WELCOME

# CERN Courier – digital edition

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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DIGITAL EDITION CREATED BY JESSE KARJALAINEN/IOP PUBLISHING, UK

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERNCOURIER

VOLUME 54 NUMBER 7 SEPTEMBER 2014

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

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

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**Produced for CERN by IOP Publishing Ltd**
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Bristol BS1 6HG, UK
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or +44 (0)117 930 1164 (for recruitment advertising);
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**General distribution** Courrier Adressage, CERN, 1211 Geneva 23, Switzerland
E-mail: courrier-adressage@cern.ch
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E-mail: mark.wells@stfc.ac.uk
**US/Canada** Published by Cern Courier, 6N246 Willow Drive,
St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US
Fax 630 377 1569. E-mail: creative_mailing@att.net
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147,
St Charles, IL 60174, US

**Published by** European Organization for Nuclear Research, CERN,
1211 Geneva 23, Switzerland
Tel +41 (0) 22 767 61 11. Telefax +41 (0) 22 767 65 55

**Printed by** Warners (Midlands) plc, Bourne, Lincolnshire, UK


 ISSN 0304-288X

IOP Publishing

# CERN COURIER

VOLUME 54 NUMBER 7 SEPTEMBER 2014





**On the cover:** IPAC'14 took place in the beautiful city of Dresden, where it was hosted by the Helmholtz-Zentrum Dresden-Rossendorf (p27). (Image credit: Thomas888|Dreamstime.com.)



CERN COURIER
VOLUME 54 NUMBER 7 SEPTEMBER 2014
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# News

CERN

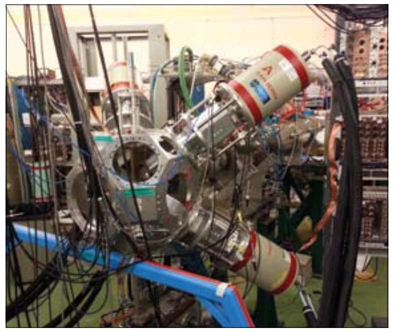
## Countdown to physics

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.

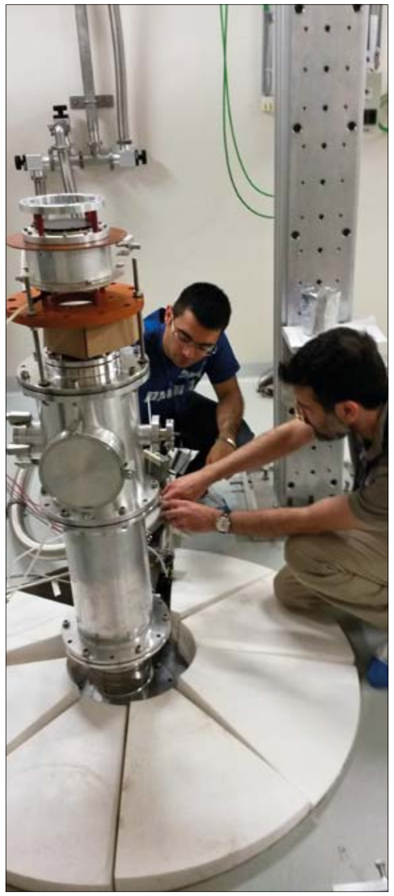
First in line were experiments in the East Area of the PS, where the T9 and T10 beam lines are up and running. These test beams serve projects such as the Advanced European Infrastructures for Detectors at Accelerators (AIDA), which looks at new detector solutions for future accelerators, and the ALICE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



*Above: The ISOLDE Decay Station (IDS), one of ISOLDE's two new permanent experimental stations. (Image credit: ISOLDE collaboration.)*



*Right: The last part of the EAR2 beam line: the neutrons come from the underground target and reach the top of the beam line, where they hit the samples. (Image credit: Frank Gunsing/n_TOF collaboration.)*

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.

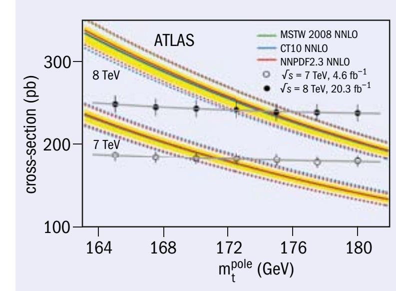
### Sommaire en français

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 ($\sqrt{s}$) 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.




*Measurements of the top-pair production cross-section at $\sqrt{s}$ = 7 and 8 TeV and corresponding QCD theoretical predictions, as a function of the assumed top-quark mass.*

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 $m_t$, so the measurements can be interpreted as a determination of $m_t$, giving $m_t = 172.9^{+2.5}_{-2.6}$ 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.

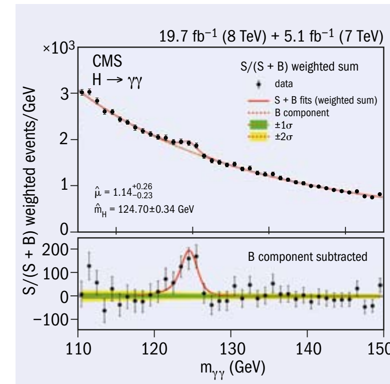
**Further reading**

ATLAS Collaboration 2014 arXiv:1406.5375 [hep-ex], submitted to *Eur. Phys. J. C*.

# CMS releases final Run 1 results on H → γγ

The CMS collaboration achieved an important milestone this summer with completion 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 → γγ, 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 → ZZ → 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 → γγ 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.




*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 → γγ 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 ▷

mainly used to separate events into a total of 25 exclusive categories that not only increase the sensitivity but also allow measurement of the different production processes for the Higgs boson in the $H\to\gamma\gamma$ channel alone. The expected final sensitivity for the observation has increased from $4.2\sigma$ for the preliminary result to $5.2\sigma$. The data show a $5.7\sigma$ excess at the Higgs boson mass of 125 GeV, therefore providing the definitive observation of the Higgs boson in the diphoton decay channel alone.

The final results of the analysis indicate that the yield of diphoton decays relative to the predictions of the Standard Model (the signal strength modifier) is $1.14^{+0.26}_{-0.23}$ – in very good agreement with the Standard Model. In addition, the mass of the Higgs boson is measured to be $124.70\pm0.34$ GeV – the most precise measurement to date.

The figure (p7) shows the combined weighted diphoton mass distribution, where a large excess in the region of 125 GeV is clearly visible. The publication presents a host of additional measurements, including the signal-strength modifiers associated with different production mechanisms, direct upper bounds on the Higgs boson width, the search for quasi-degenerate states decaying into two photons, and a spin analysis.

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 $1.00\pm0.13$, again in striking agreement with the predictions of the Standard Model.

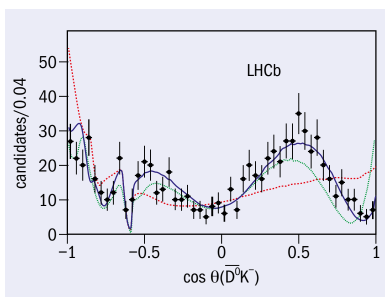
**Further reading**

CMS Collaboration 2014a arXiv:1407.0558 [hep-ex] submitted to *Eur. Phys. J. C.*
CMS Collaboration 2014b CMS-PAS-HIG-14-009.

# The 1-2-3 of $D_s$ meson spectroscopy

The LHCb collaboration has shown that a $\bar{D}^0K^-$ structure with invariant mass 2860 MeV/$c^2$ 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 experiment is designed primarily to study CP violation and rare decays of b hadrons. However, the large samples of decays collected 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 (*CERN Courier* March 2013 p8 and June 2014 p12). Now, for the first time, the collaboration has used amplitude analysis techniques to study $B_s^0\to\bar{D}^0K^-\pi^+$ decays. The well-defined initial and final states allow the determination of the spin and parity of any intermediate $\bar{D}^0K^-$ resonance through the angular orientation of the decay products.




*The angular distribution for the peak found in the $\bar{D}^0K^-$ invariant mass is well fitted by a model that includes both spin-1 and spin-3 particles (see text for further explanation).*

The figure shows the angular distribution of events seen in a peak with $\bar{D}^0K^-$ invariant mass around 2860 MeV/$c^2$. The data points are well fitted by a model that includes both spin-1 and spin-3 particles (solid blue curve). The models with either only a spin-1 (red curve) or a spin-3 (green curve) resonance are excluded with significance more than $10\sigma$. A similar analysis of the angular distribution for events around the $D_{s2}^*(2573)^-$ peak establishes, for the first time, that this resonance is indeed spin 2. In addition, the mass of this resonance is determined much more precisely than previous measurements, suggesting that renaming as $D_{s2}^*(2568)^-$ might be in order.

The identification of a spin-3 resonance at a mass of 2860 MeV/$c^2$ fits with the theoretical expectation for, in spectroscopic notation, the $^{2S+1}L_J = {}^3D_3$ state, where S is the sum of the quark spins, L is the orbital angular momentum between the quarks and J is the total spin. It remains to be seen whether the production rate can be explained, because states with spin greater than two have never previously been observed in B-meson decays. With further analyses of the large samples available from LHCb and its upgrade, a new era of heavy-flavour spectroscopy could be beginning.

