier July/August 2014 p26). Its unitarity relates to observable quantities of many different measurements to a small number of parameters, thereby allowing for a stringent test of the electroweak part of the Standard Model. The CP violation in $B^-\rightarrow J/\psi K_s$ arises from the interference of the direct decay and the decay after $B^-\rightarrow B^0$ oscillation. It marks the transition between the decay rates of $B^0$ and $\bar{B}^0$ mesons that depends on the decay time, t. 

$A_{CP} = \frac{\text{Signal} - \text{Background}}{\text{Signal} + \text{Background}}$ 

Here, S and C are the CP observables, and $A_{CP}$ is the frequency of the $B^-\rightarrow B^0$ oscillation. Because the decay is dominated by a single decay amplitude, C is expected to vanish and S and C cannot be identified as $2\beta$. The LHCb collaboration has also analysed the full data set from Run 1 of the LHC, comprising 114,000 reconstructed and selected $B^-\rightarrow J/\psi K_s$ decays (LHC 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 its anti-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 41–50% of $B^-\rightarrow J/\psi K_s$ decays, and is correct in 64% of the cases.

The LHCb measurement yields $\sin 2\beta = (0.020 \pm 0.019 \text{ (stat.)} \pm 0.012 \text{ (syst.)})$, and is in good agreement with the value expected from CKM unitarity when excluding direct measurements of $\sin 2\beta$, $\sin 2\beta_{\pm} = 0.741(19)_{-0.161}^{+0.157}$ (Charles et al. 2015). Despite the challenges of the hadronic environment of the LHC, the result is at a close observational distance to the $B^-\rightarrow J/\psi K_s$ analyses of the BaBar and Belle experiments at the PEP-II and KEKB B-factories. BaBar and Belle established CP violation in the $B^-\rightarrow B^0$ system by observing it in $B^-\rightarrow J/\psi K_s$ decays for the first time in 2001 (CERN Courier April 2001 p5). They have since contributed to progress in establishing $\sin 2\beta$ leading to a very precise world-average value of 0.962 ± 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 3. LHCb will then contribute significantly to our knowledge of this fundamental parameter, and will challenge all more stringent tests of CKM unitarity.


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

As the experiment continues, 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 are often overlapped 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 900 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→TH) in a fully hadronic final state. 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.

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.

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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 neuromuscular 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 water all of the time—have no middle ear, and that they too can detect sound in air (Christensen et al. 2015b).

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.

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 and colleagues have found that 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).

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 chimpanzees: five 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.

Magnetars

Magnetars are neutron stars with huge magnetic fields of around $10^{18}$ to $10^{25}$ 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 electrodynamic interaction of ultraluminous 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 electronweak 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


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Astrowatch

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.

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_{\nu}, 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 p16). 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

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 ‘‘play back’’ 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 CLASH team; J Lutz (STScI) and the Frontier Fields team; M Postman (STScI) and the CLASH team; and Z Levay (STScI)).

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N A L

First pulses at 200 GeV

The National Accelerator Laboratory came into being in the summer of 1961 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 Malament 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 1010 protons per pulse at 32 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 was achieved several months ahead of the initial schedule and within the forecast construction budget.

B U B B L E  C H A M B E R S

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 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 17x. Preliminary measuring can be carried out in the image plane with a precision of ±70 μm (equivalent to ±0.1 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 Jol. 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 of 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 pp120–123.
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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.

