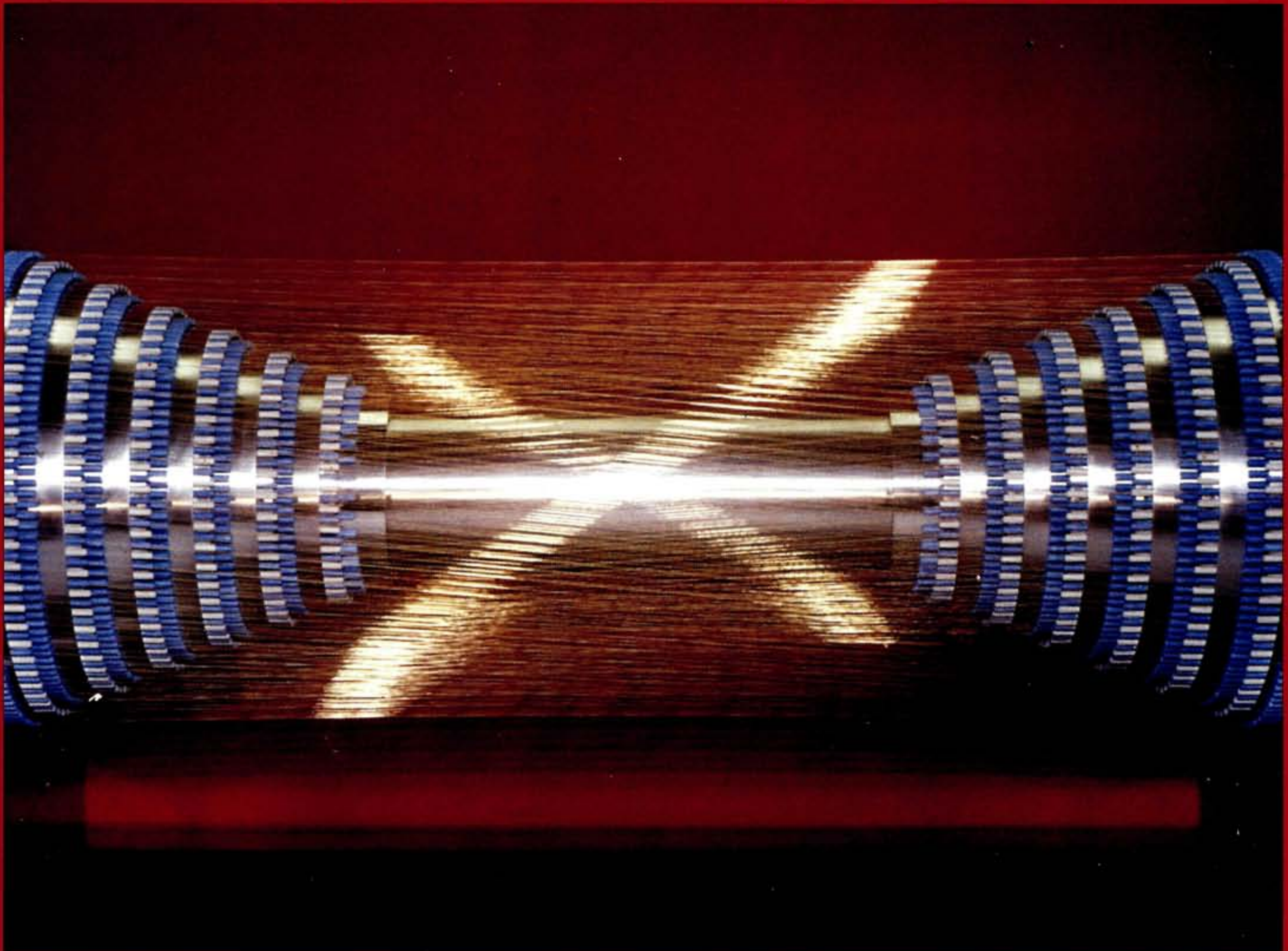
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 45 NUMBER 6 JULY/AUGUST 2005



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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 Institute of Physics Publishing Ltd
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Tel: +44 (0)117 929 7481; E-mail: jo.nicholas@iop.org; Web: iop.org

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General distribution Jacques Dallemagne, CERN, 1211 Geneva 23, Switzerland. E-mail: courrier-adressage@cern.ch
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UK Barrie Bunning, Library and Information Services Group, R61 Library, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX, UK. E-mail: B.J.Bunning@rl.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: vosses@aol.com
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

CERN COURIER

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Seeing neutrinos from Siberia p24

Dragon meets physicist p34

Cover: The ZD inner drift chamber of the CLEO-c detector – an essential component of the CLEO collaboration's new measurements that test lattice QCD predictions for the decays of D mesons. The two rings of light are produced by the wires of the ZD, which are all at angles to the axis, alternating positive and negative. These "stereo" wires provide measurements of the z-coordinates of tracks close to the interaction point. The ZD has six layers of sense wires within an outer diameter of about 23 cm and the length is about 74 cm. The sensitive volume covers 93% of the solid angle. (Courtesy Karl Ecklund and Daniel Peterson, Cornell LEPP.)

SAES® Getters' Technology Preserves UHV Conditions in the Vacuum Chambers of SOLEIL Synchrotron

IntegraTorr™ sputtered non-evaporable getter thin film has been chosen to coat quadrupole and sextupole vacuum chambers of the third generation SOLEIL synchrotron.

