WELCOME

CERN Courier – digital edition

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

It is 60 years since a proton beam was first used to treat cancer at the Berkeley cyclotron. Since then, research has spread to other countries and other beams, notably carbon ions. In February, experts at the ICTR-PHE 2014 conference in Geneva discussed current progress in using these and other techniques derived from nuclear and particle physics in the service of medicine.

It is 80 years since two theoretical physicists first calculated the neutrino cross-section and concluded that "there is no practically possible way of observing neutrinos". Forty years later, measurements of neutrinos by the Gargamelle team at CERN helped to reveal the quark structure of matter. Now, another 40 years later, the MINERvA experiment at Fermilab continues a long tradition at the two labs in studying neutrinos.

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CERNCOURIER

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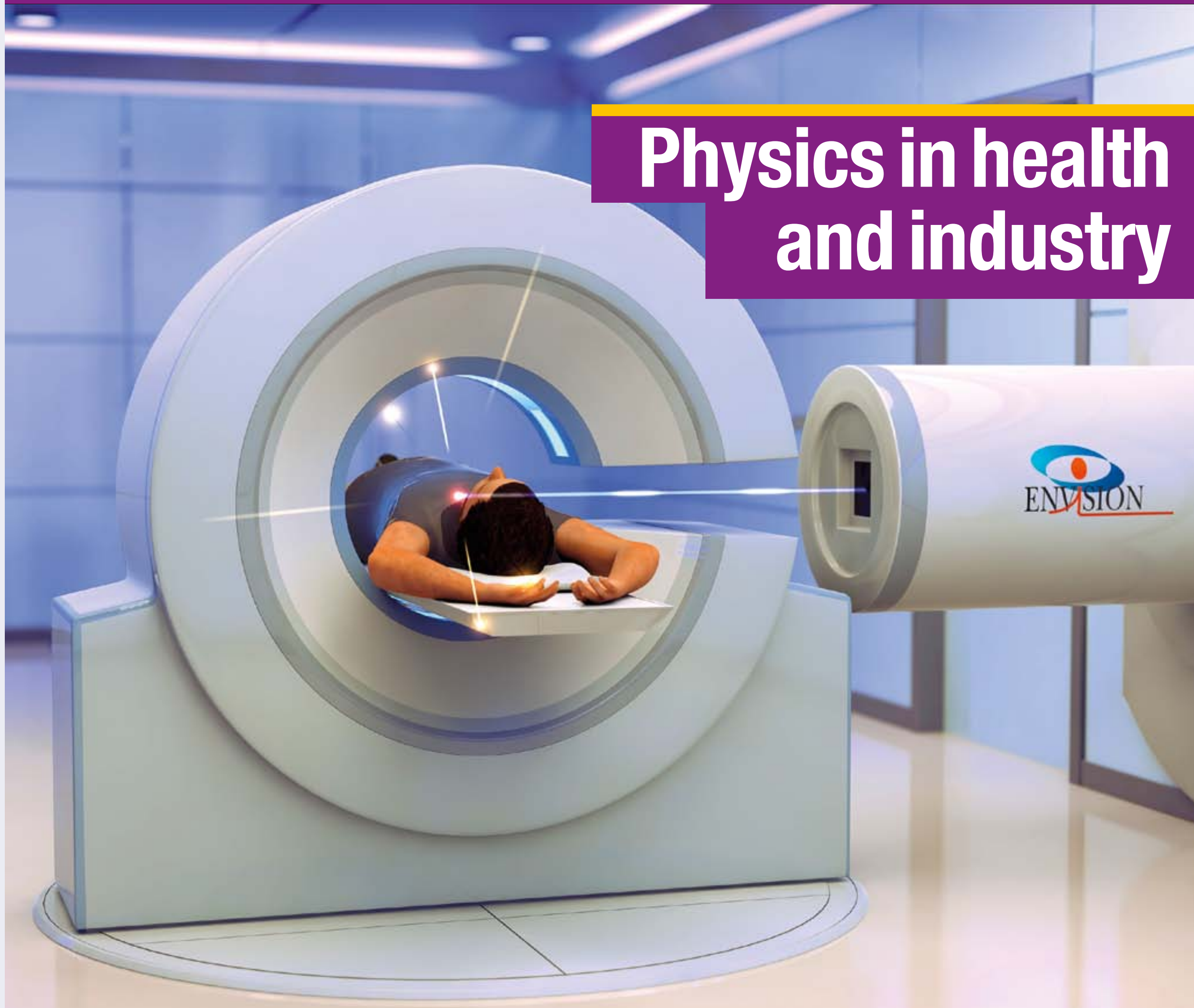

Physics in health and industry

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

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

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CERN COURIER

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On the cover: Increasing collaboration with the particle-physics community is helping to make advances in medicine (p19) and industry (p31). (Image credit: Nymus3d/ENVISION.)

News

CERN

LS1: on the home straight



Left: Sporting the flags of Pakistan and France on his hard hat, a member of a SMACC team inspects a splice inside an opened "M-line" stainless-steel sleeve. On 6 February, the team opened the last M-line. Middle: Rebrazing the last LHC splice during LS1 on 10 March. Right: Members of the operations team – here Reyes Alemany Fernández, left – are joining in the work in the tunnel during LS1. (Image credits: left to right, Michael Struik/CERN, CERN-PHOTO-201403-045 – 04, CERN-PHOTO-201401-013 – 23.)

When the shift crew in the CERN Control Centre extracted the beams from the LHC on 14 February last year, it marked the beginning of the first long shutdown, LS1, not only for the LHC but for all of CERN's accelerator complex, after an unprecedented three years of almost continuous running. By the end of last summer, the programme for LS1 had already reached some key milestones (*CERN Courier* October 2013 p5). Now, with the cooling of the LHC to begin in May and the restart of the Proton Synchrotron (PS) and Super Proton Synchrotron (SPS) planned for later this year, LS1 is well on schedule.

Throughout LS1, the Superconducting Magnets and Circuits Consolidation (SMACC) project has been responsible for opening interconnections between the LHC magnets for the series of operations needed for magnet-circuit consolidation. A major objective has been to install a shunt on each splice, straddling the main electrical connection and the busbars of the neighbouring magnets. This is to avoid the serious consequences of electric arcs that could arise from discontinuities in the splices (*CERN Courier* September 2010 p27).

Despite the complexity of the work on the 27-km-long LHC, there has been excellent progress, with SMACC teams working on different sectors of the accelerator in parallel. By October, the outer "W" sleeves had been removed from the equivalent of seven of the eight sectors, and leak tests were in progress in several sub-sectors. A month later, the first SMACC team had arrived in sector 4-5 and with the opening of the "W" bellows had completed the full tour of the LHC. One-third of the shunts were by then in place and the closure of internal sleeves had begun in sector 7-8. On 28 November, CERN's director-general, Rolf Heuer, was present for the welding of the last W sleeve in sector 6-7, and expressed his appreciation to the teams involved in the LS1 work. By mid-February, 80% of the interconnections had been consolidated and 85% of the 27,000 shunts had been installed.

On 15 January, the first pressure tests began in sector 6-7, after all of its vacuum subsectors had been closed and tested. The objective was to check the mechanical integrity and overall leak-tightness of the sector by injecting it with pressurized helium. The tests were a success. Next, the cryogenic teams prepared the sector for new electrical quality-assurance tests at ambient temperature, which were also successful. Two weeks of intensive cleaning followed to flush out any dust and dirt from the repair and consolidation work.

Elsewhere around the LHC, X-ray testing has been used to look for any faults in the machine's cryogenic distribution system, and 1,344 DN200 safety valves have been installed to release helium in the event of pressure build-up. Compensators on the LHC's cryogenic distribution lines have been replaced, as has a faulty RF cryomodule. Tests on the back-up electrical supply have also been completed.

Meanwhile, at the PS Booster, a new beam dump and its shielding blocks were installed from October onwards. At the PS itself, the cooling and ventilation system – dating back to 1957 – was replaced with a new ventilation system to aerate radioactive areas more efficiently. At the same time, testing of the newly installed access system was underway. By late October, consolidation of the seven main PS magnets had begun, with magnets being removed from the beam line and delivered to the magnet workshop, to be worked on by a specialized team from Russia.

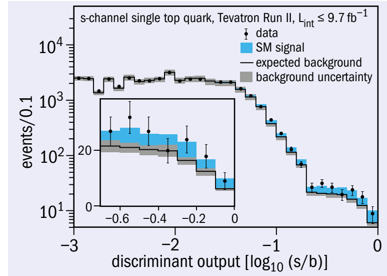
Thanks to the know-how, motivation and commitment of hundreds of professionals at CERN – as well as teams from member states and beyond – the LHC, its experiments and its injectors are on course to be ready to start the next LHC run in January 2015.

● See cds.cern.ch/journal/CERNBulletin/.

Sommaire en français

FERMILAB

Tevatron experiments find missing piece in top-quark puzzle



Single top-quark s-channel discriminant distribution ranked by expected signal/background. The s-channel signal, all of the backgrounds and the background uncertainty are normalized to their expected value.

Data from the CDF and D0 experiments at the Tevatron have revealed one of the rarest methods of producing a top quark. The two collaborations announced jointly on 21 February that they have observed s-channel production of single top quarks.

The top quark, t, which was discovered in proton–antiproton collisions at the Tevatron in 1995, is the heaviest elementary particle of the Standard Model, with a mass of 173 GeV. Only the Tevatron and the LHC colliders have so far been capable of making t quarks. In s-channel production, a quark from a proton and an antiquark from an antiproton create a W boson, which decays to a t quark and a b quark. The t quark in turn decays to a new W boson and a b, leading to a final state of Wbb. The production of single t quarks in the s-channel is among the rarest decays of the W boson, given that one of the final state particles (t) has a rest mass more than twice that of the parent W boson.

Selecting a region of high signal-to-background, as shown in the figure, required the development of sophisticated analysis methods. These included identifying jets from the hadronization of the b quarks efficiently and with low background. Between them, the CDF and D0 collaborations analysed more than 2×10^{10} events recorded to tape during operation of the Tevatron as a collider between 2001 and 2011.

Each experiment saw a substantial excess of events – about 40 in total – that could be attributed to single s-channel production of the t quark (CDF 2014 and D0 2013). However, only by combining the results from both experiments to make full use of the Tevatron data set, could the teams push the significance of the observation to 6.3σ, consistent with the discovery of a new process (CDF and D0 2014). The measured production cross-section in the s-channel of 1.29 pb agrees with the Standard Model prediction and so excludes the possibility of a particle other than the W boson, not predicted by the Standard Model, as a source of single t quarks.

Detection of this extremely rare process was one of the final goals of the Tevatron programme to be achieved. However, it is not the end of the story for the top quark because many more studies will continue, both with Tevatron data and at the LHC, to understand fully the heaviest known elementary particle.

Further reading

CDF and D0 collaborations 2014 arXiv:1402.5126 [hep-ex], submitted to *Phys. Rev. Lett.*

CDF collaboration 2014a arXiv:1402.0484 [hep-ex], submitted to *Phys. Rev. Lett.*

CDF collaboration 2014b arXiv:1402.3756 [hep-ex], submitted to *Phys. Rev. Lett.*

D0 collaboration 2013 *Phys. Lett. B* **726** 656.

PARTICLE ASTROPHYSICS

CDMS puts new constraints on dark-matter particles

While it is now generally accepted that dark matter makes up the majority of the mass in the universe, little is known about what it is. A favoured hypothesis among particle physicists has long been that dark matter is made of new elementary particles. However, experiments searching for such particles face a serious challenge: neither the particles' mass nor the strength of their interaction with normal matter is known. So the experiments must cast an ever-widening net in search of these elusive particles.

At the end of February, the Cryogenic Dark Matter Search collaboration announced new results, obtained with the SuperCDMS detector. They expanded their search down to a previously untested dark-matter particle-mass range of 4–6 GeV/c^2 and a dark-matter nucleon cross-section range of 1×10^{-40}–1×10^{-41} cm^2. Their exclusion results contradict recent hints of dark-matter detection by another experiment, CoGeNT, which uses particle detectors made of germanium – the same material used by SuperCDMS.

For their new results, CDMS employed a redesigned cryogenic detector known as iZIP that has ionization and phonon sensors interleaved on both sides of the germanium crystals. This substantially improves rejection of surface events from residual radioactivity, which have limited dark-matter sensitivity in previous searches. The collaboration operated these detectors 0.7 km underground in the Soudan mine in northern Minnesota, to shield them from cosmic-ray backgrounds.

There have been several recent hints for low-mass dark-matter particle detection, from previous data using silicon instead of germanium detectors in CDMS, and from three other experiments—DAMA, CoGeNT and CRESST—all finding their data compatible with the existence of dark-matter particles between 5 and 20 GeV/c^2. But such light dark-matter particles are hard to pin down. The lower the mass of the dark-matter particles, the less energy they leave in detectors, and the more likely it is that background noise will drown out any signals.

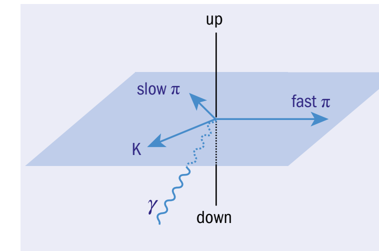
The new CDMS iZIP detectors, with their improved background rejection, are continuing this search at Soudan, and hopefully soon in the lower background environment at SNOLAB. Confirmation of a signal of the direct detection of dark matter, and understanding of the interaction of dark matter with normal matter, is likely to require spotting these particles with different target nuclei in at least two different experiments.

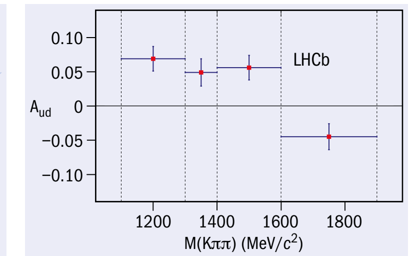
Further reading

CDMS collaboration 2014 arxiv.org/abs/1402.7137 [hep-ex].

LHC PHYSICS

Beauty-quark decays reveal photon polarization





Left: Definition of the upward and downward directions for the photon emission. Right: Results for the asymmetry in bins of Kππ mass.

The Standard Model predicts that the photons emitted in b→sγ transitions, which can only occur through loop-level processes, are predominantly left-handed. This means that the asymmetry between the amplitudes with right- and left-handed photons – photon polarization – is close to its minimum value of –1. This quantity has never been observed in a direct measurement and remains largely unexplored. As a consequence, there still exist several extensions of the Standard Model that predict a photon polarization significantly closer to zero but have not been ruled out by other measurements of b→sγ transitions.

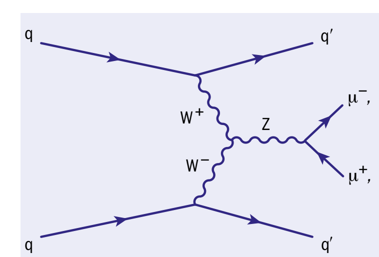
The LHCb collaboration has exploited $B^+ \to K^+\pi^-\pi^+\gamma$ decays, which are governed by the b→sγ transition, to probe the photon polarization. The "up–down" asymmetry between the number of photons detected above and below the plane defined by the momenta of the kaon and the two pions in their centre-of-mass frame is proportional to the photon polarization. So, a measurement of a nonzero asymmetry implies observation of photon polarization. The investigation is conceptually similar to the experiment that discovered parity violation in 1957 by measuring a nonzero up–down asymmetry for the electrons emitted in the weak decay of ^{60}Co nuclei with respect to their spin direction.

Using the full data sample collected with the LHCb detector in 2011 and 2012, the collaboration has reconstructed almost 14,000 $B^+ \to K^+\pi^-\pi^+\gamma$ events. Their angular distribution has been studied in four regions of the $K^+\pi^-\pi^+$ system's mass, where different kaon resonances and their interferences can result in different sensitivities to the photon polarization. From determination of the up–down asymmetry, A_{ud}, in each of these mass regions, LHCb finds a combined significance with respect to the null hypothesis of 5.2σ, and therefore observes photon polarization for the first time in such decays (LHCb collaboration 2014). This important result opens the door to the future determination of the value of the polarization of the photon, which will provide a strong new test of the validity of the Standard Model.

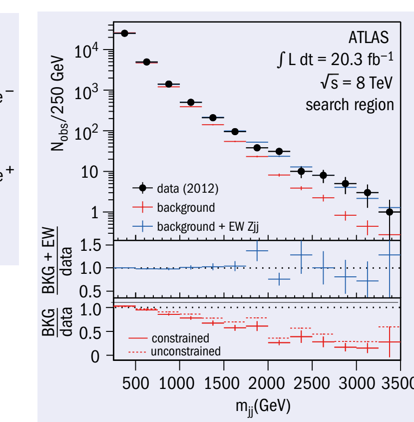
Further reading

LHCb collaboration 2014 arXiv:1402.6852 [hep-ex], submitted to *Phys. Rev. Lett.*

First observation of Z-boson production via weak-boson fusion



Above: Fig. 1. Z-boson production via weak-boson fusion.



Right: Fig. 2. The dijet invariant-mass distribution in the signal-enhanced search region.

The fusion of two weak bosons is an important process that can be used to probe the electroweak sector of the Standard Model. Measurements of Higgs production via weak-boson fusion are crucial for precise extraction of the Higgs-boson couplings and have the potential to help pin down the charge conjugation and parity of the Higgs boson. A similar process, weak-boson scattering, is sensitive to alternative electroweak symmetry-breaking models and to anomalous weak-boson gauge couplings. These processes are extremely rare and the experimental observation of the production of heavy bosons via weak-boson fusion has become possible only recently with the large centre-of-mass energy and luminosity provided by the LHC. Extracting the signals from the huge backgrounds in the high pile-up conditions at the LHC is a major challenge.

The production of a Z boson via weak-boson fusion (figure 1) is an excellent benchmark for these rare processes. Weak-boson fusion has the characteristic signature of two low-angle jets, one on each side of the detector. These "tagging" jets typically have transverse momentum of the order of the W mass, because they arise from quarks in each proton recoiling against the two W bosons that fuse to produce the Z boson. Another interesting feature is the lack of colour flow between the tagging jets, which means there is little hadronic activity in that region. These features have been exploited by the ▷

ATLAS collaboration to extract the purely electroweak contribution to Z-plus-two-jet production, which includes the weak-boson fusion process.

The analysis was carried out using proton–proton collisions at a centre-of-mass energy of 8 TeV recorded by the ATLAS detector in 2012. Events containing a Z boson candidate in association with two high-transverse-momentum jets were selected in the e^+e^- and $\mu^+\mu^-$ decay channels. The electroweak component was extracted by a fit to the dijet invariant mass spectrum in an electroweak-enhanced region that was defined, in part, by a veto on additional jet activity in the interval between the tagging jets. The background model was constrained using data in a signal-suppressed control region that was defined by reversing the jet-veto requirement. This data-driven constraint reduced the experimental and theoretical modelling uncertainties on the background model, allowing the electroweak signal to be extracted with a significance above the 5σ level. Figure 2 (p7) clearly demonstrates that the background-only model is inconsistent with the data in the electroweak-enhanced region. The cross-section measured for electroweak Z-plus-two-jet production, $\sigma = 54.7 \pm 4.6\,(\text{stat.})\,^{+9.8}_{-10.4}\,(\text{syst.}) \pm 1.5\,(\text{lumi.})$ fb, is in good agreement with the Standard Model prediction of 46.1±1.2 fb.

● Further reading

ATLAS collaboration 2014 arXiv:1401.7610 [hep-ex], submitted to JHEP.

