Welcome to the digital edition of the September 2014 issue of CERN Courier.

The International Particle Accelerator Conference (IPAC) provides the annual showcase for worldwide developments in particle accelerators. This year, topics not only encompassed frontiers in accelerator energy, intensity and brightness, but also included applications and engagement with industry. An important application is the use of particle beams for cancer therapy, which was pioneered at Berkeley Lab in 1954, the year that CERN was founded. The convention that led to the establishment of CERN had been signed a year earlier – an event that was commemorated in Paris on 1 July this year, as part of CERN’s 60th anniversary celebrations.

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Following the restart of the first elements in CERN’s accelerator complex in June (CERN Courier July/August p5), beams are now being delivered to experiments from the Proton Synchrotron (PS) and the PS Booster.

First in line were experiments in the East Area of the PS, where the T9 and T10 beam lines are up and running. These test beams serve projects such as the Advanced European Infrastructures for Detectors at Accelerators (AIDA), which looks at new detector solutions for future accelerators, and the ALICE collaboration’s tests of components for their inner tracking system.

By the evening of 14 July, beam was hitting the East Area’s target and the next day, beams were back in T9 and T10.

Next to receive beams for physics were experiments at the neutron time-of-flight facility, n_TOF, and the Isotope mass Separator On-Line facility, iSOlDe. On 25 July, detectors measured the first neutron beam in n_TOF’s new Experimental Area 2 (EAR2). It was a low-intensity beam, but it showed that the whole chain – from the spallation target to the experimental hall, including the sweeping magnet and the collimators – is working well. Built about 20 m above the neutron production target, EAR2 is a bunker connected to the underground facilities via a vertical flight path through a duct 80 cm in diameter, where the beamline is installed. At n_TOF, neutron-induced reactions are studied with high accuracy, thanks to the high instantaneous neutron flux that the facility provides. The first experiments will be installed in EAR2 this autumn and the schedule is full until the end of 2015.

A week later, on 1 August, iSOlDe restarted its physics programme with beams from the PS Booster, after a shutdown of almost a year and a half during which many improvements were made. One of the main projects was the installation of new robots for handling the targets that become very radioactive. The previous robots were more than 20 years old and beginning to suffer from the effects of radiation. The long shutdown of CERN’s accelerator complex, LS1, provided the perfect opportunity to replace them with more modern robots with electronic-sensor feedback. On the civil engineering side, three iSOlDe buildings have been demolished and replaced with a single building that includes a new control room, a data-storage room, three laser laboratories, and a biology and materials laboratory. In the iSOlDe hall, new permanent experimental stations have also been installed. Almost 40 experiments are planned for the remainder of 2014.

After the PS, the Super Proton Synchrotron (SPS) will be next to receive beam. On 27 June, the SPS closed its doors to the LS1 engineers, bringing almost 17 months of activities to an end. The machine has now entered the hardware-testing phase, in preparation for a restart in October.

Meanwhile at the LHC, early August saw the start of the cool down of a third sector – sector 1-2. By the end of August, five sectors of the machine should be in the process of cooling down, with one (sector 6-7) already cold. Meanwhile, the copper stabilizer continuity measurements (CSCM) have been completed in the first sector (6-7), with no-defect found. CSCM tests are to start in the second sector in mid-August. Elsewhere in the machine, the last pressure tests were carried out on 31 July, and the last short-circuit tests should be complete by mid-August.
LHC PHYSICS
Precise measurements of top-quark production

The top quark is the heaviest known fundamental particle, whose mass of about 173 GeV is much larger than that of the other quarks, and comparable to those of the W, Z and Higgs bosons. The copious production of top-quark–antiquark pairs via the strong interaction in proton–proton collisions at the LHC allows a rich programme of studies, but it also makes top-pairs one of the key backgrounds to be understood in the search for physics beyond the Standard Model. In a recent paper, the ATLAS collaboration reports on precise measurements of the top-pair cross-section, i.e. the production rate, at centre-of-mass energies (√s) of both 7 and 8 TeV, using the full data sample from 2011 to 2012. The measurements are made using a distinctive final state in which one top quark decays to an electron, a neutrino and a b quark, and the other to a muon, neutrino and b-quark. This gives rise to events with an opposite-sign electron–muon pair, and collimated jets of particles “tagged” as being likely to have originated from b quarks. Events with both one and two such b-tagged jets are counted, reducing the uncertainties associated with jet reconstruction and b-quark tagging compared with earlier measurements at the LHC and at the Tevatron at Fermilab. The total uncertainties are around 4%, giving the most precise top-pair production measurements to date. Theoretical predictions for the top-pair cross-section are now available at next-to-next-to-leading order (NNLO) accuracy in QCD, with uncertainties of about 5%. The results are in good agreement with these predictions, and give sensitivity to the fraction of the proton momentum carried by gluons. As the figure shows, the cross-section predictions depend on the assumed mass of the top-quark mt, so the measurements can be interpreted as a determination of mt, giving \( m_t = 172.9 \pm 0.7 \) GeV. This technique measures the top-quark pole mass, and the resulting value is in good agreement with values obtained from direct reconstruction of top-quark decay products, involving different theoretical assumptions. Finally, the agreement between measurements and QCD predictions leaves little room for additional top-quark production from physics processes beyond the Standard Model, such as supersymmetry. For example, the measurements exclude supersymmetric top quarks with masses between \( m_t \) and 177 GeV that decay to top quarks and invisible neutralinos – a mass range that is difficult to address with more traditional searches.

Further reading

Combined weighted distribution of the diphoton invariant mass. The weight given to the events approximates what is “seen” by the final fit. In the bottom panel the same distribution is shown after subtracting the background obtained from fits to the data in all of the different categories. The observation of the Higgs boson in the \( H \rightarrow \gamma \gamma \) channel alone is apparent from these plots.

The first preliminary results on the full Run 1 data were presented by CMS in March 2013. Since then, a large amount of work has gone into all aspects of the analysis: the understanding of the energy scale for photons was greatly improved, exclusive selections addressing all possible production processes were deployed, and major improvements in the statistical treatment of the background estimation were achieved. All of these changes have led to an increase in sensitivity of approximately 25% and to a reduction of the systematic uncertainty in the mass measurement by a factor three.

The analysis is based on various multivariate discriminants that are

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CMS releases final Run 1 results on \( H \rightarrow \gamma \gamma \)

The CMS collaboration achieved an important milestone this summer with the completion of the analysis of the last of the five main channels that contributed to the discovery of a Higgs boson in July 2012. The subsequent measurements of the particle’s properties are now complete.

The results of the final analysis in the decay channel into a photon pair, \( H \rightarrow \gamma \gamma \), were presented at the 2014 International Conference on High Energy Physics in Valencia and, at the same time, submitted for publication (CMS 2014a). This is one of the two Higgs decay channels – the other being \( H \rightarrow ZZ \rightarrow four\) leptons – that have very good mass resolution and therefore allow the unquestionable detection of the Higgs boson and the precise measurement of its mass. However, \( H \rightarrow \gamma \gamma \) is probably the most difficult decay to exploit at the LHC. It requires a great deal of effort on the optimization and calibration of the electromagnetic calorimeter for photon identification and energy measurement, as well as highly sophisticated analysis methods designed to beat the large backgrounds from sources other than the Higgs.
The 1-2-3 of $D_s$ meson spectroscopy

The $LHCb$ collaboration has shown that a $3P_2$ structure with invariant mass 2860 MeV is composed of two resonances, one with spin 1 and the other with spin 3. This is the first time that a heavy flavoured spin 3 particle has been observed, and it should lead to new insights into hadron spectroscopy.

The $LHCb$ collaboration is designed primarily to study CP violation and rare decays of b hadrons. However, the large samples of decay channels are also allowing detailed studies into the spectroscopy of lighter particles that are produced in various different decay channels. $LHCb$ has already determined the quantum numbers of the $X(3872)$ particle and established that the $Z(4430)^+$ state is indeed a resonance ($X(3872)$ particle and established that the

search for quasi-degenerate states decaying into two hadrons have produced thousands of signal. $CMS$ also performed a preliminary combination of these results with the previously published results for the other channels ($CMS$ 2014b). The overall signal strength from this combination is found to be 1.00 $\pm$ 0.23, again in agreement with the predictions of the Standard Model.

**Further reading**


ICFA Global strategies for particle physics

The International Committee for Future Accelerators (ICFA) has issued a statement that endorses the strategic plans for the future of high-energy physics designed in the "P5" roadmap of this year by the Asia and the US. It also reaffirms ICFA’s support of the International Linear Collider (ILC) and its encouragement of international studies of future circular colliders.

The statement was issued at ICFA’s first meeting after the publication of the "P5" roadmap for the future of US particle physics (CERN Courier July/August 2014 p12). Previously published Asian and European strategies share common priorities. These strategies, which are the result of processes that involved each region’s particle-physics communities, provide guidelines for governments to make decisions in science policy.

For the ICFA statement, see www.fnal.gov/office/icfa/icfa_Statement_20140706.pdf.

The massive MicroBooNE neutrino detector is gently lowered into the main cavern of the Liquid-Argon Test Facility at Fermilab on 23 June. The banner on the side reads “MicroBooNE — Driving Nu Physics.” (Image credit: Fermilab.)

The P5 report strongly supports this larger experiment, which will be designed and funded through a global collaboration.

MicroBooNE detector is moved into place

The particle detector for MicroBooNE, a new short-baseline neutrino experiment at Fermi National Accelerator Laboratory, was gently lowered into place on 23 June. It is expected to detect its first neutrinos this winter.

The detector — a time-projection chamber surrounded by a 12-m-long cylindrical vessel — was carefully transported by truck across the Fermilab site, from the assembly building where the detector was constructed to the experimental hall nearly 5 km away. The 30-tonne object was then hoisted up by a crane, lowered through the open roof of a new building and placed into its permanent home, directly in the path of Fermilab’s Booster neutrino beamline.

When filled with 170 tonnes of liquid argon, MicroBooNE will look for low-energy neutrino oscillations to help resolve the origin of a mysterious low-energy excess of particle events seen by the $MiniBooNE$ experiment, which used the same beam line and relied on a Cherenkov detector filled with mineral oil.

The $MicroBooNE$ time-projection chamber is the largest ever built in the US and is equipped with 8256 delicate gold-plated wires. The three layers of wires will capture pictures of particle interactions at different points in space and time. The superb resolution of the time-projection chamber will allow scientists to check whether the excess of $MiniBooNE$ events is due to neutrino or electron interactions recorded every day and create 3D images of the most interesting ones.