Project Outline

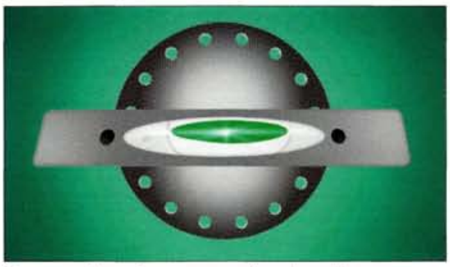
IntegraTorr™, SAES' new Non-Evaporable Getter (NEG) thin film technology for ultra-high vacuum pumping, will be used to coat 110 quadrupole and sextupole vacuum chambers of the SOLEIL synchrotron machine, the dedicated high-luminosity light source under construction at Saint-Aubin in Essonne, south of Paris.

Pioneering the development of the getter technology, the SAES® Getters Group is the world leader in a variety of scientific and industrial applications where stringent vacuum conditions or ultra-high pure gases are required. For 60 years its getter solutions have been supporting innovation in the information display and lamp industries, in technologies spanning from large vacuum power tubes to miniaturized silicon-based micromechanical devices, as well as in vacuum thermal insulation. SAES Getters is also a key-player in the manufacturing and marketing of advanced solutions for ultra-high vacuum applications, including particle accelerators. Dozens of machines around the world, encompassing electron and positron storage rings, synchrotrons, ion colliders and nuclear radiation facilities, already employ SAES' NEG technology for primary pumping of their vacuum chambers and systems. With the SOLEIL project, however, it is the first time ever that a third generation synchrotron machine will make such extensive use of NEG-coated chambers.

The SOLEIL accelerator complex includes a 100 MeV LINAC pre-injector, a full energy booster synchrotron and a 2.75 GeV electron storage ring with a 354-meter circumference, which provides synchrotron light to 24 photon beam lines. The commissioning of the storage ring will start early 2006, the first ten photon beam lines will be open to users in 2006 and the whole beam line project will be progressively completed and delivered by 2009.

Total UHV Solutions with a Simpler Vacuum Chamber Geometry

In order to guarantee optimal operation of the facility, the pressure in the storage ring must be in the low 10^{-9} mbar range when a beam is stored, while the expected pressure without beam is in the 10^{-10} mbar range. Photon stimulated desorption causes a pressure increase when an electron beam is present. IntegraTorr NEG coating of the straight parts of the vacuum system will cover 50% of the overall storage ring surface and will be essential to reduce the desorption yields and to improve base dynamic vacuum conditions.



Cross section of a vacuum chamber with IntegraTorr non-evaporable getter coating.

Detail of SAES' sputtering system used to apply the IntegraTorr coating, capable of processing up to seven-meter long chambers.

The NEG coating is also expected to significantly reduce bremsstrahlung radiation and the synchrotron conditioning time, thus greatly enhancing the usable beam time of the facility.

The technique of sputtering NEG thin film coatings for use as vacuum pumping for particle accelerators was originally developed and patented by CERN in Geneva, to meet specific requirements of the Large Hadron Collider (LHC) project. Thanks to a license agreement and a successful technology transfer, this sputtering technique has become part of SAES Getters' NEG product portfolio under the IntegraTorr trademark.

IntegraTorr is a highly innovative way to integrate non-evaporable getter pumping into a particle accelerator vacuum chamber. It is achieved by depositing a sputtered NEG film about 1 micron thick onto the walls of the vacuum chamber, thus providing a very effective barrier to the gas species which would otherwise desorb from the chamber surface.

The NEG film also acts as a powerful, fully distributed "in situ" pump, efficiently absorbing molecules and keeping extremely low pressures, unmatched by any other technique. If the whole vacuum chamber is coated, a distributed pump with huge sorption speed is created: under these conditions, IntegraTorr has the potential to achieve pressures in the extreme high vacuum (XHV) range, below 1×10^{-12} mbar.

Due to its unique features, IntegraTorr significantly improves the ultimate dynamic vacuum in high energy machines, facilitating stable beam conditions and improved current parameters.

In addition, the adoption of IntegraTorr allows a much simpler chamber design, avoiding the need to add frequent pumping ports for discrete pumping or separate antechambers for distributed pumping. IntegraTorr's integrated pumping approach promises to be a strategic advantage for application in electron storage rings and synchrotron light sources, where narrow and conductance-limited vacuum chambers typically set severe space constraints on the vacuum system architecture.

saes getters

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CERN

CERN Council looks to strategy for European particle physics

During its meeting in Geneva on 17 June, the CERN Council agreed to take on the role of defining the strategy and direction of European particle-physics research, a task already present in the founding convention.

A strategic planning team is to be established in support of this role, consisting of the chair of the European Committee for Future Accelerators, the chair of CERN's Scientific Policy Committee, CERN's director-general, one member nominated by each of CERN's member-state delegations, and representatives of the major European national laboratories. In spring 2006, the team will provide the CERN Council with a status report in Berlin, with a full report to follow later that year.

Progress on the Large Hadron Collider – welding interconnections between magnets.

At the same meeting, the Council also heard from project leader of the Large Hadron Collider (LHC), Lyn Evans, who told attendees that all efforts are currently being made to ensure that the LHC will be ready for commissioning in the summer of 2007. CERN's chief scientific officer, Jos Engelen, also reported that all the LHC's experiments expect to be in a position to take data in 2007, and that the LHC computing grid is progressing according to plan.