Heavy stable charged particles: an exotic window to new physics

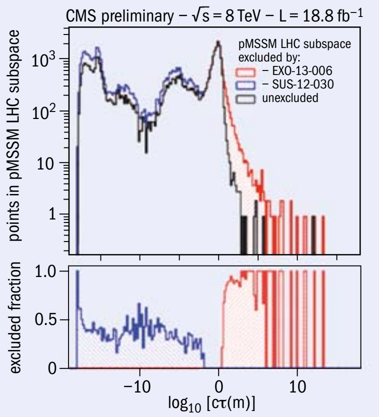
As the LHC experiments improve the precision of their measurements of Standard Model processes, the extent of possibilities for new physics open to exploration is becoming ever more apparent. Even within a constrained framework for new physics, such as the phenomenological minimal supersymmetric standard model (pMSSM), there is an impressive variety of final-state topologies and unique phenomena. For instance, in regions of the pMSSM where the chargino–neutralino mass difference is small, the chargino can become metastable and exhibit macroscopic lifetimes, potentially travelling anywhere between a few centimetres and many kilometres before it decays. An experiment like CMS can identify these heavy stable charged particles (HSCPs) through specialized techniques, such as patterns of anomalously high ionization in the inner tracker, as well as out-of-time signals in the muon detectors.

The CMS collaboration recently released a reinterpretation of a previously published search for HSCPs that used these techniques to constrain several broad classes of new physics models (CMS 2013a). There are two purposes for this reinterpretation. The first is to provide a simplified description of the acceptance and efficiency of the analysis as a function of a few key variables. This simplified "map" allows theorists and others interested to determine an approximate sensitivity of the CMS experiment to any model that produces HSCPs. This is an essential tool for the broader scientific community, because HSCPs are predicted in a large variety of models and it is important to understand if the gaps in their coverage are still present.

The second purpose is to provide a concrete example of a reinterpretation in terms of the pMSSM. In this analysis, CMS chose a limited subspace of the full pMSSM, requiring, among other things, that sparticle masses extend only up to about 3 TeV. The figure shows the number of points in this restricted pMSSM subspace that are excluded as a function of the average decay length, cτ, of the chargino. The red points are excluded by the HSCP interpretation described here (CMS 2013b). The blue points are excluded by another CMS search dedicated to "prompt" chargino production (CMS 2012a). The bottom panel shows the fraction of parameter points excluded by each of these two searches. Only a few parameter points, with chargino cτ >1 km, are still not excluded. This is because the theoretical cross-section for these parameter points is small – around 0.1 fb.

This analysis demonstrates the power of the CMS search for HSCPs to cover a broad range of models of new physics. By mapping the sensitivity of the analysis as a function of the HSCP kinematics and the detector geometry, it also makes the results from the search accessible for studies by the broader scientific community.

Although this analysis searches for metastable particles, another open possibility is the production of new, exotic particles that traverse a short distance – around 1 mm to 100 cm – before decaying to visible particles within the detector. CMS has also released results from two searches for such particles. One search looks for decays of these long-lived particles into two jets, and another into two oppositely charged leptons (CMS 2012b and 2012c). The results from these searches exclude production cross-sections for such particles as low as about 0.5 fb, depending on the lifetime and kinematics of the decay.



Number (top) and fraction (bottom) of excluded points of the considered pMSSM subspace as a function of the average chargino decay length, for the HSCP (red) and supersymmetry (blue) searches.

● Further reading

CMS 2013a *JHEP* 07122.
CMS 2013b CMS-PAS-EXO-13-006.
CMS 2012a CMS-PAS-SUS-12-030.
CMS 2012b CMS-PAS-EXO-12-038.
CMS 2012c CMS-PAS-EXO-12-037.

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CERN Courier welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send proposals to the editor at cern.courier@cern.ch.

ACCELERATORS

New results mark progress towards polarized ion beams in laser-induced acceleration

The Arcturus Laser at Heinrich-Heine University Düsseldorf, where two 200 TW beam lines can be used for particle-acceleration studies. (Image credit: T Toncian, University Düsseldorf.)

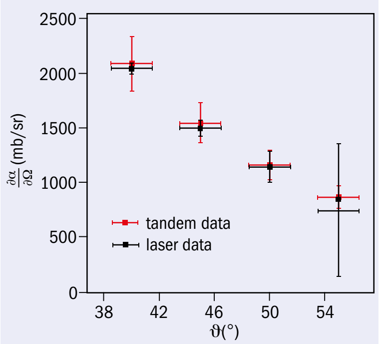
The field of laser-induced relativistic plasmas and, in particular, laser-driven particle acceleration, has undergone impressive progress in recent years. Despite many advances in understanding fundamental physical phenomena, one unexplored issue is how the particle spins are influenced by the huge magnetic fields inherently present in the plasmas.

Laser-induced generation of polarized-ion beams would without doubt be important in research at particle accelerators. In this context, $^3He^{2+}$ ions have been discussed widely. They can serve as a substitute for polarized neutron beams, because in a ^3He nucleus the two protons have opposite spin directions, so the spin of the nucleus is carried by the neutron. However, such beams are currently not available owing to a lack of corresponding ion sources. A promising approach for a laser-based ion source would be to use pre-polarized ^3He gas as the target material. Polarization conservation of ^3He ions in plasmas is also crucial for the feasibility of proposals aiming at an increase in efficiency of fusion reactors by using polarized fuel, because this efficiency depends strongly on the cross-section of the fusion reactions.

A group from Forschungszentrum Jülich (FZJ) and Heinrich-Heine University Düsseldorf has developed a method to measure the degree of polarization for laser-accelerated proton and ion beams. In a first experiment at the Arcturus Laser facility, protons of a few million electron volts – generated most easily by using thin foil targets – were used to measure the differential cross-section $d^2\sigma/d\vartheta d\phi$ of the Si(p, p')Si reaction in a secondary scattering target. The result for the dependence on scattering angle is in excellent agreement with existing data, demonstrating the feasibility of a classical accelerator measurement with a laser-driven particle source.

The azimuthal-angle (ϕ) dependence of the scattering distributions allowed the degree of polarization of the laser-accelerated protons to be determined for the first time. As expected from computer simulations for the given target configuration, the data are consistent with an unpolarized beam. This "negative" result indicates that the particle spins are not affected by the strong magnetic fields and field gradients in the plasma. This is promising for future measurements using pre-polarized targets, which are underway at Arcturus.

The polarization measurements are also an important step towards *Ju*SPARC, the Jülich Short Pulse Particle and Radiation Centre at FZJ. This proposed laser facility will provide not only polarized beams but also intense X-ray and thermal neutron pulses to users from different fields of fundamental and applied research.



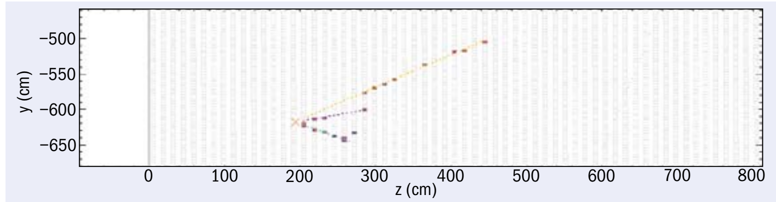
Differential cross-sections for the Si(p, p')Si reaction at a proton energy of 3.2 MeV, measured at the Cologne tandem accelerator and with laser-generated protons at Arcturus. The laser data are the average over 10 laser shots with a duration of 25 fs each.

● Further reading

N Raab *et al.* 2014 *Phys. Plasmas* **21** 023104.

NEUTRINOS

NOvA experiment sees its first long-distance neutrinos



One of the first interactions captured at the NOvA far detector. (Image credit: NOvA collaboration.)

On 11 February, the NOvA collaboration announced the detection of the first neutrinos in the long-baseline experiment's far detector in northern Minnesota. The neutrino beam is generated at Fermilab and sent 800 km through the Earth's surface to the far detector. Once completed, the near and far detectors will weigh 300 and 14,000 tonnes, respectively. Installation of the last module of the far detector is scheduled for early this spring and outfitting of both detectors with electronics should be completed in summer.

FUNDAMENTAL CONSTANTS

New precision reached on electron mass

Knowledge of the electron mass has been improved by a factor of 13, thanks to a clever extension of previous Penning-trap experiments. A team from the Max-Planck-Institut für Kernphysik in Heidelberg, GSI and the ExtreMe Matter Institute in Darmstadt, and the Johannes Gutenberg-Universität in Mainz, used a Penning trap to measure the magnetic moment of an electron bound to a carbon nucleus in the hydrogen-like ion $^{12}C^{5+}$. The cyclotron frequency of the combined system allowed precise determination of the magnetic field at the position of the electron, while the precession frequency allowed for measurement of the mass of the electron.

The result, in atomic-mass units, is 0.000548579909067(14)(9)(2) where the last error is theoretical. This new value for the electron's mass value will allow comparison of the magnetic moment of the electron to theory – which is good to about 0.08 parts in 10^{12} – to better than one part in 10^{12}.

● **Further reading**
S Sturm *et al.* 2014 *Nature* **506** 467.

Sciencewatch

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

Modelling the mechanics of curly hair

Nothing in nature is exempt from investigation by physicists, and the shape of suspended hairs has now come under scrutiny. James Miller and colleagues at Massachusetts Institute of Technology and the Université Pierre et Marie Curie in Paris combined precision desktop experiments with theoretical analyses to study the shapes taken by thin elastic rods suspended by their own weight – essentially a hanging hair. Being thin, such rods can acquire large twists while remaining in the small-strain regime.

The researchers constructed a phase diagram in terms of a dimensionless curvature and weight, and found three distinct regions: planar curls, localized helices and global helices. Given curvature, length, weight and stiffness, their model will predict the shape of a hair, steel pipe or cable suspended under its own weight. The work is relevant for computer animations – where flowing curly hair has been difficult to simulate – and covers a surprising range of systems including DNA and plant tendrils, as well as hanging pipes and cables.

Flexible segments of tubing that James Miller made with varying degrees of curliness and used for the lab experiments. (Image credit: James Miller and Pedro Reis.)

● **Further reading**
J T Miller *et al.* 2014 *Phys. Rev. Lett.* **112** 068103.

Cracks toughen glass

Many brittle materials, such as glass or ceramic tiles, can be broken readily if the surface is cracked first. It might come as a surprise then to find that such materials can be toughened by etching a pattern of tiny cracks into them.

Taking a hint from strong natural materials such as teeth and mollusc shells, M Mirkhalaf and colleagues at McGill University in Montreal laser-etched a 3D pattern of micro cracks (up to about 25 μm across and spaced by 130 μm) into glass and filled them with shock-absorbent polyurethane. This impedes the ability of cracks to propagate into the bulk and gives a bio-inspired glass that is more deformable and 200 times tougher. The technique should be extendable to other brittle materials.

● **Further reading**
M Mirkhalaf *et al.* 2014 *Nature Comm.* **5** 3166.

Subdiffraction-limited imaging inside a cell

Non-classical light can be used to circumvent traditional diffraction limits on imaging, and has now been demonstrated to look inside a living cell. To do this, Michael A Taylor of the University of Queensland and colleagues tracked lipid nanoparticles as they diffused through a live yeast cell using squeezed light in a photonic force microscope (PFM).

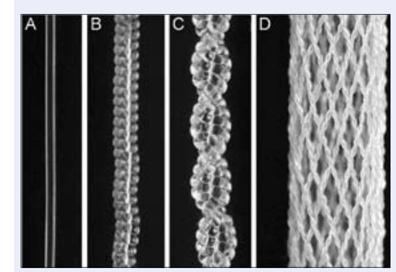
A PFM is similar to an atomic force microscope, but uses a nanoscale particle trapped in optical tweezers instead of the usual probe tip. Using squeezed light reduced the measurement signal-to-noise, allowing the construction of 1D spatial profiles within a cell down to 10 nm. Seeing below 1 nm *in vivo* looks possible. This is the first time that squeezed light has been used in biological imaging.

● **Further reading**
M A Taylor *et al.* 2014 *Phys. Rev. X* **4** 011017.

Artificial muscles

A new type of artificial muscle made from fishing line and sewing thread dramatically outperforms predecessors. Carter S Haines of the University of Texas at Dallas and colleagues have shown how inexpensive, high-strength polymer fibres used for fishing line and sewing thread can be made into artificial muscles, with their force provided by temperature-dependent twisting. With high degrees of twisting, these can contract by 49%, lift more than 100 times the load that the same length and weight of human muscle can, and generate 5.3 kW of work per kilogram of muscle – comparable to a jet engine.

● **Further reading**
C S Haines *et al.* 2014 *Science* **343** 868.



(A) A non-twisted 300-μm-diameter fibre; (B) fibre A after coiling by twist insertion; (C) a two-ply muscle formed from coil B; (D) a braid made from 32 two-ply, coiled, 102-μm fibres produced as in (C).

One-way sound

Sound transmission is usually reciprocal – if you want to listen to someone you have to let them be able to hear you. Now, Romain Fleury of the University of Texas at Austin and colleagues have found how to obtain sound transmission that favours one direction over the opposite one. They found the required time-reversal invariance violation – sound propagation normally knows no direction of time – in an acoustic analogue of the Zeeman effect, where a magnetic field makes a material birefringent.

In place of a magnetic field, they used airflow around a circular cell so that sound propagates differently with or against the flow. Their device, built from simple off-the-shelf components, gives 40 dB of non-reciprocal sound isolation.

● **Further reading**
R Fleury *et al.* 2014 *Science* **343** 516.

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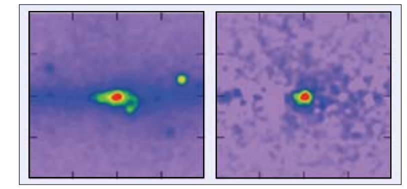
Astrowatch

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

Fermi gamma-rays match dark-matter signal

A new analysis of observations of the galactic centre by the Fermi Gamma-ray Space Telescope strengthens the case for a signal from annihilating dark matter. The authors claim that the excess emission has a spectral shape, spatial extent and normalization in good agreement with predictions of simple models of dark-matter annihilation.

Although still elusive in particle-physics experiments, dark matter is a reality for astronomers. Its presence is implied by the fluctuations in the cosmic microwave background as measured by the Planck mission (*CERN Courier* May 2013 p12). It is essential for the formation of the first stars and galaxies, and it provides the additional gravitational pull to hold clusters of galaxies together. Nonetheless, dark matter is only detected indirectly, via its effect on ordinary matter, or at most through its gravitational lensing effect on background galaxies observed through a massive galaxy cluster (*CERN Courier* July/August 2013 p14). Weakly interacting massive particles (WIMPs) are a prime candidate for cold dark matter in the universe. With a mass above about 1 GeV and interacting only through the weak nuclear force and gravity, they can remain invisible because of their lack of electromagnetic interactions. However, the annihilation of WIMPs could potentially produce gamma rays, cosmic rays and neutrinos. Theoretical candidates for WIMPs include the lightest supersymmetric particle, neutralinos and sterile neutrinos.



Gamma-ray emission in the 1–3.16 GeV energy band of the central 10° × 10° area of the Milky Way before (left) and after (right) subtracting all known contributions, leaving an unexpected excess that can be attributed to dark matter annihilation. (Image credit: T Daylan et al.*, Fermi Space Telescope, NASA.)*

As with all galaxies, the Milky Way is thought to be surrounded by a spherical halo of dark matter. The density gradient towards the galactic centre makes the latter the best place to search for a gamma-ray signal associated with dark-matter annihilation. The Fermi satellite is well suited for this search at energies between 100 MeV and 300 GeV (*CERN Courier* November 2008 p13). In the past few years, the analysis of Fermi's observations of the central region of the Galaxy by different groups has detected a significant excess with a maximum emission at around 1–3 GeV.

A new analysis by a US team led by Tansu Daylan from Harvard University is now attracting attention. The team used a more restrictive selection of gamma rays, including only those with a small positional uncertainty. This allows the researchers to produce gamma-ray maps at higher resolution, enabling an easier separation of the putative spherically-symmetric dark-matter signal from the contribution of the Galaxy's diffuse emission and the "bubbles" found by Fermi (*CERN Courier* January/February 2011 p11). The team finds an excess emission out to angles of around 10° from the centre of the Galaxy, with no significant deviation from spherical symmetry. The excess has a high significance and a best-fit spatial distribution following a generalized Navarro-Frenk-White halo profile, with an inner slope of $\gamma = 1.26$. Such a broad distribution disfavours the proposed alternative that this emission originates from a population of thousands of millisecond pulsars.

The derived spectrum associated with this excess is well fitted by dark-matter particles with mass 31–40 GeV annihilating to b quarks. The new study disfavours the previously considered 7–10 GeV mass window in which the dark matter annihilates significantly to τ leptons. The annihilation cross-section required to account for the signal is also found to be in good agreement with predictions for dark matter in the form of a simple thermal relic. While this analysis does not provide a discovery of dark-matter annihilation, it is nevertheless a compelling case for this process that will have to be confirmed by corroborating observations in dwarf galaxies around the Milky Way.

● Further reading

T Daylan *et al.* 2014 arXiv:1402.6703.

Picture of the month

This new image by the Hubble Space Telescope shows the spiral galaxy ESO 137-001, framed against a bright background as it moves through the heart of the Norma cluster of galaxies. The image captures not only the galaxy and its backdrop in stunning detail, but also something more dramatic – intense blue streaks streaming outwards from the galaxy, seen shining brightly in ultraviolet light. These streaks are hot young stars, encased in wispy streams of gas that are being torn away from the galaxy by its surroundings as it moves through space. This violent galactic disrobing is the result of a process known as ram pressure stripping – a drag force felt by an object moving through a fluid. The fluid in question here is superheated gas, which lurks at the centre of galaxy clusters and emits X-rays (Picture of the month, *CERN Courier* November 2008 p11). (Image credit: NASA, ESA. Acknowledgements: Ming Sun (UAH), and Serge Meunier.)

CERN Courier Archive: 1971

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

CERN

The Medical Service

Since June 1965, the Medical Service has been responsible for surveying the health of the personnel and for sanitary control. The Staff Rules and Regulations and CERN Safety Codes define medical procedures, which punctuate the career of each member of the personnel: a medical examination on arrival, on the resumption of work after an illness, regular examinations to check on occupational diseases and an examination on leaving CERN.

In addition, blood tests, biological tests, audiometric tests and X-rays are carried out on arrival and periodically as required.

The emergency treatment of sick and injured persons is carried out with the Site Security Service and a well-equipped central infirmary provides first-aid for accidents. The specific problems of the physically handicapped are carefully studied. The Service also acts as a consultant in matters concerning general hygiene (environment, drinking water, canteens, etc.) as well as in social problems where medical factors often play an important part.

The medical service personnel consists of trained nurses, laboratory technicians, an administrative staff and the medical officer.

Collecting one of the thousands of samples on which blood tests are carried out each year.

● Compiled from texts on pp98–99.

Batavia

From buildings to buffalo

Left: R Sheldon (left) and H Hinterberger hold the model of the building to house the hydrogen bubble chamber at Batavia. The geodesic dome is to be constructed from triangular panels, as seen in the background, built of empty beverage cans (inset). Right: Some members of the buffalo herd at Batavia. (Photos NAL.)

A novel idea for solving environmental problems was put forward by R Sheldon (who went to NAL from Rutherford and has been involved with the main ring magnets) while thinking about materials for a geodesic dome to sit on top of the 15-foot hydrogen bubble chamber building.

The idea, developed with H Hinterberger (NAL Director of Technical Services), is to build panels using empty beverage cans. Thanks to standardization of sizes, cans carrying different labels fit together. The tops and bottoms are knocked out (by a specially developed machine, which clears a thousand cans an hour) so that they pass light, and they are assembled into panels by bonding thin glass fibre reinforced plastic sheets over the open ends forming a sandwich about 10 cm thick.

The panels are cheap as their main component, normally discarded cans, is free. They have proved to be extremely sturdy and well able to withstand wind and snow loads. They are light, easily handled and can be assembled into virtually any desired shape. For the geodesic dome they will be equilateral triangles of about 3 m sides.

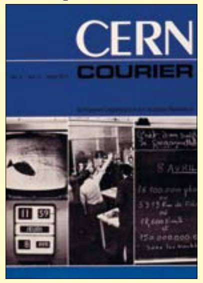
As a bonus, they rid the environment of empty cans. Following an appeal cans have been pouring into the Laboratory.

Environment again. In 1969 NAL acquired five buffalo, the nucleus of what it is hoped will grow into a small herd, which will eventually be free to graze within the 2 km diameter main ring. Following further additions, the buffalo have become one of the "tourist attractions" of the site.