The $MicroBooNE$ team will use that data to learn more about neutrino oscillations and to narrow the search for a hypothesized fourth type of neutrino. MicroBooNE is a cornerstone of Fermilab’s short-baseline neutrino programme, which could also see the addition of two more neutrino detectors along the Booster neutrino beamline, to refute or confirm hints of a fourth type of neutrino first reported by the LSND collaboration at Los Alamos National Laboratory. In its recent report, the Particle Physics Project Prioritization Panel (P5) expressed strong support for a short-baseline neutrino programme at Fermilab.

The report was commissioned by the High Energy Physics Advisory Panel, which advises both the US Department of Energy and the National Science Foundation on funding priorities.

The detector technology used in $MicroBooNE$ will serve as a prototype for a much larger liquid-argon detector that has been proposed as part of a long-baseline neutrino facility to be hosted at Fermilab.

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

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Watching charge transfer in a molecule

The transfer of an electron in a molecular bond has now been followed in time as the bond breaks, thanks to a clever pump-probe approach employed in an experiment at the Linac Coherent Light Source at SLAC. Benjamin Erk of DESY and Max-Planck Institutes in Hamburg and Heidelberg, and colleagues, have used an 800-nm infrared pulse to break gas-phase methyl iodide into a methyl group and an iodine atom, either or both of which might be positively charged. A subsequent ultrashort X-ray free-electron pulse almost exclusively ionizes the iodine M-shell electron, producing a localized positive charge on the iodine, which then spreads across the molecule.

By looking at the charge and kinetic energies of the decay products as a function of the delay between the infrared dissociation pulse and the X-ray pulse, the team can map out how electrons are shared being carried by the positron. Direct energy measurements would allow the antineutrino spectrum from the reactor to be determined and—with a 20-tonne detector just outside a reactor building—could reveal the plutonium content, because plutonium emits a softer antineutrino spectrum. Using North Korean reactors and the IR-40 reactor in Arak, Iran, as test cases, the researchers found that the removal of as little as 2 kg of plutonium could be detected within the 90 days required by the International Atomic Energy Authority. Some improvement on current technology for neutrino detectors would be needed, but this might be achievable within five years.

Further reading


Nuclear monitoring with antineutrinos

With increasing concerns about nuclear proliferation, a suggestion by Eric Christensen of Virginia Tech in Blacksburg and colleagues could be of great value. The idea echoes the discovery of the neutrino by Fred Reines and Clyde Cowan, by using a large volume of scintillator to look at antineutrino collisions with protons that produce a positron and a neutron, with most of the kinetic energy as a function of the distance between the two fragments. The charge transfer can take place at up to approximately 10 times the normal bond length. Beyond that, the system is no longer a molecule. The results on this critical distance are in agreement with the classical over-the-barrier model.

Further reading


A prism in the eye

Revealing yet another remarkable feat of biological evolution, Amichai M Labin of the Technion Institute in Haifa and colleagues have shown that cells in the retina split light as a prism does, and so send specific wavelengths to different receptors to improve daytime vision. So-called “Müller” cells concentrate red and green light onto the daytime sensing cones, boosting what they get by a factor of 10, while allowing blue light to leak out to the rod cells used in night vision. The work used computer simulations of human eye cells and was confirmed in guinea-pig retinas.

Further reading

The distribution of ultra-high-energy cosmic rays (UHECR) recorded by the Telescope Array (TA) in the northern sky is displaying an intriguing “hotspot” in the direction of the Ursa Major constellation. The 19 events out of 72 with energies above 57 EeV (1 EeV = 10^18 eV) clustering in a circle 4° in diameter represent a statistical excess of 5.1σ. The calculated probability of chance occurrence out of an isotropic distribution is only 3.7 in 10,000, but there is no obvious association with known sources in this field.

The origin of cosmic rays has intrigued physicists since their discovery in 1912. The difficulty is that, unlike light rays, these charged particles are deflected by the Galaxy’s magnetic field and their arrival direction is therefore randomized. It is only recently, through indirect methods, that the Fermi Gamma-ray Space Telescope was able to find evidence for cosmic rays being accelerated in supernova remnants (CERN Courier April 2013 p12).

UHECR – particles with energies above 1 EeV – are thought to be of different origin. Those with the highest energy (E > 60 EeV) are the least affected by magnetic fields and should roughly keep their original direction and point towards their emission source. They are also interesting because they cannot come from distances much further than 300 million light-years, because they would interact with the cosmic-microwave background to produce pions. In 2007, the collaboration behind the Pierre Auger Observatory (PAO) announced a correlation between the distribution in the southern sky of UHECRs and nearby active galactic nuclei (CERN Courier December 2007 p5). After the initial enthusiasm, however, additional data slightly weakened the significance of this result, rather than increasing it.

Nevertheless, what is obvious is that the galactic plane is not the prime source of the UHECR. They must therefore originate from somewhere in the large-scale structures of the local universe.

A new study of the distribution of UHECR is now claiming a strongly anisotropic distribution with a large “hotspot” centred in the well-known constellation of Ursa Major. The study uses data obtained in the years 2008–2013 by the TA—the northern-sky analogue of the PAO—covering an area of around 700 km^2 in Utah, with 3 m^2 scintillation detectors placed every 1.2 km on a square grid, the TA is currently the largest UHECR detector in the northern hemisphere.

During the six-year study, only 72 events with energies above 57 EeV were detected. Assuming an uncertainty in the direction of 20°—a circle 40° wide—is associated with each event—the researchers found a clustering of events, extending over roughly 40°, with a statistical excess of 5.1σ. To account for random clustering better, the collaboration simulated a million Monte Carlo data sets of 72 spatially random events in the field of view and obtained 365 instances of a clustering on different scales higher than the observed one. This corresponds to a chance probability of only 3.7 x 10^-4, equivalent to a one-sided significance of 3.4σ.

The collaboration, with physicists mainly from the Universities of Tokyo and Utah, notes that there are no specific sources at the position of the excess. If the hotspot is real, it might be associated with the supergalactic plane, which contains local galaxy clusters such as the Ursa Major, Coma and Virgo clusters. This would imply a deflection by more than around 40° from this plane to the observed hotspot, which is too large an angle for protons and could indicate cosmic rays of other heavy nuclei, which are deflected more by magnetic fields. The TA54 project, an extension of the TA, would provide a speed-up of the detection rate to confirm the existence of the excess.

Further reading

Picture of the month
This image from the NASA/ESA Hubble Space Telescope shows the galaxy cluster MACS J0416.1-2403, which is one of six such clusters being studied by the Hubble Frontier Fields programme. This programme seeks to analyse the distribution of dark matter in these huge clusters and to use their gravitational-lensing effect to peer even deeper into the distant universe (CERN Courier January/February 2013 p14 and April 2008 p11). A team of researchers has identified 86 distant galaxies from almost 200 different distorted images of lensed galaxies in this deep view by Hubble’s Advanced Camera for Surveys. The study of the bending and magnification by the huge cluster allows its mass to be measured more precisely than ever. The total mass within MCMC J0416.1-2403—which is modelled to be more than 650,000 light-years across—was found to be 160 x 10^14 times the mass of the Sun, to a precision of 1%. (Image credit: ESA/Hubble, NASA, HST Frontier Fields.)
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TRIUMF
Coming together

The TRIUMF project, involving four Canadian Universities – Alberta, Simon Fraser, Victoria and British Columbia – is one of the three “meson factories” currently under construction (the others being the linear accelerator, LAMPF, at Los Alamos, and the two-cyclotron system of SIN at Villigen). The TRIUMF-cyclotron is scheduled to come into operation in 1973 and construction on almost all components is in line with the programme. Two of the large magnet sectors have arrived at the site and installation of the first of them in the machine vault has started. All six sectors should be delivered by the end of the year and be in place by June 1972. Compiled from texts on p248 (picture above right, p279; CERN Courier October 1971).

Compiler’s Note
Most of us still have a woefully inadequate understanding of the supposedly detrimental effects of radiation, so willingly sticking one’s head into ion beams more than 40 years ago seems to have been rather cavalier. However, several of those pioneering radiobiologists – engaged in the pursuit of knowledge – went on to develop technologies that are widely used today in nuclear medicine and hadron therapy (p27, current issue).

For the record, the massive 18-m-diameter, 4000-tonne TRIUMF cyclotron magnet assembled at the manufacturer’s (Davie Shipbuilding Limited, Quebec) prior to dispatch to the site at the University of British Columbia.
IAXO: the International Axion Observatory

A large superconducting magnet could open a new window on the dark universe.

The recent discovery of a Higgs boson at CERN appears to rephrase the summit in the successful experimental verification of the Standard Model of particle physics. However, although essentially all of the data from particle accelerators are so far in perfect agreement with the model’s predictions, a number of important theoretical and observational considerations point to the necessity of physics beyond the Standard Model. An especially powerful argument comes from cosmology. The currently accepted cosmological model invokes two exotic ingredients – dark matter and dark energy – which pervade the universe. In particular, the observational evidence for dark matter (via its gravitational effects on visible matter) is now overwhelming, even though the particle-physics nature of both dark matter and dark energy remains a mystery. At the same time, the theoretical foundations of the Standard Model have shortcomings that prompt theorists to propose and explore hypothetical ways to extend it. Supersymmetry is one such hypothesis, which also naturally provides particles as candidates for dark matter, known as weakly interacting massive particles (WIMPs). Other extensions to the Standard Model predict particles that could lie hidden at the low-energy frontier, of which the axion is the prototype. The fact that supersymmetry has not yet been observed at the LHC, and that no clear signal of WIMPs has appeared in dark-matter experiments, has increased the community’s interest in searching for axions. However, there are independent and powerful motivations for axions, and dark matter composed of both WIMPs and axions is viable, implying that they should not be considered as alternative, exclusive solutions to the same problem.

Axions appear in Standard Model extensions that include the Peccei-Quinn mechanism, which provides the most promising solution so far to one of the problems of the Standard Model: why do strong interactions seem not to violate charge–parity symmetry, while according to QCD, the standard theory of strong interactions, they should? Unlike many particles predicted by theories that go beyond the Standard Model, axions should be light, and it might seem that they should have been detected already. Nevertheless, they could exist and remain unnoticed because they naturally couple only weakly with Standard Model particles. A generic property of axions is that they couple with photons in a way that axion–photon conversion (and vice versa) can occur in the presence of strong magnetic or electric fields. This phenomenon is the basis of axion production in the stars, as well as of most strategies for detecting axions. Magnets are therefore at the core of any axion experiment, as is the case for axion helioscopes, which look for axions from the Sun. This is the strategy followed by the CERN Axion Solar Telescope (CAST), which uses a decommisioned LHC test magnet (CERN Courier April 2010 p22). After more than a decade of searching for solar axions, CAST has put the strongest limits yet on axion–photon coupling across a range of axion masses, surpassing previous astrophysical limits for the first time and probing relevant axion models of sub-electron-volt mass. However, to improve these results and go deep into unexplored axion parameter space requires a completely new experiment.