**Further reading**

LHCb collaboration 2014 LHCb-PAPER-2014-035 to be submitted to *Phys. Rev. Lett.*
LHCb collaboration 2014 LHCb-PAPER-2014-036 to be submitted to *Phys. Rev. D.*

FERMILAB

# 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 to 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 photons or electrons.

Using one of the most sophisticated processing programs ever designed for a neutrino experiment, computers will sift through the thousands of neutrino 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 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.

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 in Europe, 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/directorate/icfa/ICFA_Statement_20140706.pdf.



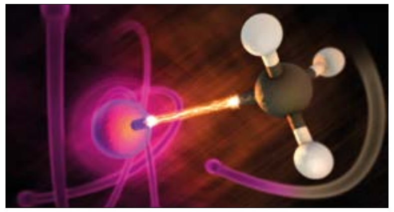

# Sciencewatch

Compiled by John Swain, Northeastern University

## 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 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.



*Artist's concept of an exploding methyl-iodide molecule and its jumping electrons. (Image credit: SLAC National Accelerator Laboratory.)*

● **Further reading**
B Erk *et al.* 2014 *Science* **345** 288.

## How to measure cosmic acceleration directly

An exciting new proposal could directly measure cosmic acceleration not with supernovae, but with much simpler and better understood systems: hydrogen atoms. Hao-Ran Yu of Beijing Normal University and colleagues suggest that direct measurements of recession-velocity drifts (the Sandage–Loeb effect) of 21-cm absorption systems could be made at two different times to derive their acceleration.

This would constitute two measurements of the velocity of the same system and should be highly model-independent. With a modest change in data analysis and storage of a wide-sky radio survey such as the Canadian Hydrogen Intensity Mapping Experiment (CHIME), the acceleration of a $\Lambda$CDM universe (with cold dark matter and a cosmological constant) could be determined with $5\sigma$ confidence within a decade.

● **Further reading**
H-R Yu *et al.* 2014 *Phys. Rev. Lett.* **113** 041303.

## 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 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**
E Christensen *et al.* 2014 *Phys. Rev. Lett.* **113** 042503.

## Brine on Mars

Evidence for deliquescence of perchlorate salts in the Martian polar region seemed to be in contradiction to the possible brine flows observed near the equator, the idea being that bulk deliquescence is too slow to occur during the Martian diurnal periods. Erik Fischer of the University of Michigan in Ann Arbor and colleagues have now resolved the puzzle by looking at the formation of saline solutions in Mars-like conditions in the laboratory.

They found that if only water vapour is present, there is a problem. However, if the salts are in contact with water ice, brine forms in minutes. This shows that aqueous solutions could form where salts and ice are both present on or just below the Martian surface.

● **Further reading**
E Fischer *et al.* 2014 *Geophys. Res. Lett.* 10.1002/2014GL060302.

*Colour-coded data from a mineral-mapping spectrometer supported the idea that the seasonal dark marks on the photo of Martian slope are linked to brine flows. (Image credit: NASA/JPL-Caltech/UA/JHU-APL.)*

## 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**
A M Labin *et al.* 2014 *Nature Communications* **5** 4319.

# Astrowatch

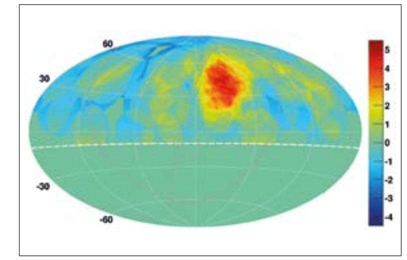
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva, and CHIPP, University of Zurich

## Study hints at cosmic-ray ‘hotspot’

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 40° 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.



*Map of the sky showing an excess of UHECR from a region (red and yellow spot) in the northern-sky hemisphere, observed by the Telescope Array. (Image credit: K Kawata/University of Tokyo Institute for Cosmic Ray Research.)*

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 $3.7 \times 10^{-4}$, 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 rather heavy nuclei, which are deflected more by magnetic fields. The TAx4 project, an extension of the TA, would provide a speed-up of the detection rate to confirm the existence of the excess.

**Further reading**

The Telescope Array Collaboration 2014 *ApJ* **790** L21.

### Picture of the month

This image from the NASA/ESA Hubble Space Telescope shows the galaxy cluster MCS 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 68 distant galaxies from almost 200 different distorted images of lensed galaxies in this very 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 MCS J0416.1-2403 – modelled to be more than 650,000 light-years across – was found to be $160 \times 10^{12}$ times the mass of the Sun, to a precision of 1%. (Image credit: ESA/Hubble, NASA, HST Frontier Fields.)

# CERN Courier Archive: 1971

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

BERKELEY

## Seeing particles

It has become a standard part of the patter in introducing newcomers to the mysteries of particle detectors to say that particles are so tiny that they cannot be seen with the human eye. However, research carried out at Berkeley and elsewhere over the past year seems to demonstrate that this is not strictly true.

Light-flash phenomena (or "phosphenes", from the Greek "*phos*", for light, and "*phainen*", to show) from sources other than normal light have been known for a long time. As early as 1755 it was recorded that small electric currents can produce phosphenes – any enthusiastic reader might try leads from a 3 V torch battery to the forehead and back of the head, preferably in a darkened room. They can also be induced by dipping the head in a magnetic field (of about 0.1 tesla, for example), by exposure to X-rays in the dark, or by pressure on the closed eye.

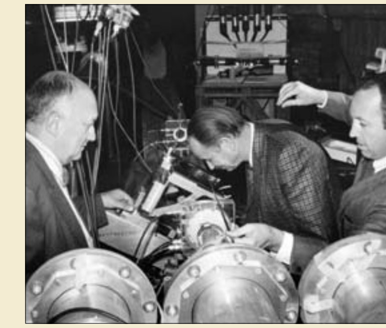
The study of a new type of phosphene was stimulated by the experience of astronauts on space-flight Apollo missions. When it was dark in the spacecraft they reported seeing light flashes (pinpoints and streaks) at a frequency of one or two per minute. The postulate was that the flashes were caused by heavy cosmic-ray particles (carbon, nitrogen, oxygen) entering the eye. Laboratory experiments therefore simulated such cosmic rays by producing recoil carbon, nitrogen and oxygen nuclear fragments in the eye, initially exposing "dark adapted" people to a low-intensity neutron beam at energies going up to 640 MeV at the Berkeley cyclotron. Light flashes were observed.

Lower-energy experiments at the University of Washington, Seattle, cyclotron revealed a further source – slow-recoil protons and alpha particles, with an energy deposition greater than about 100 MeV per gram per cm$^2$. The frequency of the flashes with regard to the orientation of the head in the beam indicated that the eye is the site of the phenomena rather than something triggered directly in the brain itself.

The investigation moved back to the Berkeley cyclotron and attempted to obtain more quantitative data using a carefully controlled beam of 240 MeV helium ions. It was definitely established that the phenomena originated in the retina and an idea was obtained of the efficiency of the eye in detecting the particles (about 40% if the particles were coming at a rate of around 10 per second – falling off at lower and higher rates). This gives a very rough calibration on man as a detector of certain classes of cosmic rays.

The astronauts on the Apollo flights were seeing light flashes at a rate of one or two per minute. Calculations of the expected concentration of heavy cosmic rays (from carbon atoms up) give values of two to four per minute passing through an area equivalent to the retina of the human eye. Slow protons and helium ions could also be contributing, so that, within the very tentative estimates that can be made, the postulate of cosmic rays as the source of the astronauts' light flashes looks good.

● Compiled from texts on p248 (picture above right, p279, *CERN Courier* October 1971).



*On 24 August, a nitrogen-ion beam (250 MeV per nucleon) was used to stimulate visual phenomena in the scientifically skeptical eye of the Berkeley Laboratory director, E M McMillan, [seen here with light-flash investigators T F Budinger and C A Tobias]. With only 30 particles through the retina, McMillan had to confess to "a whole constellation". (Photo LBL.)*

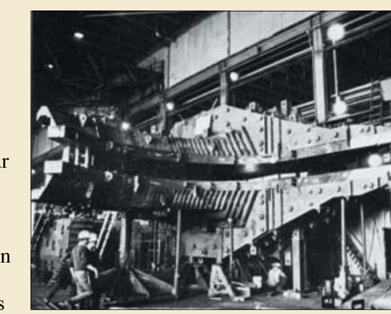
TRIUMF

## 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).

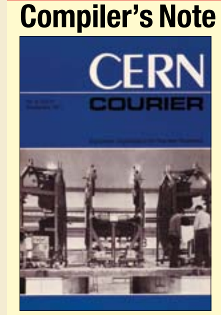
The TRIUMF cyclotron is scheduled to come into operation in 1973 and construction on almost all components is in line with the programme. Two of the large magnet sectors have arrived at the site and installation of the first of them in the machine vault has started. All six sectors should be delivered by the end of the year and be in place by June 1972.

● Compiled from texts on pp250–251.



*The first sector of the TRIUMF cyclotron magnet assembled at the manufacturer's (Davie Shipbuilding Limited, Quebec) prior to dispatch to the site at the University of British Columbia.*

### 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 (p21, current issue).

For the record, the massive 18-m-diameter, 4000-tonne TRIUMF cyclotron magnet produces a field of 0.46 T – too high for head-dipping, light-flash seekers? In fact, of all of the ways suggested to provoke this illuminating sensation, it is probably advisable for any enthusiastic reader to stay with pressure on the closed eye.