Over 100 years ago, great herds of bison roamed the western plains of America, their number being estimated at around 20 million in 1850. Relentless hunting ate into this until at one time it had reached a crisis figure of around 550. Preservation efforts have redeemed the situation and the present population is tens of thousands – some of them alive and well and living at Batavia.

● Compiled from texts on pp102–103.

Compiler's Note



CERN's conservation credentials may not be as glamorous as those of Fermilab (formerly the National Accelerator Laboratory, NAL), the nearest bison being on a farm in nearby Colovrex. But only 210 of CERN's 650 hectares are taken up by buildings, roads and parking lots. The rest are fenced-off green areas, fields, woods and pasture. The Meyrin site has orchid sanctuaries boasting 19 different species and there is a resident herd of fallow deer on the Prévessin site. Sheep graze on both sites while red deer, roe deer and wild boar roam in CERN's woods.

For those in search of something more exotic, aurochs can be seen in the Marais des Bidonnes on the Franco-Swiss border between Divonne-les-Bains and Bogis-Bossey.

The Future Circular Collider study

An international study has been launched to examine options for a circular collider at CERN in the post-LHC era.

More than 350 world experts in accelerators and particle physics, including several laboratory directors, came together at the University of Geneva on 12–15 February to launch the Future Circular Collider (FCC) study, which will examine options for an energy-frontier collider based on a new 80–100-km-circumference tunnel infrastructure. The FCC study, which will be organized as a worldwide international collaboration, comprises a 100 TeV proton (and heavy-ion) collider at the energy frontier, a high-luminosity e^+e^- (H, Z, W, and $t\bar{t}$) factory as a potential intermediate step, and an analysis of options for a hadron-lepton collider. The goal of the study is to deliver a conceptual design report (CDR) together with a cost review by 2018, in time for the next update of the European Strategy for Particle Physics. The CDR will integrate physics, detector, accelerator and infrastructure aspects.

The FCC design study responds to a high-priority request in the 2013 update of the European Strategy for Particle Physics (*CERN Courier* July/August 2013 p9) stating that "A conceptual design study of options for a future high-energy frontier circular collider at CERN for the post-LHC era shall be carried out". February's kick-off meeting was co-sponsored by the Extreme Beams work package 5 of the EuCARD-2 project, within the European Commission's FP7 Capacities Programme. Participants came from all over the world, with particularly strong representation from China, Japan, Russia and the US, in addition to the many attendees from laboratories and universities across Europe. The goals of the meeting were to introduce the FCC study, to discuss its scope and organization, and to prepare and establish global collaborations.

In his opening address, CERN's director-general, Rolf Heuer, presented an exciting perspective and explained the main motivations for the FCC, while also cautioning that it was too early to make any cost estimate. Nima Arkani-Hamed of the Institute for Advanced Study in Princeton, and recently appointed as the first director of the Centre for Future High Energy Physics at the Institute of High Energy Physics (IHEP) in Beijing, highlighted the compelling physics case for the 100 TeV hadron collider. Precision physics will be essential at both the lepton and hadron colliders, as Christoph Grojean from the Institut de Física d'Altes Energies in Barcelona underlined.

A similar study for a 50–70 km, double-purpose lepton and hadron collider is being pursued in China, with an attractive site proposal and ambitious schedule. In presenting the project, Yifang Wang, director of IHEP in Beijing, conceded that it would be a difficult project but it would also be very exciting. Even if implemented somewhere other than in China, it would still be beneficial to the field of particle physics in general and to the Chinese high-energy physics and scientific community in particular. To this end, IHEP fully supports a global effort. Fermilab's associate director for accelerators, Stuart Henderson, also reported a broad acknowledgement in the US that any future collider would need to be a global enterprise, requiring financial and human resources from across the world. He stressed that the US community wishes to play a role in any future collider, while also mentioning several domestic "grass-roots" activities.

Frédérick Bordry, CERN's director of accelerators and technology, presented the roadmap for CERN. Europe's top priority for the next two decades is the exploitation of the LHC, with nominal parameters and a total integrated luminosity of about 300 fb^{-1} by 2023, and with the High-Luminosity LHC upgrade to reach 3000 fb^{-1} by 2035 (*CERN Courier* January/February 2014 p12 and p23). In parallel, as one of the next-highest-priority items, the FCC design study will be pursued along with CLIC as a potential post-LHC accelerator project at CERN. Michael Benedikt, the FCC study co-ordinator, reviewed the baseline parameters, design challenges and preparations for global collaboration, stressing that new partner institutes will be welcome throughout the duration of the study. Key technologies are high-field magnets for the hadron collider and an efficient high-power superconducting RF (SRF) system for the lepton collider. Possible R&D goals for the study include the development of short 16-T dipole models in all regions (America, Asia and Europe) by 2018 and, in parallel, demonstration of 20-T magnet technology based on the combination of high- and low-temperature superconductors as well as SRF developments, targeted at overall optimization of system efficiency and cost.

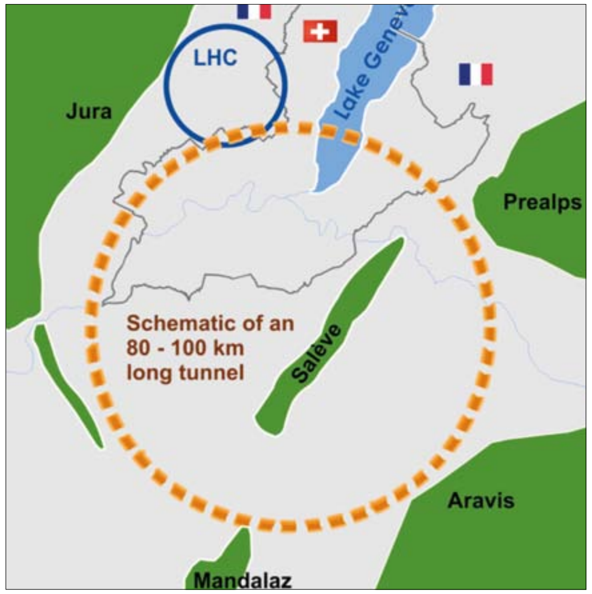
The FCC study logo reflects the three different colliders that could be housed in the new tunnel.

Philippe Lebrun, former head of CERN's Accelerator Technology Department, pointed out that, although CERN's experience in building machines of increasing size and performance can be applied to the study of 80–100 km circular accelerators in the Geneva basin, the step from the 27 km Large Electron–Positron collider and the LHC to the FCC represents major challenges. These will require inventive solutions in accelerator science and technology as well as in conventional facilities. Felix Amberg from Amberg Engineering – a company involved in the Gotthard Base Tunnel project – reported and analysed specific aspects of building long tunnels. His presentation suggested that tunnelling costs and risks can be predicted fairly reliably, provided that the project does not extend over too long a time interval and that the legal framework remains stable during the construction period.

After two days of plenary sessions, which surveyed the scope, plan, international situation and design starting points of the FCC, seven parallel sessions gave space for feedback, additional presentations and lively international discussions. Worldwide collaboration in all areas – physics, experiments and accelerators – was found to be essential to reach the level for a CDR by 2018. Key R&D areas for the FCC, such as superconducting high-field magnets and SRF, are of general interest and relevant for many other applications. Significant R&D investments have been made over the past decade(s), for example in the framework of the LHC and High-Luminosity LHC. Further continuation will ensure efficient use of these investments. At the kick-off meeting a consensus emerged on the approach to form a global collaboration for this study, and many participants expressed a strong interest – both for themselves and their institutes.

Institutes worldwide are now invited to join the global FCC effort, and to submit non-committing written "expressions of interest" with regard to specific contributions by the end of May 2014.

Participants of the kick-off meeting at the University of Geneva. (Image credit: Michael Hoch/CERN.)



Sketch of a future 80–100-km-long tunnel in the Geneva area, which would allow for a 100-TeV, energy-frontier proton collider and also, as a potential intermediate step, a high-luminosity e^+e^- collider serving as a W, Z, H and $t\bar{t}$ factory. (Image credit: CERN.)

Further reading

For all of the presentations, see http://indico.cern.ch/e/fcc-kickoff/.

Résumé

Étude sur le futur collisionneur circulaire

Une étude internationale a été lancée afin d'examiner les options possibles concernant un futur collisionneur circulaire de haute énergie au CERN, qui serait abrité dans un tunnel de 80 à 100 km de circonférence. Cette étude, qui sera menée dans le cadre d'une collaboration internationale planétaire, portera sur un collisionneur hadronique de haute énergie de 100 TeV, un collisionneur e^+e^- haute luminosité qui servirait d'étape intermédiaire et permettrait d'étudier les options possibles pour un collisionneur hadron-lepton. L'objectif est d'élaborer un rapport préliminaire de conception (CDR) et une analyse des coûts d'ici à 2018, à temps pour la prochaine mise à jour de la stratégie européenne pour la physique des particules.

Michael Benedikt and **Frank Zimmermann**, CERN.

ICTR-PHE: uniting physics, medicine and biology

The ICTR-PHE 2014 conference attracted 400 participants from around the world to discuss some of the most advanced techniques to fight cancer.

Where physics meets medicine. Artist's view of an in-beam PET device for hadron-therapy monitoring. (Image credit: Nymus3d/ENVISION.)

Physicists, biologists, physicians, chemists, nuclear-medicine experts, radio-oncologists, engineers and software developers – researchers and practitioners from many disciplines came to Geneva on 10–14 February for ICTR-PHE 2014, which brought together for the second time the International Conference on Translational Research in Radio-Oncology and Physics for Health in Europe. The joint conference aims to unite physics, biology and medicine for better healthcare, and the goal of this second meeting was to review the most recent advances in translational research – where developments in basic research are "translated" into means for improving health – in physics, biology and clinical oncology.

The conference featured the many advances that have occurred during the past two years since the first joint conference. The resolution and precision of medical imaging is continuing to grow with the use of combined modalities, such as positron-emission tomography (PET) with computed tomography (CT), and PET with magnetic resonance imaging (MRI) – an important technical breakthrough. Biologists and chemists are performing studies to develop new radiation carriers – including antibodies and nanoparticles – to target tumours. The Centro Nazionale di Adroterapia Oncologica (CNAO) in Italy has started hadron therapy with proton beams and carbon-ion beams, obtaining the necessary certification labels for both treatments. Another new centre, MedAustron in Austria, is being built and is reaching the commissioning phase. Moreover, while the use of proton therapy continues to grow around the world, the Japanese centres and the Heidelberg Ion-Beam Therapy Centre in Germany are using carbon-ion therapy on an increasing number of patients. For all of the experts involved in such a variety of different fields, the ICTR-PHE conference was the ideal place to take stock of the work done so far, and to define the next steps that the community should take to keep the momentum high.

Although the first patient was treated with protons 60 years ago in Berkeley, the field has not yet implemented all of the phases of the clinical trials required for evidence-based medicine and the national health systems. In particular, several experts discussed the need to perform randomized trials. This, of course, comes with unavoidable ethical issues and methodological concerns. The community is geographically scattered and several important factors – such as the integrated dose that should be delivered, the fractionation and the types of tumours to be treated – are still being studied. On one hand, it is a hard task for the various scientists to define common protocols to be followed to perform the trials. On the other hand, physicians and patients might be sceptical towards new therapies that are not yet felt to be tested extensively. Despite the fact that every year several thousand patients are diagnosed using radiopharmaceuticals and subsequently treated with hadron therapy, the use of particles is still often considered with scepticism.

The situation is made even more complex by the fact that the fight against cancer is taking on a more personalized approach. Although highly beneficial to patients, this makes it difficult for doctors to apply the same treatment plan to a large number of people. Cancer is not really a single disease. Its many facets require different therapies for different patients, depending on the specific type of malignant cell, the location of the tumour, its dimensions, etc. Several presentations at the conference focused on the important impact that such personalized treatment has in the disease's prognosis.

In this respect, the challenge for today's oncologists starts with high-quality imaging that allows them to define the active tumour volume as well as the possible metastasis in the body. Again, depending on the type of tumour, researchers can now select the best radiopharmaceutical that, once injected into the body and in conjunction with a detection modality such as PET, is able ▷

Physics highlights

Even though the conference focused on translational research and medical applications of physics, it would have been impossible to ignore the discovery by the ATLAS and CMS experiments at the LHC of a Higgs boson – the particle linked to a mechanism that gives mass to many fundamental particles – and the subsequent award of the 2013 Nobel Prize in Physics to two of the theoreticians who proposed the mechanism. Fabiola Gianotti, former spokesperson of the ATLAS experiment at the LHC, opened the conference and captivated the audience with the tale of the many years of Higgs hunting by thousands of researchers across the world.

The role of physics and physicists was highlighted also by Ugo Amaldi in his public talk "Physics is beautiful and useful". The father of the word "hadrontherapy" showed how, following the discovery of X-rays in 1895, fundamental physics, particle therapy and diagnostics became three intertwined yarns: the advances in one field have an impact on the other two. Amaldi concluded his much-appreciated talk by presenting an overview of possible future developments, including "Tulip" – a Turning Linac for Protontherapy – which is a new prototype that aims to supply protons with compact, less-expensive instrumentation.

to identify the target cells precisely. Moreover, the same carrier molecules that are able to bring the radiating isotopes to the malignant cells and make them visible to the detecting instruments could be used with more powerful isotopes, to bring a lethal dose into the tumour volume directly. Some of the most recent studies involve the use of specific peptides associated with isotopes obtained at particle accelerators. Others involve innovative nanoparticles as vehicles to bring radiation into the target. Each single solution implies the use of specific isotopes. At CERN, the MEDICIS project aims to produce isotopes for medical research. Although the project has only recently entered the construction phase, the collaboration between the MEDICIS team and specialized teams of radiobiologists and chemists has already begun.

Imaging has reached spatial resolutions down to 2 mm. The combination of various imaging techniques, such as PET/CT or PET/MRI, allows oncologists to gather information not only about the geometry of a tumour but also about its functionality. Further improvements could come from both better hardware and more sophisticated software and algorithms for integration of the information. Significant improvement to the hardware could be introduced by the time-of-flight technique – well known to particle physicists for its use in many high-energy experiments.

The best treatment

Once the oncologists have acquired the information about the malignant cells and tumour volume, as well as other important data about the patient, they can define the best treatment for a specific case. Computer simulations made with the GEANT4 and FLUKA software suites are used to define the most suitable treatment planning. These codes are in continuous development and are able to deliver increasingly precise information about the dose distribution. In addition to new advances in computer simulations, the ICTR-PHE conference also featured a presentation about the first 3D mapping over a known distance of the dose distribution along the whole path of a 62 MeV proton beam. These studies are extremely useful in the determination of collateral damage, including possible secondary tumours caused by particle beams.

Unwanted damage to healthy tissues is a key point when it comes to comparing conventional photon-radiation therapy with hadron therapy. Thanks to the intensity modulation and volumetric arc techniques, and image-guided treatments, today's conventional radiation therapy has reached levels of effectiveness that challenge hadron therapy. Nevertheless, because of the specific way they deliver their energy (the well known Bragg peak), hadrons can target tumours much more precisely. Therefore, hadron beams are potentially much less dangerous to nearby healthy tissues. However, their overall biological impact is still to be evaluated precisely and the cost of the infrastructures is significantly higher than for widely used conventional radiation. The debate remains open, and a final word will only come once the various teams involved have carried out the necessary clinical trials. The importance of sharing information and data among all active partners was highlighted throughout the conference.

In general, the results presented at the conference were, in many cases, very promising. Not only has the knowledge of cancer increased hugely during recent years, in particular at the molecular level, but also – and even more importantly – a different awareness is gaining momentum within the various communities. As one of the plenary speakers emphasized, the idea that one single oncologist can effectively fight cancer should be abandoned. Instead, the collaboration among chemists, biologists, engineers, physicists and physicians should surely improve the prognosis and the end result.

The beneficial impact of such collaboration was particularly evident when the speakers presented results from the combination of various techniques, including surgery and chemotherapy. This is because several factors play a role in the response of malignant cells to radiation: drugs, of course, and also the patient's immunology, the hypoxia (oxygen deprivation) rate and the inner nature of the tumour cells. Recent studies have shown, for example, that malignant cells infected by the HPV virus have a better response to radiation, which translates into a better prognosis.

The role played by hypoxia and the various ways to overcome it were popular topics. A particularly interesting talk emphasized the need to go a step further and, having already acquired a deep knowledge of hypoxia in the malignant tissues, proceed to treat it with drugs before starting any further therapies. This is not yet the case in the current protocols, despite the many confirmations coming from research studies.

Indeed, the time needed for a new medical advance developed by scientists to reach the patient is a key issue. In this respect, the ICTR-PHE conference has a unique role. Medical doctors can learn about the latest radio-pharmaceuticals, the latest imaging instruments and the latest therapies that other scientists have worked on. At the same time, physicists, specialized industry, radiobiologists, etc, can hear from the medical field where they should concentrate their efforts for future research.

The impression was that the community is very willing to build a new collaboration model and that CERN could play an important role. The newly created CERN Office for Medical Applications is an example of the strength of the laboratory's wish to contribute to the growth of the field. Medical doctors need cost-effective instruments that are easy to use and reliable over time. This presents a challenge for physicists, who will have to use the most advanced technologies to design new accelerator facilities to produce the hadron beams for patient treatment.

A technical exhibition provided the opportunity for participants to find out more and to meet each other during breaks. (Image credit: CERN-PHOTO-201402-028 – 48.)

In addition to new accelerators, there is a plethora of opportunities for the physics field. These include the construction of a biomedical facility at CERN to provide particle beams of different types and energies for external users for radiobiology and detector development; the construction and testing of innovative detectors for beam control and medical imaging; the development of state-of-the-art instruments for accurate dosimetry; the MEDICIS facility for the production of rare radioisotopes; and a powerful computing grid for image treatment and storage.

As one of the speakers said, quoting the novelist William Gibson: "The future is here. It is just not evenly distributed yet." This is the next challenge for the community of scientists who attended ICTR-PHE 2014 – to take all of these advances to the patients as quickly as possible.

• Further reading

For more about ICTR-PHE 2014, see http://ictr-phe14.web.cern.ch/ICTR-PHE14/.

Résumé

ICTR-PHE : unir la physique, la médecine et la biologie

La conférence ICTR-PHE 2014 a réuni à Genève quelque 400 participants du monde entier venus discuter des dernières techniques de lutte contre le cancer. Chercheurs et praticiens de nombreuses disciplines ont passé en revue les dernières avancées de la recherche translationnelle, grâce à laquelle les innovations de la recherche fondamentale trouvent des applications dans le domaine de la santé (physique, biologie ou oncologie clinique). Pour tous les spécialistes concernés, la conférence ICTR-PHE est l'endroit idéal pour faire le point des travaux réalisés jusque-là et définir les prochaines étapes afin de maintenir la dynamique.

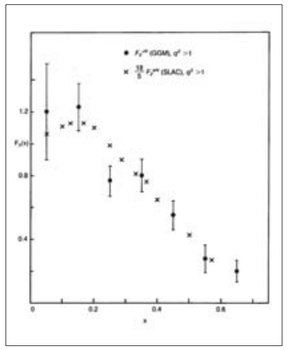
Manjit Dosanjh, CERN, and **Jacques Bernier**, Clinique de Genolier and Eaux-Vives Centre of Oncology in Geneva.

Neutrinos and nucleons

Measurements with neutrinos seemed impossible eight decades ago, but by 1974 the Gargamelle team had used them to help reveal the quark structure of matter.

On 7 April 1934, the journal *Nature* published a paper – The "Neutrino" – in which Hans Bethe and Rudolf Peierls considered some of the consequences of Wolfgang Pauli's proposal that a lightweight neutral, spin ½ particle is emitted in beta decay together with an electron (Bethe and Peierls 1934). Enrico Fermi had only recently put forward his theory of beta decay, in which he considered both the electron and the neutral particle – the neutrino – not as pre-existing in the nucleus, but as created at the time of the decay. As Bethe and Peierls pointed out, such a creation process implies annihilation processes, in particular one in which a neutrino interacts with a nucleus and disappears, giving rise to an electron (or positron) and a different nucleus with a charge changed by one unit. They went on to estimate the cross-section for such a reaction and argued that for a neutrino energy of 2.3 MeV it would be less than 10^{-44} cm^2 – "corresponding to a penetrating power of 10^{14} km in solid matter". This led them to conclude that even with a cross-section rising with energy as expected in Fermi's theory, "it seems highly improbable that, even for cosmic ray energies, the cross-section becomes large enough to allow the process to be observed".