In his presentation to the Council, CERN's director-general, Robert Aymar, applauded the progress that is being made towards the LHC. However, while the laboratory is on course for LHC start-up in 2007, current expenditure profiles indicate that CERN's budget could be entirely committed to paying for the project right through to the next decade. This subject will be discussed at the Council's meeting in September.

EXOTIC ATOMS

DEAR pins down kaonic hydrogen

The DEAR (DAFNE Exotic Atoms Research) experiment at the DAFNE ϕ factory at Frascati has performed the most accurate determination of the effect of the strong interaction on the binding energy of kaonic hydrogen.

Kaonic hydrogen is an exotic atom where the electron is replaced by a K^-, and it turns out to be an excellent laboratory for studies of quantum chromodynamics. Especially interesting is the determination of the strangeness content of the nucleon, which has traditionally been determined from low-energy kaon–nucleon scattering amplitudes. A significantly more accurate approach has now been discovered, which involves measuring the ground-state X-ray transitions in kaonic hydrogen atoms.

The DEAR collaboration took advantage of the low-energy monoenergetic kaons from the decay of ϕ mesons resonantly produced by e^+e^- collisions at one of the two interaction points at DAFNE. The kaons travelled through the thin beam pipe of DEAR and stopped in a gaseous hydrogen target. CCD detectors with a pixel size of $22.5 \times 22.5\ \mu m^2$ cooled to 165 K detected the X-rays emitted.

The DEAR experiment follows the steps of the KpX experiment at KEK in Japan, which first measured the ground-state X-ray peak of kaonic hydrogen. DEAR's values are about a factor of two more accurate, and roughly 40% lower than those of the Japanese collaboration. The ground-state shift, ε_{1s}, was measured to be -193 ± 37 (stat.) ± 6 (syst.) eV, with a 1s strong interaction width of $\Gamma_{1s} = 249 \pm 111$ (stat.) ± 30 (syst.) eV.

DEAR has also become the first experiment to observe transitions from different excited states, clearly identifying K_α, K_β and K_γ lines.

Further reading

G Beer *et al.* 2005 *Phys. Rev. Lett.* **94** 212302.

CERN Courier turns bilingual

With this issue, *CERN Courier* takes on a slightly different look, with the inclusion of articles in French. This is because CERN has, with regret, taken the decision to cease the publication of separate French and English editions. In the new bilingual edition, articles submitted in English will remain in English while French articles will be published in French. There will, however, be summaries of feature articles in the other language, and the news items, as here, will be listed in French.

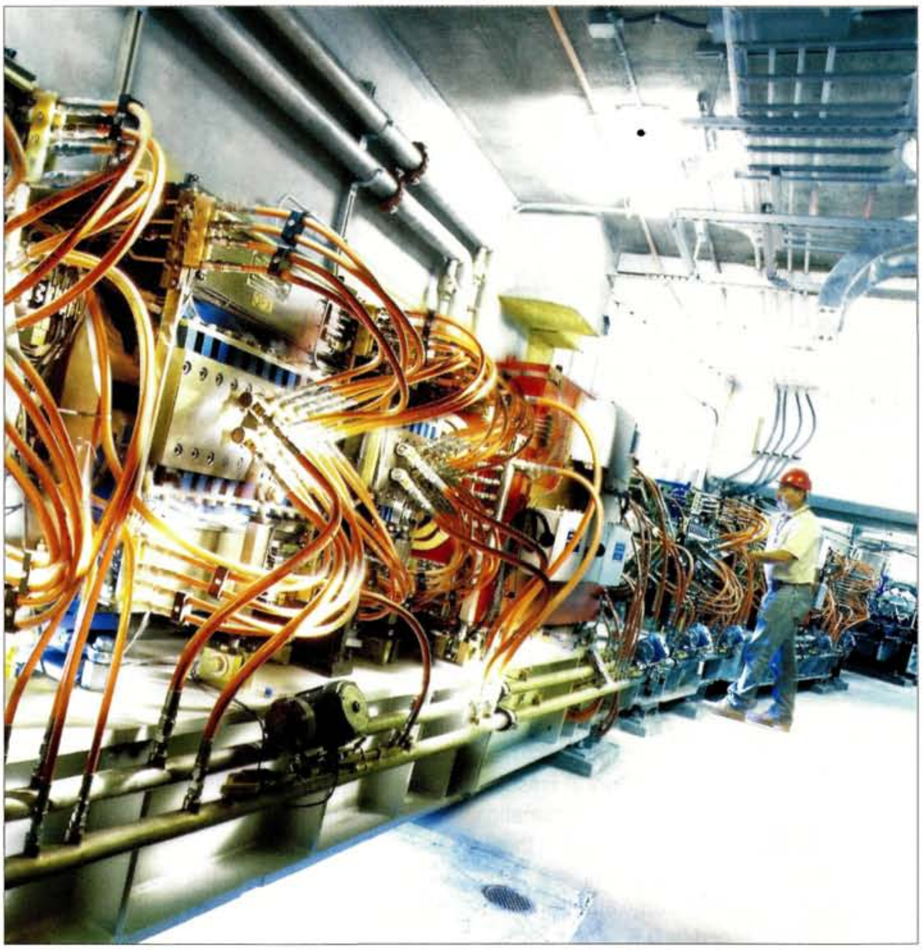
LABORATORIES

SLAC reorganizes and prepares for next major breakthroughs

On 24 May, Jonathan Dorfan, director of the Stanford Linear Accelerator Center (SLAC), announced a complete reorganization of the structure and senior management of the laboratory, which Stanford University has operated for more than 40 years for the US Department of Energy. The new organizational structure is built around four divisions: Photon Science, Particle and Particle Astrophysics, Linac Coherent Light Source (LCLS) Construction, and Operations.