# 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 represent 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 do? 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 decommissioned 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 $10^5$ 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.

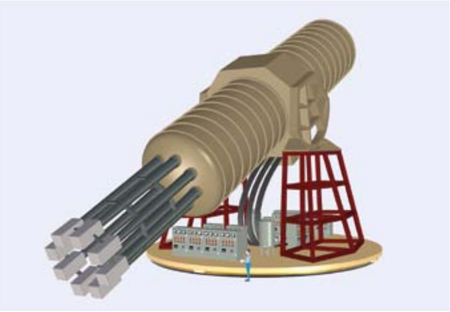


*Fig.1. Conceptual design of IAXO, showing the magnet cryostat, the eight telescope/detector systems, the flexible lines guiding services into the magnet, cryogenics and powering service units, and the inclination system and rotating platform. The size of the experiment can be gauged by comparison with the human figure. (Image credit: CERN.)*

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-m-diameter toroid assembled from eight coils, generating 2.5 T in eight bores of 600 mm diameter, thereby ▷

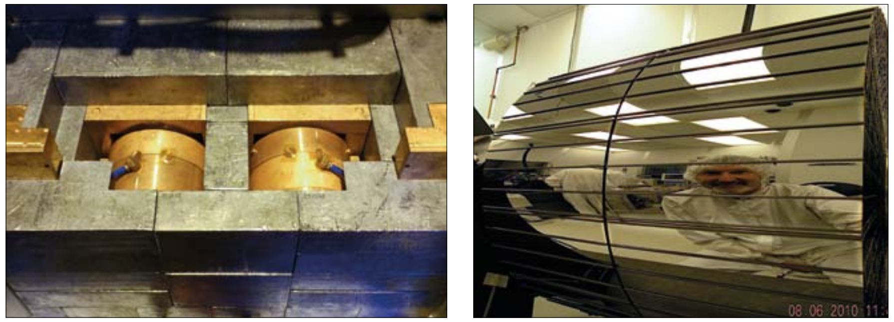


*Fig. 2. Left: Two lead- and copper-shielded, ultra-low background Micromegas X-ray detectors currently in use at CAST. Right: The NuSTAR X-ray telescope, with optics that are similar to that proposed for IAXO. (Image credits: U de Zaragoza/CAST and Todd Decker/LLNL, respectively.)*

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 aluminum – 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 "axion 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.

### Further reading

Conceptual Design of the International Axion Observatory (IAXO) 2014 *JINST* **9** T05002.

Letter of Intent to the CERN SPS Committee http://cds.cern.ch/record/1567109?ln=en.

### Résumé

*IAXO: l'Observatoire international des axions*

*Les particules hypothétiques appelées axions pourraient constituer un élément important de la matière noire. Le but de l'Observatoire international des axions proposé (IAXO) est de rechercher les axions avec un rapport signal-bruit $10^5$ fois meilleur que le Télescope solaire à axions du CERN (CAST), pionnier dans ce domaine. Cette amélioration n'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 toroïde 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.

Interview

# 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.

*Eleanor Blakely, talking at CERN on 60 years of particle therapy. (Image credit: Henry Barnard/CERN.)*

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. Excelling 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 Ducoff, a leading expert in radiation biology at the University of Illinois, Urbana-Champaign. Because she was fascinated by basic biological mechanisms, Ducoff 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 on murine skin and subsequent changes in blood electrolytes, which led to a Masters' degree in biophysics.

After gaining her PhD studying the natural radioresistance of cultured insect cells, Blakely joined the staff at Berkeley Lab in 1975, arriving soon after the Bevatron – the accelerator where the antiproton was discovered – had been linked up to the heavy-ion linear accelerator, the SuperHILAC. The combination, known as the Bevalac, could accelerate ions as heavy as uranium to high energies. Blakely joined the group led by Cornelius Tobias. His research included studies related to the effects of cosmic rays on the retina, for which he exposed his own eye to ion beams to confirm his explanation of why astronauts saw light flashes during space flight. "It was a spectacular beginning, seeing my boss getting his eye irradiated," Blakely recalls. For her own work, Tobias showed her a theoretical plot of the stopping power versus range for the different ion beams available at Berkeley. Her task was to work out which would be the best beam for cancer therapy. "I had no idea how much work that was going to be," she says, "and it is still not settled!"

Thirty years before Blakely arrived at Berkeley, Robert Wilson, later founding director of Fermilab, had been working there with Ernest Lawrence when he realized that because protons and heavier ions deposit most of their energy near the end of their range in matter – the famous "Bragg peak" – they offered the opportunity of treating deep-seated tumours while minimizing damage to surrounding tissue (*CERN Courier* December 2006 p17). Assigned the task of studying the biological effectiveness of a variety of particles and energies available from Berkeley's accelerators, Blakely irradiated dishes of human cell cultures, 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 Bragg 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 γ 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 ▷

## Interview

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 a desire 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 though 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.

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 p17 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 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. P20 Exploratory Planning Grants for a National Center for Particle Beam Radiation Therapy Research in the US are now pending. "Sadly this doesn't give us money to build a machine – legally the government isn't allowed to do that – but the P20 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 envies 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 p19). "Networking is really import 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 commençait 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/1742288.

CERN Courier September 2014
60 years of CERN

# CERN and UNESCO celebrate signing the CERN Convention

*The convention establishing CERN was signed by 12 states, subject to ratification, at the sixth session of Council, which took place in Paris on 29 June–1 July 1953. (Image credit: CERN-HI-5307006.)*


*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.)*

*Participants in the event at the French Academy of Sciences in a scene reminiscent of 61 years ago, except for the smartphones. (Image credit: CERN-PHOTO-201407-140 – 2.)*

## 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.

The commemoration ceremony, held in UNESCO's headquarters in Paris, was opened by Maciej 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, Rolf Heuer, director-general of CERN, and Agnieszka Zalewska, 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 panellist – Fernando Quevedo from Guatemala, now director of the Abdus Salam International Centre for Theoretical Physics (ICTP) – was particularly honoured to be part of the celebrations because his first postdoctoral work had been at CERN at a time when the laboratory had only just opened up to postdoctoral scientists from non-member states. The closing remarks came from Frédérick Bordry, CERN's director of accelerators and technology.

Following the ceremony at UNESCO, a complementary event took place at the French Academy of Sciences in Paris. In 1949, the Nobel laureate Louis de Broglie, then perpetual secretary for the academy, launched the idea for a nuclear-physics laboratory on a European scale. It was therefore appropriate that the event on 1 July was opened by Catherine Bréchignac, current perpetual secretary, followed by Catherine Cesarky, who is vice-president of CERN Council.

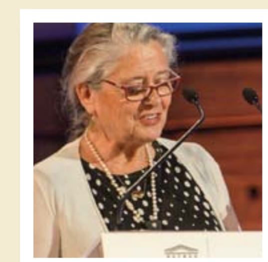
● For a recording of the CERN–UNESCO event, visit http://cds.cern.ch/record/1713023.

**Résumé**

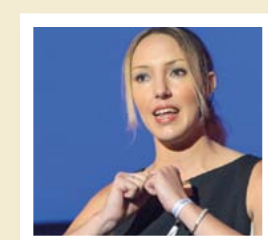
*Le CERN et l'UNESCO célèbrent la Convention du CERN*

*Le 1er juillet, le CERN et l'Organisation des Nations Unies pour l'Éducation, la Science et la Culture (UNESCO) ont commémoré au siège de l'UNESCO, à Paris, la signature de la Convention instituant le CERN. La cérémonie a eu lieu en présence des actuels Directeurs généraux de l'UNESCO et du CERN, ainsi que de la Présidente du Conseil du CERN. À cette occasion, une table ronde a été organisée sur le thème « La science au service de la paix ». Une autre manifestation a eu lieu le même jour à l'Académie des Sciences.*

*Speeches at the ceremony at the UNESCO headquarters in Paris included that of Agnieszka Zalewska, president of CERN Council. (Image credit: CERN-PHOTO-201407-133 – 49.)*



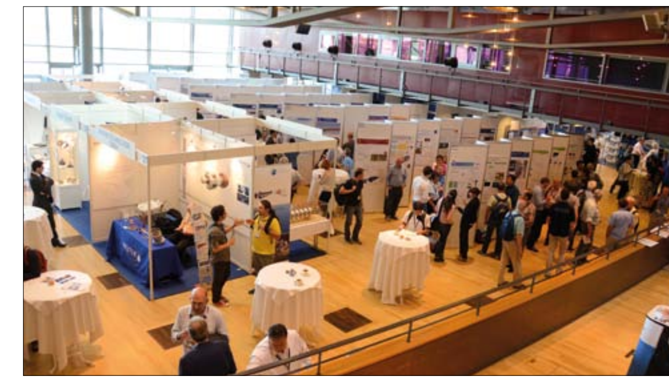
*A hommage to François de Rose, a founding father of CERN who passed away earlier this year (*CERN Courier *May 2014 p24), was given by his daughter Laurence Rousselot. (Image credit: CERN-PHOTO-201407-133 – 58.)*



*ATLAS physicist Claire Lee, from South Africa, gave a passionate speech on how CERN is seen by a young person. (Image credit: CERN-PHOTO-201407-133 – 71.)*

# Accelerators come into focus in Dresden

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



*Dresden's International Congress Centre provided plenty of space for industrial exhibitors and poster sessions at IPAC'14. (Image credit: T Pritchard.)*

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 ($Nb_3Sn$) 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 $Nb_3Sn$ 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 efficiencies in the experiments. Design and construction are well ▷

## 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.

Altogether there were 46 invited talks and 51 contributed oral presentations, and 1300 posters were scheduled during lively dedicated sessions at the end of each afternoon. A special student 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 Eléonore Roussel of PhLAM/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). Agostino Marinelli of SLAC, Tsumoru Shintake of Okinawa Institute of Science and Technology Graduate University 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 work of the dynamic team and the careful preparations and guidance of Christine Petit-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 assistance of Volker Schaa of GSI and chair of 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 University 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 are also space-charge effects to overcome.