However, as Peierls commented 50 years later, they had not allowed for "the existence of nuclear reactors producing neutrinos in vast quantities" or for the "ingenuity of experimentalists" (Peierls 1983). These two factors combined to underpin the first observation of neutrinos by Clyde Cowan and Fred Reines at the Savannah River nuclear reactor in 1956, and during the following years the continuing ingenuity of the particle-physics community led to the production of neutrinos with much higher energies at particle accelerators. With the reasonably large numbers of neutrinos that could be produced at accelerators, and cross-sections increasing with energy, their measurement became a respectable line of research, and ingenious experimentalists began to turn neutrinos into a tool to investigate different aspects of particle physics. Following the idea of Mel Schwarz, studies with neutrino beams began at the Alternating Gradient Synchrotron at Brookhaven and at the Proton Synchrotron (PS) at CERN in the early 1960s, and were taken to higher energies at Fermilab and at CERN's Super Proton Synchrotron in the 1970s. They continue today, using high-intensity beams produced at Fermilab and the Japan Proton Accelerator Research Complex.



$F_2(x)$ per nucleon, as measured from SLAC deep inelastic electron-deuteron scattering (crosses) and from Gargamelle neutrino/antineutrino data. The SLAC-MIT values have been divided by 5/18, the mean square charge of the u and d quarks in the nucleon according to Gell-Mann and Zweig. (Perkins 2001.)

At CERN, the story began in earnest in 1963 with an intense neutrino beam provided courtesy of Simon van der Meer's invention of the neutrino horn – a magnetic device that focuses the charged particles (pions and kaons) whose decays give rise to the neutrinos – coupled with a scheme for fast ejection of the proton beam from the PS devised by Berend Kuiper and Günther Plass in 1959. First in line to receive the neutrinos was the 500-litre Heavy-Liquid Bubble Chamber (HLBC) built by a team led by Colin Ramm (*CERN Courier* November 1966 p211 and November 2009 p11).

The combination worked well, allowing the measurement of neutrino cross-sections for various kinds of interactions. Studies of quasi-electric scattering, such as $\nu + n \rightarrow \mu + p$, mirrored for the weak interaction – the only way that neutrinos can interact – measurements that had been made for several years in elastic electron-nucleon scattering at Stanford. The cross-sections measured in electron scattering were used to derive electromagnetic "form factors" – an expression of how much the scattering is "smeared out" by an extended object, in comparison with the expectation from point-like scattering. The early results from the HLBC showed the weak form factors to be similar to those measured in electron scattering. Electrons and neutrinos were apparently "seeing" the same thing in (quasi-)elastic scattering.

Less easy to understand at the time were the "deep" inelastic events where the nucleus was more severely disrupted and several pions produced, as in $\nu + N \rightarrow \mu + N + n\pi$. The measurements of such events revealed a cross-section that increased with neutrino energy, rising to more than 10 times the quasi-elastic cross-section. Don Perkins of Oxford University reported on these results at a conference in Siena in 1963. "They were clearly trying to tell us a very simple thing," he recalled nearly 40 years later, "but unfortunately, we were just not listening!" (Perkins 2001)

The following year, Murray Gell-Mann and George Zweig put forward their ideas about a new substructure to matter – the "quarks" or "aces" that made up the hadrons, including the protons and ▷

60 years of CERN

neutrons of the nucleus. Today, this sub-structure is a fundamental part of the Standard Model of particle physics, and many young people learn about quarks as basic building blocks of matter while still at school. At the time, however, it was a different story because there was no evidence for real particles with charges of 1/3 and 2/3 that the proposals required. Indeed, most physicists thought that this sub-structure was more of a mathematical convenience.

The picture began to change at a conference in Vienna in 1968, when deep-inelastic electron-scattering measurements at SLAC's 3 km linear accelerator by the SLAC-MIT experiment – the direct descendent of the earlier experiments in Stanford – made people sit up and listen. The deep-inelastic cross-section divided by the cross-section expected from a point charge (Mott scattering) showed a surprisingly flat dependence on the square of the momentum transfer (q^2). This was consistent with scattering from points within the nucleons rather than the smeared-out structure seen in elastic scattering, which gives a cross-section that falls away rapidly with q^2. Moreover, the measurements yielded a structure function – akin to the form factor of elastic scattering – that depended very little on q^2 at large values of energy transfer, ν. Indeed, the data appeared consistent with a proposal by James Bjorken that in the limit of high q^2, the deep-inelastic structure functions would depend only on a dimensionless variable, $x = q^2/2M\nu$, for a target nucleon mass M. This behaviour, called "scaling", implied point-like scattering.

What did this imply for neutrinos? If they really were seeing the same structure as electrons – if the deep-inelastic structure function depended only on the dimensionless variable x – then the total cross-section should simply rise linearly with neutrino energy. As soon as Perkins saw the first results from SLAC in 1968, he quickly revisited the data from the Heavy-Liquid Bubble Chamber and found that this was indeed the case (Perkins 2001).

The "points" in the nucleons became known as partons – a name coined by Richard Feynman, who had being trying to understand high-energy proton–proton collisions in terms of point-like constituents. A key question to be resolved was whether the partons had the attributes of quarks, such as spin 1/2 and the predicted fractional charges. The SLAC-MIT group went on to make an outstanding series of systematic measurements over the next couple of years, which provided undisputable evidence for the point-like structure within the nucleon – and led in 1990 to the award of the Nobel Prize in Physics to Jerome Friedman, Henry Kendall and Richard Taylor. This wealth of data included results that clearly indicated that the partons must have spin 1/2.

In the meantime, a new heavy-liquid bubble chamber had been installed at the PS at CERN. Gargamelle was 4.8 m long and contained 18 tonnes of Freon, and had been designed and built at Orsay under the inspired leadership of André Lagarrigue, of the Ecole Polytechnique. It was to become famous for the first observation of weak neutral currents in 1973 (*CERN Courier* September 2009 p25). The same year saw the first publication of total cross-sections measured in Gargamelle, based on a few thousand events, not only with neutrinos but also antineutrinos. The results had in fact been aired first the previous year at Fermilab, at the 16th International Conference on High-Energy Physics (ICHEP). They showed clearly the linear rise with energy consistent with point-like scattering. Moreover, the neutrino cross-section was around three times larger than that for antineutrinos, which confirmed that neutrinos and antineutrinos were also seeing structure with spin 1/2.

However, there was still more. With data from both neutrinos and antineutrinos, the team could derive one of the structure functions that was also measured in deep-inelastic electron-scattering. Electrons scatter electromagnetically in proportion to the square of the charge of whatever is doing the scattering. Neutrinos, by contrast, are blind to charge and scatter only weakly. A comparison of the two structure functions should depend only on the mean charge squared seen by the electrons, which for quarks of charges 2/3 and –1/3 in equal numbers in the deuterium target used in the experiment at SLAC would be 5/18. So, the structure function from neutrino scattering, with no charge dependence, should be 18/5 of that for electron-scattering. As Feynman himself said: " If you never did believe that 'nonsense' that quarks have non-integral charges, we have a chance now, in comparing neutrino to electron scattering, to finally discover for the first time whether the idea…is physically sensible, physically sound; that's exciting." (Feynman 1974)

At the 17th ICHEP held in London in 1974, particle physicists from around the world were able to see the results from Gargamelle for themselves – the neutrino structure function, when multiplied by 18/5, did indeed fit closely with the data from the SLAC-MIT experiment (see figure p23). Forty years on from the paper by Bethe and Peierls, neutrino cross-sections were not only being measured, they were revealing a more fundamental layer to nature – the quarks.

These early experiments were just the beginning of what became a prodigious effort, mainly at CERN and Fermilab, using neutrinos to probe the structure of the nucleon within the context of quantum chromodynamics, the theory of quarks and the gluons that bind them together. And the effort is not finished, because neutrinos are still being used to understand puzzles that remain in the structure of the nucleus. But that is another story (p26).

Further reading

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Résumé

Neutrinos et nucléons

Le 7 avril 193, la revue Nature *publiait un article dans lequel Hans Bethe et Rudolf Peierls effectuaient un premier calcul de la section efficace du neutrino, avec la conclusion suivante : « Il semble très improbable que, même aux énergies des rayons cosmiques, la section efficace devienne assez grande pour que le processus puisse être observé ». Quarante ans plus tard, non seulement on pouvait mesurer des sections efficaces de neutrino dans la chambre à bulles Gargamelle, auprès du Synchrotron à protons du CERN, mais ces mesures permettaient d'accéder à un niveau plus fondamental de la nature : les quarks.*

Christine Sutton, CERN.

CERN Courier April 2014
Fermilab

MINERvA searches for wisdom among neutrinos

Precise measurements of cross-sections on nuclear targets continue Fermilab's rich history in neutrino physics.

Neutrino physicists enjoy a challenge, and the members of the MINERvA (Main INjector ExpeRiment for ν-A) collaboration at Fermilab are no exception. MINERvA seeks to make precise measurements of neutrino reactions using the Neutrinos at the Main Injector (NuMI) beam on both light and heavy nuclei. Does this goal reflect the wisdom of the collaboration's namesake? Current and future accelerator-based neutrino-oscillation experiments must precisely predict neutrino reactions on the nuclei if they are to search successfully for CP violation in oscillations. Understanding matter–antimatter asymmetries might in turn lead to a microphysical mechanism to answer the most existential of questions: why are we here? Although MINERvA might provide vital assistance in meeting this worthy goal, neutrinos never yield answers easily. Moreover, using neutrinos to probe the dynamics of reactions on complicated nuclei convolutes two challenges.

The history of neutrinos is wrought with theorists underestimating the persistence of experimentalists (Close 2010). Wolfgang Pauli's quip about the prediction of the neutrino, "I have done a terrible thing. I have postulated a particle that cannot be detected," is a famous example. *Nature* rejected Enrico Fermi's 1933 paper explaining β decay, saying it "contained speculations too remote from reality to be of interest to readers". Eighty years ago, when Hans Bethe and Rudolf Peierls calculated the first prediction for the neutrino cross-section, they said, "there is no practical way of detecting a neutrino" (p23). But when does practicality ever stop physicists? The theoretical framework developed during the following two decades predicted numerous measurements of great interest using neutrinos, but the technology of the time was not sufficient to enable those measurements. The story of neutrinos across the ensuing decades is that of many dedicated experimentalists overcoming these barriers. Today, the MINERvA experiment continues Fermilab's rich history of difficult neutrino measurements.

Neutrinos at Fermilab

Fermilab's research on neutrinos is as old as the lab itself. While it was still being built, the first director, Robert Wilson, said in 1971 that the initial aim of experiments on the accelerator system was to detect a neutrino. "I feel that we then will be in business to do experiments on our accelerator…[Experiment E1A collaborators'] enthusiasm and improvisation gives us a real incentive to provide them with the neutrinos they are waiting for." The first experiment, E1A, was designed to study the weak interaction using neutrinos, and was one of the first experiments to see evidence of the weak neutral current. In the early years, neutrino detectors at Fermilab were both the "15 foot" (4.6 m) bubble chamber filled with neon or hydrogen, and coarse-grained calorimeters. As the lab grew, the detector technologies expanded to include emulsion, oil-based Cherenkov detectors, totally active scintillator detectors, and liquid-argon time-projection chambers. The physics programme expanded as well, to include 42 neutrino experiments either completed (37), running (3) or being commissioned (2). The NuTeV experiment collected an unprecedented million high-energy neutrino and antineutrino interactions, of both charged and neutral currents. It provided precise measurements of structure functions and a measurement of the weak mixing angle in an off-shell process with comparable precision to contemporary W-mass measurements (Formaggio and Zeller 2013). Then in 2001, the DONuT experiment observed the τ neutrino – the last of the fundamental fermions to be detected (*CERN Courier* September 2000 p6).

The most recent progress at Fermilab comes from making neutrino beams of lower energies but higher intensities.

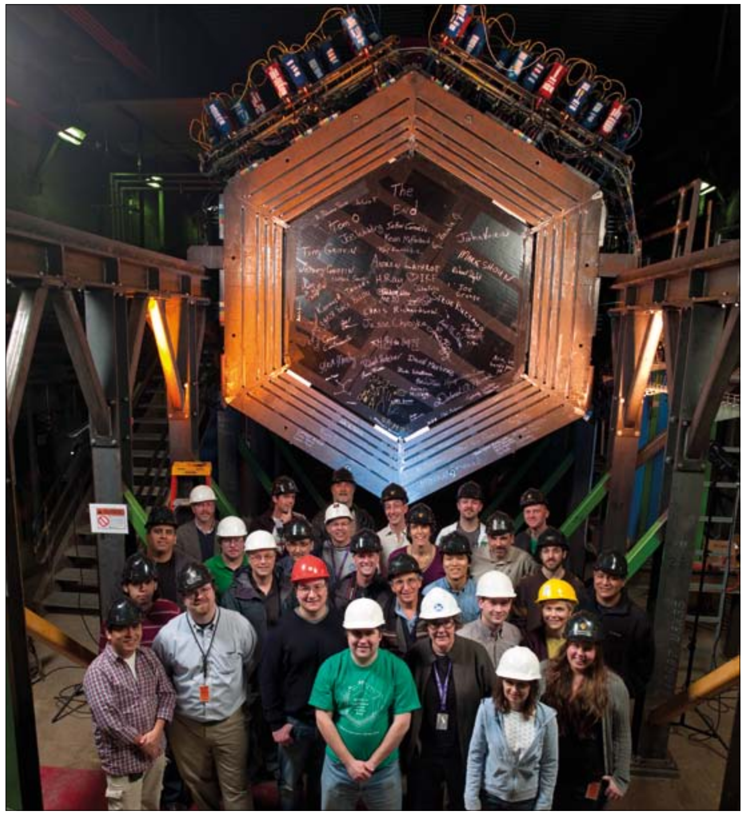
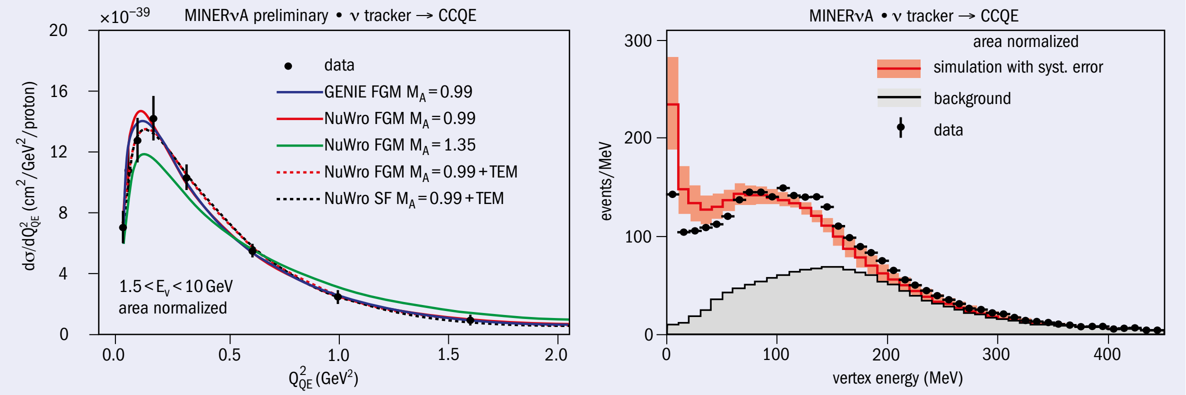


Fig. 1. Members of the MINERvA collaboration in front of their detector, many of whom signed the last module installed. (Image credit: Reidar Hahn/Fermilab.)



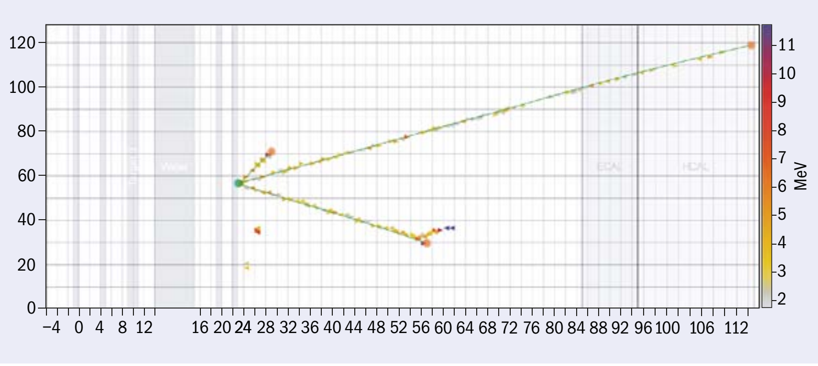


Fig. 2. An example of an event where a neutrino (coming from the left) interacts on a passive nuclear target in the detector. The colours correspond to the energy deposited (only one of three views of the event is shown). (Image credit: MINERvA collaboration.)

Fig. 3. Above left: The neutrino quasi-elastic cross-section as a function of the square of the momentum transferred to the nucleus (using a quasi-elastic hypothesis). Several theoretical predictions are also shown, including one inspired by the MiniBooNE quasi-elastic measurement (M_A = 1.35). The theoretical predictions are normalized to the data. Above right: The energy deposited within 30 cm of the neutrino interaction point, together with a prediction that assumes no correlations between initial-state nucleons.

While much of the progress of particle physics has come by making proton beams of higher and higher energies, the most recent progress at Fermilab has come from making neutrino beams of lower energies but higher intensities. This shift reflects the new focus on neutrino oscillations, where the small neutrino mass demands low-energy beams sent over long distances. While NuTeV and DONuT used beams of 100 GeV neutrinos in the 1990s, the MiniBooNE experiment, started in 2001, used a 1 GeV neutrino beam to search for oscillations over a short distance. The MINOS experiment, which started in 2005, used 3 GeV neutrinos and measured them both at Fermilab and in a detector 735 km away, to study oscillations that were seen in atmospheric neutrinos. MicroBooNE and NOvA – two experiments completing construction at the time of this article – will place yet more sensitive detectors in these neutrino beamlines. Fermilab is also planning the Long-Baseline Neutrino Experiment to be broadly sensitive to resolve CP violation in neutrinos.

A spectrum of interactions

Depending on the energy of the neutrino, different types of interactions will take place (Formaggio and Zeller 2013, Kopeliovich *et al.* 2012). In low-energy interactions, the neutrino will scatter from the entire nucleus, perhaps ejecting one or more of the constituent nucleons in a process referred to as quasi-elastic scattering. At slightly higher energies, the neutrinos interact with nucleons and can excite a nucleon into a baryon resonance that ▷

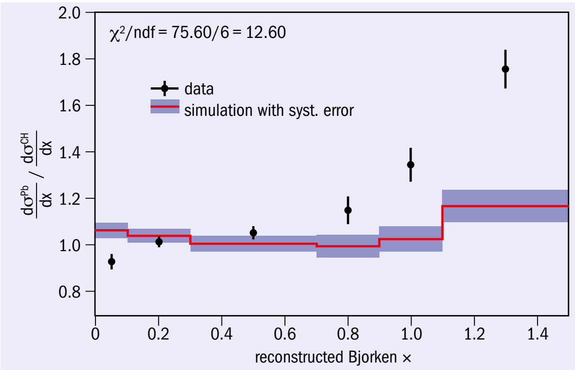


Fig. 4. The ratio of charged-current cross-section ratios between lead (Pb) and scintillator (CH) as a function of Bjorken-x, which in the quark–parton model is simply the fractional momentum of the struck quark. The ratio at low (high) x is dominated by inelastic (elastic) scattering processes.

typically decays to create new final-state hadrons. In the high-energy limit, much of the scattering can be described as neutrinos scattering from individual quarks in the familiar deep-inelastic scattering framework. MINERvA seeks to study this entire spectrum of interactions.