The International Axion Observatory (IAXO) aims for a signal-to-noise ratio 10^4 better than CAST. Such an improvement is possible only by building a large magnet, together with optics and detectors that optimize the axion helioscope’s figure of merit, while building on experience and concepts of the pioneering CAST project.

The central component of IAXO is a superconducting toroid magnet. The detector relies on a high magnetic field distributed across a large volume to convert solar axions to detectable X-ray photons. The magnet’s figure of merit is proportional to the square of the product of magnetic field and length, multiplied by the cross-sectional area filled with the magnetic field. This consideration leads to a 25-m-long and 5.2 cm-diameter toroid assembled from eight coils, generating 2.5 T in eight bores of 600 mm diameter, thereby...
having a figure of merit that is 300 times better than the CAST magnet. The toroid’s stored energy is 500 MJ.

The design is inspired by the barrel and endcap toroids of the ATLAS experiment at the LHC, which has the largest superconducting toroids ever built and currently in operation at CERN. The superconductor used is a NbTi/Cu-based Rutherford cable co-extruded with aluminium – a successful technology common to most modern detector magnets. The IAXO detector needs to track the Sun for the longest possible period, so to allow rotation around the two axes, the 250-tonne magnet is supported at its centre of mass by a system used for large telescopes (figure 1,p17). The necessary services for vacuum, helium supply, current and controls rotate together with the magnet.

Each of the eight magnet bores will be equipped with X-ray focusing optics that rely on the fact that at X-ray energies the index of refraction is less than unity for most materials. By working at shallow (or grazing) incident angles, it is possible to make mirrors with high reflectivity. Mirrors are commonly used at synchrotrons and free-electron lasers to condition or focus the intense X-ray beams for user experiments, but IAXO requires optics with much larger apertures. For nearly 50 years, the X-ray astronomy and astrophysics community has been building telescopes following the design principle of Hans Wolter, employing two conic-shaped mirrors to provide true-imaging optics. This class of optics allows “nesting” – that is, placing concentric co-focal X-ray mirrors inside one another to achieve high throughput.

The IAXO collaboration envisions using optics similar to those used on NASA’s NuSTAR – an X-ray astrophysics satellite with two focusing telescopes that operate in the 3–79 keV band. NuSTAR’s optics consist of thousands of thermally formed glass substrates deposited with multilayer coatings to enhance the reflectivity above 10 keV (figure 2). For IAXO, the multilayer coatings will be designed to match the softer 1–10 keV solar-axion spectrum. At the focal plane in each of the optics, IAXO will have small time-projection chambers read by pixelized planes of Micromegas. These detectors (figure 2) have been developed extensively within the CAST collaboration and show promise for detecting X-rays with a record background level of $10^{-8} – 10^{-7}$ counts/keV/cm$^2$/s. This is achieved by the use of radiopure detector components, appropriate shielding, and offline discrimination algorithms on the 3D event topology in the gas registered by the pixelized read-out. Beyond the baseline described above, additional enhancements are being considered to explore extensions of the physics case for IAXO. Because a high magnetic field in a large volume is an essential component in any axion experiment, IAXO could evolve into a generic “axon facility” and facilitate various detection techniques. Most intriguing is the possibility of hosting microwave cavities and antennas to search for dark-matter axions in mass ranges that are complementary to those in previous searches.

The growing IAXO collaboration has recently finished the conceptual design of the experiment, and last year a Letter of Intent was submitted to the SPS and PS Experiments Committee of CERN. The committee acknowledged the physics goals of IAXO and recommended proceeding with the next stage – the creation of the Technical Design Report. These are the first steps towards the realization of the most ambitious axion experiment so far.

After more than three decades, the axion hypothesis remains one of the most compelling portals to new physics beyond the Standard Model, and must be considered seriously. IAXO will use CERN’s expertise efficiently to venture deep into unexplored axion parameter space. Complementing the successful high-energy frontier at the LHC, the IAXO facility would open a new window on the dark universe.

Résumé
IAXO / Observatoire international des axons

Les particules hypothétiques appelées axions pourraient constituer un élément important de la matière noire. Le but de l’Observatoire international des axons (IAXO) est de rechercher les axions avec un rapport signal-bruit 100 fois meilleur que le télescope solaire à axions du CERN (CAST), pionnier dans ce domaine. Cette amélioration est possible que par la construction d’un grand aimant, assorti d’une optique et de détecteurs qui optimisent les capacités de l’expérience. L’élément central d’IAXO sera un aimant toroidal supraconducteur, et le détecteur utilisera un champ magnétique élevé réparti sur un grand volume afin de convertir les axions solaires en photons de rayons X détectables.

Igor G Irastorza, Universidad de Zaragoza, Michael Pivovaroff, Lawrence Livermore National Laboratory, and Herman Ten Kate, CERN, on behalf of the IAXO collaboration.

More reading

Conceptual Design of the International Axion Observatory (IAXO) 2014 JINST T05002.
Letter of Intent to the CERN SPS Committee http://cds.cern.ch/record/1567109

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A lifetime in biophysics

Eleanor Blakely talks about her work at Berkeley that began with pioneering research into the use of ion beams for hadron therapy.

Shake hands with Eleanor Blakely and you are only one handshake away from John Lawrence – a pioneer of nuclear medicine and brother of Ernest Lawrence, the Nobel-prize-winning inventor of the cyclotron, the first circular particle accelerator. In 1954 – the year that CERN was founded – John Lawrence began the first use of proton beams from a cyclotron to treat patients with cancer. Twenty years later, as a newly fledged biophysicist, Blakely arrived at the medical laboratory that John had set up at what is now the Ernest Orlando Lawrence Berkeley National Laboratory. There she came to know John personally and was to become established as a leading expert in the use of ion beams for cancer therapy.

With ideas of becoming a biology teacher, Blakely went to the University of San Diego in 1965 to study biology and chemistry. While there, she spent a summer as an intern at Oak Ridge National Laboratory and developed an interest in radiation biology. Exciting in her studies, she was encouraged to move towards medicine after obtaining her BA in 1969. However, armed with a fellowship from the Atomic Energy Commission that allowed her to choose where to go next, she decided to join the group of Howard Dusoff, a leading expert in radiation biology at the University of Illinois, Urbana-Champaign. Because she was fascinated by basic biological mechanisms, Dusoff encouraged her to take up biophysics, a field so new that he told her that it was “whatever you want to make it”. A requirement of the fellowship was to spend time at a national laboratory, so Blakely was assigned a summer at Berkeley Laboratory, where she worked on NASA-funded studies of proton radiation damage to surrounding tissue. In 1975, arriving soon after the Bevatron – the accelerator where the first use of proton beams from a cyclotron to treat patients with cancer was made – John Lawrence began the first use of proton beams from a cyclotron to treat patients with cancer. Twenty years later, as a newly fledged biophysicist, Blakely arrived at the medical laboratory that John had set up at what is now the Ernest Orlando Lawrence Berkeley National Laboratory. There she came to know John personally and was to become established as a leading expert in the use of ion beams for cancer therapy.

After gaining her PhD studying the natural radioresistance of cultured insect cells, Blakely joined the staff at Berkeley Lab in 1976, working along increasing depths of the Bragg peak for the various beams under different conditions. In particular, by spreading the energy of the incident particles the team could broaden the peak from a few millimetres to several centimetres.

The studies revealed that for carbon and neon ions, in the region before the Bragg peak there was a clear difference in cell survival under aerobic (oxygen) or hypoxic (nitrogen) conditions, while in the Bragg peak the relative biological effectiveness, as measured by cell survival, was more independent of oxygen than for X-rays or gamma-rays (Blakely et al. 1979). This boded well for the use of these ions in treating tumours, because many tumour cells are resistant to radiation damage under hypoxic conditions. For argon and silicon, however, the survival curves in oxygen and nitrogen already indicated high cell killing and a reduced oxygen effect in the entrance region of the Bragg curve before the peak, indicating that at higher atomic number, these ions were already too damaging and did not afford the radioprotection of the particles with lower atomic number.

Eleanor Blakely, talking at CERN on 60 years of particle therapy. (Image credit: Henry Barnard/CERN.)
December 2011 p37). Another new centre, MedAustron in Austria, is now reaching the commissioning phase (2010 p22). During the last 10 years, Europe has followed suit, with the Heidelberg Ion-Beam Therapy centre in Germany, and the Centro Nazionale di Adroterapia Oncologica in Italy using carbon-ion beams on an increasing number of patients (Europe (ions was to become of major importance, first in Japan and then in

Interview

CERN Courier September 2014

number in the beam entrance. The work had important ramifications for the development of hadron therapy today: while Berkeley went on to use neon ions for treatments, therapy with carbon ions was to become of major importance, first in Japan and then in Europe (CERN Courier December 2011 p37).

At Berkeley, she was plunged into a world of physics. “I had to learn to talk to physicists,” she recalls. “I had only basic physics from school – I learnt a lot of particle physics.” And in common with many physicists, it is to understand how things work that has driven Blakely’s research, with the added attraction of being able to help people. Her interest lies deep in the cell cycle and what happens to the DNA, for example, as a function of radiation exposure. While her work has been of great value in helping oncologists, it is the fundamental processes that fascinate her as “a bench-top scientist”, to use her own words. “I’m interested in the body’s feedback mechanisms,” she explains.

That does not reduce her humanity. Some of the treatments at Berkeley used a beam of helium ions directed through the lens to destroy tumours of the retina. Blakely was devastated to learn that although the tumour was destroyed, the patients developed cataracts – a late radiation effect of exposure to the lens adjacent to some retinal tumours, which required lens-replacement surgery. As a result, she not only helped to propose a more complex technique to irradiate the tumours by directing the beam through the sclera (the tough, white outer layer of the eye) instead of the lens, but also became interested in the effects of radiation on the lens of the eye – a field in which she is a leading expert.