In particle physics, Fermilab aims to double the beam power of the Main Injector by using the Recycler to slip-stack protons during

*Catarina Biscari, second left, chaired the awards session and presented prizes to, left to right, Juan Esteban Müller, Agostino Marinelli, Mikael Eriksson and Tsumoru Shintake. (Image credit: IPAC'14.)*

the ramp to reach 700 kW at 120 GeV. With 460 kW expected by the end of 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.

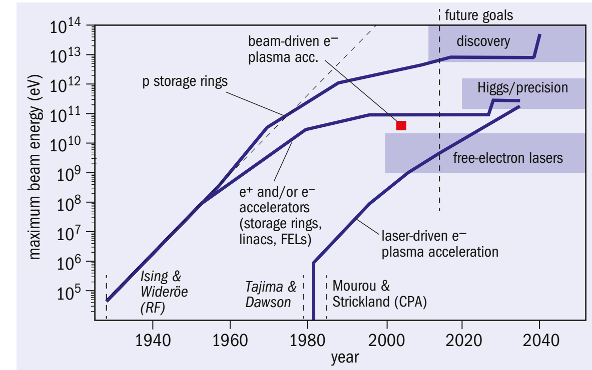
High intensities, as with high energies, come at a price, and the design options have to balance the cost against technical risk. The European Spallation Source is designed as an intense source of neutrons provided by 5 MW of average proton beam power on the spallation target, with a peak of 125 MW for 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 costs down, 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 increasingly 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 community. 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 structures and ultra-high brightness by reducing the beam emittance down to the so-called diffraction limit. For storage rings this presents







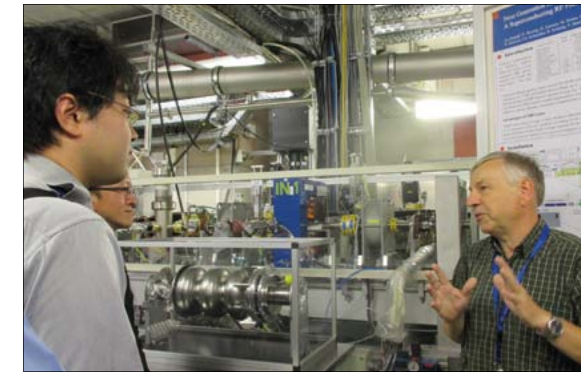

*The Livingston plot for various types of RF-based particle accelerator, with the recent impressive increase in plasma acceleration shown to the right. (Image credit: R Assmann.)*

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-IV in Lund, which is the first to use a highly 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 kilometre of the existing tunnel, based on superconducting RF cavities with a nitrogen-doping surface layer to enable the required, unprecedented performance. A new undulator will receive electrons 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.

A more specialized area for the application of accelerator technology is 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 technologies 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 pilot for a standard carbon-ion radiotherapy facility at Gunma University,



*Participants were offered a choice of technical tours, which included the ELBE high-power radiation source at HZDR. (Image credit: C Sutton.)*

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 3D 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 ongoing 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 accelerators. Another future market could be for electron linacs to provide radiation with photon energy up to 10 MeV for cargo and vehicle inspection. In addition, the traditional industrial exhibition, which took place during the first three days of the conference, attracted exhibitors from 93 companies who occupied 100 booths – the highest number for IPAC to date – to present their high-technology products and services to the delegates.

For many years, the measure of progress for accelerators has been the Livingston curve, but the straight line of the first 50 years has flattened out since the 1980s. One hope, following its proposal in 1979, has been to harness the high electric-field gradients that can be created in plasmas, and here a parallel almost-straight line is emerging on the Livingston plot (see figure above). The technique relies on high-power pulsed lasers or short electron bunches to excite ultra-strong wakefields in plasmas (*CERN Courier* November 2013 p17). Experiments have produced accelerating gradients from 10 GV/m up to 100 GV/m, and an absolute energy gain for electron beams of up to more than 40 GeV. However, ▷

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 the drive to higher energies. Projects such as the FCC with which the conference started are 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 Dresde*

*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 Dresde, 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 brillance 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.




# Faces & Places

PRIZES

## EPS honours ALICE's heavy-ion researchers




*The winners of the 2014 Lise Meitner Prize. Left to right: Johanna Stachel, Peter Braun-Munzinger, Paolo Giubellino and Jürgen Schukraft. (Image credits: A Saba/ALIC and, 2nd from right, CERN-GE-1210203-03.)*

The European Physical Society (EPS), through its Nuclear Physics Division, has awarded the 2014 Lise Meitner Prize jointly to Johanna Stachel of the Physikalisches Institut der Universität Heidelberg, Peter Braun-Munzinger of GSI, Paolo Giubellino of INFN Torino and CERN, and Jürgen Schukraft of CERN. They are rewarded "for their outstanding contributions to the experimental exploration of the quark–gluon plasma using ultra-relativistic nucleus–nucleus collisions, in particular to the design and construction of ALICE and shaping its physics programme and scientific results, bringing to light unique and unexpected features of a deconfined state of strongly interacting matter at the highest temperatures ever produced in the laboratory". The prize is given every two years for outstanding work in the fields of experimental, theoretical or applied nuclear science.

Quark–gluon plasma is the state of deconfined and thermalized QCD matter at high temperature. It is a fundamentally new state of matter that most likely permeated the early universe after the electroweak phase transition. Its study bridges nuclear and particle physics, with connections to astrophysics and cosmology. The first period of LHC data-taking brought to light unique and unexpected features of such a deconfined state of strongly interacting matter at the highest temperatures ever produced in the laboratory. Striking highlights of results from ALICE include the bulk production of charmonium exhibiting novel mechanisms of hadronization; jet quenching, with an unexpected momentum dependence of the production of identified particles at high momentum; substantial heavy-quark energy loss, as seen via the topological reconstruction of charmed D mesons; and the production of antimatter and antihypernuclei. The field of lattice QCD has also benefitted strongly from these new and exciting results.

APPOINTMENTS

## Lykken and Meyer join Fermilab management

The beginning of July brought changes at the top of Fermilab's management, with a new deputy director and chief operating officer beginning their terms. Joe Lykken, a theoretical physicist at Fermilab, became the laboratory's newest deputy director on 1 July, filling a position that had been vacant since the arrival of the current director, Nigel Lockyer, in September 2013. Also on 1 July, Tim Meyer, previously of the Canadian national laboratory TRIUMF, assumed the role of Fermilab's chief operating officer.


*Joe Lykken, far left, and Tim Meyer join Fermilab's management. (Image credit: Fermilab Visual Media Services.)*

As deputy director, Lykken will work to implement the recommendations of the US Particle Physics Project Prioritization Panel (*CERN Courier* July/August 2014 p12), with a focus on establishing and strengthening Fermilab's international partnerships and communicating the laboratory's scientific vision and programme with stakeholders. Having joined Fermilab in 1989, he will continue to serve as a member of the Theory Group. He is also active on the CMS experiment at CERN's LHC, both in searches for supersymmetry and measuring properties of the Higgs boson.

Before coming to Fermilab, Meyer was head of strategic planning and communication at TRIUMF for seven years. In addition, he served as an expert in science and public policy at the US National Academies in Washington, DC, and as a senior programme officer for their Board on Physics and Astronomy.

# Chattopadhyay returns to new challenges in the US

*Swapan Chattopadhyay – moving from the UK to Illinois. (Image credit: J Chattopadhyay.)*

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 fulfil its part of the P5 vision for the future of particle physics (*CERN Courier* July/August 2014 p12).

CO-OPERATION

# 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 Lucio Rossi presiding for the last time. Rossi has handed the baton to colleague Miguel Jimenez, head of CERN's Technology Department, and will now concentrate on a different challenge – the 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).