To measure CP violation in neutrino-oscillation experiments, quasi-elastic scattering is an important channel. In a simple model where the nucleons of the nucleus live in a nuclear binding potential, the reaction rate can be predicted. In addition, an accurate estimate of the energy of the incoming neutrino can be made using only the final-state charged lepton's energy and angle, which are easy to measure even in a massive neutrino-oscillation experiment. However, the MiniBooNE experiment at Fermilab and the NOMAD experiment at CERN both measured the quasi-elastic cross-section and found contradictory results in the framework of this simple model (Formaggio and Zeller 2013, Kopeliovich *et al*. 2012).

One possible explanation of this discrepancy can be found in more sophisticated treatments of the environment in which the interaction occurs (Formaggio and Zeller 2013, Kopeliovich *et al*. 2012). The simple relativistic Fermi-gas model treats the nucleus as quasi-free independent nucleons with Fermi motion in a uniform binding potential. The spectral-function model includes more correlation among the nucleons in the nucleus. However, more complete models that include the interactions among the many nucleons in the nucleus modify the quasi-elastic reaction significantly. In addition to modelling the nuclear environment on the initial reaction, final-state interactions of produced hadrons inside the nucleus must also be modelled. For example, if a pion is created inside the nucleus, it might be absorbed on interacting with other nucleons before leaving the nucleus. Experimentalists must provide sufficient data to distinguish between the models.

The ever-elusive neutrino has forced experimentalists to develop clever ways to measure neutrino cross-sections, and this is exactly what MINERvA is designed to do with precision. The experiment uses the NuMI beam – a highly intense neutrino beam (*CERN Courier* November 2013 p5). The MINERvA detector is made of finely segmented scintillators, allowing the measurement of the angles and energies of the particles within. Figures 1 and 2 (p26 and p27) show the detector and a typical event in the nuclear targets. The MINOS near-detector, located just behind MINERvA, is used to measure the momentum and charge of the muons. With this information, MINERvA can measure precise cross-sections of different types of neutrino interactions: quasi-elastic, resonance production, and deep-inelastic scatters, among others.

The MINERvA collaboration began by studying the quasi-elastic muon neutrino scattering for both neutrinos (MINERvA 2013b) and antineutrinos (MINERvA 2013a). By measuring the muon kinematics to estimate the neutrino energies, they were able to measure the neutrino and antineutrino cross-sections. The data, shown in figure 3 (p27), suggest that the nucleons do spend some time in the nucleus joined together in pairs. When the neutrino interacts with the pair, the pair is kicked out of the nucleus. Using the visible energy around the nucleus allowed a search for evidence of the pair of nucleons. Experience from electron quasi-elastic scattering leads to an expectation of final-state proton–proton pairs for neutrino quasi-elastic scattering and neutron–neutron pairs for antineutrino scattering. MINERvA's measurements of the energy around the vertex in both neutrino and antineutrino quasi-elastic scattering support this expectation (figure 3, right).

A 30-year-old puzzle

Another surprise beyond the standard picture in lepton–nucleus scattering emerged 30 years ago in deep-inelastic muon scattering. The European Muon Collaboration (EMC) observed a modification of the structure functions in heavy nuclei that is still theoretically unresolved, in part because there is no other reaction in which an analogous effect is observed (*CERN Courier* May 2013 p35). Neutrino and antineutrino deep-inelastic scattering might see related effects with different leptonic currents, and therefore different couplings to the constituents of the nucleus (Gallagher *et al*. 2010, Kopeliovich *et al*. 2012). MINERvA has begun this study using large targets of active scintillator and passive graphite, iron and lead (MINERvA 2014). Figure 4 shows the ratio of lead to scintillator and illustrates behaviour that is not in agreement with a model based on charged-lepton scattering modifications of deep-inelastic scattering and the elastic physics described above. Similar behaviour, but with smaller deviations from the model, is observed in the ratio of iron to scintillator. MINERvA's investigation of this effect will benefit greatly from its current operation in the upgraded NuMI beam for the NOvA experiment, which is more intense and higher in (the beamline's on-axis) energy. Both features will allow more access to the kinematic regions where deep-inelastic scattering dominates. By including a long period of antineutrino operation needed for NOvA's oscillation studies, an even more complete survey of the nucleons can be done. The end result of these investigations will be a data set that can offer a new window on the process behind the EMC effect.

The end result will be a data set that can offer a new window on the EMC effect.

Initially in the history of the neutrino, theory led experiment by several decades. Now, experiment leads theory. Neutrino physics has repeatedly identified interesting and unexpected physics. Currently, physics is trying to understand how the most abundant particle in the universe interacts in the simplest of situations. MINERvA is just getting started on answering these types of questions and there are many more interactions to study. The collaboration is also looking at what happens when neutrinos make pions or kaons when they hit a nucleus, and how well they can measure the number of times a neutrino scatters off an electron – the only "standard candle" in this business.

Time after time, models fail to predict what is seen in neutrino physics. The MINERvA experiment, among others, has shown that quasi-elastic scattering is a wonderful tool to study the nuclear environment. Maybe the use of neutrinos, once thought to be impossible to detect, as a probe to study inside the nucleus, would make Pauli, Fermi, Bethe, Peierls and the rest chuckle.

● Further reading

For more about the history of neutrino physics at Fermilab, visit http://history.fnal.gov/neutrino.html.

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B Z Kopeliovich *et al.* 2012 arXiv:1208.6541 [hep-ph].
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Résumé

MINERvA chemine vers la sagesse avec les neutrinos

Les physiciens des neutrinos aiment relever les défis et les membres de la collaboration MINERvA (Main INjector ExpeRiment for ν-A) au Fermilab ne font pas exception. L'expérience MINERvA a pour but de mesurer avec précision les sections efficaces neutrino-noyau sur des noyaux légers et lourds. À l'aide du faisceau intense de neutrinos du laboratoire et d'un détecteur composé de scintillateurs finement segmentés ainsi que d'un détecteur mesurant les muons, l'expérience déterminera la section efficace de différents types d'interactions des neutrinos, quasi-élastiques, production de résonance, diffusions profondément inélastiques, entre autres. L'expérience maintiendra ainsi la riche tradition du Fermilab concernant les difficiles mesures des neutrinos.

Emily Maher, Massachusetts College of Liberal Arts, **Deborah Harris**, Fermilab, and **Kevin McFarland**, University of Rochester.

Advanced radiation detectors in industry

A meeting organized under the auspices of the EPS looked at the latest advances in technologies to detect ionizing radiation and their applications through industry, in fields ranging from medicine to materials science.

Speakers and organizers at the EPS-TIG workshop in Ravenna. (Image credit: Giampiero Corelli Fotoreporter, Ravenna.)

The European Physical Society's Technology and Innovation Group (EPS-TIG) was set up in 2011 to work at the boundary between basic and applied sciences, with annual workshops organized in collaboration with CERN as its main workhorse (*CERN Courier* April 2013 p31). The second workshop, organized in conjunction with the department of physics and astronomy and the "Fondazione Flaminia" of Bologna University, took place in Ravenna on 11–12 November 2013. The subject – advanced radiation detectors for industrial use – brought experts involved in the research and development of advanced sensors, together with representatives from related spin-off companies.

The first session, on technology-transfer topics, opened with a keynote speech by Karsten Buse, director of the Fraunhofer Institute for Physical Measurement Technique (IPM), Freiburg. In the spirit of Joseph von Fraunhofer (1787–1826) – a researcher, inventor and entrepreneur – the Fraunhofer Gesellschaft promotes innovation and applied research that is of direct use for industry. Outlining the IPM's mission and the specific competences and services it provides, Buse presented an impressive overview of technology projects that have been initiated and developed or improved and supported by the institute. He also emphasized the need to build up and secure intellectual property, and explained contract matters. The success stories include the MP3 audio-compression algorithm, white LEDs to replace conventional light bulbs, and all-solid-state widely tunable lasers. Buse concluded by observing that bridging the gap between academia and industry requires some attention, but is less difficult than often thought and also highly rewarding. A lively discussion followed in the audience of students, researchers and partners from industry.

The second talk focused on knowledge transfer (KT) from the perspective of CERN's KT Group. First, Giovanni Anelli described the KT activities based on CERN's technology portfolio and on people – that is, students and fellows. In the second part, Manjit Dosanjh presented the organization's successful and continued transfer to medical applications of advanced technologies in the fields of accelerators, detectors and informatics technologies. Catalysing and facilitating collaborations between medical doctors, physicists and engineers, CERN plays an important role in "physics for health" projects at the European level via conferences and networks such as ENLIGHT, set up to bring medical doctors and physics researchers together (*CERN Courier* December 2012 p19).

Andrea Vacchi of INFN/Trieste reviewed the INFN's KT activities. He emphasized that awareness of the value of the technology assets developed inside INFN is growing. In the past, technology transfer between INFN and industry happened mostly through the involvement of suppliers in the development of technologies. In future, INFN will take more proactive measures to encourage technology transfer between INFN research institutions and industry.

From lab to industry

The first afternoon was rounded up by Colin Latimer of the University of Belfast and member of the EPS Executive Committee. He illustrated the varying timescales between invention and mass-application multi-billion-dollar markets, with a number of example technologies including optical fibres (1928), liquid-crystal displays (1936), magnetic-resonance imaging (MRI) scanners (1945) and lasers (1958), with high-temperature superconductors (1986) and graphene (2004) still waiting to make a major impact. Latimer ▷

went on to present results from the recent study commissioned by the EPS from the Centre for Economics and Business Research, which has shown the importance of physics to the European economy (EPS/Cebr 2013).

The second part of the workshop was devoted to sensors and innovation in instrumentation and industrial applications, starting with a series of talks that reviewed the latest developments. This was followed by presentations from industry on various sensor products, application markets and technological developments.

Erik Heijne, a pioneer of silicon and silicon-pixel detectors at CERN, started by discussing innovation in instrumentation through the use of microelectronics technology. Miniaturization to sub-micron silicon technologies allows many functions to be compacted into a small volume. This has led in turn to the integration of sensors and processing electronics in powerful devices, and has opened up new fields of applications (*CERN Courier* March 2014 p26). In high-energy particle physics, the new experiments at the LHC have been based on sophisticated chips that allow unprecedented event rates of up to 40 MHz. Some of the chips – or at least the underlying ideas – have found applications in materials analysis, medical imaging and other types of industrial equipment. The radiation imaging matrix, for example, based on silicon-pixel and integrated read-out chips, has many applications already.

Detector applications

Julia Jungmann of PSI emphasized the use of active pixel detectors for imaging in mass spectrometry in molecular pathology, in research done at the FOM Institute AMOLF in Amsterdam. The devices have promising features for fast, sensitive ion-imaging with time and space information from the same detector, high spatial resolution, direct imaging acquisition and highly parallel detection. The technique, which is based on the family of Medipix/Timepix devices, provides detailed information on molecular identity and localization – vital, for example in detecting the molecular basis of a pathology without the need to label bio-molecules. Applications include disease studies, drug-distribution studies and forensics. The wish list is now for chips with 100 ps time bins, a 1 ms measurement interval, multi-hit capabilities at the pixel level, higher read-out rates and high fluence tolerance.

In a similar vein, Alberto Del Guerra of the University of Pisa presented the technique of positron-emission tomography (PET) and its applications. Outlining the physics and technology of PET, he showed improved variants of PET systems and applications to molecular imaging, which also allow the visual representation, characterization and quantification of biological processes at the cellular and subcellular levels within living organisms. Clinical systems of hybrid PET and computerized tomography (CT) for application in oncology and neurology, human PET and micro-PET equipment, combined with small-animal CT, are available from industry, and today there are also systems where PET and magnetic resonance imaging (MRI) are combined. Such systems are being used in hadron therapy in Italy for monitoring purposes at the 62 MeV proton cyclotron of the CATANA facility in Catania, and at the proton and carbon synchrotron of the CNAO centre in Pavia. An optimized tri-modality imaging tool for schizophrenia

The Philips whole-body PET/MR scanner, which allows sequential PET and MR images to be acquired in the same session. (Image credit: Philips.)

is even being developed, combining PET with MRI and electroencephalography measurements. Del Guerra's take-home message was that technology transfer in the medical field needs long-term investment – industry can withdraw halfway if a technology is not profitable (for example, Siemens in the case of proton therapy). In future, applications will be multimodal with PET combined with other imaging techniques (CT, MRI, optical projection tomography), for applications to specific organs such as the brain, breast, prostate and more.

The next topic related to recent developments in the silicon drift detector (SDD) and its applications. Chiara Guazzoni, of the Politecnico di Milano and INFN Milan, gave an excellent overview of SDDs, which were invented by Emilio Gatti and Pavel Rehak 30 years ago. These detectors are now widely used in X-ray spectroscopy and are commercially available. Conventional and non-conventional applications include the non-destructive analysis of cultural heritage and biomedical imaging based on X-ray fluorescence, proton-induced X-ray emission studies, gamma-ray imaging and spectroscopy, X-ray scatter imaging, etc. As Gatti and Rehak stated in their first patent, "additional objects and advantages of the invention will become apparent to those skilled in the art," and Guazzoni hopes that the art will keep "drifting on" towards new horizons.

Moving on to presentations from industry and start-up companies, Jürgen Knobloch of KETEK GmbH in Munich presented new high-throughput, large-area SDDs, starting with a historical review of the work of Josef Kemmer, who in 1970 started to develop planar silicon technology for semiconductor detectors. Collaborating with Rehak and the Max-Planck Institute in Munich, Kemmer went on to produce the first SDDs with a homogeneous entrance window, with depleted field-effect transistor (DEPFET) and MOS-type DEPFET (DEPMOS) technologies. In 1989 he founded the start-up company KETEK, which is now the global commercial market leader in SSD technology. Knobloch presented the range of products from KETEK and concluded with a list of recommendations for better collaboration between research and industry. KETEK's view on how science and industry can better collaborate includes: workshops of the kind organized by EPS-TIG; meetings between scientists and technology companies to set out practical needs and future requirements; involvement of technology-transfer offices to resolve intellectual-property issues; encouragement of industry to accept longer times for returns in investments; and the strengthening of synergies between basic research and industry R&D.

The take-home message was that technology transfer in the medical field needs long-term investment.

Knobloch's colleague at KETEK, Werner Hartinger, then described new silicon photomultipliers (SiPMs) with high proton-detection efficiency, and listed the characteristics of a series of KETEK's SiPM sensors, which also feature a huge gain ($>10^6$) with low excess noise and a low temperature coefficient. KETEK has off-the-shelf SiPM devices and also customizes devices for CERN. The next steps will be continuous noise reduction (in both dark rate and cross-talk) by enhancing the KETEK "trench" technology, enhancement of the pulse shape and timing properties by optimizing parasitic elements and read-out, and the production of chip-size packages and arrays at the package level.

New start-ups

PIXIRAD, a new X-ray imaging system based on chromatic photon-counting technology, was presented by Ronaldo Bellazzini of PIXIRAD Imaging Counters srl – a recently constituted INFN spin-off company. The detector can deliver extremely clear and highly detailed X-ray images for medical, biological, industrial and scientific applications in the energy range 1–100 keV. Photon counting, colour mode and high spatial resolution lead to an optimal ratio of image quality to absorbed dose. Modules with units of 1, 2, 4 and 8 tiles have been built with almost zero dead space between the blocks. A complete X-ray camera based on the PIXIRAD-1 single-module assembly is available for customers in scientific and industrial markets for X-ray diffraction, micro-CT, etc. A dedicated machine to perform X-ray slot-scanning imaging has been designed and built and is currently under test. This system, which uses the PIXIRAD-8 module and is able to produce large-area images with fine position resolution, has been designed for digital mammography, which is one of the most demanding X-ray imaging applications.

CIVIDEC Instrumentation – another start-up company – was founded in 2009 by Erich Griesmayer. He presented several examples of applications of the products, which are based on diamond-detector technology. They have found use at the LHC and other accelerator beamlines as beam-loss and beam-position monitors for time measurements, high-radiation-level measurements, neutron time of flight, and as low-temperature detectors in superconducting quadrupoles. The company provides turn-key solutions that connect via the internet, supplying clients worldwide.

Nicola Tartoni, head of the detector group at the Diamond Light Source, outlined the layout of the facility and its diversified programmes. He presented an overview of the detector development and beamlines of this outstanding user facility in partnership with industry, with diverse R&D projects of increasing complexity.

Last, Carlos Granja, of the Institute of Experimental and Applied Physics (IEAP) at the Czech Technical University (CTU) in Prague, described the research carried out with the European Space Agency (ESA) demonstrating the impressive development in detection and particle tracking of individual radiation quanta in space. This has used the Timepix hybrid semiconductor pixel-detector developed by the Medipix collaboration at CERN. The Timepix-based space-qualified payload, produced by IEAP CTU in collaboration with the CSRC company of the Czech Republic, has been operating continuously on board ESA's Proba-V satellite in low-Earth orbit at 820 km altitude, since being launched in May 2013. Highly miniaturized devices produced by IEAP CTU are also flying on board the International Space Station for the University of Houston and NASA for high-sensitivity quantum dosimetry of the space-station crew.

In other work, IEAP CTU has developed a micro-tracker particle telescope in which particle tracking and directional sensitivity are enhanced by the stacked layers of the Timepix device. For improved and wide-application radiation imaging, edgeless Timepix sensors developed at VTT and Advacam in Finland, with advanced read-out instrumentation and micrometre-precision tiling technology (available at IEAP CTU and the WIDEPIX spin-off company, of the Czech Republic), enable large sensitive areas up to 14 cm square to be covered by up to 100 Timepix sensors. This development allows the extension of high-resolution X-ray and neutron imaging at the micrometre level to a range of scientific and industrial applications.

● For more about the workshop, visit www.emrg.it/TIG_Workshop_2013/program.php?language=en. For the presentations, see http://indico.cern.ch/event/284070/.

● Further reading

EPS/Cebr 2013 www.eps.org/?page=policy_economy.
INFN TT webpage www.pg.infn.it/cntt7.

Résumé

Des détecteurs de rayonnements de pointe pour l'industrie

Le groupe Technologie et Innovation de la Société européenne de physique a été créé en 2011 dans le but de travailler aux frontières des sciences fondamentales et appliquées, dans le cadre d'ateliers organisés chaque année en collaboration avec le CERN. Le deuxième de ces ateliers, organisé conjointement avec le département de physique et d'astronomie et la Fondazione Flaminia *de l'Université de Bologne, s'est déroulé à Ravenne (Italie), les 11 et 12 novembre 2013. Il avait pour thème les détecteurs de rayonnement de pointe à usage industriel et a rassemblé des spécialistes en matière de recherche et de développement de capteurs de pointe, ainsi que des représentants d'entreprises dérivées.*

The EPS-TIG team: **Giovanni Anelli**, CERN, **Andrea Contin**, University of Bologna, **Manjit Dosanjh**, CERN, **Erik Heijne**, CERN, IEAP CTU and Nikhef, and **Horst Wenninger**, CERN.

Faces & Places

AWARDS

Sessler honoured with Enrico Fermi Award

Andrew Sessler, well known both for his work in accelerator physics and as a humanitarian, has been awarded the US government's Enrico Fermi Award. He shares the award with Allen Bard, of the University of Texas at Austin, who was selected for his pioneering contributions to the field of electrochemistry. The two scientists received the award in a ceremony that took place in Washington, DC, on 3 February. Beforehand, they had the opportunity to meet the US president, Barack Obama, at the White House.

A former director of the Lawrence Berkeley National Laboratory (1973–1980), Sessler first made his scientific mark in the 1950s, with foundational work in particle accelerators that provided the basis for today's colliders, synchrotron light sources and free-electron lasers. The Fermi Award honours him for his "outstanding contributions to the establishment of the beam-physics knowledge basis that has underpinned the development of current-generation particle accelerators and storage rings deployed at leading research institutions throughout the world".

Sessler is also recognized for his public advocacy of scientific freedom and other humanitarian causes. During the Cold War era, he was a co-founder of the human rights group Scientists for Sakharov, Orlov and Sharansky (SOS) – scientists who were persecuted as dissidents in what was then the Soviet Union.

The Fermi Award, which is one of the US federal government's oldest and most prestigious prizes for scientific achievement, is administered on behalf of the White House by the US Department of Energy.

Andrew Sessler, well known for his contributions to accelerator physics. (Image credit: Roy Kaltschmidt/LBNL.)

● A revised and expanded edition of *Engines of Discovery: A Century of Particle Accelerators* by Andrew Sessler and Edmund Wilson is due out in April.