In 1993, the Bevalac was shut down, leaving Blakely and her colleagues at Berkeley without an accelerator with energies high enough for hadron therapy. “It was such an old machine,” she says. “Everyone had worked their hearts out to treat the patients.” The Bevalac had produced the heavier ion beams, while the 184-inch accelerator had produced beams of helium ions, and together almost 2500 cancer patients had been treated.

With her interest in irradiation of the eye, Blakely followed her first group leader “into space” – at least as a “bench-top” scientist – with studies of the effects of low radiation doses for the US Space Agency, NASA. “In space, people are exposed to chronic low doses of radiation,” she explains. In particular, she has been studying heavy-ion-induced tumourigenesis in mice with a broad gene pool similar to humans, to evaluate any risks in space travel. As a result, she not only helped to propose a more complex technique to irradiate the tumours by directing the beam through the sclera (the tough, white outer layer of the eye) instead of the lens, but also became interested in the effects of radiation on the lens of the eye – a field in which she is a leading expert.

Given that hadron therapy began 60 years ago at Berkeley, it is striking that nowadays there are no treatment centres in the US that use nuclei any heavier than the single protons of hydrogen. Japan was the first country to have a heavy-ion accelerator built for medical purposes – the Heavy Ion Medical Accelerator in Chiba (HIMAC) that started in 1994 (CERN Courier July/August 2007 p37 and June 2010 p22). During the last 10 years, Europe has followed suit, with the Heidelberg Ion-Beam Therapy Centre in Germany, and the Centro Nazionale di Adroterapia Oncologica in Italy using carbon-ion beams on an increasing number of patients (CERN Courier December 2011 p37). Another new centre, MedAustron in Austria, is now reaching the commissioning phase (CERN Courier October/November 2011 p33). Blakely describes the situation in her homeland as “a tragedy – the technology emerged from the US but we don’t have the machines”. Part of the problem lies with the country’s health-care plan, she says. “The treatments are not yet reimbursable, and the government won’t support building machines.”

Nevertheless, there is a glimmer of hope, following a workshop on ion-beam therapy organized by the US Department of Energy and the National Cancer Institute in Bethesda in January 2013, with participants from medicine, physics, engineering and biology. P2O Exploratory Planning Grants for a National Center for Particle Beam Radiation Therapy Research in the US are now pending. “Sadly this does not give us money to build a machine – legally the government isn’t allowed to do that – but the P2O can provide for infrastructure, research and networking once you have a machine,” Blakely explains. However, there is support for patients from the US to take part in randomized clinical trials – the “gold standard” for determining the best modality for treating a patient. At the same time, she envisages the networking and other achievements of the European Network for Light Ion Hadron Therapy (ENLIGHT), co-ordinated at CERN, which promotes international R&D, networking and training (CERN Courier December 2012 p9). “Networking is really important but it wasn’t something they taught us at school,” she says, “and training for students and staff is essential for the use of hadron therapy to have a future…” The many programmes that have been developed (by ENLIGHT) are extremely important and valuable, and I wish we had them in the US.”

Looking back on a career that spans 40 years, Blakely says: “It has been fulfilling, but a lot of work.” And what aspect is she most proud of? “Probably the paper from 1979,” she answers, “the result of many nights working at the accelerator.” When the focal point of hadron therapy moved to Japan, researchers there repeated her work. “They found the data were exactly reproducible,” she says with clear pleasure. Would she recommend the same work to a young person today? “With the current funding situation in the US,” she says, “I tell people that you have to love it more than eating – you need to be really committed.” Perhaps, one day, hadron therapy will return home, and the line of research begun by pioneers such as John Lawrence and Cornelius Tobias will inspire a new generation of people like Blakely.

Further reading
E A Blakely et al. 1979 Radiation Research 80 122.

Résumé
Une vie de biophysique

En 1954, année de la fondation du CERN, une autre aventure scientifique commence dans ce qui devait devenir le Laboratoire national Lawrence Berkeley. Des faisceaux de protons issus d’un accélérateur de particules étaient utilisés pour la première fois par John Lawrence, médecin et frère d’Ernest Lawrence, le physicien qui donnera son nom au laboratoire, pour traiter les patients atteints de cancer. Eleanor Blakely participe en première ligne à cette aventure depuis de nombreuses années. Dans cet entretien, elle parle de son activité de biophysique à Berkeley, et de ses espoirs concernant le futur de la thérapie par ions légers aux États-Unis.

Christine Sutton. CERN. For a video of Eleanor Blakely’s talk at CERN on 60 years of particle therapy, visit https://cds.cern.ch/record/1742238.
On 1 July, CERN and UNESCO commemorated a major step in the founding of the laboratory.

The convention that led to the establishment of the European Organization for Nuclear Research – CERN – was signed by 12 founding member states in Paris on 1 July 1953, under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The convention entered into force a little more than a year later, on 29 September 1954 – the official date of the laboratory’s foundation.

CERN was created with a view to relaunching fundamental research in Europe in the aftermath of the Second World War. Sixty years on, it has become one of the world’s most successful examples of scientific collaboration. After initial discussions between scientists in the late 1940s and the first official declarations encouraging scientific co-operation in Europe at the start of the 1950s, UNESCO was to play a vital role in establishing the new laboratory. Because one of the UN organization’s mandates was “to encourage the creation of regional scientific laboratories”, it was only fitting that CERN be created under its auspices. The eminent physicist Pierre Auger, who was then director of natural sciences at UNESCO, was a driving force in the negotiations that led to the laboratory’s foundation.

Starting in 1950, UNESCO organized several major conferences, during which the creation of a large nuclear-physics laboratory was discussed. In December 1951, the first resolution to found a European Nuclear Research Council – Conseil européen pour la recherche nucléaire in French, hence the acronym CERN – was adopted. The provisional council that was set up a few weeks later drew up the convention that would establish the future laboratory. After lengthy negotiations on the details, this was approved finally on 1 July 1953. CERN and UNESCO have maintained close ties – a relationship that has allowed them to co-operate on many projects, mainly in the field of education. Today, the two organizations are working together on projects to establish digital libraries in Africa and to train science teachers in developing countries.

A round-table discussion on “Science for Peace”, moderated by journalist Katya Adler, centre, included, left to right, Zehra Sayers, co-chair of the Scientific Advisory Committee of the SESAME facility, Fernando Quevedo, director of ICTP, Jan van den Biesen, vice-president of Philips Research Public R&D Programs, and Alexei Grinbaum, researcher and philosopher, Commissariat à l’énergie atomique et aux énergies alternatives. (Image credit: CERN-PHOTO-201407-133 – 87.)

The commemoration ceremony, held in UNESCO’s headquarters in Paris, was opened by Macej Nalecz, director of the UNESCO Division of Science Policy and Capacity Building, the division responsible for collaboration with CERN. This was followed by speeches from Irina Bokova, director-general of UNESCO, Roel Heer, director-general of CERN, and Agnieszka Zielawska, the president of CERN Council.

A round-table discussion on “Science for Peace” – the theme of CERN’s 60th anniversary – looked not only to the past, but also to how science can work to forge peace both now and in the future. One panelist – Fernando Quevedo from Guatemala, now director of the Abdus Salam International Centre for Theoretical Physics (ICTP) – was particularly honored to be part of the celebrations because his first postdoctoral work had been at CERN at a time when the laboratory had just opened up to postdoctoral scientists from non-member states. The closing remarks came from Frédéric Bordry, CERN’s director of accelerators and technology.

For a recording of the CERN–UNESCO event, visit http://cds.cern.ch/record/1713023.

Résumé
Le CERN et l’UNESCO célèbrent la Convention du CERN


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Résumé
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Research in the field of accelerators ranges from investigations into the underlying physics, to R&D into new materials and methods – a span that is matched by the breadth of interest in institutes and laboratories around the world. The International Particle Accelerator Conference (IPAC) provides an annual showcase for worldwide developments in particle accelerators, from recent experience with operational machines to studies for new and innovative concepts. This year the conference, which rotates between Europe, America and Asia, took place in Dresden – the Florence of the Elbe – on 15–20 June, attracting more than 1200 participants (see box, p28).

Topics at IPAC’14 ranged from the smallest to the largest accelerators, from the lowest to the highest energies and encompassed ideas for future projects to explore frontiers in energy, intensity and brightness in the decades to come. This report selects a few highlights, with a slant towards the use of accelerators in particle physics.

Three years ago, when IPAC was last in Europe, CERN’s LHC had a starring role as the world’s high-energy accelerator (CERN Courier December 2011 p15). Now, as the teams begin to reawaken the LHC after its first long shutdown, interest is shifting towards pushing the high-energy frontier even further. The opening talk of the conference set the bar high, with a review of the challenges for big circular colliders, in particular the Future Circular Collider (FCC) design study (CERN Courier April 2014 p16). A tunnel with a circumference of 100 km equipped with 16-T magnets – about twice the field strength of the current LHC dipoles – would allow proton–proton collisions at 100 TeV in the centre of mass. An intermediate step could be a high-luminosity circular electron–positron collider operating at a centre-of-mass energy of up to 350 GeV or higher. A high-luminosity lepton–hadron collider using the same infrastructure would be another possibility (CERN Courier June 2014 p33). A tentative timeline for such a project would see physics starting around 2035, taking the field comfortably into the second half of the century. A study for a similar but smaller electron–positron collider – the CePC – is under way in China. With a circumference of 54 km and a beam energy of up to 120 GeV, it would be associated with a 30–50 TeV proton collider – the SpPC.

Such schemes present many challenges, not least in the design of high-field magnets. The High Luminosity LHC project is already driving R&D on magnets based on a niobium-tin (Nb3Sn) superconductor, which can sustain higher maximum fields than the standard niobium-titanium (Nb-Ti) compound. Collaborative work between laboratories in the US and CERN has made good progress on models and prototypes, both for interaction-region quadrupoles with a field gradient of 140 T/m and for dipoles with a nominal field of around 11 T. High-temperature superconducting materials offer the promise of reaching higher magnetic fields, but the challenge is to produce suitable cables for the magnetic-coil windings. In the case of Nb-Ti, the solution was the Rutherford cable structure. The cuprate superconductors BSCCO 2223 and REBCO are commercially available now as tape in lengths of up to a kilometre, and fields above 30 T have been achieved in solenoids. There has also been recent progress in the development of BSCCO 2212 round wire, which has been used to make Rutherford cables. By combining inserts of a high-temperature superconductor within outer windings of Nb3Sn and Nb-Ti, magnets with fields of 25–30 T could be possible.