*From left to right: Neil Mitchell (ITER Magnet Division Leader), Lucio Rossi (CERN), Miguel Jimenez (CERN) and Arnaud Devred (ITER Superconductor & Feeder Section Leader). (Image credit: ITER/Sabina Griffith.)*



*About 140 physicists met in Orsay and Paris at the 5th Higgs Hunting Workshop held on 21–23 July, to discuss the developments of ongoing analyses and detailed studies of the boson discovered two years ago by ATLAS and CMS, as well as possible deviations from the properties predicted by the Standard Model. Searches for additional bosons, prospects with future accelerators and recent theoretical developments were also covered. Among those attending were four pioneers in the development of the Standard Model and discovery of the new boson. From left to right, Jim Virdee, Jean Iliopoulos, Tom Kibble and Luciano Maiani. (Image credit: L Fayard.)*

INDUSTRY

# CERN supports new business incubation centre in the Netherlands


*CERN's director-general, Rolf Heuer, left, with Nikhef's director Frank Linde. (Image credit: Hanne Nijhuis/Nikhef.)*

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, cooling technology 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.

60 YEARS/ANS CERN

*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.)*

CONFERENCE

# Half a century of Bell's theorem

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 experimentally – 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 the theorem that no one talks or even thinks about yet, and so is still to discover.

*John Bell. (Image credit: Renate Bertlmann.)*

**● 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-physik-fb-chemie/austrian_central_physics_library.html.

J S Bell 1964 *Physics* **1** 195.

MEETING

The **Dark Matter at the Large Hadron Collider (DM@LHC)** workshop will take place at Merton College, Oxford, on 25–27 September. The aim is to develop further simplified models and effective-field-theory approaches to dark matter, taking stock of the final results of the 8 TeV LHC run, and to prepare for the next phase of data taking at higher energies. There will be particular emphasis on exploring new dark-matter signals and on more sophisticated techniques to improve the existing searches. It is a discussion-oriented workshop featuring short talks by theorists and experimentalists working actively on LHC signals of dark matter. For further information, visit http://indico.cern.ch/e/DM-LHC2014.

CERN Courier September 2014

Faces & Places

LHC EXPERIMENTS

# MoEDAL prepares for new physics at LHC restart

*Participants at MoEDAL's second collaboration meeting held at CERN in June. (Image credit: Richard Soluk.)*

The MoEDAL (Monopole and Exotics Detector at the LHC) collaboration – which now consists of 64 physicists from 21 institutes worldwide – held its second CERN-based collaboration meeting on 19–21 June. There were many new collaborators at the meeting, from Canada, Finland, Italy, Korea and the UK. Notably, the most recent addition to the MoEDAL collaboration – the Langton Star Centre based at the Simon Langton Grammar School for Boys in the UK – was represented by Becky Parker and Tom Whyntie. A high school as a collaborating institute in a high-energy-physics experiment is surely a world first.

The meeting had two main themes: first, the installation of the full detector system around the LHCb experiment's relatively open interaction point; second, the exploitation of the extensive and potentially revolutionary fundamental-physics reach of the experiment. MoEDAL's purpose is the search for highly ionizing particle avatars of new physics, such as the magnetic monopole and massive (pseudo)-stable charged particles. In this way, it expands the discovery horizon of the LHC in a complementary way. Unlike other LHC detectors, MoEDAL is largely passive, except for its system of TimePix pixel devices (TMPX) for real-time radiation monitoring. It has a dual nature, capable both of "photographing" signals for new physics via its nuclear-track detector system (NDT) and of capturing highly ionizing particles in its magnetic monopole trapper (MMT) volumes. Importantly, it is the only LHC detector that can trap and detect magnetic and electric charge.

The first day of the collaboration meeting concentrated on physics issues. Nick Mavromatos of King's College London, the physics co-ordinator, set the scene with a review of the MoEDAL experiment and its aims. The first invited speaker was Yongmin Cho from Konkuk University, who was the first to show that there is a singular topological monopole solution of the Weinberg–Salam model – an "electroweak" monopole. Next, Philippe Mermod of the University of Geneva reminded participants that the hunt for cosmic monopoles is a vital complementary aspect of the search for magnetic charge.

The final talk of the first day introduced a poignant note to the proceedings, as Laura Patrizii from INFN Bologna spoke of the seminal contributions that Giorgio Giacomelli made to the quest for the magnetic monopole. Giacomelli, who was MoEDAL's deputy spokesperson, died early in 2014 (*CERN Courier* June 2014 p45). He was remembered not only as a leading experimental particle physicist but also as a great human being. As a token of respect, the collaboration dedicated its recent paper on MoEDAL's physics programme to his memory.

The second day was devoted to detector issues and to how the data will be gathered and analysed. Vasliki Mitsou of the University of Valencia started the day with a report from the MoEDAL software group, which has the important task of understanding how the detector will respond to the highly ionizing particles of various new-physics scenarios. MoEDAL's technical co-ordinator, Richard Soluk of the University of Alberta, then described the plans for the detector installation. The main challenge here is the need to co-ordinate with the LHCb collaboration, which shares the same intersection region.

The next order of business concerned the reports from the sub-detector groups: Mermod for the MMT, Petr Beneš of the Czech Technical University for the TMPX, and Vincent Togo of INFN Bologna for the NTD. A member of the University of Münster's MoEDAL group gave the last presentation of the day, before the attendees went to visit the experiment site. He described the development of an exciting new computer-controlled ultra-fast scanning microscope for analysis of the NTDs.

At the end of the three-day meeting, the mood of the collaboration was buoyant and optimistic. Although there are challenges to face, there are no show-stoppers. The MoEDAL experiment is well on its way to meeting the discovery challenge of its first data run at the next high-energy frontier of 13 TeV, which will open up in the spring of 2015.

CORRECTION

The first name of physicist Bernard Bonnier was unfortunately missing in the recently published obituary of Robert Vin Mau (*CERN Courier* July/August 2014 p42). Many apologies to all concerned.

## Visits

The Georgian minister of education and science, **Tamar Sanikidze**, centre right, visited CERN on 4 June. Before seeing the CMS experimental cavern with deputy spokesperson of the CMS collaboration **Kerstin Borras**, right, she was shown a scale model of the detector. (Image credit: CERN-PHOTO-201406-120 – 17.)

On 6 June, **Ying-tai Lung**, Taiwanese minister of culture, centre, witnessed an "Accelerate@CERN" agreement between Taiwan and CERN, signed by the director of the Taiwan Cultural Centre in Paris, **Hsiao-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.)

**K Kellie Leitch**, centre right, Canadian minister of labour and minister of status of women, came to CERN on 10 June, visiting the ATLAS underground experimental area, in the company of ATLAS collaboration spokesperson, **Dave Charlton**, right. (Image credit: CERN-PHOTO-201406-123 – 7.)

During a visit to CERN on 11 June, **Seán Sherlock**, Irish minister of state, Department of Enterprise, Jobs & Innovation and Department of Education & Skills with responsibility for research and innovation in Ireland, left, was shown the LHC tunnel by CERN's director of accelerators and technology **Frédérick Bordry**, right (Image credit: CERN-PHOTO-201406-126 – 47.)

Right to left: Japanese vice-minister of education, culture, sports, science and technology **Tsutomu Tomioka**, in the LHC tunnel during his visit to CERN on 2 July, where he saw the inner triplet magnets constructed by KEK in Japan and Fermilab in the US, accompanied by ATLAS physicists **Katsuo Tokushuku** and **Tatsuo Kawamoto**, and **Yuko Nagano**, Japan's Strategic Programs Division. (Image credit: CERN-PHOTO-201407-139 – 5.)





## Obituaries

# 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 1953 and 1956, respectively, her thesis being on π-mesic atoms, under Gregor Wenzel. An MA from the University of Oxford followed in 1967.

She began her career as a research fellow in Rudolf Peierls'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 1961. 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 Byers in her office at home in 2008. (Image credit: Maggie Michaelson.)*

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 Jr until his death, Nina is survived by her step-children Gretchen, Merimee, Anthony and Anne, 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 the 1960s Bob Sachs invited Tom to become director of the High Energy Physics Division, and a big challenge at that time was to assemble a team, led by Gale Pewitt, to construct the 12-foot hydrogen bubble chamber.

*Tom Fields on the occasion of the 50th anniversary of the Argonne High Energy Physics Division and his 80th birthday. (Image credit: ANL.)*

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 a 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

Advance Photon Source project.

When Tom tried to retire, Fermilab's director John Peoples asked him to become project manager for the MINOS long-baseline neutrino project, using a new neutrino beam from Fermilab and a large iron calorimeter at the Soudan mine. He continued working on many aspects of the MINOS experiment, helping to parameterize the seasonal behaviour of cosmic rays in a paper that was published the week of his death. Tom's calm demeanour, keen insights and tireless drive will be missed by all of his friends and colleagues.

● *Maury Goodman, ANL.*

# Willem Cornelis Middelkoop 1933–2014

Former division leader at CERN, Wim Middelkoop died on 20 May in his 82nd year.

After graduating from the Technical University of Delft in 1955, Wim spent two years as an officer (2nd lieutenant) in the Royal Netherlands Air Force. He joined CERN as a fellow in the Synchrocyclotron (SC) Division in 1957, becoming a staff member in 1960, and completing a PhD on elastic scattering at the SC in 1962.

He entered the accelerator sector in 1963 when he moved to the Accelerator Research Division to replace Bas de Raad, who was on sabbatical at Stanford. The division's main research activity was around the CERN Electron Storage and Accumulator Ring (CESAR), on which the technique of stacking and accumulating particles was verified – an essential precursor of the Intersecting Storage Rings (ISR). Following approval of the ISR in 1966, Wim moved to the newly formed Beam Transfer Group, where he became responsible for the fast pulsed magnets and the beam dumps.