Maiani receives the 2013 Pontecorvo Award

Luciano Maiani has been awarded the 2013 Bruno Pontecorvo Prize by the Joint Institute for Nuclear Research (JINR). Maiani is honoured for his "outstanding contribution to particle physics, in particular his work on weak interaction physics and neutrino physics". A former director-general of CERN (1999–2003), he was also the president of Italy's INFN and of the National Research Council. He is particularly well known for his work with Sheldon Glashow and John Iliopoulos on a model that suppressed strangeness-changing weak neutral currents through the introduction of a fourth quark – charm.

The award was presented at the 115th session of the JINR Scientific Council by the vice-director of JINR, Richard Lednicky. During the ceremony Maiani gave a talk on perspectives in theoretical and experimental physics following the discovery of a Higgs boson, in which he highlighted investment in accelerators for the advancement of science.

Luciano Maiani, right, receives the 2013 Pontcorvo Award from Richard Lednicky, vice-director of JINR. (Image credit: JINR.)

François Englert receives honorary doctorate

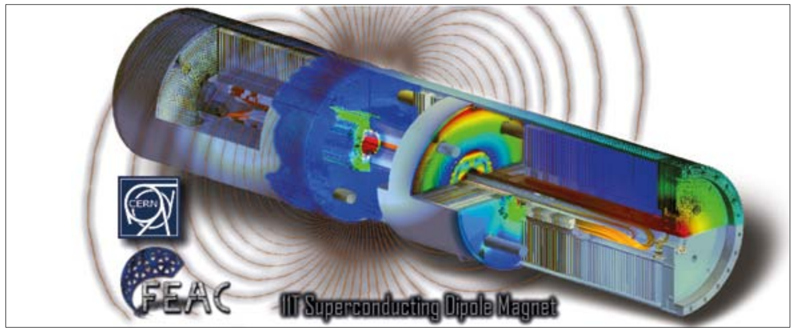
On 12 November, four weeks before the Nobel prize award ceremony in Stockholm, François Englert was made Doctor Honoris Causa of the Blaise Pascal University (UBP) in Clermont-Ferrand, on a proposal of the Laboratoire de Physique Corpusculaire (LPC). Previous Nobel laureates in physics proposed by the LPC for honorary doctorates from UBP include Jack Steinberger in 1995 and Richard Taylor in 1997.

The LPC – a joint laboratory of CNRS-IN2P3/UBP – has worked with CERN since the early 1960s. Its contribution to LHC experiments is particularly notable, with teams involved in the ATLAS, ALICE and LHCb experiments.

Clermont-Ferrand is the birthplace of the writer, philosopher, mathematician and physicist, Blaise Pascal. He wrote this premonitory sentence about the vacuum in 1647: "Empty space is in between matter and nothingness" – or in 17th century French language: *"l'espace vide tient le milieu entre la matière et le néant"*.

François Englert, right, with former student Jean Orloff, theoretician at Laboratoire de Physique Corpusculaire and mentor for this award. (Image credit Danyel Massacrier.)

Magnet design for HiLumi LHC wins competition



The winning design image, for an 11 T LHC magnet. (Image credit: FEAC Engineering.)

When Charilaos Kokkinos returned to Greece after a fellowship at CERN on the HiLumi LHC Design Study, he set up an engineering consultancy called FEAC Engineering. Now, the company has won a competition with his work on the design of an 11 T superconducting dipole magnet for the HiLumi LHC project. It was one of the winners of "best-in-class" in the corporate category of the 2014 ANSYS Inc. Hall of Fame Competition.

This annual image competition aims to highlight some of engineering's most complex design challenges. The contest gives users of ANSYS engineering design tools the chance to showcase their simulation and engineering skills through the production of eye-catching simulation images and animations.

Based in Greece, the new company, FEAC Engineering, provides consulting services from product concept and computer-aided design drafting to advanced multi-physics finite-element analysis and design optimization by using state-of-the-art computer-aided engineering tools.

● For more details, see www.feacomp.com.

TOTEM and CDF studies win INFN thesis prize

Mirko Berretti from Siena University and Federico Sforza of INFN Pisa have won the 2013 INFN Conversi Prize for their PhD theses. They received their awards in a ceremony that was held on 7 February at the seat of the INFN Presidency in Rome.

Berretti earned his doctorate in studies at CERN's LHC, specifically the "Measurement of the forward charged particle pseudorapidity density in pp collisions at $\sqrt{s} = 7$ TeV with the TOTEM experiment". In particular, he did important work on the pattern recognition and reconstruction of the charged-track multiplicity in the T2 particle telescope. Sforza's work was on measurement of the production of pairs of vector bosons with the CDF experiment at Fermilab. His thesis is on "Evidence for diboson production in the lepton plus heavy flavor jets final state at CDF".

This annual award by INFN celebrates the role of Marcello Conversi (1917–1988). The competition is open to members of INFN who have gained doctorates in the past year with a thesis in the field of subnuclear physics.

Mirko Berretti receives his prize from INFN president, Fernando Ferroni, left, while Federico Sforza, right, looks on. (Image credit: INFN.)

Willibald Jentschke (centre left) toasts Donatus Degèle, Hermann Kumpfert and the synchrotron team in the DESY control room on 26 February 1964, after the first particles successfully circulated repeatedly through the vacuum system of the DESY synchrotron, approximately 300 m in circumference. After two weeks of at times frustrating efforts by the accelerator team, all went quickly. The first electrons reached 2.5 GeV in about 8000 orbits, with 5 GeV obtained the following day, just 1 GeV below the design energy. Today, 50 years later, the DESY accelerator continues to operate reliably, delivering beams of up to 1.8×10^{10} particles at 6.3 GeV, and is still in demand as a test beam for studies of future detectors. In this image, Norwegian accelerator pioneer Rolf Widerøe watches far left. (Image credit: DESY.)

60 YEARS/ANS CERN

The Proton Synchrotron (PS) is the oldest accelerator operating at CERN. Its origins date back to 1952, when the provisional CERN Council decided to build a "high-energy" PS. Within a few months, the PS group convinced Council to launch a study for an alternating-gradient PS of "about 30 GeV" as the main project of the new laboratory (CERN Courier January/February 2004 p15). On 3 February 1959, the first of the 100 main magnet units was installed in the empty PS tunnel hauled by a small electric battery-driven vehicle. Nobody in 1952 could have imagined that the PS would remain the backbone of CERN's scientific activities well into the 21st century. Keeping it in operation has involved some serious maintenance. Since 2003 there has been a huge campaign to refurbish the magnets, which has required removing and reinstalling them with the old vehicle – itself refurbished. Here, right, it is seen moving a refurbished magnet in a now crowded tunnel on 3 February 2009. (Image credits: CERN-IT-0106040 and CERN-AC-0902012 – 13).

APPOINTMENTS

Brookhaven names new deputy director for science and technology

Experimental physicist Robert Tribble has become deputy director for science and technology at the US Department of Energy's Brookhaven National Laboratory. He joins Brookhaven from Texas A&M University (TAMU), where he was distinguished professor of physics and astronomy and director of the Cyclotron Institute and the Nuclear Solutions Institute.

Tribble joined TAMU in 1975, following a PhD from Princeton University. An experimental physicist whose work spans a broad range of topics, he is widely credited with developing new tools and techniques that have advanced the field. He has served as a member or chair of numerous long-range planning committees for the American Physical Society and the Nuclear Science Advisory Committee (NSAC), leading the development of the most recent NSAC Long Range Plan for Nuclear Science, as well as evaluating the state of nuclear-physics facilities around the world. He played a key role in communicating the importance of the US nuclear-science programme – including research that takes place at Brookhaven's Relativistic Heavy-Ion Collider (RHIC).

In moving to Brookhaven, with its two major accelerator facilities – RHIC and the new National Synchrotron Light Source II – Tribble joins a team that is taking on new challenges, from expanding RHIC to the electron–ion collider eRHIC, to synthesizing new nanomaterials for materials and biosciences, improving energy efficiency and developing new sustainable energy sources.

Robert Tribble is now deputy director for science and technology at Brookhaven. (Image credit: Brookhaven National Laboratory.)

CENTENARY

Pisa celebrates Bruno Pontecorvo

Left: The room in the exhibition "Bruno Pontecorvo from Pisa to Moscow, a long journey through history and science" dedicated to his years in Russia. (Image credit: Federico Borghesi.) Right: Some of the symposium participants during a talk. At front left to right are Jack Steinberger, Giorgio Bellettini and Italo Mannelli, with Guido Altarelli and Josè Bernabeu visible behind. (Image credit: Giuseppe Fausto.)

The interplay between science, life and society was at the centre of a series of events organized in Pisa last year to celebrate one of its most renowned citizens, Bruno Pontecorvo, on the centenary of his birth.

On 18–20 September, distinguished scientists from around the world gathered to commemorate Bruno and his scientific ideas at an international scientific symposium organized by INFN, Pisa University, Scuola Normale Superiore, JINR Dubna and CERN. The first day was dedicated to his life story and to personal recollections by friends and former students, among them Jack Steinberger, Ettore Fiorini, Guenakh Mitselmakher and Samoil Bilenky. During the second and third days, scientific presentations by international experts gave a complete overview of the state-of-the-art in the different fields constituting the legacy of Bruno's ideas: the theory of neutrino mass and mixing; solar, reactor, atmospheric and geo-neutrinos; double beta decay and direct measurements of neutrino mass; lepton-flavour violation processes and neutrinos in cosmology and astrophysics.

The centenary of Bruno's birth was also the occasion to explore his life not only as a scientist but also as a man, in connection with history and society. This was the aim of the exhibition "Bruno Pontecorvo from Pisa to Moscow, a long journey through history and science", held from 11 September to 22 December at the Limonaia di Palazzo Ruschi in Pisa. The exhibition portrayed Bruno's life through the places and countries where he lived, starting with Pisa, where he was born on 22 August 1913 into a wealthy, non-observant Jewish family. Here, his grandfather, Pellegrino Pontecorvo, owned a textile factory that employed about 2000 workers in the 1930s. One of the buildings of the Pontecorvo factory now hosts the physics department and the local INFN division. The reconstruction of his life as a student was enriched by original documents from his high-school and university years.

At the age of 18, Bruno left Pisa for Rome to complete his physics studies under the supervision of Enrico Fermi. Here, as the youngest physicist of the group, he participated in the experiments with slow neutrons for which Fermi was awarded the Nobel prize in 1938. Bruno then moved to Paris in 1936 to work with Frédéric Joliot-Curie, and later to the US and Canada to escape from racial persecution in Europe. His return to Europe (the UK) in 1949 and his subsequent move to the USSR in 1950, which raised heated discussions and debates at the time, were then presented. Bruno reappeared "officially" in Moscow in 1955, and from then on spent his life and scientific activity in Dubna, where he contributed to nuclear and elementary particle physics, especially in the field of neutrinos. The final section of the exhibition dealt with the years after 1978, when Bruno returned to Italy after 30 years of absence for the 70th birthday of his friend Edoardo Amaldi.

Each room of the exhibition displayed precious material illustrating Bruno's work and life. In particular, the original equipment and sources (kindly lent by the physics museum of Rome "La Sapienza" University) used for the discovery of the artificial radioactivity induced by slow neutrons, together with hand-written logbooks with comments from Bruno, Fermi and co-workers, were a bonus for both physicists and the general public visiting the exhibition. Some of Bruno's precious personal belongings were also on show: the briefcase that he used to carry his papers and documents in Dubna, the Lenin Prize and the experimental logbooks where he wrote the results of the first experiments he performed in Dubna in the years 1950–1954. These notes witness Bruno's remarkable insights into the existence of a muon neutrino and on the conservation of strangeness in strong interactions, well before their official claims.

A series of movies and images from the years 1930–1990 clarified the historical and scientific background in which some of the most brilliant ideas in particle physics where developed. A special room was dedicated to Bruno's scientific legacy: instruments, interviews, movies and photos presented some of the present-day experiments motivated by his ideas – for example, neutrino oscillations, universality in weak interactions, lepton flavour and number violation and solar neutrinos.

In parallel with the exhibition, events were also organized to celebrate two of his brothers: projections of the most important films by the movie director Gillo Pontecorvo, and a conference about Guido Pontecorvo, the famous geneticist. A conference on "Pisa and the Pontecorvo family" underlined the importance of the whole family to the city of Pisa.

The centenary of Bruno's birth was the occasion to explore, once again, the relationship between science and society, and to meditate on a famous saying of Bruno's: "What's more important in life: to make the right choices or to be a good person? I think I've made many mistakes, but I've always been a good person."

● For more about the symposium, see www.pi.infn.it/pontecorvo100/. For more on the exhibition, visit www.pontecorvopisa.it/.

CELEBRATION

Beijing honours the memory of Sanqiang Qian and Zehui He

Sanqiang Qian, right, obtained his doctorate in 1940 in Paris, with a thesis supervised by Irène Curie, centre, and her husband Frédéric Joliot, left. In 1948, Sanqiang Qian and his wife Zehui He, also a physicist, returned to China, where they both became deeply involved in the development of nuclear and particle physics in their home country. Commemorative envelopes were issued as part of the centenary celebrations for Sanqiang Qian and Zehui He. (Image credits: Qian family and China Post.)

The Chinese physics community recently celebrated the centenaries of the birth of two of the country's pioneers in nuclear physics. The centenary of Sanqiang Qian (1913–1992) on 16 October 2013 was followed by that of his wife Zehui He (1914–2011) on 5 March this year.

A symposium to honour the scientific achievements of the two eminent physicists was held in Beijing on the centenary of Sanqiang Qian's birth. Organized by the Chinese Academy of Sciences (CAS), the China Association for Science and Technology (CAST) and the China National Nuclear Corporation (CNNC), about 350 friends, colleagues and students, as well as members of the Qian and He families, attended. There were key speeches by the president of CAS, the executive vice-president and chief executive-secretary of CAST, former students and colleagues of Sanqiang Qian and Zehui He, young students and the daughter and son of the two professors. The speakers recollected the lives and achievements of the two pioneering scientists from various perspectives, and their important contributions to Chinese nuclear research and Chinese science in general. Sanqiang Qian was vice-president of CAS and vice-president (and later honorary president) of CAST in the 1970s and 1980s. All of the speakers hoped that the scientific and technological achievements of Sanqiang Qian and Zehui He would inspire younger Chinese scientists in their current and future research.

Sanqiang Qian and Zehui He both graduated from the physics department of Tsinghua University in 1936. A year later, Sanqiang Qian went to Paris to the laboratory of Irène Curie (Marie Curie's daughter) and her husband Frédéric Joliot, obtaining his doctorate there in 1940 with a thesis supervised by the Joliot-Curies. Zehui He went to Berlin after graduating, and after several years pursuing a doctorate and further research in Germany, she moved to Paris in 1946 and married Sanqiang Qian – with whom she had kept in contact via letter – and then started to work with him at the Curie Institute. Two years later, they returned to China where they both became deeply involved in the development of nuclear and particle physics in their home country (*CERN Courier* September 1992 p40, January/February 1994 p30 and December 2011 p29).

During the symposium, three newly published books were distributed – a long biographical chronology of Sanqiang Qian and biographies of Sanqiang Qian and Zehui He – as well as two commemorative envelopes issued by China Post. In the afternoon, another ceremony with about 200 participants was organized by the CNNC at the China Institute of Atomic Energy, to open a retrospective exhibition commemorating the centenary of Sanqiang Qian's birth.

Hélène Langevin-Joliot and Pierre (and Anne) Joliot – the daughter and son (and his wife) of Frédéric and Irène Joliot-Curie, and the only two grandchildren of Pierre and Marie Curie – travelled to Beijing to participate in the afternoon ceremony. Hélène gave a speech recollecting Sanqiang Qian's study and research in France during 1937–1948 under the supervision of her parents, and his friendship with her family.

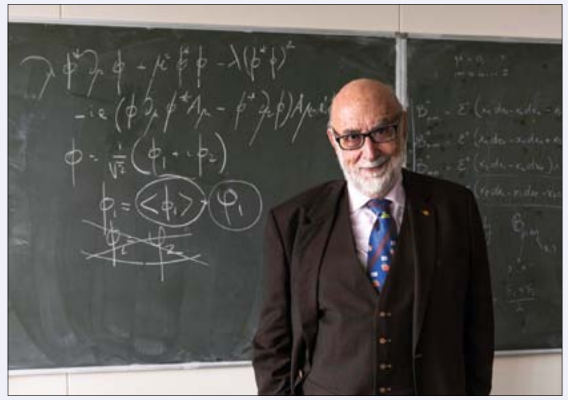
On the morning of 17 October, Weichen Shen, the executive vice-president and chief executive-secretary of CAST, met with Hélène, Pierre and Anne at the headquarters of CAST. Weichen Shen thanked the French guests for coming to Beijing to participate in the centenary commemoration programme. On behalf of Chinese scientists and researchers, he acknowledged the valuable help that their parents had given to Chinese scientific research during its difficult beginnings in the early 1950s. The French visitors were impressed by their meeting with Weichen Shen and other CAST officers, and considered it to be one of the best meetings during their visit to Beijing.

The following day, Hélène, Pierre and Anne went to Peking University (PKU) in the afternoon to give lectures in the School of Physics in celebration of its centenary, which by coincidence was on 19 October. Hélène and Pierre gave talks on "The Curies: from radioactivity to nuclear energy, beyond the Nobel Prizes" and "Basic and applied research, yesterday and today".

On 3 March, a centennial commemoration symposium for Zehui He was held at the Institute of High Energy Physics (IHEP) of CAS, where she had served as deputy director from 1973 to 1984. About 100 colleagues, friends and members of her family attended. The Chinese *Journal of Modern Physics* also published a special 22-page section in its March issue, with articles celebrating her life.

Visits

Dutch state secretary for education, culture and science, **Sander Dekker**, right, visited CERN on 29 January. During his extensive tour of the laboratory, he was shown the LHC tunnel by **Gijs de Rijk**, of CERN's Technology Department. (Image credit: CERN-PHOTO-201401-019 – 11.)



Nobel laureate **François Englert**, pictured here in front of the equation describing the Brout–Englert–Higgs (BEH) mechanism, came to CERN on 21 March to present "The BEH mechanism and its scalar bosons" – his first public talk since receiving the 2013 Nobel Prize in Physics together with Peter Higgs. (Image credit: CERN-PHOTO-201402-033 – 2.)

Industry

German companies display their wares at CERN

The 12th Germany at CERN, held on 28–29 January, saw the largest gathering of German industrial representatives at CERN to date. A heated marquee outside the CERN restaurant accommodated 59 companies, which presented their latest ideas and technologies for the maintenance, renovation and expansion of CERN's accelerator complex to interested scientists and buyers.

The exhibitors were from a broad range of technical fields, with the majority engaging in those of electronics and vacuum technologies. The event was organized by CERN in collaboration with the German Federal Ministry of Education and Research (BMBF). Karl-Eugen Huthmacher, head of the BMBF's directorate-general 7: Provision for the Future – Basic and Sustainability Research, visited the stands after inaugurating the exhibition together with CERN's director-general Rolf Heuer.

BMBF's Karl-Eugen Huthmacher, right, is welcomed to the 12th Germany at CERN exhibition. (Image credit: CERN-PHOTO-201401-017 – 32.)

Obituaries

Sergey Kruglov 1929–2014

Sergey Pavlovich Kruglov, professor and chief researcher at the Petersburg Nuclear Physics Institute (PNPI), Gatchina, passed away on 20 January following a brief hospitalization. Sergey was an honoured scientist of the Russian Federation and a leading figure in meson physics and electromagnetic interactions, with the study of muon spin rotation (μSR) one of his most notable contributions.

Sergey was born in Vologda on 5 April 1929. Admitted to the St Petersburg State Polytechnic University (the former Leningrad Polytechnic Institute), he received his MA degree in nuclear physics in 1953. He then went to PNPI (the former Leningrad Nuclear Physics Institute and Ioffe Physical-Technical Institute) and in 1961 received his PhD on the comparison of ionization and calorimetric measurements of the energy flux of gamma radiation from electron accelerators, with Anton Komar as his adviser. Sergey summarized this study in the book *Measurement of the total energy of the beams from the electron bremsstrahlung accelerators* (1972 Nauka) with Komar and Igor Lopatin. He had a major impact on the development of both the PNPI High Energy Physics Division and the field of hadron physics at Gatchina and worldwide.