Technologies developed for fundamental research in particle, astroparticle 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 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  
HETech members

Institution | Country | HEPTech members
--- | --- | ---
Commissariat à l’énergie atomique et aux énergies alternatives (CEA) | France | HEPTech members
European Organization for Nuclear Research (CERN) | Switzerland | HEPTech members
Centre National de la Recherche Scientifique (CNRS) | France | HEPTech members
Centro Nacional de Física de Partículas (CNPq) | Brazil | HEPTech members
University of Belgrade (Center for Technology Transfer and Institute of Physics) | Serbia | HEPTech members
Demokritos National Centre for Scientific Research (INR) | Greece | HEPTech members
Deutsches Elektronen-Synchrotron (DESY) | Germany | HEPTech members
ELI@PS | Hungary | HEPTech members
ELI Beamlines, Institute of Physics of the Academy of Sciences | Czech Republic | HEPTech members
École Polytechnique Fédérale de Lausanne (EPFL) | Switzerland | HEPTech members
European Spallation Source (ESS) | Sweden/Denmark | HEPTech members
Helmholtzzentrum für Schwerionenforschung (GSI) | Germany | HEPTech members
Horàs Huban HUB University of Physics and Nuclear Engineering (PNN-HH) | Romania | HEPTech members
Istituto Nazionale di Fisica Nucleare (INFN) | Italy | HEPTech members
Innovacenter - Czech Technical University | Czech Republic | HEPTech members
Jaželj Stefan Institute (IJS) | Slovenia | HEPTech members
Knowledge Transfer Network (KTN) | UK | HEPTech members
Laboratório de Instrumentação e Física Experimental de Partículas (LIP) | Portugal | HEPTech members
National Technical University of Athens (NTUA) | Greece | HEPTech members
Sofo University St. Klement Ohridski | Bulgaria | HEPTech members
Science and Technology Facilities Council (STFC) | UK | HEPTech members
Weizmann Institute of Science | Israel | HEPTech members
Wigner Research Centre for Physics | Hungary | HEPTech members

topics ranged from the dissemination of microtipon-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.

“HE এর 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 these collaborations.

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 automates the process of identifying publications, patents and data from various sources, selects pertinent information and populates a database that is later used to automatically generate interactive socio-grams 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 AIDE show that it is difficult to conduct a strict impact analysis on the AIMEs. “The impact is often more subtle and subtle improvements can make a significant difference in driving the network forward. For example, it can take some years before becoming visible, an increase in the number of co-publications and co-patents among attendees is as much as possible, at least until the results of the collaboration are available to the community. In other words, the impact of the AIMEs is often gradual and may not become evident immediately.”

Another area of activity is the collaboration building. For example, the AIMEs are used as a basis for developing IP regulations at Sotia University, Bulgaria. In 2013-2014, a survey focusing on the needs and skills of HEPTech members was conducted within the remit of this workshop. 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 contracts 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

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.

Elenora 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.

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 universe that we live in.

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 international source 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, of the near detector at a distance of approximately 300 km from the source, and of the far detector at a distance of approximately 120,000 m3 in size – nearly equivalent to the volume of Wembley’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 LaT-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 to allow for a timely and complete understanding of the neutrino-mass hierarchy – a key step in our understanding of the universe.
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.

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 538.4 m in circumference and a booster (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.

Four-stage commissioning

The task of commissioning the TPS comprised four major stages involving: the linac system, transportation of the electron beam from the linac to the booster ring; the booster ring; the transport system, which could have allowed budget re-adjustments.

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.

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 formations. 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 aluminium 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 but still acceptable at light-source facilities worldwide.

The power supplies of the booster dipole magnets were produced abroad and had several problems. These included protection...
circuit that overshadowed the extent to which 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 0.01 mm.

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.

Like the linac, the TPS cryogenic system was commissioned at a separate, specially constructed test site. The helium cryogenic plant was disassembled 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 into 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.

There were no false starts on the TPS construction and development project. After the commissioning of the linac, the TPS project was immediately commissioned, and it was possible to maintain the beam in the main ring while the linac was disassembled and reinstalled. For more details, see http://www.nsrrc.org.tw/english/index.aspx.

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 Taiwan (TPS) sur le 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 décennies 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.
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 multiscalar 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–positron–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 establish itself as the theory of quarkonium physics at the 10th meeting organized by the Quarkonium Working Group.