He joined de Raad on the 300 GeV project – the construction of the Super Proton Synchrotron (SPS) and its experimental areas – in 1971. Following his experience at the ISR, he was responsible for the design and construction of all of the fast-pulsed magnets, septa and beam dumps. From 1983 to 1988 he was deputy division leader of the SPS Division, which evolved from the 300 GeV laboratory.

*Wim Middelkoop. (Image credit: Middelkoop family.)*

In 1988, he moved into the area of administration, becoming chairman of the governing board of the pension fund. He was appointed division leader of the Personnel Division in 1991, where one of his major tasks was a complete overhaul of the staff rules and regulations, and of the grade structure.

From 1996 until his retirement in 1998, Wim joined the Office of the LHC Project Leader, where he was responsible for all technical specifications, protocols and collaboration agreements. As chairman of the Specification Committee, he processed every technical specification in the LHC project. His meticulous attention to detail was invaluable. One of his heroic efforts was the circumnavigation of the world in four days, negotiating contracts for superconducting cable in the US and Japan.

After retiring, he continued to work as industrial liaison officer for the German delegation. As usual, he performed his task meticulously, but this time on the other side of the table from CERN management. He was awarded the German Bundesverdienstkreuz (Order of Merit of the Federal Republic of Germany) in 2006.

Wim was a faithful servant of CERN throughout his career. He always applied himself to the problem at hand with his full energy, whether it was technical work or administration. It was a privilege to have worked with him. He will be remembered for his tireless devotion to CERN. He is survived by his widow, two daughters and three sons.

● *Lyn Evans, CERN/Imperial College London.*

# 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 P, C, T and CP. This 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 set of neutron detectors that were used to study charge-symmetric reactions around the Δ. At Saclay, his research group studied decay modes of the η meson, and at ELSA in Bonn he worked on the photoproduction of the η near threshold.

*Ben Nefkens. (Image credit: UCLA Physics Department.)*

One of Ben's greatest achievements was refurbishing the famous Crystal Ball detector that was used at SLAC and HERA. He took the "ball" to Brookhaven National Laboratory to use at the Alternating Gradient Synchrotron until the fixed-target programme 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.

Ben held visiting appointments at Saclay (1978–1979 and 1988–1989) and CERN (1972–1973). He was a member of the CELSIUS/WASA project at 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 Nucleon Physics (MENU).

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.

Besides physics, he was interested in music and the arts. He gave wonderful colloquia on symmetries in nature, art and music. Above all, Ben loved his family and, as he would say to his collaborators, "I highly recommend playing with grandchildren."

● *William J Briscoe, The George Washington University, John W Price, California State University, Dominguez Hills and Willem T H van Oers, University of Manitoba.*

## New products

**Aerotech** has announced the MPS75SLE – a compact, precision ball-screw stage with linear encoder that provides a positioning resolution capability to 25 nm. The low thermal expansion (3.3 ppm/°C) encoder results in high accuracy and repeatable positioning. Motor options include a DC servomotor with a high-resolution rotary encoder or a stepper motor. For more information contact Steve McLane, tel +1 412 967 6854, e-mail smclane@aerotech.com, or visit www.aerotech.com/product-catalog/stages/linear-stages/mps75sle.aspx.

**Intersil Corporation** has announced the expansion of its line of rad-hard voltage references to include four new devices – the ISL71091SEH10, 20, 33 and 40. Providing voltages previously unavailable for the rad-hard space market, the new family enables better overall accuracy for 11-bit and 12-bit ADC resolution applications. The devices are offered in the smallest surface-mount leaded package available. For further details, visit www.intersil.com/en/products/space-and-harsh-environment/rad-hard-products/isl71091-voltage-reference-family.html. Intersil has also announced the ISL2802x family of digital power monitors, capable of supporting a wide common-mode input-voltage range of 0–60 V. The ISL2802x family delivers accurate measurements through an integrated 16-bit native-resolution sigma-delta ADC (gain error = ±0.05% Typ), providing designers with a high safety margin. In addition, the wide specified temperature range from –40 °C to 125 °C offers greater design flexibility. Visit http://go.intersil.com/digital-power-monitor.html.

**Narda Safety Test Solutions** has introduced the IDA 2, a second-generation interference and direction analyser in a hand-held device weighing only 3 kg. The device also offers a persistence spectrum display, which simultaneously shows changing useful signals and the underlying interference signals, and captures with a usable bandwidth of up to 22 MHz. For more information, tel +49 7121/97 32 0, e-mail info.narda-de@L-3com.com or visit www.narda-sts.com.

**Optical Surfaces Ltd** has introduced new smaller-diameter (25–60 mm) reflective beam expanders for space-restricted applications such as with high-power lasers and multi-wavelength interferometry. These aspheric mirror-based devices offer beam expansion or reduction capabilities, and are available in standard (2.5×, 5× and 10× fixed magnification) or customer-specified (fixed or variable magnification) configurations. For more information, tel +44 208 668 6126 or e-mail sales@optisurf.com.

**Physik Instrumente (PI)** has introduced two new, vacuum-compatible versions of its compact N-470 PiezoMike precision screw-type actuator family. Providing a positional resolution of 20 nm and travel ranges between ¼" and 1", the actuators are now available for ambient applications and also in high-vacuum (HV, $10^{-6}$ Torr) and ultra-high-vacuum (UHV, $10^{-9}$ Torr) configurations. PI has also announced a new six-axis positioning system with 1000 lbs load capacity. The H-850KMLD hexapod system provides 1-µm minimum incremental motion across a 100-mm travel range in XY and 0.5 µm in the Z direction. The repeatability in the three linear axes is ±1 µm, and ±5 µrad/9 µrad in the rotary axes. For further information, visit http://www.physikinstrumente.com.

**RST** is offering its new pressure-equalization calculator, which is based on a physical mathematical formula, to provide extra support for its products. The online tool allows easy determination of the precise airflow needed to keep a particular system functioning. It therefore provides the right pressure-equalization solution for an application to minimize the generation of harmful condensate, for example, in electronics housings. The tool is available free of charge at www.ventcalculator.com.

**Teledyne LeCroy** has launched the WaveSurfer 3000 series of mid-range oscilloscopes. The series offers 200 MHz, 350 MHz and 500 MHz bandwidths; up to 4 GS/s sample rate; and fast waveform update, with up to 130 k wfms/s. The instruments also feature a 10.1" touch-screen display, 16 digital channels with 500 MS/s sample rate and a WaveSource Function Generator. For further details, tel +44 1793 784389 or e-mail sales@ppm.co.uk.

**XP Power** has extended its GCS series of open-frame AC-DC supplies up to 250 W. Certified to both industrial and medical international safety standards, and comprising 150, 180 and now 250 W models, the GCS series is available in multiple mechanical formats – in an industry standard 3 × 5" (127 × 76.2 mm) open-frame package; an enclosed covered version; and top- or end-mounted fan-cover options. For further information, contact Markus Zemp, tel +41 56 448 90 80, e-mail mzemp@xppower.com, or visit www.xppower.com/.

*Les physiciens des particules du monde entier sont invités à apporter leurs contributions aux CERN Courier, en français ou en anglais. Les articles retenus seront publiés dans la langue d'origine. Si vous souhaitez proposer un article, faites part de vos suggestions à la rédaction à l'adresse cern.courier@cern.ch.*

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Argonne NATIONAL LABORATORY

## 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 1940's.

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 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 could 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-job. Correspondence and supporting letters of recommendation should be submitted to Named-Postdoc@anl.gov.

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

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INDIANA UNIVERSITY

## Post-Doctoral Position
## High Energy Neutrino Physics
## 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 LBNE. The successful applicant will be expected to contribute to these efforts.

The position is available for a near term start date. The successful candidate will have a Ph.D. 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/902**. Questions regarding the position or application process can be directed to Professor Jim Musser Indiana University Physics 727 E. 3rd St. Swain West 117 Bloomington, IN 47405, 812-855-1247 or **jmusser@indiana.edu**.

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

*Indiana University is an Equal Opportunity/Affirmative Action Employer, and encourages applications from women and members of minority groups.*

## PhD Scholarships in Portugal

PD F FCT PhD PROGRAMMES

The MAP-fis Physics Doctoral Program, a joint initiative of three major Portuguese Universities, Minho, Aveiro and Porto, is announcing 8 first year PhD scholarships for the 2014-2015 edition. Recognized as program of excellence by Portugal's National Science Foundation (FCT), MAP-fis joins three Physics Departments and 6 research centers. Fellowships include a monthly stipend and tuition fees.

MAP-fis constitutes a unified effort to prepare highly qualified human resources in Physics and an effort to strengthen research in this area in these universities. It is supported by an academic staff of about **130 faculty members**, and a total of **280 PhD researchers** working in **6 Research Centers**.

These centers have impressive state-of-the art computing and laboratory facilities occupying 7000 m²; In the 2008-13 period, they ran projects in the amount of **19 M€**, of which **7.6 M€** from international sources.