"One thing that is recurrent in world-class scientific research is change," Dorfan said. "Recognizing new science goals and discovery opportunities, and adapting rapidly to exploit them efficiently, cost-effectively and safely is the mark of a great laboratory. Thanks to the support of the Department of Energy's Office of Science and Stanford University, SLAC is ideally placed to make important breakthroughs over a wide spectrum of discovery in photon science and particle and particle astrophysics. These fields are evolving rapidly, and we are remodelling the management structure to mobilize SLAC's exceptional staff to better serve its large user community. The new structure is adapted to allow them to get on with what they do best – making major discoveries."

Two of the new divisions – Photon Science, and Particle and Particle Astrophysics – encompass SLAC's major research directions. As director of the Photon Science Division, Keith Hodgson has responsibility for the Stanford Synchrotron Radiation Laboratory, the science and instrument programme for the LCLS (the world's first X-ray-free electron laser) and the new Ultrafast Science Center. Persis Drell, director of the Particle and Particle Astrophysics Division, oversees the B-Factory (an international collaboration studying matter and antimatter), the Kavli Institute for Particle Astrophysics and Cosmology, the International Linear Collider effort, accelerator research and non-accelerator particle-physics programmes.



The Stanford Synchrotron Radiation Laboratory, managed by Keith Hodgson, is just one aspect of SLAC's multi-faceted research activities. (Courtesy SLAC.)

Construction of the $379 million LCLS, a key element in the future of accelerator-based science at SLAC, started this fiscal year. A significant part of the laboratory's resources and manpower are being devoted to building LCLS, with completion of the project scheduled for 2009. Commissioning will begin in 2008 and science experiments are planned for 2009. John Galayda serves as director of the LCLS Construction division.

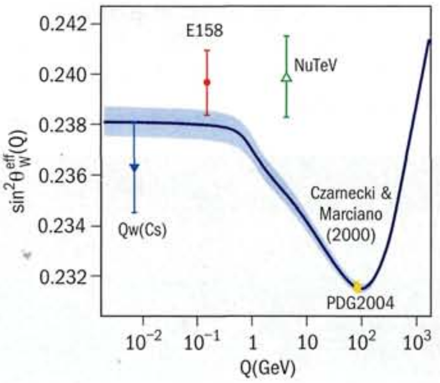
To reinforce SLAC's administrative and operational efficiency, and to stress the importance of strong and effective line management at the laboratory, a new position of chief operating officer has been created, filled by John Cornuelle. This fourth division, Operations, has broad responsibilities for operational support and R&D efforts that are central to the science divisions. Included in Operations will be environmental safety and health, scientific computing and computing services, mechanical and electrical support departments, business services, central facilities and maintenance.

SLAC

Variation in weak force found by E158

The E158 experiment at the Stanford Linear Accelerator Center has made a landmark observation: the strength of the weak force acting on two electrons lessens when the electrons are far apart. The results will be published in *Physical Review Letters*.

Because there is an asymmetry in how the weak force acts, there is a difference between how often left- and right-handed electrons scatter via a Z particle (the neutral carrier of the weak force). Two years ago, the team made the first observation of this parity-violation effect in electron–electron interactions.



Predicted variation of $\sin^2\theta_W^{eff}$ as a function of momentum transfer Q (solid line) and its estimated theoretical uncertainty (shaded). Results of previous low-energy experiments are shown with the Particle Data Group value (PDG2004) at the scale of the Z mass.

For the new results, E185 used its improved precision asymmetry measurement to calculate the long-distance (low momentum transfer, Q) weak charge of the electron, which determines the strength of the weak force between two electrons. The result is the world's best determination of the weak mixing angle at low energy: $\sin^2\theta_W^{eff} = 0.2397 \pm 0.0010$ (stat.) ± 0.0008 (syst.), evaluated at $Q^2 = 0.026\ GeV^2$.

Previous experiments at SLAC and CERN measured the electron's weak charge at high momentum transfer (short distances). E158's long-distance measurement observes this weak charge to be half the size of the charge at short distances. Comparing the short-distance measurements with the long-distance results demonstrates (with 6σ significance) the variation of the strength of the weak force with distance, and confirms an important aspect of Standard Model theory. Using the result for $\sin^2\theta_W^{eff}$, E158 finds the electron's weak charge to be -0.041 ± 0.006 – half the value expected if there were no variation.

E158 was also sensitive to indirect signals from hypothetical Z′ particles, suggesting they are at least 10 times the mass of the Z.

Further reading

SLAC E158 Collaboration 2005 http://arxiv.org/abs/hep-ex/0504049.

RF CAVITIES

Superconducting cavities from single-crystal niobium could offer stability and lower costs

A potentially cost-saving and performance-enhancing new approach to fabricating superconducting radiofrequency (SRF) accelerating cavities has been demonstrated by the Institute for Superconducting Radiofrequency Science & Technology (ISRFST) at Jefferson Lab in Newport News, Virginia.

Several single-cell niobium cavities were made from material sliced from large-grain niobium ingots – rather than fine-grain material melted from ingots and formed into sheets by the traditional process of forging, annealing, rolling and chemical etching.

In tests carried out by ISRFST, these cavities performed extremely well. If multi-cell cavities are also successful, the method could have a substantial impact on the economics of high-performance RF superconductivity.