Almost 200 experts met at CERN in November to discuss the latest developments in quarkonium physics at the 10th meeting of the Quarkonium Working Group (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 Zc ± and Zb ± – 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.

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...
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 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 obtained in the past.

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_cJ and χ_bJ 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 years by the experiments A LICE, CMS and LHCb all presented data on the enormous amount of data provided during 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.

Further reading

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


Résumé

Praiserav le quarkonium


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

**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 5912-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 Bker, for their leadership on the project. (Image credit: BNL.)

**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 over at the Cockcroft Institute at Daresbury in July 2014. 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 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.
**Awards**

Lahiri to receive the Hevesy Medal

Susanta Lahiri of the Saha Institute of Nuclear Physics, Kolkata, 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 Kartesh 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.

**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” exhibition, 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, 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 2016 exhibition was inaugurated on 19 January in the Planetarium Science Centre (PSC), one of the main attractions in the modern library in Alexandria. The exhibition covers four main themes: what we know, open issues, accelerators and detectors, computing and applications.

**Outreach**

Build your own Lego LHC

A PhD student working on the ATLAS experiment has created a replica of the LHC using Lego bricks. Nathan Readoff, 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.

Readoff’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 oversized – 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, Readoff 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://buildyourown-particle-detector.org. To vote for Readoff’s LHC design, register with Lego Ideas and click the “Support” button on the Lego LHC page https://ideas.lego.com/projects/94885.

**Conference**

Poland looks at participation in future accelerators

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 Magis 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 (LHC 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 AWARE project of plasma acceleration at CERN, and to Fermilab’s programme of intense proton beams aimed at neutron 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 Jezabek, the general director of Cracow’s Institute of Nuclear Physics.

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Readoff’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 oversized – 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, Readoff 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://buildyourown-particle-detector.org. To vote for Readoff’s LHC design, register with Lego Ideas and click the “Support” button on the Lego LHC page https://ideas.lego.com/projects/94885.
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).

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, confirming 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 spectroscopy. In 1983, 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 1996 article “The Convergence of Science and Religion” established him as a unique 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.

**People Fellowship at Fermilab**

The Peoples Fellowship at Fermilab seeks applications from newly minted PhDs (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 PRLx include (but are not limited to): single particle and collective nonlinear dynamics of intense beams, microwaves/optical and electron cooling of phase-space, high intensity proton beams, high intensity neutrino sources, high-field superconducting magnets, superconducting wide-frequency science and technology, high luminosity and high energy, 1-100 TeV class future colliders for leptons and hadrons, novel accelerator concepts, accelerator control and feedback, and computational physics, simulazione and modelling.

The Peoples Fellowship provides an attractive salary and benefit 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 excellence and leadership 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
- Able by all environmental, safety and health regulations.
- Physical Activity and Work Requirements
- 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

For further information please contact Helmut Riesenfeld. Attn: Peoples Fellowship Committee

**WIPAC**

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

**IceCube WinterOver Experiments Operator**

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

**DESY**

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

**PARTICLE PHYSICS.**

DESY is one of the world’s leading research centres for particle science, 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.

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

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.

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 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:

- 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.
Post-Doctoral Opportunity in Accelerator Physics at Fermilab

The position is for an initial period of up to three (3) years with the potential for extension.

Fermi National Accelerator Laboratory seeks a highly qualified candidate for a postdoctoral Research Associate position in its ATLAS Division's OTRVA/ANSA Department to work on the Theoretical Advanced Accelerator R&D Program with the focus on the development of novel concepts for future frontier experiments. The successful candidate will be expected to participate in a comprehensive research program addressing a broad range of experimental needs in high energy physics, focusing on the application of quantum field theory to high energy phenomena. This work includes new strategies for the development of acceleration technologies, a better understanding of the underlying physics, and the definition of advanced detector technologies.