At the opposite extreme from projects such as the FCC, the Extra Low Energy Antiproton ring (ELENA) at CERN will turn the concept behind accelerators on its head by decelerating antiprotons. The 30-m-circumference synchrotron will reduce the energy of beam from the Antiproton Decelerator (AD) from 5.3 MeV to 100 keV. The challenge here is to reduce the emittance in all three planes to allow a substantial increase in the antiproton capture efficiency in the experiments. Design and construction are well underway.

With its mix of plenary, parallel and poster sessions, IPAC’14 put the many facets of accelerator studies on show.
Participants, prizes and proceedings

IPAC’14 attracted more than 1200 full-time delegates from 36 different countries from all of the inhabited continents. The attendance of more than 90 young scientists from across the world was made possible through the sponsorship of societies, institutes and laboratories worldwide. Hosted by the Helmholtz-Zentrum Dresden-Rossendorf (HZDR), the conference was supported by the GSI Helmholtz-Zentrum für Schwerionenforschung, the Helmholtz-Zentrum Berlin (HZB) and DESY.

Alltogether there were 46 invited talks and 51 contributed oral presentations, and 130 posters were scheduled during four dedicated sessions of the 12 sessions at the end of each afternoon. A special poster session took place during registration, the day before the conference opened. Prizes awarded by the European Physical Society’s Accelerator Group (EPS-AG) for the best student posters were presented later in the week during the special awards session. The prizes went to Elodie Rousset of PH-LAM/CERCLA and Marton Ady of CERN. Lieselotte Obst of HZDR received the EPS student poster prize for a Master’s Thesis student.

This year the awards session featured the EPS-AG prizes announced earlier this year (CERN Courier May 2014 p31). Stefano Manfredini of SLAC, Tsumoru Shitake of Osaka University, and Technology Graduate Institute and Mikael Eriksson of the Max IV Laboratory were all at the conference to receive their prizes and make short presentations about their work. In addition, Juan Esteban Müller of CERN/EPFL received the EPS-AG prize – awarded to a student registered for a PhD or diploma in accelerator physics or engineering, or to a trainee accelerator physicist or engineer in the educational phase of their professional career, for the quality of their work and promise for the future – for his work on a ‘High-accuracy Diagnostic Tool for Electron Cloud Observation in the LHC based on Synchronous Phase Measurements’.

The proceedings of IPAC’14 are published on the JACoW website (www.jacow.org). Thanks to the team and the careful preparations and guidance of Christine Peltier-Jean-Genaz (recently retired from CERN), a pre-press version with close to 1300 contributions was published at mid-day on the last day of the conference. The final version, with the invaluable support of Neil Slade and staff at JACoW, was published on the JACoW website just three weeks after the conference – another impressive record set by the JACoW collaboration.

under way, with a view to the first operation for physics in 2017. The highest-energy accelerators for particle physics are few in number, but projects at the high-intensity frontier are increasingly required for many types of science. Here the figure of merit concerns beam power rather than energy. For neutron sources, beam power is already reaching 1 MW, while for heavy ions the Facility for Rare Isotope Beams under construction at Michigan State Univer- sity aims to achieve 400 kW – two orders of magnitude greater than existing comparable facilities. The key technology in all cases is the use of superconducting radiofrequency (SRF) cavities. High powers also imply fast protection systems to prevent damage from beam loss, as well as innovative ideas for the particle sources, and there is much to accommodate.

In particle physics, Fermilab aims to double the beam power of the Main Injector by using the recycler to slip-stack protons during the ramp to reach 700 kW at 120 GeV. With 460 kW expected by the end of the summer, the programme is on course to reach its target once RF upgrades to the Booster are complete in 2015 (CERN Courier December 2013 p24). At the Japan Proton Accelerator Complex, the plan is to reach a record intensity for a proton accelerator in the Rapid Cycling Synchrotron (RCS). Last year, the linac was upgraded from 181 MeV to the design value of 400 MeV. This allowed the RCS to demonstrate operation with beam power up to 550 kW, with low beam losses (<0.5%) earlier this year. Operation at 1 MW is planned after the front end of the linac is replaced this summer. High intensities, as with high energies, come at a price, and the design options have to balance the cost against technical risk. The European Spallation Source is designed as an intense source of neutrons provided by 5 MW of average proton beam power on the spallation target, with a peak of 125 MW for the study of rare processes (CERN Courier June 2014 p21). The cost, as for any high-intensity hadron linac, is driven by the RF system mainly. Based on long pulses, the ESS does not require a compressor ring and can deliver a given peak current at any beam energy. A review in 2013 led to an elegant solution centred on a reduction in energy and a corresponding increase in the gradient and peak current to keep down the beam losses while increasing the technical risk to some extent. However, the risk has been mitigated by reserving space to allow the installation of additional cryo-modules.

While the ESS will provide an intense source of neutrons for a variety of science, other facilities – the light sources – generate beams of X-rays or ultraviolet light. Synchrotron-radiation light sources, which began to emerge in the 1970s, are now being joined increas- ingly by linac-based free-electron lasers (FELs) to provide beams for studies ranging from materials science to biology. A large number of facilities have emerged during the past couple of decades in countries that are often quite small, forming an impressive worldwide commu- nity. The potential of existing facilities continues to be maximized through upgrades based on new technical innovations, while new facilities are being designed to push the limits even further.

Fourth-generation light sources aim at short time scales and ultra-high brightness by reducing the beam emittance down to the so-called diffraction limit. For storage rings this presents challenges in the design of ultra-low-emittance lattices. Machines are already being built with emittances of the order of 100 pm-rad – for example, MAX-I in Lund, which is in the funding phase for a uniformly fast technical multi-bend achromat lattice. Studies are also looking towards sub-10-pm-rad emittances for the future, although the solutions are likely to be costly.

The Linac Coherent Light Source (LCLS) at SLAC – a FEL, making use of SLAC’s famous linac – was the first hard X-ray FEL with a peak X-ray brightness 10 orders of magnitude higher than that of the best synchrotron radiation source (CERN Courier December 2010 p17). Following the recommendation of a subcommittee of the US Department of Energy for “a new light source with revolutionary capabilities”, the project for the upgrade to LCLS-II saw a radical change in August 2013. The new plan is to build a 4-GeV continuous-wave superconducting linac in the first kilo- metre of the existing tunnel, based on superconducting RF cavi- ties with a nitrogen-doping surface layer to enable the required, unprecedented performance. A new undulator will receive elec- trons from either the new linac (to provide 1–5 keV photons) or the existing copper linac (to provide 1–25 keV X-rays). LCLS-II is expected to deliver its first light in September 2019.

Costs are specialties of the game for the application of accelerator tech- nology in cancer therapy, where the requirements for the beam – in terms of emittance, intensity, and stability, for example – are different from those in a nuclear-physics laboratory. Size, weight and price are also important, stimulating the application of new developments in superconductivity and novel accelerator types. In addition, the movement of the body as a result of breathing, motion of the gut and changes in the patient’s position provide challenges in beam delivery and control. Coupling the latest imaging tech- nologies with advanced computer-modelling methods can provide a way to tell a therapist where precisely to aim the radiation beams in the treatment of a range of common cancers.

Accelerator-based therapy with carbon ions is coming of age, since the first clinical trials began 20 years ago at the Heavy-Ion Medical Accelerator in Chiba, Japan (CERN Courier June 2010 p22). The experience gained there led to the construction of a standard carbon-ion radiotherapy facility at Gunma University, and its successful operation in turn led to projects for two more facilities. In addition, the National Institute of Radiological Sciences is developing a new treatment procedure based on pencil-beam scanning for both static and moving targets. This has been working successfully since May 2011 and will now be used in the ion-beam Radiation Oncology Centre in Kanagawa.

Accelerators could also be applied in future to address the ongo- ing shortages in reactor-based supplies of molybdenum-99, which is used in hospitals to produce technetium-99m, a gamma emitter that is important in imaging. Alternative production methods could use conventional or laser-based particle accelerators.

Medical applications are one aspect of a wider industrial and commercial involvement in the field of accelerators that formed the topic of a special session entitled “Engagement with Industry”. Large-scale science projects require collaboration with industry for the “mass-production” of large numbers of highly specialized components – 100 superconducting RF modules in the case of the European XFEL project – which presents challenges for both sides. On the other hand, applications such as particle therapy require the industrial development of commercially available acceler- ators. Another future market could be for electron linacs to provide radiation beams for medical uses. In Japan, for example, a treatment centre based on a linear accelerator – 100 superconducting RF modules in the case of the European XFEL project – which presents challenges for both sides. In Japan, for example, a treatment centre based on a linear accelerator for electron beams was developed and has been working successfully since May 2011 and will now be used in the ion-beam Radiation Oncology Centre in Kanagawa.
The challenge remains to achieve a beam of useful quality, whether for science or for other applications, and initiatives are under way in various countries to investigate the underlying physics further.

Using the interaction of intense laser beams with a solid target as a means to accelerate protons and ions has a shorter history, following the discovery of such an effect in 2000. For some years the proton energy produced seemed limited to 70 MeV, but recent experiments have shown that the “laser break-out afterburner” mechanism can produce protons with energies up to 130 MeV. Other effort has gone into testing methods for producing useful intense, mono-energetic beams. These systems offer potential for opening up ion-beam physics and neutron science based on short-pulse lasers in universities, and could become ideal compact sources of ion beams for medical applications.

The programme at IPAC’14 highlighted the diverse demands that exist today on accelerator R&D, coming from a variety of fields – neutron sources, synchrotron radiation, medical applications, etc. Accelerator physics and technology is maturing into a research field in its own right and needs well-planned R&D programmes to provide long-term solutions to these requests. In this respect, the field has outgrown its origins in high-energy physics, but the conference ended back at the high-energy frontier, where recent results from the LHC and other facilities have had a significant impact on particle physics. However, outstanding questions remain, and these will continue to drive to higher energies. Projects such as the FCC with which the conference started will remain among the important options for the future – a future that seems set to see the breadth of accelerator research continue to grow.

IPAC’14 was organized under the auspices of the European Physical Society Accelerator Group (EPS-AG), the Asian Committee for Future Accelerators (ACFA), the American Physical Society Division of Physics of Beams (APS-DPB) and the International Union of Pure and Applied Physics (IUPAP). For the programme and all of the contributions, see http://accelconf.web.cern.ch/AccelConf/IPAC2014/. In 2015, IPAC will return to North America and take place in Richmond, Virginia.