The work aimed to provide a deeper understanding of the influence of grain boundaries on the often-observed drop in Q (the cavity-performance quality factor) at accelerating gradients above 20 MV/m. "Q-drop" is not well understood, but it may be linked to contaminants and grain boundaries in the niobium.

The researchers used single-crystal niobium sheets for forming into half-cells, omitting expensive processing steps and producing cavities with few or no grain boundaries. Reference Metals Company Inc of Bridgeville, Pennsylvania, provided the niobium in a research collaboration with JLab.

This proof-of-principle work could have wide repercussions. Most notably, it could lead to more reliable production and reduced costs.

The research also has important implications for the forthcoming International Linear Collider (ILC), a 500 GeV machine that will need some 17 000 SRF cavities performing above 28 MV/m. Using a scaled version of a low-loss design proposed for the ILC, a test cavity supported an accelerating gradient of 45 MV/m. This figure is very close to both Cornell's current world record and the theoretical limit.

PHYSICSWATCH

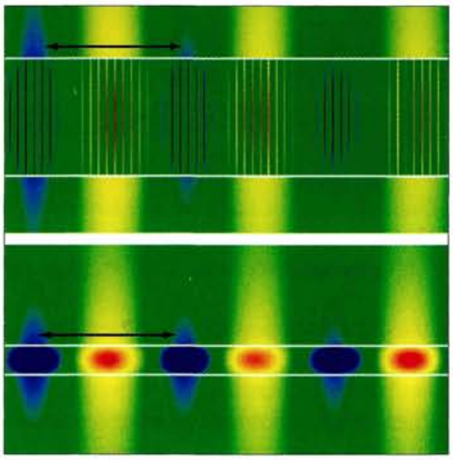
Compiled by Steve Reucroft and John Swain, Northeastern University

Metallic 'picket fence' cuts the speed of light

Materials in which light slows down are usually thought of as being fairly uniform, like water or glass. Now, however, Jung-Tsung Shen, Peter Catrysse and Shanhui Fan of Stanford University, California, have suggested a novel way to produce refraction, involving a periodic arrangement of metal films. Moreover, the resulting refractive index, which is positive, does not depend on frequency, and can be arbitrarily large.

The idea is to pass light through a miniature picket-fence-like structure made of metal slats that are thicker than the spaces between them, and with gaps smaller than the wavelength of light. While there is no electric field possible inside the metal, waves with a magnetic field parallel to the slats can get through, even though the wavelength is much larger than the space between the slats. The structure then acts like a refractive material – in effect, a dielectric slab with a refractive index, n, equal to the width of the slats, d, divided by the distance between them, a.

This means that the refractive index can be tuned by changing the geometry of the structure, independent of frequency. In particular, a positive index of refraction can be made arbitrarily large, with potential applications in the miniaturization of optical or electromagnetic devices, and in imaging.



Calculated variations in the magnetic field in fundamental waveguide modes show the equivalence of a slotted metal film (top) and the corresponding dielectric slab for a refractive index of 4. (Red indicates positive amplitude, while blue is negative.)

Further reading

J-T Shen, Peter Catrysse and Shanhui Fan 2005 *Phys. Rev. Lett.* **94** 197401.

Special relativity becomes more general

Special relativity arises, in a basic sense, from the introduction of an invariant velocity – the speed of light – and, as every physicist knows, this requires a radical revision of the nature of space and time. Recent works, however, have suggested the existence of other invariant scales, leading to so-called doubly and triply special relativities. Now Dharam V Ahluwalia-Khalilova of the University of Zacatecas, Mexico, has pulled many of these suggestions together, while arguing that nonlinear deformations are not needed. He finds that, to have a stable algebraic structure, one is led to two invariant length scales. One is small and perhaps related to the Planck length, while the other is large and presumably related to the size of the universe.

The word "stable" here indicates that the structure can withstand small changes, as special relativity can withstand small changes in the speed of light without becoming a fundamentally different theory. In a sense, this is about as general a theory of special relativity as there is, and can test special relativity with just two free parameters. Now the challenge is to think of some good experimental tests.

Further reading

D V Ahluwalia-Khalilova 2005 *Class. Quant. Grav.* **22** 1433.

Handheld fusion device generates a future in neutrons

A novel way to generate neutrons using fusion in a handheld device could find many applications where modest numbers of neutrons are useful. Brian Naranjo and colleagues have found that the key is a pyroelectric crystal attached to a tungsten probe and immersed in low-pressure deuterium gas.

On heating, the crystal generates remarkable charge separations, which translate to an electric field of an amazing 25 V/nm at the tungsten probe. This field ionizes deuterium and then repels the ions into a target of erbium deuteride where deuterium–deuterium fusion produces a neutron and a helium-3 nucleus.

This is unlikely to be used to generate energy via fusion, but it could lead to convenient sources of thousands to millions of neutrons.

Further reading

B Naranjo *et al.* 2005 *Nature* **434** 1115.

How cerium-based metallic glasses show their soft side

Metals with low melting points, or which at least become plastic at low temperatures, are always of technological interest. Now Wei Hua Wang and colleagues at the Institute of Physics, Beijing, and Cambridge University have found a class of cerium-based metallic glasses with a glass-transition temperature so low that in boiling water they become soft like putty.

The glass transition is gentle with malleability starting at 68 °C, and the materials show remarkable resistance to crystallization. This makes them attractive both for practical applications and for studies of glass transition.

Further reading

B Zhang *et. al.* 2005 *Phys. Rev. Lett.* **94** 205502.