Sergey Kruglov. (Image credit: Nance Briscoe.)

Sergey later focused on the complete experiment for pion–nucleon elastic scattering to determine partial-wave amplitudes and parameters of low-lying non-strange nucleon resonances. He led the effort to build two meson channels at the 1-GeV PNPI proton synchrocyclotron, and supervised the construction of the two main detectors and the unpolarized and polarized hydrogen targets used to measure cross-sections and polarization observables. The partial-wave analysis technique allowed him to interpret data from Gatchina and around the world. In 1985, Sergey received his habilitation qualification on the study of elastic pion–nucleon scattering in the region of low-lying pion–nucleon resonances. Later, he was involved in the Crystal Ball activity at Brookhaven National Laboratory to study hadronic physics using both pion and kaon secondary beams. Finally, he returned to his favourite task – the physics of electromagnetic processes – using the Crystal Ball at the Mainz Microtron.

Sergey supervised more than 20 PhD students who now work at nuclear-physics facilities worldwide. He was a great mentor and friend, and an excellent teacher with infectious enthusiasm and a strong supporter of his students. The community will miss him greatly.

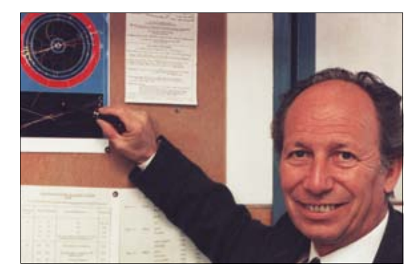
● *William Briscoe, Anatoly Gridnev, Nikolai Kozlenko, Igor Lopatin, Igor Strakovsky and Victorin Sumachev.*

Lorenzo Foà 1937–2014

Lorenzo Foà, a protagonist of experimental high-energy physics for five decades and mentor of dozens of students, passed away quietly and unexpectedly in Pisa on 13 January. He was professor at the Scuola Normale Superiore in Pisa and spent most of his scientific career at CERN.

Lorenzo was among the proponents of two experiments in the early 1960s that allowed the first measurement of the π^0 and η lifetimes via the Primakoff effect at Frascati and then at DESY. Later he joined first the CERN-Orsay-Pisa collaboration studying polarization in hadron scattering and then the Pisa-Stony Brook collaboration at CERN's Intersecting Storage Rings (ISR). This experiment discovered that the total proton–proton cross-section starts increasing at ISR energies – a departure from what had previously appeared to be flat "asymptotic" behaviour.

In the 1970s, Lorenzo was the founder and spokesperson of the FRAMM (for frammentazione, or fragmentation) collaboration, which established the basis of the NA1 and NA7 experiments. In NA1, a multiparticle spectrometer was used in conjunction with the first active targets to measure the lifetimes of charmed mesons. In NA7, the same spectrometer in a different configuration allowed precise measurements of the electromagnetic form factors of pions and kaons in the space-like region and of the pion in the time-like region. FRAMM was a key stepping stone for the development of new detectors and their successive introduction in modern physics.



Lorenzo Foà, a founding father of ALEPH. (Image credit: Courtesy Foà family.)

Lorenzo went on to become one of the founding fathers of the ALEPH experiment in the 1980s. He organized Italian participation in the collaboration and co-ordinated many projects, both in the construction phase and during the physics exploitation. He was spokesperson of the collaboration in the years 1993 and 1994.

As scientific director of CERN, Lorenzo was instrumental in approval of the LHC in December 1994, following the cancellation of the Superconducting Super Collider project in the US in 1993. After approval, he played a leading role in getting the international community (Japan and US) on board to complete funding of the construction of the accelerator in a single stage.

In 1998, Lorenzo joined the CMS collaboration and was chair of the board from 2000 until 2009, during the delicate period of the end of the construction and commissioning of the experiment. His actions were vital in strengthening the collaboration and improving the structures and procedures, with particular attention given to promoting young physicists.

The whole high-energy physics community owes a great deal to Lorenzo's vision, wisdom and charisma. He was a great scientist and a protagonist in science management at the European and worldwide level. He was also a special person: very generous and always around, he was able to tell his friends and students about what is important in science and life.

● *His colleagues and friends.*

● A conference in memory of Lorenzo Foà will be held in Pisa on 12 June. See http://particlephysics.sns.it/index.php.

François Etienne 1944–2014

It is with great sorrow that colleagues at the Centre de Physique des Particules de Marseille (CPPM), at CNRS-IN2P3 and at the CNRS IT Division learnt of the passing away of François Etienne in January.

François had a distinguished and fruitful career, focused on triggering, data extraction and computing. He started working in the 1970s in Strasbourg, in connection with CERN, Fermilab and the Massachusetts Institute of Technology, on a system to analyse pictures from bubble chambers. He defended his "thèse d'Etat" on the production of charmed particles in 1984 at the University Louis Pasteur. Later, at the Large Electron–Positron collider at CERN, he made substantial contributions to reconstruction, data analysis and visualization software for DELPHI, and then for ALEPH when he joined CPPM in 1986.

At CPPM, François was in charge of setting up a computing group that grew successfully into a computing department, which remained under his responsibility until 1998. Initiator and organizer of the 1st IN2P3 Computing School in 1990, and organizer of many of the following ones, he was also a member of the CERN Computing School International Advisory Committee, and organizer of international conferences.

François Etienne in 1994. (Image credit: François Touchard.)

François was very active on the ATLAS experiment at the LHC from its inception, and created a group at CPPM to work on event triggering and filtering. He played a leading role in the ATLAS trigger data-acquisition (TDAQ) community, notably as a member of its steering committee, as chairman of the TDAQ Institute Board – where his poised management and professionalism were highly appreciated – and as co-ordinator of the ATLAS Event Filter. He was also chair of the RD47 research project at CERN and a member of RD13.

His unique, innovative and thoughtful vision of the ever-growing and critical role of computing in particle physics and in other fields led him to play a prominent role in the early days of grid computing, as one of the founders of DataGrid and as the head of the DataGrid test bed, which eventually grew into Europe's Enabling Grids for E-sciencE project and the European Grid Initiative and into the Wordwide LHC Computing Grid (LCG). He was at the core of a small team that decided, with strong support from CNRS, the resolute positioning of France in the grid initiatives. Under his guidance, the IN2P3 Computing Centre in Villeurbanne was set up as a powerful main node (Tier-1), while several strong secondary nodes (Tier-2) were in the making and LCG-France was taking shape.

With his internationally recognized expertise and highly appreciated management skills, François chaired several committees on computing at CERN and in France. He served for many years (1999–2006) as computing adviser for the IN2P3 director. His numerous talents gained him wide national and international recognition, from researchers as well as computing professionals. From 2006 to his retirement in 2009, he was head of the CNRS IT Division.

In daily life, François always had a friendly, dedicated and trustworthy attitude. More than a colleague, we have lost a friend. Our deepest condolences go to his family, particularly to his wife, and to his friends and colleagues.

● *His colleagues and friends at CCPM.*

Obituary note

Godfrey Stafford 1920–2013

On 23 January, more than 200 people gathered at the Rutherford Appleton Laboratory to celebrate the life and legacy of Godfrey Stafford – one of the leaders in the foundation of the laboratory and a former director (1969–1981), who died in July last year (*CERN Courier* November 2013 p43). For presentations and a webcast of the event, see https://indico.cern.ch/event/298115/.

Meeting

AWLC14, the **Americas Workshop on Linear Colliders**, will be held at Fermilab on 12–16 May. As the next in the series of regional linear-collider workshops held around the world, this meeting welcomes strong international participation. Its purpose is the continued development of the physics case for a high-energy linear electron–positron collider and the advancement of detector and accelerator designs. This meeting will particularly address the developments for the International Linear Collider, which Japan is considering to host. The workshop will consist of plenary and parallel sessions as well as meetings of the collaborations involved in the development of linear colliders. The deadline for early registration is 4 May. For more information, visit www.linearcollider.org/awlc14/.

New product

Edwards Limited has launched a special variant to its nXDS range of dry scroll vacuum pumps, which is ideally suited for pumping rare or critical gases. nXDS dry scroll pumps are free of lubrication in the entire pumped path of the gas. The special variant nXDS-R is optmized for situations where an application demands the pumping or recirculation of rare or critical gases without the risk of accidental introduction of atmospheric air. The pump also features intelligent and easy-to-control functions with simple operation. For further information, visit www.edwardsvacuum.com.

Recruitment

CERN Courier April 2014

Fermilab

Fermilab offers Intensity Frontier Fellowships to outstanding researchers in the areas of neutrino physics, muon physics, and other topics in the Intensity Frontier. Fellows will receive funding to allow enhanced participation in Fermilab experimental and data analysis efforts, in relevant areas of particle physics theory, or in future projects. The fellowships provide the ability for researchers to spend significant time at Fermilab working within the Intensity Frontier Department, with the goal of expanding and sustaining an intellectual center of excellence within the laboratory and the department.

Successful candidates will ordinarily be resident at Fermilab for 50% or more of the duration of the Fellowship.

- Term: 6 months to 1 year.
- During the requested award period, candidates must be employed by a U.S. or non-U.S. institution. Fermilab employees are not eligible.
- Renewable to maximum of 2 years, with new proposal.
- Financial support: up to 50% of researcher's overall compensation, with remainder from researcher's home institution.
- Awards may include a travel budget.

Application Information
Applications for the current round of awards will be accepted until 11 May, 2014. It is anticipated that awards will be given out twice yearly. Applicants should be notified by 25 May, 2014.

Applications should be made electronically via:
https://academicjobsonline.org/ajo/jobs/3940

Further queries should be sent to:
intensity_frontier_fellowships@fnal.gov

SPRACE

The São Paulo Research and Analysis Center
(SPRACE – http://www.sprace.org.br)
is a research group from São Paulo State University and ABC Federal University working on the Compact Muon Solenoid (CMS) experiment of the CERN Large Hadron Collider (LHC). The SPRACE project is mainly supported by funds provided by the São Paulo Research Foundation, (FAPESP) supplemented by Federal funds.

The SPRACE research team is engaged in two CMS physics analysis groups: Beyond the Standard Model and Heavy Ion physics. SPRACE also operates a Tier-2 facility of the Worldwide LHC Computing Grid (WLCG) and is responsible for the implementation of a statewide grid infrastructure – GridUNESP – that serves more than 50 research groups from different scientific communities. SPRACE participates in R&D activities on the conceptual design, simulation and proof-of-concept of a Level 1 trigger for the pixel tracking detector of the CMS experiment.

The SPRACE group has currently open positions for Ph.D. students, Postdoctoral Fellows and Electrical Engineers. In order to apply for those positions, candidates should send an application letter, résumé of work experience, and at least two letters of recommendation to Sergio.Novaes@cern.ch.

SPRACE is committed to the principles of equal opportunity and affirmative action. Applications from women and members of minority groups are encouraged.

KEK, High Energy Accelerator Research Organization

Call for Nomination for Next Director-General of KEK

KEK, High Energy Accelerator Research Organization, invites nominations for the next Director-General whose term will begin April 1, 2015.

KEK is an Inter-University Research Institute Corporation open to domestic and international researchers, and comprises the Institute of Particle and Nuclear Studies, the Institute of Materials Structure Science, the Accelerator Laboratory, and the Applied Research Laboratory. KEK pursues a wide range of research activities based on accelerators, such as particle and nuclear physics, material sciences, biosciences, accelerator physics and engineering, etc.

The role of Director-General, therefore, is to promote with long-term vision and strong scientific leadership, the highly advanced, internationalized, and inter-disciplinary research activities of KEK by getting support from the public. The successful candidate is also expected to establish and carry out the medium-term goals and plans.

The term of appointment is three years. When reappointed, the term can be extended up to 9 years.

We widely accept the nomination of the candidates regardless of their nationalities.

We would like to ask you to recommend the best person who satisfies requirements for the position written above.

Nomination should be accompanied by: 1) letter of recommendation, 2) brief personal history of the candidate, and 3) list of major achievements (publications, academic papers, commendations and membership of councils, etc.). The nomination should be submitted to the following address no later than May 30, 2014:

Documents should be written either in English or in Japanese.

Forms are available at :
http://legacy.kek.jp/intra-e/info/2014/030109/.

Hiroshi Takeda
The Chair of Director-General Selection Committee
High Energy Accelerator Research Organization

Inquiries concerning the nomination should be addressed to:

General Affairs Division
General Management Department
KEK, High Energy Accelerator Research Organization
1-1 Oho, Tsukuba, Japan 305-0801
Tel +81-29-864-5114 Fax +81-29-864-5560
Email: shomu@mail.kek.jp

Faculty positions at Inter-Institutional Centre for High Energy Physics, Madurai, India (Nodal Centre for India-based Neutrino Observatory)

Inter-Institutional Centre for High Energy Physics (IICHEP) is the Nodal Centre for the India-based Neutrino Observatory (INO). Located in the city of Madurai in south India, the IICHEP will be the nodal centre of the multi-institutional INO project, entrusted with building a large underground Laboratory, geared to take off soon. At present the IICHEP will be administered through the Tata Institute of Fundamental Research (TIFR), Mumbai. Once fully operational it is expected to become an autonomous research centre under Department of Atomic Energy, Govt. of India.

IICHEP expects to have faculty positions at the level of Reader in Pay Band-4 at its centre at Madurai soon. Selected scientists will be involved in the construction and operation of the neutrino detector (ICAL) that is coming up at the INO underground laboratory at Bodi West Hills, Tamil Nadu. They are also expected to participate in the analysis of data as well as in the R & D program for future detector development. Expertise related to particle detector development, associated electronics, data acquisition is desirable. Preference will be given to candidates having hardware and data analysis experience with large detector systems used in nuclear and particle physics. Positions are also available for phenomenologists with expertise in the area of neutrino physics and particle physics with experience in simulation and data analysis. In future, opportunities may exist to participate in other experiments related to dark matter detection, double beta decay etc that may come up at INO.

Applicant should have Ph.D. and 5 years of post-doctoral experience.

Exceptionally good candidate having less post-doctoral experience may be considered for Reader in Pay Band-3. Application along with CV, research interest as well as list of referees should be sent to projdir.ino@tifr.res.in as email attachment (preferred) or to Project Director, India-based Neutrino observatory, TIFR, Homi Bhabha Road, Mumbai 400005, India by mail.

IFAE INSTITUT DE FÍSICA D'ALTES ENERGIES
Consorci de la Generalitat de Catalunya
i de la Universitat Autònoma de Barcelona

"la Caixa" EXCELENCIA SEVERO OCHOA

"La Caixa – Severo Ochoa" predoctoral positions in Theoretical and Experimental Particle Physics, Astroparticle Physics, Cosmology and Instrumentation R&D at IFAE Barcelona.

The "Institut de Física d'Altes Energies" (IFAE) in Barcelona announces the opening of four predoctoral positions for outstanding young graduates interested in working towards a PhD thesis at IFAE. These positions are funded by the "La Caixa" Foundation under the Severo Ochoa Program for Scientific Excellence, a distinction recently awarded to IFAE.

The contracts will have a duration of four years (the typical time to prepare a PhD thesis at IFAE), and will enjoy competitive conditions, with a progressively increasing salary averaging 22.384 € per year.

Interested candidates with an excellent CV and willing to work in the areas of research of IFAE, namely, theoretical particle physics, experimental particle physics (ATLAS and T2K), astroparticle physics (MAGIC and CTA), observational cosmology (DES, PAU and Euclid) and instrumentation development (ATLAS upgrades and medical imaging), should fill an application form as described at:

http://www.ifae.es/eng/work/open-positions.html

and upload the requested information, which includes a cover letter, a CV, a one-page statement of interest, and the names and email addresses of two professors willing to provide reference letters.

The application deadline will be March 31, 2014. The review process will take place during April, and offers will be made in early May. In case of a positive evaluation, hiring will take place during September and October 2014.

General information about IFAE and its Severo Ochoa program is available at **http://www.ifae.es**.

UNIVERSITÉ DE GENÈVE

Post one:

FULL PROFESSOR, Associate professor or Assistant professor in THEORETICAL PHYSICS

RESPONSIBILITIES: We are looking for an outstanding condensed-matter theorist with a pronounced interest and proven expertise in quantum transport and correlated electron systems. He(she) is capable of developing a broad and independent research line in theory, with the interest and ability to interact with experimentalists. She(he) is expected to contribute to the excellent international scientific reputation of our Physics Section.

This is a full time tenured or tenure track (in the case of assistant professor) position. Duties include developing a research program at the highest international level, teaching at undergraduate and postgraduate level, and securing external funding. Moreover, the successful candidate will supervise master and doctoral thesis and will take up administrative and organizational duties at the department level.

REQUIREMENTS: PhD degree or equivalent.
Experience in research and teaching.
Publications in international top journals.

Applications including a CV, teaching and research statement and a complete list of publications must be submitted online before March 31st, 2014 at: **https://jobs.icams.unige.ch**. Complementary information may be obtained at the following e-mail address: **scienceopenings@unigech**.

Applications from women are particularly welcome.

Post two:

FULL PROFESSOR, Associate professor or Assistant professor in THEORETICAL PHYSICS

RESPONSIBILITIES: We are looking for an outstanding theoretical physicist with pronounced interest and expertise in applications of mathematical physics to condensed matter systems (examples are integrability and AdS/CMT). The candidate is capable of developing a broad and independent line of research in theoretical physics with interest to interact with mathematicians. She/he is expected to contribute to the excellent international scientific reputation of our physics section.

This is a full time tenured position (or tenure track in the case of an assistant professor). Duties include developing a research program at the highest international level, teaching at undergraduate and postgraduate level, and securing external funding. Moreover, the successful candidate will supervise master and doctoral thesis and will take up administrative and organizational duties at the departmental level.

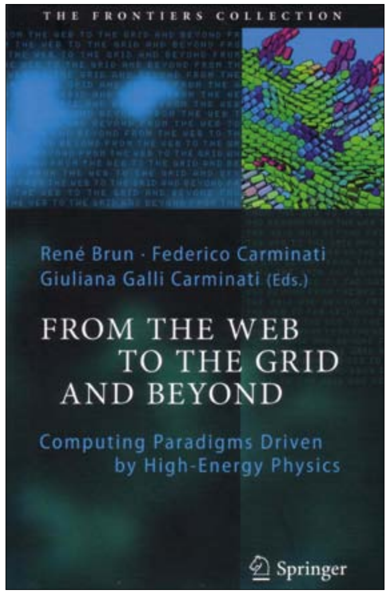
REQUIREMENTS: PhD degree or equivalent.
Experience in research and teaching.
Publications in international top journals.

Applications including CV, research and teaching statement and a complete list of publications must be submitted online before March 31st, 2014 at: **https://jobs.icams.unige.ch**.Complementary information may be obtained at the following e-mail address: **scienceopenings@unige.ch**.

Applications from women are particularly welcome.

Bookshelf

From the Web to the Grid and Beyond: Computing Paradigms Driven by High-Energy Physics
By René Brun, Federico Carminati and Giuliana Galli Carminati (eds.)
Springer
Hardback: £62.99 €74.85 $99.00
E-book: £49.99 €59.49 $69.95



To tell the story behind the title, the editors of this book have brought together chapters written by many well-known people in the field of computing in high-energy physics.

It starts with enlightening accounts by René Brun and Ben Segal of how things that I have been familiar with since being a postdoc came to be. I was intrigued to discover how we alighted on so much of what we now take for granted, such as C++, TCP/IP, Unix, code-management systems and ROOT. There is a nice – and at times frightening – account of the environment in which the World Wide Web was born, describing the conditions that needed to be present for it to happen as it did, and which nearly might not have been the case. The reader is reminded that ground-breaking developments in high-energy physics do not, in general, come about from hierarchical management plans, but from giving space to visionaries.