Résumé
Les accélérateurs à l'honneur à Dresden

La Conférence internationale sur les accélérateurs de particules (IPAC), associant sessions plénières, sessions parallèles et affichages, est la grande rencontre annuelle sur l’actualité des accélérateurs de particules. Il y est question aussi bien de l’expérience observée avec des machines opérationnelles que des études portant sur des concepts innovants. Cette année, IPAC’14 a eu lieu à Dresden, en juin, et a rassemblé plus de 1200 participants. Il y a été question de très petits et de très grands accélérateurs, à des énergies très faibles ou très élevées ; des idées ont été échangées sur les projets futurs visant à explorer les frontières de l’énergie, de l’intensité et de la brilliance dans les décennies à venir. Les applications des accélérateurs et les interactions avec l’industrie ont également figuré en bonne place au programme.

Christine Sutton, CERN, with thanks to Gianluigi Arduini, CERN, chair of the Scientific Programme Committee.
Chattopadhyay returns to new challenges in the US

After more than seven years at the helm of the UK’s Cockcroft Institute as inaugural director and Sir John Cockcroft Chair of Physics (jointly with the Universities of Liverpool, Manchester and Lancaster), Swapan Chattopadhyay is to join Fermilab’s senior leadership team in a joint appointment with Northern Illinois University, where he will serve as a distinguished professor and director of accelerator research. This appointment will boost Fermilab’s aspirations in accelerator-driven particle physics, while building up a collaborative academic and advanced-accelerator R&D programme.

Chattopadhyay’s tenure at the Cockcroft Institute witnessed its growth from inception to a fully established, staffed and internationally recognized scientific centre of excellence. During this time he helped to re-establish a vibrant accelerator research programme in the UK, and was a key player in cementing the links between the country’s accelerator community and CERN. He will continue this role in the summer months as a senior scientific associate at CERN and the UK’s Science and Technology Facilities Council (STFC), advancing collaborative research between CERN, the STFC and Fermilab.

The new appointment comes on the heels of the recently released report from the Particle Physics Project Prioritization Panel (P5). Chattopadhyay’s expertise will help Fermilab to align with the P5 recommendations and fulfill its part of the P5 vision for the future of particle physics (CERN Courier July/August 2014 p12).

CERN-ITER collaboration under new leadership

On 24 June, the CERN-ITER collaboration steering committee came together at the ITER headquarters for its annual meeting, with CERN’s Lluc Rossi presiding for the last time. Rossi has handed the baton to colleague Miguel Jimenez, head of CERN’s High Luminosity LHc (CERN Courier January/February 2014 p23).

Since 2008, when the two organizations signed a co-operation agreement, CERN and the global fusion project ITER have collaborated in the design and manufacturing of superconducting magnets and associated technologies (CERN Courier May 2008 p26).

As part of this collaboration, CERN became the “reference laboratory” for testing ITER’s superconducting strands (CERN Courier January/February 2010 p6).

CERN supports new business incubation centre in the Netherlands

CERN and Nikhef, the Dutch National Institute for Subatomic Physics, have announced the opening of a new business incubation centre (BIC) hosted at the Amsterdam Science Park, where Nikhef is located. The centre will provide new technology-transfer opportunities to bridge the gap between basic science and industry, supporting businesses and entrepreneurs in taking innovative technologies related to high-energy physics from technical concept to market reality. The announcement was made on the occasion of a symposium in Amsterdam organized by Nikhef to mark CERN’S 60th anniversary and highlighting Dutch contributions to the advance of fundamental physics and related technologies.

The BIC will support the development and exploitation of innovative ideas in technical fields related broadly to CERN’s activities in high-energy physics, such as detectors, computing, and high-performance computing. CERN will contribute with the transfer of technology and know-how through technical visits to CERN, support at the BIC and licensing of CERN intellectual property at preferential rates. Nikhef will provide office space, expertise, business and fundraising support.

The collaboration between CERN and Nikhef builds on Nikhef’s incentive scheme to support entrepreneurship, and on the establishment of Amsterdam Venture Lab, an initiative of the University of Amsterdam and partners, which is located close to Nikhef and provides facilities and support for early-stage research-based start-ups.

In 1965, CERN Council approved a project that was to go beyond the basic programme agreed in the convention signed in 1953 (p24). The Intersecting Storage Rings not only greatly extended the energy reach of experiments at CERN by being the world’s first hadron collider, the project also required the extension of CERN’s site into France, in an agreement signed in September 1965. The black-and-white photo shows the ISR under construction in September 1970. While the fields in the foreground are in Switzerland, the building site is all in France, since the border dog-legs in the direction of the woods to the top left. Meyrin village is dimly visible to the top right. The colour photo shows the site taken from the opposite direction in January 2004, with the Jura mountains in the distance. The water tower is clearly visible in both images.

(Image credits: CERN-SI-7009161 and CERN-SI-0402020.)
This year sees the 50th anniversary not only of the proposal of quarks, but also of what is arguably one of the most groundbreaking theoretical findings in physics: Bell’s theorem (Bell 1964). To celebrate the theorem and the work of the Irish physicist John Stewart Bell, who was on leave from CERN when he wrote his seminal paper, the University of Vienna held the conference Quantum [Un]Speakables II on 19–22 June. Distinguished invited specialists in the question of non-locality brought up by Bell’s theorem discussed the impacts of the theorem and the future of scientific investigations, together with 400 participants.

John Clauser, who was the first to investigate Bell’s theorem experimentally, mentioned the difficulties he had in acquiring money for his experiments. The breakthrough did not come until the 1980s, when Alain Aspect measured a clear violation of Bell’s proposed inequalities. The philosophical debate between Niels Bohr and Albert Einstein on whether quantum mechanics is complete or not thus seemed also to be settled for good — in favour of Bohr. In his talk, Aspect stressed Bell’s ingenious idea to discover the practical implications of what had until then been merely a philosophical debate.

An important further development of Bell’s theorem was the Greenberger–Horne–Zeilinger experiment, in which the entanglement of three instead of only two particles was considered. Another important contribution was achieved with the Kochen–Specker Theorem — next to Bell’s theorem, this is the second important “no-go” theorem for hidden variables in quantum mechanics. In their talks, Daniel Greenberger, Michael Horne and Simon Kochen focused on current questions in their research. Anton Zeilinger, who was co-chair of the conference with Reinhold Bertlmann, stressed the huge impact of Bell’s theorem for technical applications: quantum computing, quantum teleportation and quantum cryptography, which are based on the concept of non-locality as outlined by Bell.

More personal remarks came from Bertlmann, who had worked with Bell as a postdoc at CERN and is the protagonist of his famous paper “Bertlmann’s socks and the nature of reality”, and from Bell’s widow Mary Bell, an accelerator physicist. The conference title refers to a paper that Bell wrote in 1984, in which he identified what he called “unspeakables”. These are notions that he wanted to eliminate from the vocabulary of physics, because for him they did not qualify as well defined — among them measurement, apparatus and information. However, the title also allowed for another meaning. After 50 years, many important implications of Bell’s theorem have been found, but there is much that follows from it that no one knows or even thinks about yet, and so is still to discover.

Further reading
Videos of the talks will be available on the website of the Austrian Central Library for Physics of the University of Vienna. Visit http://bibliothek.univie.ac.at/zb-physics.ih-chemische/autriuener_central_physics_library.html.
JS Bell 1964/153/155.
Nina Byers 1930–2014

Nina Byers, a prominent theoretical physicist, passed away at her home in Santa Monica on 5 June, succumbing to a haemorrhagic stroke. She was a pioneering physicist, contributing to the understanding of both particle physics and superconductivity.

Nina was born to Irving and Eva Byers on 19 January 1930 in Los Angeles. She received her BA with highest honours from the University of California, Berkeley in 1950 and her MA and PhD from the University of Chicago in 1955 and 1956, respectively, her thesis being on n-mesic atoms, under Gregory Wenzel. An MA from the University of Oxford followed in 1967.

She began her career as a research fellow in Rolf Heuer’s group at the University of Birmingham in the UK in 1956. She then moved to Stanford University in 1958, where she worked on superconductivity, before beginning her long relationship with the University of California, Los Angeles (UCLA), as an assistant professor in 1960. She was the first female assistant professor in the physics department at UCLA and the only one for more than 20 years. At UCLA, she collaborated at first on studies in CP violation and pion–nucleon charge-exchange scattering. In the 1970s, her interests turned to the new gauge theories of electroweak interactions, quarkonium and bound-state systems.

Nina was active in efforts to increase the representation of women in physics. She also worked to document the accomplishments of women physicists, culminating in the book Out of the Shadows: Contributions of Twentieth-Century Women to Physics, co-edited with her colleague at UCLA, Gary Williams. She retired in 1993, but was an active professor emeritus until the end. During her long career, she was a visiting scholar at Harvard and Oxford, and held several fellowships and published numerous papers.

In addition to her passion for physics, Nina never stopped learning about the world around her. She was politically aware, advocating against the proliferation of nuclear weapons for more than six decades, and was a staunch anti-war activist. She also supported many social-justice and environmental causes. Her passions included the arts, with a love of classical music and film, and an inclination towards modern art and theatre.

Married to Arthur Milhaupt until his death, Nina is survived by her step-children Gretchen, Merimee, Anthony and Amy, her niece Morissa, nephew Mark, and a multitude of extended family, colleagues, students and lifelong friends scattered throughout the globe. A truly independent and inspirational woman, she will be missed greatly by her global family.

Nina’s friends and colleagues.

Tom Fields 1930–2014

Thomas Fields, a renowned physicist and former two-time director of Argonne National Laboratory’s High Energy Physics division, died at the age of 83 on 27 June. His career included building bubble chambers, studying hard quark scattering and neutrino oscillations, and fostering international co-operation between the US and the Soviet Union and China.

Tom’s interest in bubble chambers began when he finished his PhD at Carnegie Institute of Technology in 1955, and his adviser, Roger Sutton, suggested that he build a “new type of detector called a bubble chamber”. Tom started with a two-inch chamber, and in the years 1957–1958 built a six-inch chamber, followed by a 10-inch helium chamber when he moved to Northwestern University and Argonne. For this, he learnt how to build a superconducting magnet, the first one used in particle physics, which is now owned by the Smithsonian Museum in Washington.

In 1970 Tom was a member of a delegation negotiating the first agreements for exchanges in high-energy physics between the US and the Soviet Union. Then, in 1979, he was a member of the first US-China committee for co-operation in high-energy physics.