Compiled by Marc Türler, INTEGRAL Science Data Centre and Geneva Observatory

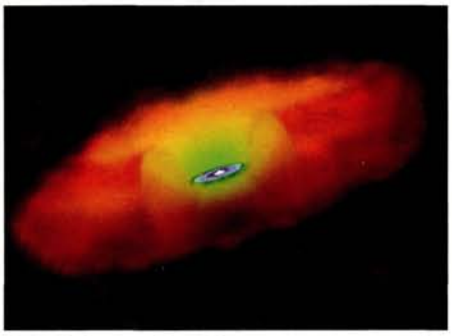
Theory demystifies supermassive black holes

The existence of powerful quasars at high redshift raises the question of the rapid formation of supermassive black holes. How could early black holes accrete 1 billion solar masses in less than 1 billion years after the Big Bang? Was there an epoch with conditions particularly favourable for such a rapid growth of black holes?

These questions have been tackled by cosmologists Marta Volonteri and Martin Rees at Cambridge University. They attempt to identify what was different in the early universe that allowed black holes to grow as quickly as suggested by the existence of fully mature quasars in the Sloan Digital Sky Survey (SDSS) dataset at a redshift of about 6.

The first problem is the origin of the seed black holes. They could be low-mass (less than 1.5 solar masses) primordial black holes, formed during the first seconds of the Big Bang, but Volonteri and Rees do not want to rely on such a hypothesis. They propose that the seeds are intermediate-mass black holes, formed by the core collapse of massive stars of the very first generation.

Such Population III stars, which are composed only of primordial hydrogen and helium, can have masses up to 1000 times that of the Sun, thus exceeding by an order of magnitude the most massive metal-rich stars existing today. When exploding as supernovae at the end of their lives they would form black holes with masses approximately 20–600 times that of the Sun.



Artist's impression of a mature quasar with a thin accretion disc enshrouded in a torus of metal-rich gas. (Courtesy CXC/M Weiss.)

These pregalactic seed black holes would form in gas halos, collapsing at a redshift of 20–30 at the peaks of the primordial density field. Before too many heavy nuclei were released by stars, the newborn black holes would benefit from unique conditions to accrete gas at a very high rate. The calculations of Volonteri and Rees indeed suggest that there was a brief window of rapid black-hole growth during the "dark ages", before the stellar radiation fully re-ionized the intergalactic gas (*CERN Courier* October 2003 p13).

Their calculations show that the absence of heavy nuclei and the effective cooling by hydrogen atoms via line emission allow the formation of a "fat" disc of relatively cold (approximately 5000–10 000 K) gas around the seed black hole at the centre of the halo. The thickness of the disc allows quasi-spherical accretion into the black hole's event horizon at a much higher rate than for thin discs. However, the growth of the black hole increases the radius of the inner disc, which becomes increasingly thin with respect to the size of the black hole. This super-accretion will therefore no longer be sustained once the black hole has reached a significant mass.

Although the details of the process are still quite uncertain, the absence of heavy nuclei seems to play a critical role in the early growth of massive black holes. Super-accretion with a very low luminosity compared with the amount of matter falling into the black hole was likely to have stopped once the universe had been enriched by metals at a redshift of 6–10. But by then, a population of supermassive black holes would already have formed, which became fully mature quasars by turning matter into light much more efficiently than before.

Further reading

M Volonteri and M J Rees 2005 http://arxiv.org/abs/astro-ph/0506040.

Picture of the month

This false-colour infrared image taken by NASA's Spitzer Space Telescope shows the South Pillar region of a star-forming area called the Carina Nebula. Eta Carinae, the famous and most massive star of the nebula, is above the picture frame, too bright to be observed by Spitzer. The inset visible-light picture shows dark dust pillars eroded by the ultraviolet emission of this star of 100 solar masses. In the image from Spitzer, the pillars appear pink, with much more detail. Their transparency in infrared light reveals newborn stars (yellow or white) being formed inside them. Hot gases are shown in green and foreground stars are blue. (Image courtesy NASA/JPL-Caltech/ N Smith, University of Colorado at Boulder.)

A look back to CERN Courier vol. 2, August 1962

CONFERENCE

HEP conference comes to CERN

On Tuesday afternoon 3 July, and to a greater extent the following morning, the entrance hall and landings of the CERN Administration Building, normally fairly empty except at lunch time, became the scene of great activity. Some 450 physicists, representing 158 laboratories in 39 countries were gathering for the 1962 international conference on high-energy physics and for the next week they were to be joined by their colleagues already at CERN for what proved to be one of the most exciting conferences ever held in this field.

Now under the auspices of the International Union for Pure and Applied Physics, this was the 11th "Rochester" Conference, the latest in the series started by Prof. R E Marshak in 1950. At the first, at the University of Rochester, US, there were only about 50 participants. This year there were eleven times that number, and there could have been many more if the number of invitations did not have to be so limited. Nowadays, too, the meetings are held once every two years, instead of every year, successively in the US, Western Europe, and the USSR. In 1960 the conference was "at home" in Rochester; two years from now it will be at the Joint Institute for Nuclear Research, in Dubna.

What they talked about and the conclusions they came to

When he began his closing talk at 5 pm on the last day, Professor V F Weisskopf said: "I am here to perform an impossible task. I am supposed to summarize this conference that has been summarized by rapporteurs during the last three days, and I am supposed to do it in one hour." Although the steady flow of experimental results and theoretical ideas since the last conference at Rochester in 1960 has added continually to our understanding, the meeting at CERN provided an opportunity to review it all as a whole, together with the latest results. Comparison with the picture of two years ago shows, in fact, how much progress has been made. As Professor Weisskopf remarked: a new world has emerged.