MAP-fis welcomes collaborations with other institutions and has already awarded several joint PhD's with foreign Universities. It covers all areas of Physics, both fundamental and applied, in particular:

- **Atomic and Molecular Physics;**
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- **Optics, Lasers and Photonics;**
- **Computational Physics;**
- **Meteorology and Oceanography.**

For more information, and to apply, see the MAP-fis site http://www.map.edu.pt/fis/

**Applications are opened until September 15, 2014.**



Argonne NATIONAL LABORATORY

## DIRECTOR, HIGH ENERGY PHYSICS DIVISION
## ARGONNE NATIONAL LABORATORY

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 in the field of particle physics. For a description of Divisional programs, please visit HEP's Home Page at **http://www.hep.anl.gov**.

Argonne offers an excellent compensation and benefits package. For full consideration, please apply by September 30, 2014 at **www.anl.gov/careers** to **Requisition 322438**. Interested candidates should include curriculum vitae, list of publications, awards, patents, and a salary history as well as arrange for at least 4 professional references to be sent by email to pse-ald@anl.gov.

Argonne National Laboratory is a multi-program laboratory managed by UChicago Argonne, LLC for the U.S. Department of Energy's Office of Science. We are an equal opportunity employer and value diversity in our workforce. Argonne's site is located about 25 miles southwest of Chicago on a beautiful 1500 acre campus. For additional information, please refer to Argonne's Home Page at **http://www.anl.gov**.

IFAE — EXCELENCIA SEVERO OCHOA

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

**CALL FOR APPLICATIONS: DIRECTOR OF IFAE**

The Institute of High Energy Physics (IFAE), **www.ifae.es/eng** is a consortium of the Universitat Autònoma de Barcelona and the Generalitat of Catalonia. IFAE is part of the Catalan public network of research Institutes, CERCA (**www.cerca.cat**).

IFAE conducts experimental and theoretical research at the frontier 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 Imatek.

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**

IFAE 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 IFAE's field(s) of activity and significant research management experience are required. Salary will be commensurate with qualifications and consistent with IFAE 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 be offered 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 cover letter by e-mail to the Director of CERCA, at **applications@cerca.cat**, citing as the subject "IFAE Director call".

*The deadline for applications is October 10, 2014.*

WESTFÄLISCHE WILHELMS-UNIVERSITÄT MÜNSTER

The Institute for Nuclear Physics at the Westfälische Wilhelms-University Münster invites applications for a tenured

## Professorship in Experimental Physics (Salary scale W2)

*starting in October 2015.*

Candidates are expected to have a strong track record in the fields of Neutrino or Astroparticle Physics or in precision experiments in Physics Beyond the Standard Model. The candidate's range of activities should strengthen and extend existing activities at the Institute for Nuclear Physics. Close co-operation is expected with the theoretical and experimental groups, especially within coordinated programs. Teaching obligations are in the area of Experimental Physics and Nuclear, Particle and Astroparticle Physics. Candidates are also expected to participate in the academic administration of the department.

Prerequisite for the application are a PhD and outstanding teaching skills, as well as academic achievements made as a Junior professor (assistant professor), in a Habilitation (postdoctoral qualification), as a member of the academic staff of a university or non-university research institute, or in a research position in business, industry, administration or other relevant fields.

The University of Münster is an equal opportunity employer and is committed to increasing the proportion of senior women academics. Consequently, we actively encourage applications by women. Female candidates with equivalent qualifications and academic achievements will be preferentially considered within the framework of the legal possibilities. We also welcome applications from candidates with severe disabilities. Disabled candidates with equivalent qualifications will be preferentially considered.

Applications with a CV, including teaching experience and publication list, copies of degree certificates, and a statement of research interests shall be submitted in written form until **September 30, 2014** to the

**Dean of Physics**
**Herrn Prof. Dr. Markus Donath**
**Wilhelm-Klemm-Str. 9 – 48149 Münster - Germany**

NATIONAL TAIWAN UNIVERSITY
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For more information about LeCosPA, please visit its website at http://lecospa.ntu.edu.tw/

Three letters of recommendation should be addressed to
**Prof. Pisin Chen, Director**
**Leung Center for Cosmology and Particle Astrophysics**
**National Taiwan University**

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DESY

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### Requirements

- Ph.D. completed within the last 4 years
- Experience in experimental particle physics

DESY-Fellowships are awarded for a duration of 2 years with the possibility of prolongation by one additional year.

Please submit your application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degrees) to the DESY human resources department. Please arrange for three letters of reference to be sent before the application deadline to the DESY human resource department.

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

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Human Resources Department | Code: EM100/2014
Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-3392 |
E-Mail: recruitment@desy.de
**Deadline for applications: 30 September 2014**
**www.desy.de**

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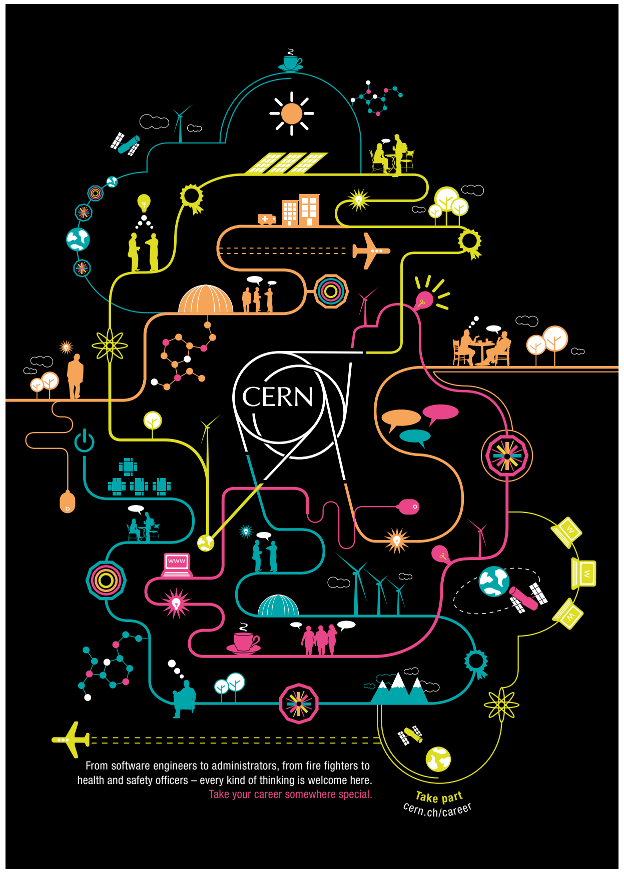


The Cockcroft Institute of Accelerator Science and Technology

**The Universities of Liverpool, Lancaster and Manchester**
**The Cockcroft Institute**

## Director

**Salary Negotiable**

The Cockcroft Institute (http://www.cockcroft.ac.uk/) is a unique international centre specifically responsible for research and development in particle accelerators, colliders and light sources for advancing the frontier of particle and nuclear physics, photon sciences and various applications to society in the areas of health, medicine, energy and security. The Institute is a partnership between the Universities of Liverpool, Manchester and Lancaster and the Science and Technology Facilities Council.

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The post is available from 1 January 2015 or as soon as possible thereafter.

**Job Ref: A-565563/CC** **Closing Date: 1 September 2014**

For full details, or to request an application pack, visit www.liv.ac.uk/working/job_vacancies/ or e-mail jobs@liv.ac.uk
Please quote job ref in all enquiries.

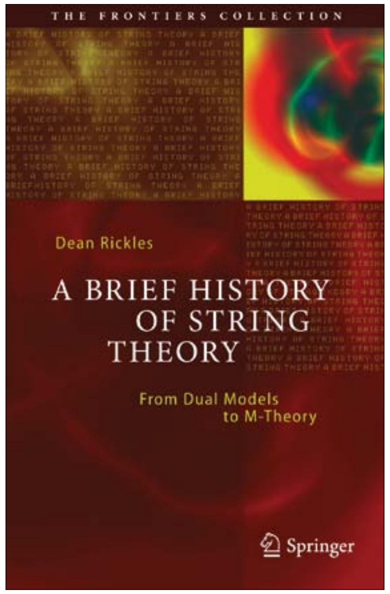
COMMITTED TO DIVERSITY AND EQUALITY OF OPPORTUNITY

Stonewall DIVERSITY CHAMPION

# Bookshelf

## A Brief History of String Theory: From Dual Models to M-Theory

*By Dean Rickles*
**Springer**
Hardback: £35.99 €32.12 $49.99
E-book: £27.99 €42.79 $39.99
Also available at the CERN bookshop




String theory provides a theoretical framework for unifying particle physics and gravity that is also consistent at the quantum level. 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 ingenious 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 reader obtains a good impression of how it took many years of collective effort and struggle to develop the theory and understand it better, often incrementally, although sometimes the direction of research changed drastically in a serendipitous manner. For example, at some point there was an unexpected shift of interpretation, namely in terms of gravity rather than hadron physics. Supersymmetry was discovered along the way as well, demonstrating that string theory has been the source and inspiration of many ideas in particle physics, gravity and related fields.

The main strength of the book is the extensively and carefully researched history of string theory, rather than profound explanations of the physics (for which enough books are available). It is full of anecdotes, quotations of physicists at the time, and historical facts, to an extent that makes it unique. Despite the author's avoidance of technicalities, the book seems to be more suitable for people educated in particle physics, and less suitable for philosophers, historians and other non-experts.