Following the closure of Argonne’s Zero Gradient Synchrotron in 1979, Tom became deeply involved in two new projects during the 1980s. First, the study of hard collisions and jet production at Fermilab, in collaboration with university groups from Pennsylvania, Wisconsin and Rice Universities. Second, the construction of an underground detector to search for proton decay at the Soudan mine in Minnesota, in collaboration with groups from Minnesota, Tufts, and Oxford Universities and the Rutherford Appleton Laboratory. He also served a second term as high-energy-physics division director, and spent a year as the acting director of the new 12-foot hydrogen bubble chamber.

On 6 June, Ying-tai Lung, Taiwanese minister of education, culture, sports, science and technology, visited CERN, accompanying the director of the Taiwan Cultural Centre in Paris, Hisao-ying Tsai, left, and CERN’s director-general, Rolf Heuer, right. This agreement allows Taiwanese artists to apply for a one-month residency at CERN. (Image credit: CERN-PHOTO-201406-121 – 24.)
Bernard Marie Karel Nefkens 1934–2014

Experimental nuclear and particle physicist Bernard M K (Ben) Nefkens died on 10 January at the age of 79 after a long illness. Ben was born in the Netherlands, where he received his PhD from Nijmegen University before moving on to research faculty positions at Purdue University and the University of Illinois. In 1966 he settled at the University of California, Los Angeles, where he remained for the next 45 years. Ben's research involved the study of the structure of the nucleon and probing the Standard Model via tests of broken symmetries such as C.P. Conservation and time reversal. His work was carried out in large part at the Los Alamos National Laboratory, where he led a series of high-precision measurements of the pion–nucleon scattering process at intermediate energies. In a second study there he produced the most complete study to date on time-reversal (T) invariance in the pion-three-body nucleus system. At TRIUMF, in Vancouver, he was responsible for a unique muon neutrino detector that was used to study charge-symmetric reactions around the A=3. At Saclay, his research group studied decay modes of the η meson, and at ELSA in Bonn he worked on the photoproduction of η mesons.

One of Ben's greatest achievements was refurbishing the famous Crystal Ball detector that was used at SLAC and HERA. He took the lead role in establishing a laboratory to use at the Alternating Gradient Synchrotron until the fixed-target program ended in 2002. There, he spearheaded a collaboration to carry out a programme of pion–nucleon and kaon–nucleon scattering. In 2002 the detector was moved to MAMI in Mainz, where the research programme continues to this day. He held visiting professorships at Saclay (1978–1979 and 1985–1986) and CERN (1972–1973). He was a member of the CERN PR 55 Apollon Project of the University of Uppsala. He was also co-founder and editor of the Pion-Nucleon Newsletter, and co-founder of the International Conference on Meson and Nuclear Physics (MENUP). He mentored many students during his career and taught at both undergraduate and graduate levels. As a teacher, he had infectious enthusiasm and empathy for his students. Rigorous training in the fundamentals is the sign of a Nefkens student.

Ben was also interested in music and the arts. He gave wonderful colloquia on symmetries in nature, art and music. Above all, Ben loved family and, as he would say to his collaborators, "I highly recommend playing with children!" He is survived by his wife, Mary, his children, and his grandchildren.

A memorial service will be held on 28 February at the University of California, Los Angeles, at 4 p.m. in the Meeting Room of the University Club (3617 Westwood Blvd. Los Angeles, CA 90024-1929). The service will be followed by a reception until 6 p.m. in the same location. For further information, visit http://www.particlephysics.umd.edu/memorial.aspx.

CERN Courier welcomes contributions from the international particle-physicists 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.
Recruitment

The Argonne Named Fellowship Program

Argonne National Laboratory is accepting applications for the 2015 Named Fellowship. Argonne awards these special fellowships internationally on an annual basis to outstanding doctoral-level scientists and engineers who are at early points in promising careers. The fellowships are named after scientific and technical luminaries who have been associated with Argonne and its predecessors, and the University of Chicago, since the 1940s. Candidates for these fellowships must display superb ability in scientific or engineering research, and must show definite promise of becoming outstanding leaders in the research they pursue. Fellowships are awarded annually and may be renewed up to three years. The 2014 fellowship carries a highly competitive salary with an additional allocation for research support and travel. The deadline for submission of application materials is October 7, 2014.

Applicants should identify an Argonne staff member to sponsor the nomination. The sponsor should be someone who is already familiar with your research work and accomplishments through previous collaborations or professional societies. If you have not yet identified an Argonne sponsor, visit the detailed websites of the various research efforts at www.anl.gov/science.

Applications must be submitted online through http://www.anl.gov/careers/apply.html. Correspondence and supporting letters of recommendation should be submitted to Named-Fellowship@anl.gov.

For more information visit the Argonne Postdoc Blog at http://blog.anl.gov/postdoc/ or by contacting the Postdoc Program Coordinator, Kristene Henne at khenne@anl.gov.

Argonne is an equal opportunity employer and we value diversity in our workforce. Argonne’s site is located about 25 miles southwest of Chicago on a beautiful 1500 acre campus.

For advertising inquiries, contact CERN Courier recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK. Tel: +44 (0)117 930 1264. Fax: +44 (0)117 930 1178. E-mail sales@cerncourier.com

Argonne National Laboratory

DIRECTOR, HIGH ENERGY PHYSICS DIVISION

Argonne National Laboratory invites applications for the position of Director of the High Energy Physics Division (HEP). The spectrum of research in the Division includes HEP and cosmology theory, and covers the three experimental frontiers: Energy, Intensity and Cosmic. The Division also manages programs in Sensor & Detector Development and Advanced Accelerator R&D, and maintains electronics and mechanical support groups. The Division includes one of the US-ATLAS Analysis Support Centers, the Argonne Wakefield Accelerator (AWA) and the Center for Development and Fabrication of Quantum Devices. The last is operated jointly with the University of Chicago. The Division is funded mainly from DOE HEP. Strong collaborations and connections exist with other Divisions within Argonne and bring expertise to HEP as well as providing HEP expertise to other disciplines. Examples include connections to Materials Science and High Performance Computing.

The Division Director will be expected to work with HEP scientific and management staff to: (1) enhance the strengths and visibility of existing staff and research programs; (2) identify new research directions that are strategically aligned with DOE’s missions; (3) strengthen and expand connections with other scientific disciplines at Argonne and beyond; (4) recruit, hire, and retain world-class researchers; (5) interface with programmatic sponsors at DOE; and (6) foster and maintain high standards in Environmental, Safety, and Health and quality assurance for all of the Division’s activities.

The successful candidate should have a Ph.D., an internationally recognized research stature, and 10+ years of scientific leadership experience. Further, the candidate should have a vision for the future of fundamental physics, namely in Particle Physics, Astrophysics and Cosmology. IFAE also works at the cutting edge of detector technology, applying its know-how to Medical Imaging and other applied research fields. It maintains a fruitful collaboration with its spinoff company, X-Ray Imatix.

In 2012, IFAE was granted the Severo Ochoa award, given by the Spanish government to a few leading national research centres.

Candidate profile and contact information

IFAÉ is seeking applicants with a distinguished record of scientific excellence and the innovative thinking necessary to lead a dynamic organisation. A PhD or comparable degree, high international visibility in IFAÉ’s fields of activity and significant research management experience are required. Salary will be commensurate with qualifications and consistent with IFAÉ’s management’s salary scale. More information, including a description of the Director’s post and responsibilities, is at www.ifae.es/eng/work/open-positions.html.

The successful candidate may offer an indefinite position as Full Research Professor. The appointment as Director will be for a period of 4 years, which could be extended. Applicants should send a CV and a letter of motivation to iafa@cerca.cat, or by email to Fundació CERCA, at applications@cerca.cat, stating as the subject “IFAÉ Director call”.

The deadline for applications is October 10, 2014.

The Argonne Named Fellowship Program

Argonne National Laboratory is accepting applications for a 2015 post-doctoral fellowship. This fellowship program is designed to attract and support early-career scientists and engineers who are interested in pursuing a career at Argonne National Laboratory. The fellowship is designed to provide opportunities for early-career scientists and engineers to develop their research and technical skills, and to gain experience in a dynamic, collaborative research environment.

The fellowship program is open to candidates who have obtained a Ph.D. degree in a relevant field within the past three years and who are not currently employed full-time in a research position at Argonne National Laboratory or any other institution.

The fellowship provides a stipend of $70,000 per year, along with a travel allowance of $5,000 per year. In addition, the fellow will have access to Argonne's state-of-the-art research facilities and will have the opportunity to work on a wide range of research projects.

Applications are accepted on a rolling basis and will be reviewed every two months. The next review date is December 15, 2014.

For more information, please visit the fellowship website at http://www.anl.gov/postdoc.

The Argonne Named Fellowship Program

The Argonne Named Fellowship Program is a prestigious fellowship program offered by Argonne National Laboratory, a U.S. Department of Energy national laboratory located outside Chicago, Illinois. The fellowship is designed to attract and support early-career scientists and engineers who are interested in pursuing a career at Argonne National Laboratory. The fellowship program is open to candidates who have obtained a Ph.D. degree in a relevant field within the past three years and who are not currently employed full-time in a research position at Argonne National Laboratory or any other institution.

The fellowship provides a stipend of $70,000 per year, along with a travel allowance of $5,000 per year. In addition, the fellow will have access to Argonne's state-of-the-art research facilities and will have the opportunity to work on a wide range of research projects.

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For more information, please visit the fellowship website at http://www.anl.gov/postdoc.

The jobs site for physics and engineering

CERN Courier

Post-Doctoral Position

High Energy Neutrino and Particle Astrophysics

Indiana University

The High Energy Neutrino and Particle Astrophysics group at Indiana University is seeking applicants for a post-doctoral position. Our group plays a leading role within both the NOvA and LBNE experiments, and is engaged in generic R&D efforts on large liquid argon time projection chambers for use by future experiments such as DUNE. The successful applicant will be expected to contribute to these efforts.

The position is available for a near term start date. Successful candidates will have a PhD in physics. We will review applications beginning August 1 and will continue to accept applications until the position is filled. The appointment will initially be for one year, with the possibility of extension for up to an additional two years.

Applications, including a curriculum vita and three letters of reference, should be submitted through the application portal located at http://indiana.peopleadmin.com/postings/9023. Questions regarding the application process can be directed to Professor Jim Mussler (indianapysics@indiana.edu).

For more information about the group please see http://physics.indiana.edu/~heap.

APPLICATIONS CLOSING DATE: September 15, 2014.
The Leung Center for Cosmology and Particle Astrophysics (LeCosPA) of National Taiwan University is pleased to announce the availability of several Post-Doctoral Fellowships with competitive salary.