There are several chapters on the Grid (Les Robertson, Patricia Méndez Lorenzo and Jamie Shiers) and the evolution from grids to clouds (Pedrag Buncic and Federico Carminati). These will be of interest to those who, like me, were involved in a series of EU Grid projects that absorbed many of us completely during the era of "e-science". The Worldwide LHC Computing Grid was built and is of course now taken for granted by all of us. The discussion of virtualization and the evolution from grids to clouds presents an interesting take on what is a change of name and what is a change of technology.

In another chapter, Carminati gives his candid take on software development – and I found myself smiling and agreeing. Many of us will remember when some sort of religion sprang up around OO design methods, UML, OMT, software reviews and so on. He gives his view of where this helped and where it hindered in our environment, where requirements change, users are developers, and forward motion is made by common consent not by top-down design.

Distributed data and its access is discussed in depth by Fabrizio Furano and Andrew Hanushevsky, who remind us that this is one of the most demanding sectors in computing for high-energy physics. A history of parallel computing by Fons Rademakers is interesting because this has become topical recently, as we struggle to deal with many-core devices. Lawrence Pinsky's chapter on software legal issues delves into how instruments such as copyright and patents are applied in an area for which they were never designed. It makes for engrossing reading, in the same way that technical issues become captivating when watching legal drama on television.

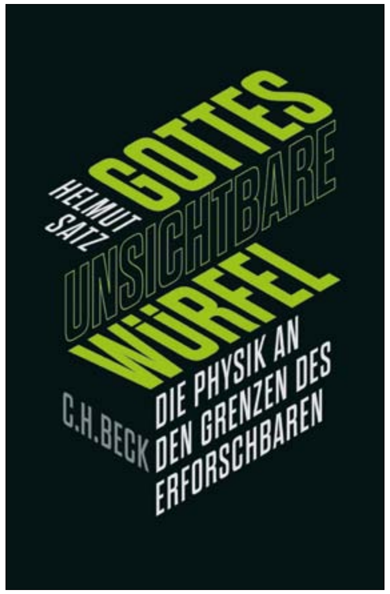
It is not clear – to me at least – whether Giuliana Galli Carminati's final chapter on "the planetary brain" is a speculation too far and should be politely passed over, as the author invites the reader to do, or whether there is something significant there that the reader should be concerned about. The speculation is whether the web and grid form something that could be considered as a brain on a planetary scale. I leave you to judge.

It is a highly interesting book, and I plan to read many of the chapters again.

● *Peter Clarke, University of Edinburgh.*

Gottes unsichtbare Würfel: Die Physik an den Grenzen des Erforschbaren
By Helmut Satz
C H Beck
Hardback: €19.95
Also available as an e-book

Also published as:
Ultimate Horizons: Probing the Limits of the Universe
Springer
Hardback: £44.99 €53.49
E-book: £35.99 €41.65



This book is one of the most interesting introductions to today's problems and advances in the fields of cosmology, particle and nuclear physics that I have seen. The author's talent in explaining complex problems with "simple" language is certainly the fruit of his life-long teaching experience at the University of Bielefeld and other places. There are numerous examples where the reader is given easy "visualizations" of scientific findings. For instance, if our eyes were sensitive to photons with a wavelength of about 7 cm, then we would see the sky illuminated even at night, thanks to the cosmic microwave background – the afterglow of the Big Bang. Another example is the Casimir effect – a curious demonstration that "the vacuum is not empty" – while Paul Dirac's sea is revisited to define empty space as a "sea of unborn particles".

It is worth emphasizing that this book does not simply present a collection of facts. The author deliberately discusses implications of certain findings and manages to connect ideas and concepts from different branches of physics extremely well. For example, the term "horizon" is transported from general relativity to the field of particle physics, in the context of quark confinement, in introducing the concept of the "colour horizon" – the

Bookshelf

distance beyond which the quarks no longer interact with each other.

Each of the different topics is introduced properly from a historical perspective, always quoting the originator of the idea carefully, which sometimes goes back to the Ancient Greeks. It is interesting to depict the historical evolution of the concept of elementary particles as the "Matryoshka doll" of physics: atoms, thought at first to be indivisible, are actually composed of electrons and nuclei, the latter being themselves composed of protons and neutrons, which are composed of quarks.

A part of the book is dedicated to the studies of quark–gluon plasma, an area where the author has done pioneering work, including a seminal paper that is currently one of the most cited publications in particle physics. Also of interest is the collection of carefully inserted historical anecdotes. Even writers and poets, such as Michael Ende, Lewis Carroll, Edgar Allan Poe and Italo Calvino, find their words in the book.

From reading the book it transpires that, often, formulating a new problem is even more important than solving it. Scientific progress is mostly made through abstract thinking. Helmut is interested in understanding old and new problems of physics and, building on many years of studies and deep reflection, successfully transmits this enthusiasm to the reader. It certainly triggers further thinking.

● *Hermine K Wöhri, CERN.*

Books received

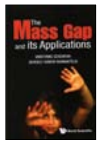
Handbook of Accelerator Physics and Engineering (2nd edition)

By Alexander Wu Chao, Karl Hubert Mess, Maury Tigner and Frank Zimmermann (eds.)
World Scientific
Hardback: £91
Paperback: £51
E-book: £38

Edited by internationally recognized authorities in the field, this expanded and updated second edition contains more than 100 new articles. With more than 2000 equations, 300 illustrations and 500 graphs and tables, it is intended as a *vade mecum* for professional engineers and physicists engaged in the design and operation of modern accelerators. In addition to the common formulae of previous compilations, it includes hard-to-find, specialized formulae, as well as material pooled from the lifetime experience of many of the world's experts. The eight chapters include both theoretical and practical matters, as well as an extensive glossary of accelerator types. A detailed name and subject index is provided, with reliable references to the literature where the most detailed information available on all of the topics can be found.

The Mass Gap and its Applications

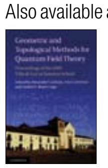
By Vakhtang Gogokhia and Gergely Gabor Barnaföldi
World Scientific
Hardback: £65
E-book: £49



QCD is the most up-to-date theory of strong interactions. However, standard perturbative procedures fail if applied to low-energy QCD. Even the discovery of a Higgs boson will not solve the problem of masses originating from the non-perturbative behaviour of QCD. This book presents a new method – the introduction of the "mass gap" – first suggested by Arthur Jaffe and Edward Witten at the turn of the millennium. As the energy difference between the lowest order and the vacuum state in Yang–Mills quantum-field theory, the mass gap is – in principle – responsible for the large-scale structure of the QCD ground state, and therefore for its non-perturbative phenomena at low energies. The book also presents the applications and outlook of the mass-gap method and includes problems for students.

Geometric and Topological Methods for Quantum Field Theory: Proceedings of the 2009 Villa de Leyva Summer School

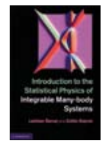
By Alexander Cardona, Iván Contreras and Andrés F Reyes-Lega (eds.)
Cambridge University Press
Hardback: £75 $125
Also available as an e-book



Based on lectures given at the Villa de Leyva Summer School, this book presents modern geometric methods in quantum field theory. Covering areas in geometry, topology, algebra, number-theory methods and their applications to quantum field theory, the book covers topics such as Dirac structures, holomorphic bundles and stability, Feynman integrals, geometric aspects of quantum field theory and the Standard Model, spectral and Riemannian geometry and index theory. It is a valuable guide for graduate students and researchers in physics and mathematics wanting to enter this interesting research field at the border between mathematics and physics.

Introduction to the Statistical Physics of Integrable Many-body Systems

By Ladislav Šamaj and Zoltán Bajnok
Cambridge University Press
Hardback: £80 $130
Also available as an e-book



Beginning with a treatise of non-relativistic 1D continuum Fermi and Bose quantum gases of identical spinless particles, this book describes the quantum inverse-scattering method and analysis of the related Yang–Baxter equation and integrable quantum Heisenberg models. It also discusses systems within condensed-matter physics, the complete solution of the sine-Gordon model and modern trends in the thermodynamic Bethe ansatz. Each chapter concludes with problems and solutions to help consolidate the reader's understanding of the theory and its applications.

On the Topology and Future Stability of the Universe

By Hans Ringström
Oxford University Press
Hardback: £80 $125
Also available as an e-book

This volume in the series of Oxford Mathematical Monographs contains a general introduction to the Cauchy problem for the Einstein–Vlasov system, a proof of future stability of spatially of locally homogeneous solutions, and a demonstration that there are models of the universe that are consistent with the observations but have arbitrary compact spatial topology. It includes a general description of results in the areas relevant to mathematicians and physicists with knowledge of general relativity.

Advanced General Relativity: Gravity Waves, Spinning Particles, and Black Holes

By Claude Barrabès and Peter A Hogan
Oxford University Press
Hardback: £55 $89.95
Also available as an e-book

This book is aimed at students making the transition from a first course on general relativity to a specialized subfield. It presents a variety of topics under the general headings of gravitational waves *in vacuo* and in a cosmological setting, equations of motion, and black holes, all having clear physical relevance and a strong emphasis on space–time geometry. Each chapter could be used as the basis for an early postgraduate project for those who are exploring avenues into research in general relativity, and who have already accumulated the technical knowledge required.

Viewpoint

The 1980s: spurring collaboration

Herwig Schopper recalls a decade of growth at CERN.

The 1980s were characterized by two outstanding achievements that were to influence the long-term future of CERN. First came the discovery of the W and Z particles, the carriers of the weak force, produced in proton–antiproton collisions at the Super Proton Synchrotron (SPS) and detected by the UA1 and UA2 experiments. These were the first, now-typical collider experiments, covering the full solid angle and requiring large groups of collaborators from many countries. The production of a sufficient number of antiprotons and their handling in the SPS underlaid these successes, which were crowned by the Nobel Prize awarded to Carlo Rubbia and Simon van der Meer in 1984.

Then came the construction and commissioning of the Large Electron–Positron (LEP) collider. With its 27 km tunnel, it is still the largest collider of this kind ever built. Four experiments were approved – ALEPH, DELPHI, L3 and OPAL – representing again a new step in international co-operation. More than 2000 physicists and engineers from 12 member states and 22 non-member states participated in the experiments. Moreover, most of the funding of several hundred million Swiss francs had to come from outside the organization. CERN contributed only about 10% and had practically no reserves in case of financial overruns. Therefore the collaborations had to achieve a certain independence, and had to learn to accept common responsibilities. A new "sociology" for international scientific co-operation was born, which later became a model for the LHC experiments.

A result of the worldwide attraction of LEP was that from 1987 onwards, more US physicists worked at CERN than particle physicists from CERN member states at US laboratories. In Europe, two more states joined CERN: Spain, which had left CERN in 1968, came back in 1983, and Portugal joined in 1985. However, negotiations at

Herwig Schopper in 1982: with LEP a "new 'sociology' for international scientific co-operation was born". (Image credit: CERN-PHOTO-8205525.)

the time with Israel and Turkey failed, for different reasons.

But the 1980s also saw "anti-growth". Previously, CERN had received special allocations to the budget for each new project, leading to a peak around 1974 and declining afterwards. When LEP was proposed in 1981, the budget was 629 million Swiss francs. After long and painful discussions, Council approved a constant yearly budget of 617 million Swiss francs for the construction of LEP, under the condition that any increase – including automatic compensation for inflation – across the construction period of eight years was excluded. The unavoidable consequence of these thorny conditions was the termination of many non-LEP programmes (e.g. the Intersecting Storage Rings and the bubble-chamber programme) and a "stripped down" LEP project. The circumference of the tunnel had to be reduced, but was maintained at 27 km in view of a possible proton–proton collider in the same tunnel – which indeed proved to be a valuable asset.

A precondition to building LEP with decreasing resources was the unification of CERN. CERN II had been established in 1971 for construction of the SPS, with its own director-general, staff and management. From 1981, CERN was united under one director-general, but staff tended to adhere to their old groups, showing solidarity with their previous superiors and colleagues. However, for the construction of LEP, all of CERN's resources had to be mobilized, and about 1000 staff were transferred to new assignments.

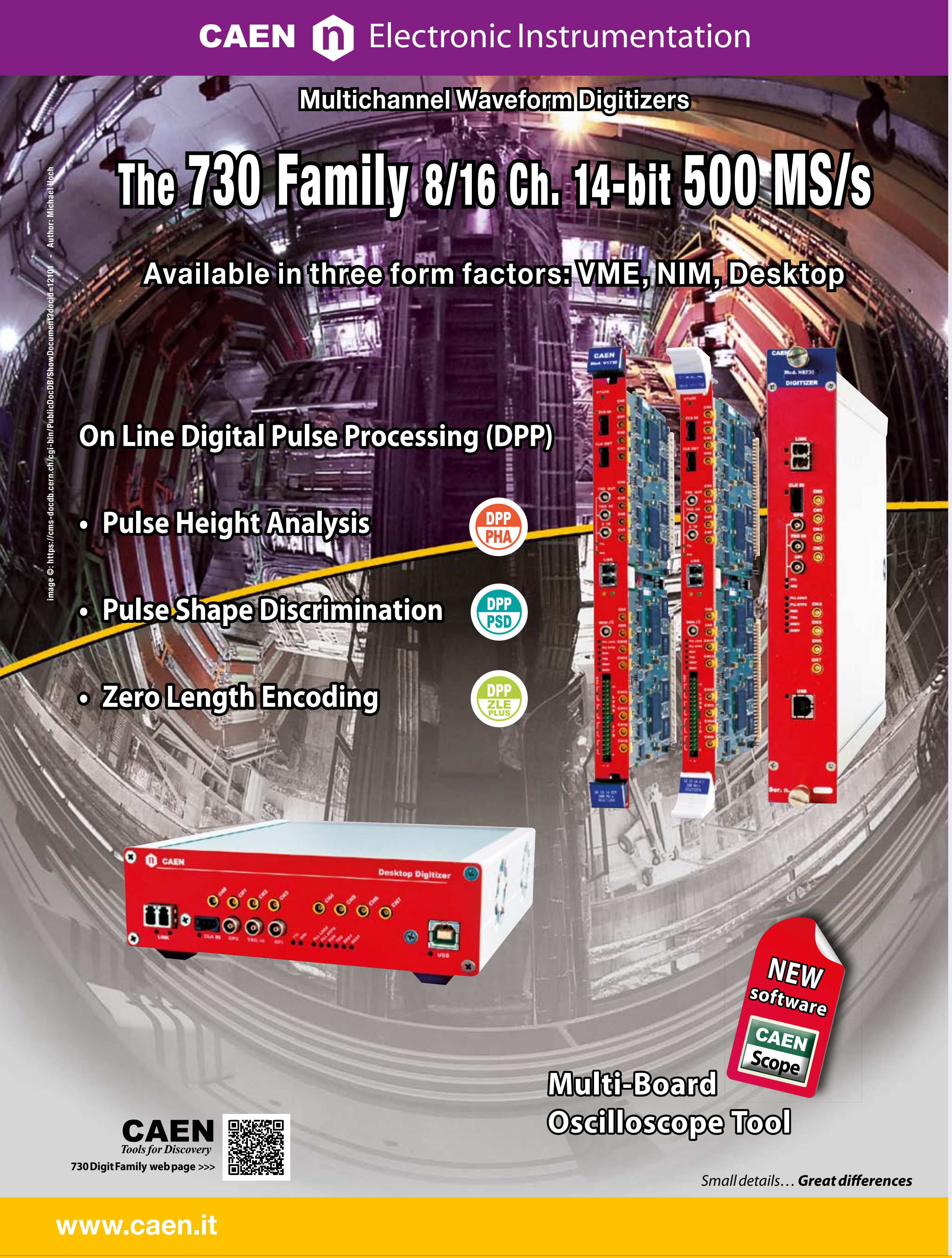
Another element of "anti-growth" had long-term consequences. Council was convinced that the scientific programme was first class, but had doubts about the efficiency of management. An evaluation committee was established to assess the human and material resources, with a view to reducing the CERN budget. In the end, the committee declined to consider a lower material budget because this would undoubtedly jeopardize the excellent scientific record of CERN. They proposed instead a reduction of staff from about 3500 to 2500, through an early retirement programme, and during the construction of the LHC this was even lowered to 2000. However, to cope with the increasing tasks and the rising number of outside users, many activities had to be outsourced, so considerable reduction of the budget was not achieved.

Yet despite these limiting conditions, LEP was built within the foreseen time and budget, thanks to the motivation and ingenuity of the CERN staff. First collisions were observed on 13 August 1989.

The theme of CERN's 60th anniversary is "science for peace" – from its foundation, CERN had the task not only to promote science but also peace. This was emphasized at a ceremony for the 30th anniversary in 1984, by the American physicist and co-founder of CERN, Isidor Rabi: "I hope that the scientists of CERN will remember…[they are] as guardians of this flame of European unity so that Europe can help preserve the peace of the world." Indeed during the 1980s, CERN continued to fulfil this obligation, with many examples such as co-operation with East European countries (in particular via JINR, Dubna) and with countries from the Far East (physicists from Mainland China and Taiwan were allowed to work together in the same experiment, L3, on LEP). Later, CERN became the cradle of SESAME, an international laboratory in the Middle East.

Unavoidably, CERN's growth into a world laboratory is changing how it functions at all levels. However, we can be confident that it will perform its tasks in the future with the same enthusiasm, dedication and efficiency as in the past.

● *Herwig Schopper, CERN director-general, 1981–1988.*



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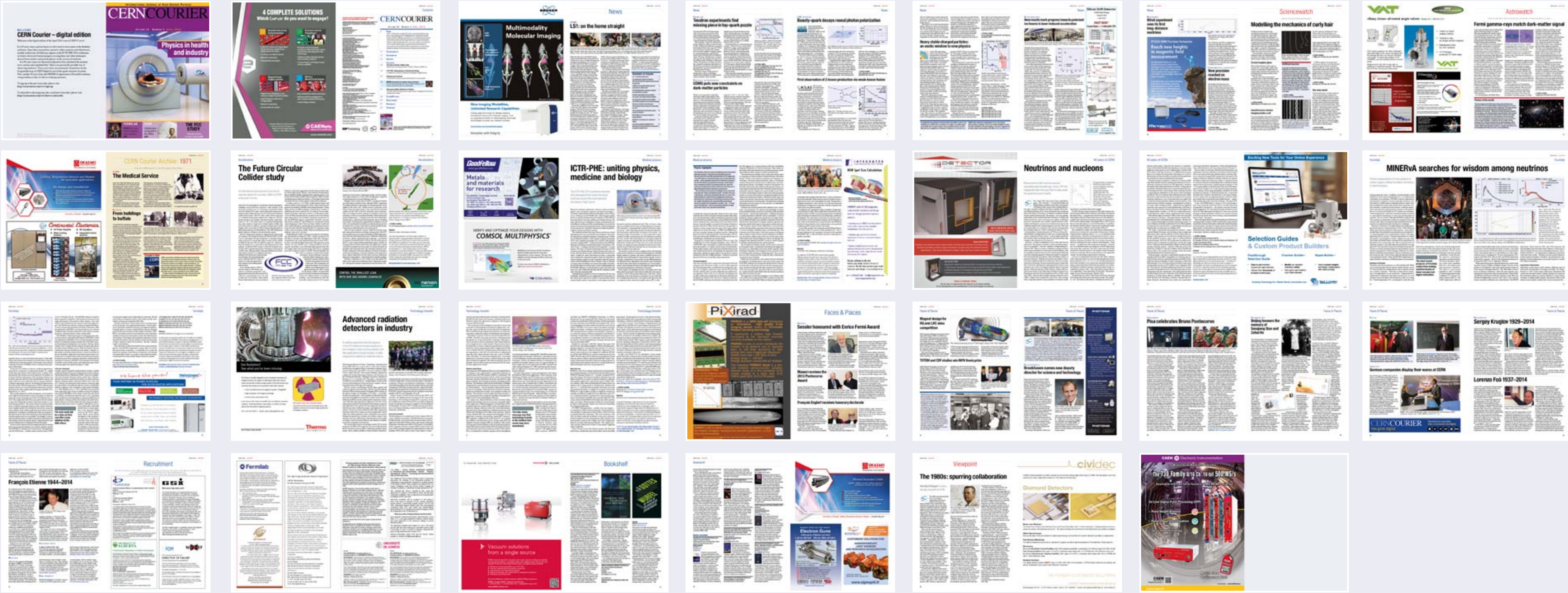

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