Qualifications and Essential Job Functions

- PhD in an equivalent degree in Physics, Accelerator Physics or related fields by the time of the appointment
- Strong record of recent accomplishments in physics
- Excellent oral and written communication skills as demonstrated by presentations at conferences and publication of results in peer-reviewed journals.

Application Instructions

Interested candidates should submit: 1) a cover letter including a brief statement of research interests and a curriculum vitae with a list of selected publications. Online application: https://fermi.hodesiq.com/apply_online_1.asp?jobid=4996444

The application deadline is May 31, 2015! For general information about this position, please contact

Dr. Alexander Viehmann at aviehmann@fnal.gov

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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Fermilab is an Equal Opportunity Employer. Applicants/individuals with disabilities are encouraged to apply.

The Fermilab European Office

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brightrecruits.com

The jobs site for physics and engineering

Quantum Field Theory for the Gifted Amateur

By Tom Lancaster and Stephen Blundell

Bulk Editions

Hardback: £31.99 $49.95

Paperback: £29.99 $49.95

Also available as 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: £32.00 $75.00

Also available as 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 advisor but no 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 were treated in chapter 46, but they do not. I found the word “quark” once – on page 308 – but as far as I can tell, “gluon” does 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” (p444f) or perhaps “vacuum instability” (p47f); don’t dismiss it. This is the “chiral symmetry” (p322f), 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 p4-9.

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. For 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 clear, high-quality work as an author he is a virtuous 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” (p336f). 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 8.40 on page 342. 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 by on 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.
The authors give a detailed discussion of the lepton-mixing matrix – the basic tool to describe oscillations – and seomodels of various types. An interesting aspect is the thorough discussion of what could be called “Majorana mass” 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 theories, 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 (SU(2) x U(1)) gauge theory and the relationship to Higgs physics. This is followed by a detailed treatment of neutrino masses 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 Kevin 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, comparing the book discusses in detail the challenges in flavour-symmetry model building to accommodate a non-zero \( \theta_{13} \) and the development of the mixing matrix from the simple tri-bimaximal 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 to very early universe phenomenology 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 leptonogenesis 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.

ChenQing Fu, Tizol Dornfur and Saeo Park, University of Hawaii.

## Books received

### Canonical Quantum Gravity: Fundamentals and Recent Developments

By Francisco Comastri et al.

World Scientific

Hardback: £164

E-book: £103

Also available at the CERN bookshop

This book aims to present a pedagogical and self-consistent introduction to canonical 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 philosophy. After presenting the basic approaches to Quantum Gravity, the authors introduce some elements of the formalism in the Einteinian theory, the basics concepts of the canonical approach to quantum mechanics are provided, focusing on the formulations relevant for canonical quantum gravity. The book is an excellent introduction to the subject, and it is highly recommended to a wide audience.

### Neutrinos in High Energy and Astroparticle Physics

By José F. Valle and Jorge Romão

World Scientific

Paperback: £75 (€91)

Also available at the CERN bookshop

This book presents a detailed account of the field of neutrino physics, covering its history, basic principles, and the latest experimental results. The book is written in a clear and concise style, making it accessible to both specialists and students. It is an excellent resource for anyone interested in neutrino physics, providing a comprehensive overview of the field.

### Physics Textbook

By Vincent F. Yie and Jorge D. Romão

World Scientific

Paperback: £75 (€91)

Also available at the CERN bookshop

This book provides a comprehensive introduction to the field of physics, covering the basic principles and concepts of various branches of physics, such as mechanics, electromagnetism, quantum mechanics, and relativity. The book is written in a clear and concise style, making it accessible to both specialists and students. It is an excellent resource for anyone interested in physics, providing a comprehensive overview of the field.
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 new developments in particle physics to comment again in this International Year of Light, 2015.

“...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.

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, enabling technology for a better world, and Bose was a master on the Indian string instrument, the esraj. (Image credits: top, E O Hopp/LIFE; below, Birla Industrial and Technological Museum.)
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