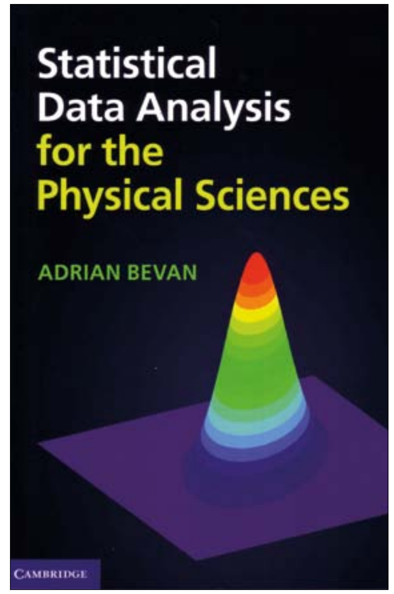
One caveat, however: the history covered in the book more or less stops at around the mid-1990s, and as the author emphasizes, the subject becomes much harder to describe after that, without going into the details more deeply. While some of the new and important developments are mentioned briefly in the last chapter – for example, the gauge/gravity correspondence – they do not get the attention that they deserve in relation to older parts of the history. In other words, while the history has been quite accurately presented until the mid-1990s, the significance of some of its earlier parts is rather overrated in comparison with more recent developments.

In summary, this is a worthwhile and enjoyable book, full of 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 colleagues entering research in string theory.

● *Wolfgang Lerche, CERN.*

## Statistical Data Analysis for the Physical Sciences

*By Adrian Bevan*
**Cambridge University Press**
Hardback: £40 $75
Paperback: £18.99 $31.99
E-book: $26
Also available at the CERN bookshop




The numerous foundational errors and misunderstandings in this book make it inappropriate for use by students or research physicists at any level. There is space here to indicate only a few of the more serious problems.

The fundamental concepts – probability, probability density function (PDF) and likelihood function – are confused throughout. Likelihood is defined as being "proportional to probability", and both are confused with a PDF in section 3.8(6). Exercise 3.11 invites the reader to "re-express the PDF as a likelihood function", which is absurd because the two are functions of different kinds of arguments.

Probability and probability density are confused most notably in section 5.5 ($\chi^2$ distribution), where the "probability of $\chi^2$" is given as the value of the PDF instead of its integral from $\chi^2$ to infinity. (The latter quantity is in fact the p value, which is introduced later in section 8.2, but is needed here already.) The student who evaluates the PDFs labelled $P(\chi^2, \nu)$ in figure 5.6 to do exercises 5.10 to 5.12 will get the wrong answers, but the numbers given in table E11 – miraculously – are correct p values. Fortunately the formulas in the book were not used for the tables.

From the beginning there is confusion about what is Bayesian and what is not. Bayesian probability is defined correctly as a degree of belief, but Bayes's theorem is introduced in the section entitled "Bayesian probability", even though it can be used equally well in frequentist statistics, and in fact nearly all of the examples use frequentist probabilities. The different factors in Bayes's theorem are given Bayesian names (one of which is wrong: the likelihood function is inexplicably called "a priori probability"), but the examples labelled "Bayesian" do not use the theorem in a Bayesian way. Worse, the example 3.7.4, labelled Bayesian, confuses the two arguments of conditional probability throughout, and equation 3.17 is wrong (as can be seen by comparing it with P(A) in section 3.2, which is correct). On the other hand, in section 8.7.1 a similar example – with frequentist probabilities again – is presented clearly and correctly. Example 3.7.5 (also labelled Bayesian) is, as far as I can see, nonsense (what is outcome A?).

The most serious errors occur in chapter 7 (confidence intervals). Confidence intervals are frequentist by definition, otherwise they should be called credible intervals. But the treatment here is a curious mixture of Bayesian, frequentist and pure invention. The definition of the confidence level (CL) is novel and involves integration under a PDF that could be the Bayesian posterior but in some examples turns out to be a likelihood function. Coverage is then defined in a frequentist-inspired way (invoking repeated experiments), but it is not the correct frequentist definition. The Feldman–Cousins (F–C) frequentist method is presented without having described the more general Neyman construction on which it is based. A good treatment of the Neyman construction would have allowed the reader to understand coverage better, which the book identifies correctly as the most important property of confidence intervals. It is true that for discrete (e.g. Poisson) data, the F–C method in general over-covers, but it should also have been stated that for this case any method (including Bayesian) that covers for all parameter values must over-cover for some. The "coverage" that this book claims to be exact for Bayesian methods is not an accepted definition because it represents subjective belief only and does not have the frequentist properties required by physicists.

● *Fred James, CERN.*



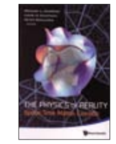


# Books received

## The Physics of Reality: Space, Time, Matter, Cosmos

*By Richard L Amoroso, Louis H Kauffman, Peter Rowlands (ed.)*
**World Scientific**
Hardback: £111
E-book: £83

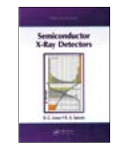
As the proceedings of the 8th Symposium Honoring Mathematical Physicist



Jean-Pierre Vigier, this book introduces a new method in theory formation, completing the tools of epistemology. Like Vigier himself, the Vigier symposia are noted for addressing avant-garde, cutting-edge topics in contemporary physics. In this, several important breakthroughs are introduced for the first time. The most interesting is a continuation of Vigier's pioneering work on tight-bound states in hydrogen. The new experimental protocol described not only promises empirical proof of large-scale extra dimensions in conjunction with avenues for testing string theory, but also implies the birth of unified field mechanics, ushering in a new age of discovery.

## Semiconductor X-Ray Detectors

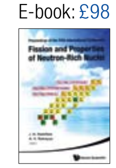
*By B G Lowe and R A Sareen*
**CRC Press**
Hardback: £108



The history and development of Si(Li) X-ray detectors is an important supplement to the knowledge required to achieve full understanding of the workings of SDDs, CCDs, and compound semiconductor detectors. This book provides an up-to-date review of the principles, practical applications, and state-of-the-art of semiconductor X-ray detectors, and describes many of the facets of X-ray detection and measurement using semiconductors – from manufacture to implementation. The initial chapters present a self-contained summary of relevant background physics, materials science and engineering aspects. Later chapters compare and contrast the assembly and physical properties of systems and materials currently employed.

## Fission and Properties of Neutron-Rich Nuclei: Proceedings of the Fifth International Conference

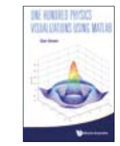
*By J H Hamilton and A V Ramayya (ed.)*
**World Scientific**
Hardback: £131
E-book: £98



The five-year interval between the international conferences covering fission and properties of neutron-rich nuclei allows for significant new results to be achieved. At the latest in the series, leaders in theory and experiments presented their latest results in areas such as the synthesis of superheavy elements, recent results and new facilities using radioactive ion beams, the structure of neutron-rich nuclei, the nuclear fission process, fission yields and nuclear astrophysics. The conference brought together more than 100 speakers from the major nuclear laboratories, along with leading researchers from around the world.

## One Hundred Physics Visualizations Using MATLAB

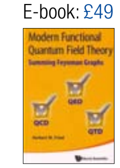
*By Dan Green*
**World Scientific**
Hardback (with DVD): £48
Paperback (with DVD: £23
E-book: £17



The aim of this book is to have an interactive MATLAB script where the user can vary parameters in a specific problem and then immediately see the outcome by way of dynamic "movies" of the response of the system in question. MATLAB tools are used throughout, and the software scripts accompany the text in symbolic mathematics, classical mechanics, electromagnetism, waves and optics, gases and fluid flow, quantum mechanics, special and general relativity, and astrophysics and cosmology. The emphasis is on building up an intuition by running many different parametric choices chosen actively by the user and watching the subsequent behaviour of the system.

## Modern Functional Quantum Field Theory: Summing Feynman Graphs

*By Herbert M Fried*
**World Scientific**
Hardback: £65
E-book: £49



These pages offer a simple, analytic, functional approach to non-perturbative QFT, using a frequently overlooked functional representation of Fradkin to calculate explicitly relevant portions of the Schwinger generating functional. In QED, this corresponds to summing all Feynman graphs representing virtual photon exchange between charged particles. It is then possible to see, analytically, the cancellation of an infinite number of perturbative, UV logarithmic divergences, leading to an approximate but reasonable statement of finite-charge renormalization. A similar treatment of QCD is then able to produce a simple, analytic derivation of quark-binding potentials. An extension into the QCD binding of two nucleons to make an effective deuteron presents a simple, analytic derivation of nuclear forces. Finally, a new QED-based solution of vacuum energy is presented as a possible candidate for dark energy.

Viewpoint

# 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 the environment, health and agriculture). SESAME will foster collaboration between its very diverse members (currently Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, 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 Ülkü) as co-vice-presidents. Many others, e.g. Eliezer Rabinovici (Hebrew University), played

*The SESAME building at Allan, 35 km north-west of Amman. (Image: SESAME.)*

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 geographical limitations) to join SESAME, and further contributions from governments in other regions, charitable foundations and philanthropists.

● *Chris Llewellyn 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.*






# CERNCOURIER

VOLUME 54 NUMBER 7 SEPTEMBER 2014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