**Overview**

The Leung Center for Cosmology and Particle Astrophysics (LeCosPA) of National Taiwan University

- **Director**: Prof. Pisin Chen
- **Website**: [http://lecospa.ntu.edu.tw/](http://lecospa.ntu.edu.tw/)

LeCosPA is a research center that focuses on various areas of theoretical and experimental research in particle astrophysics, including cosmology, particle physics, and dark matter.

**Post-Doctoral Fellowships**

LeCosPA offers post-doctoral fellowships to early-career scientists with a strong track record in the fields of cosmology, particle astrophysics, and related areas.

**Requirements**

- PhD completed within the last 4 years
- Experience in experimental particle physics
- Strong research background in the fields of cosmology and particle physics

**Responsibilities**

- Conduct independent research projects
- Collaborate with other researchers in the field
- Publish findings in peer-reviewed journals

**Salary and Benefits**

- Competitive salary
- Health insurance
- Research expenses

**Application Process**

- Submit a CV, including teaching experience and publication list, copies of degree certificates, and a statement of research interests.
- Applications must be submitted in written form until September 30, 2014.
- Applications can also be submitted by email to:

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  Ms. Yen-Ling Lee
  ntulecospa@ntu.edu.tw
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**Deadline**

- Applications are accepted until September 30, 2014.

**For more information**, visit the Leung Center for Cosmology and Particle Astrophysics website or contact the Director directly.

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**About LeCosPA**

LeCosPA is a research center that focuses on various areas of theoretical and experimental research in particle astrophysics, including cosmology, particle physics, and dark matter. It is located at National Taiwan University and is one of the leading research centers in Asia.

**Contact Information**

- **Director**: Prof. Pisin Chen
- **Website**: [http://lecospa.ntu.edu.tw/](http://lecospa.ntu.edu.tw/)
- **Email**: ntulecospa@ntu.edu.tw

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**About National Taiwan University**

National Taiwan University is a premier research university in Taiwan, known for its contributions in various fields of science and technology. Founded in 1928, it is one of the oldest universities in Asia.

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**About Cosmology and Particle Astrophysics**

Cosmology is the study of the universe and its origins, evolution, and future. Particle astrophysics deals with the interaction of subatomic particles with their environment. Both fields are crucial for understanding the fundamental laws of the universe.

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**For more information**, please contact the Director or visit the Leung Center for Cosmology and Particle Astrophysics website.
the subject becomes much harder to describe physics, and less suitable for philosophers, suitable for people educated in particle historical facts, to an extent that makes it explanations of the physics (for which enough demonstration that string theory has been interpretation, namely in terms of gravity that is also consistent at the quantum level. From apart from particle physics, it also sheds light on a vast range of problems in physics and mathematics. For example, it helps in understanding certain properties of gauge theories, black holes, the early universe and even heavy-ion physics.

This new book fills a gap by reviewing the 40-year-plus history of the subject, which it divides into four parts, with the main focus on the earlier decades. The reader learns about the work of researchers in the early days in detail, where so-called dual models were investigated with the aim of describing hadron physics. It took ingenuous insights to realize that the underlying physical interpretation is in terms of small, oscillating strings. Some of the groundbreaking work took place at CERN—for example, the discovery of the Veneziano amplitude.

The book offers a good impression of how it took many years of collective effort and struggle to develop the theory, which is often underestimated, at least at first glance. It appears, for example, that there was an unshared belief in certain aspects of string theory, namely in terms of gravity, rather than hadron physics. Supersymmetry was discovered along the way as well, demonstrating that string theory has the potential to be a better model of nature, although sometimes the direction of research changed drastically in a serendipitous manner. For example, at some point there was an unshared belief in the validity of gauge theory, which was less consistent at the quantum level. The book also discusses the importance of collaboration and the role of major conferences and workshops in the development of string theory.

In summary, this is a well-written and enjoyable book, filled with interesting details about the development of one of the main research areas of theoretical physics. It appears to be most useful to scientists educated in related fields, and I would even say that it should be a mandatory read for young colegues entering research in string theory. —Wolfgang Lerche, CERN.

The book also provides a statistical analysis of the physical sciences, covering various topics such as Bayesian and frequentist methods, and illustrates how these methods are applied in practice. It includes examples from different fields such as biology, physics, and economics. The book also discusses the philosophical implications of these methods, such as the role of prior probabilities in Bayesian statistics, and the assumptions behind frequentist methods. It also covers the Fisher–tippett–grubbs and the normal distribution, and provides a clear explanation of the central limit theorem. The book is well-written and includes many examples and exercises, making it suitable for students and researchers in the physical sciences.

In conclusion, this book provides a comprehensive and accessible introduction to the statistical analysis of physical sciences. It is a valuable resource for students and researchers in the field, and also serves as a useful reference for practitioners in the field.
A shining light in the Middle East

CERN was conceived in the late 1940s and early 1950s, when two ambitions came together—to enable construction of scientific facilities that were beyond the means of individual countries, and to foster collaboration between peoples who had recently been at war. The network of CERN users, which already included scientists from Eastern Europe and the USSR during the Cold War, expanded in the LEP era. Today, scientists from 74 countries around the world work together on LHC experiments, producing good science and also gaining a better appreciation of each other's cultures and values.

Following in CERN's footsteps, many other pan-European scientific organizations have been established. However, the organization most closely modelled on CERN is perhaps SESAME, which shares CERN's original aims and its governance structure. SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) is a third-generation light source under construction in Jordan, which will enable research in subjects ranging from biology and medical sciences through materials science, physics and chemistry to archaeology (much focussed on regional issues, e.g. related to health and agriculture). SESAME will foster cooperation between its very diverse members (currently Bahrain, Cyprus, Egypt, Iran, Jordan, Kuwait, Portugal, Russia, Turkey, and the Palestinian Authority and Turkey), some of which are in conflict.

Following a suggestion by Gus Voss (DESY) and Herman Winick (SLAC), Sergio Fubini (CERN and University of Turin, who chaired a Middle East Scientific Co-operation group) and Herwig Schopper (director-general of CERN in the years 1981–1987) persuaded the German government to donate the components of the then soon-to-be-dismantled Berlin synchrotron BESSY I for use at SESAME. At a meeting at UNESCO in 1999, an interim council was established with Schopper as president, and a Jordanian (Khaled Toukan, who has served as director since 2005) and a Turk (Dincer Ulku) as co-vice-presidents. Many others, e.g. Eliezer Rabinovici (Hebrew University), played important roles in SESAME's history—see http://mag.digitalpc.co.uk/fvx/iop/esrf/ sesamebrochure/

Progress was initially slow due to lack of funding, but has accelerated since the SESAME building came into use in 2008. The (upgraded) BESSY I microtron injector is producing a 22 MeV beam, which has been successfully stored in the (refurbished) booster synchrotron. In 2002 it was decided to build a completely new 2.5 GeV main ring, which will be installed in 2015. Four "day-one" beamlines are being constructed, and SESAME is on track technically for commissioning to begin in early 2016. The scientific programme has been developed in user meetings that bring together scientists in the region. Regional interest and scientific capacity have been fostered by an extensive training programme, involving schools, workshops and work at operating light sources and other laboratories, which has been supported generously by international agencies (particularly the IAEA), national agencies, professional scientific societies, the world's synchrotron laboratories, and small charitable foundations.

SESAME's major problem is obtaining funding. The members became involved before it was agreed to build a new main ring with no obligation to contribute to the capital cost, which would be beyond the means of the many who have limited science budgets and find it very hard to pay their rapidly increasing contributions to operational costs. The richer countries in the region are currently unwilling to join for political reasons. However, Iran, Israel, Jordan and Turkey have each agreed to make voluntary contributions of $5 million, the EU has contributed €7.5 million (including €5 million for construction of the magnets of the main ring which, very helpfully, is being managed by CERN), Italy has pledged €2 million with more possibly to come, and many of the observers (Brazil, China, France, Germany, Greece, Italy, Japan, Kuwait, Portugal, the Russian Federation, Spain, Sweden, Switzerland, the UK and the USA) have donated equipment that was surplus to requirements and support the training programme.

SESAME and CERN exemplify the "Science for Peace" mission of UNESCO, which served as a midwife for both, by fostering better understanding between scientists and engineers, building on the respect they develop for each other's professional abilities. There are of course political hurdles to be jumped (visa restrictions prevent many of the members hosting SESAME meetings; sanctions are holding up payments by Iran; frequent changes of government have so far prevented Egypt joining the other voluntary donor members; etc). However, provided SESAME is a first-class scientific instrument, leading scientists from across the region will wish to work there and the political mission will look after itself.

SESAME needs funding for a hostel and a small conference centre, which could also be used for international meetings on issues such as water resources, agriculture or the environment. I dream that, as other European organizations followed CERN, this will give birth to other international organizations in the Middle East.

SESAME was created bottom-up by scientists, who in some cases dragged their governments outside their comfort zones, but it now needs external top-down help and encouragement to ensure timely completion. I hope that this article will inspire other countries (without geopolitical limitations) to join SESAME, and further contributions from governments in other regions, charitable foundations and philanthropists.

Chris Lowery-Smith, president of the SESAME Council and director of energy research, Oxford University, director-general of CERN in the years 1994–1998, when construction of the LHC was approved and started.
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The DT5770 is the new CAEN compact Digital MCA for Gamma and X-Ray spectroscopy supporting both continuous and pulsed reset preamplifiers. The provided USB 2.0 and Ethernet communication interfaces can also power the unit, making it an ideal and portable solution for many application fields. Usability is guaranteed by the new CAEN MC² Analyzer Software.
Contents

5  News
• Countdown to physics • Precise measurements of top-quark production • CMS releases final Run 1 results on H → γγ
• The 1-2-3 of D meson spectroscopy • MicroBooNE detector is moved into place • Global strategies for particle physics

11  ScienceWatch

13  Astrowatch

15  Archive

17  Features
IAXO: the International Axion Observatory
A large superconducting magnet could cast light on the dark universe.

21  A lifetime in biophysics
Eleanor Blakely talks about pioneering research at Berkeley Lab.

24  CERN and UNESCO celebrate signing the CERN Convention
Commemorating a major step in the founding of CERN.

27  Accelerators come into focus in Dresden
With its mix of plenary, parallel and poster sessions, IPAC’14 puts the many facets of accelerator studies on show.

31  Faces&Places

40  Recruitment

44  Bookshelf

46  Viewpoint