In the field of weak interactions, there have been three important new advances, two of them very recent and just in time for the conference. Most exciting, and most surprising except to some theorists, is the discovery of the existence of two types of neutrino. This particle, with apparently no charge and no mass, and extremely low probability of interaction with other particles, aroused little interest for many years after it had been postulated to explain nuclear beta-decay. A change was brought about by the experimental evidence for its existence in 1953, and now the latest discovery, that the neutrino emitted at the same time as an electron is not the same as the one emitted with a muon, has made it (or them) a centre of interest. A whole new field of research will be opened up by attempts to discover and explain the part these particles really play in the structure of matter.

G Puppi, left, and W Heisenberg with a table of all the known particle "resonances".

Perhaps related to the existence of two neutrinos is the strange fact that the relatively short-lived muon and the stable electron appear to be otherwise identical in all their properties except that of mass. Recent experimental evidence discussed at the conference included results for the muon's anomalous magnetic moment (g-2), muon scattering from carbon nuclei, and the production of pairs of muons from high-energy gamma rays. All these processes are accurately described by the equations already developed for the same phenomena occurring with electrons.

When it comes to considering weak interactions the situation has become very difficult. In the way that the pion was introduced to explain how the nucleus was held together, an "intermediate boson" has been found useful to derive the equations describing weak interactions such as radioactive decay. Unlike the pion, though, this "W particle" has not yet been found experimentally. Moreover if it exists, and the recent doubts over the rule $\Delta S = \Delta Q$ are confirmed, one implication will be that strangeness can change by two units in weak interactions, enabling, say, a neutral kaon to change into an antikaon. Such a reaction has already been shown to be impossible, according to the present theory, by the small difference found experimentally between the masses of the two related particles called K_1^0 and K_2^0. There is still the possibility that further experiments may show $\Delta S = \Delta Q$ to be correct, but otherwise the present theory will turn out to be inadequate, and the whole problem of the explanation of weak interactions will be thrown open again.

To sum up, there is no better way than to reproduce Prof. Weisskopf's closing words: "The theoretical situation is problematic but full of interesting ideas. The experimental situation is very much better – very much better than any one of us would have guessed two years ago. The world within the nucleon is much richer and much more interesting than we ever expected. Not in vain have we put so much effort into this field everywhere in the world, not in vain have we put so much effort and money into our aim, which is after all a basic aim of man on earth: to find out what it is, this common world of ours."

• Extracted from the original 11-page article.

EDITOR'S NOTE

In July 1962 the Rochester Conference came to CERN for the first time, and for a week the heart of high-energy physics beat at CERN. Eight Nobel laureates listened to Mel Schwartz presenting the experiment that gave him, Leon Lederman and Jack Steinberger the Nobel prize three decades later. Future Nobel prize-winners from CERN, Carlo Rubbia and Georges Charpak, also presented papers at the conference.

Lattice QCD and CLEO-c tackle the CP challenge

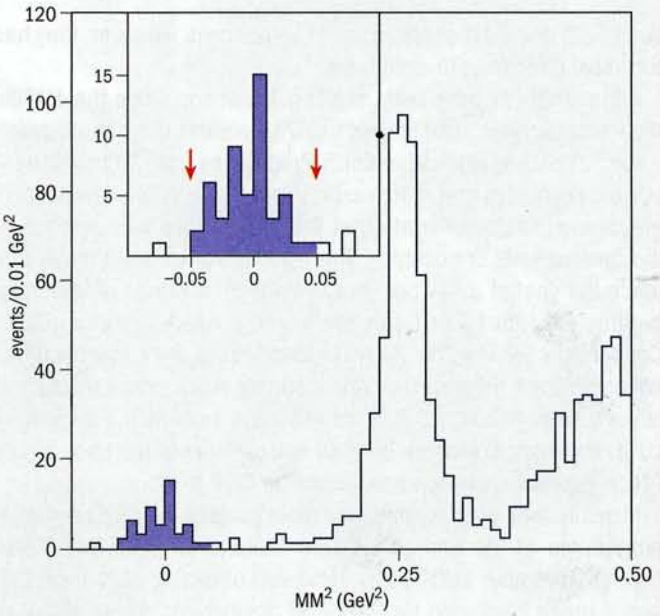
New results presented at Lepton-Photon 2005 provide important tests of the predictive powers of lattice calculations of parameters vital in the study of CP violation.

Problems in theories such as quantum chromodynamics (QCD) that involve strong coupling are among the most intractable in physics. The difficulties of accurate calculations are particularly vexing when it comes to studying charge–parity (CP) violation – a necessary ingredient for explaining the absence of the antimatter produced in the Big Bang, and a vital topic in particle physics. Progress in making accurate QCD calculations in this sector of the Standard Model could have far-reaching consequences, because the larger theory in which the Standard Model is embedded, even if not strongly coupled *ab initio*, will almost certainly have strongly coupled sectors.

The amount of CP violation that is consistent with our current understanding of the Standard Model is not enough to account for the disappearance of the antimatter produced along with the matter. The decay of B mesons is the most promising arena in which to search for other sources of CP violation, and the B-factory experiments, BaBar and Belle, have been spectacularly successful in observing and studying CP violation in those decays.

However, the search for CP violation beyond the Standard Model involves comparison of the angles of the "unitarity triangle" measured in CP violation experiments, with the lengths of the sides determined from more conventional measurements. These lengths are determined from elements of the Cabibbo–Kobayashi–Maskawa (CKM) matrix, which describes the relative strengths of the weak decays of quarks. The problem is that quarks do not appear alone, but in strongly interacting combinations such as mesons and baryons. So, there is always a strong-interaction parameter that relates decay measurements to the underlying CKM matrix element. So far, the uncertainties in these parameters severely limit the precision of measurements of the CKM matrix elements.

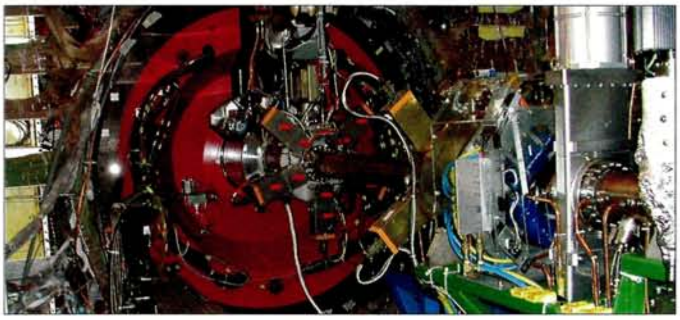
One example of such a strong-interaction parameter, called f_B, is required to extract the CKM matrix element called V_{td} from measurements of $B^0\overline{B^0}$ mixing. This parameter is a measure of the separation of the b quark and the anti-d quark in a B meson, and could, in principle, be measured in $B^+ \rightarrow \mu^+\nu$ decay. However, this decay is so slow that an accurate measurement is impossible, even with the enormous data samples that the BaBar and Belle collaborations have accumulated. This is one of the parameters that lattice QCD (LQCD) theorists can calculate, but accuracy has been limited.



Candidates for the decay $D^+ \rightarrow \mu^+\nu$ are found by computing the mass of the missing neutrinos in tagged events. The plot illustrates the distribution of the squares of missing neutrino masses for the full CLEO-c data sample. The event candidates between the arrows in the insert (blue) meet all selection criteria.

Recent progress in LQCD holds the promise of precise calculations of the parameters, including f_B, that are required to determine CKM matrix elements, but until now there has been no effective direct experimental test of the precision of these calculations.

Five years ago, some LQCD theorists and members of the CLEO collaboration at the Cornell Laboratory for Elementary-Particle Physics realized that comparing measurements of D meson decays with LQCD calculations could test the LQCD calculations needed for extracting CKM matrix elements. In particular, in the decay $D^+ \rightarrow \mu^+\nu$ there is a parameter called f_{D^+} that is analogous to f_B. The rate for $D^+ \rightarrow \mu^+\nu$ decay is larger than the corresponding B meson decay rate, so it can be measured accurately. If good agreement is found between the experimental and LQCD values for f_{D^+}, that would inspire confidence in LQCD calculations of f_B. It is also generally believed that the ratio f_B:f_{D^+} can be calculated more accurately than either one, so f_B could be determined from an experimental measurement of f_{D^+} and a LQCD calculation of the ratio. This caused the CLEO collaboration and a group of LQCD theorists to embark on D meson decay experiments and the corresponding LQCD calcula- ▷



The CLEO detector contains 900 t of iron and 250 000 detection elements. (Courtesy Cornell – Wilson Laboratory.)

tions, with goals of accuracies of a few per cent. However, they had technical difficulties to overcome.

Although there have been LQCD calculations since the 1970s, their accuracy has been limited to 20% because of a simplification – the "quenched approximation". Predictions from "unquenched" LQCD calculations that match experimental results to a few per cent are needed to demonstrate that the calculations can be done at the desired level of accuracy. The LQCD theorists were the first to reach the goal of a few per cent in their calculations of important parameters (not f_{D^+} or f_B) in the b and c quark systems (*CERN Courier* June 2004 p23). However, their results were "postdictions" not predictions, because the corresponding experimental results had already been published. Still, this success motivated the group of LQCD theorists to embark on their calculations of the strong-interaction parameters needed to determine CKM matrix elements.

Measurement of f_{D^+} is one of the main goals of the CLEO-c physics programme at the Cornell Electron Storage Ring (CESR) (*CERN Courier* November 2001 p22). However, obtaining high luminosity was a major challenge for the CESR accelerator group. Although CESR had made progress in luminosity since its first operation in 1979, much of those gains would be lost in reducing the energy from the b quark threshold region, near 5 GeV per beam, to the c quark threshold region near 2 GeV per beam, where the measurement could be made most readily. As the energy of the beams is decreased, the synchrotron radiation "damping" required for high luminosity is substantially reduced. The solution was the installation of 12 "wiggler" magnets to increase the damping at the lower energies (*CERN Courier* May 2003 p7). These magnets were installed in 2003 and 2004 in CESR-c, and the CLEO-c programme then began in earnest, funded by a five-year grant from the National Science Foundation.

The first engineering run of CESR-c with six wigglers yielded an integrated luminosity of 60 pb^{-1} in e^+e^- collisions at a total energy of 3.77 GeV, the peak of the ψ (3770) resonance. This is substantially more than the luminosities available to either the MARK III or the BES II collaborations, at SLAC and the Institute of High Energy Physics in Beijing respectively, which previously took data at the same energy. Subsequent runs with 12 wigglers brought the total integrated luminosity to 281 pb^{-1}. This is the most desirable energy for measuring D meson decays because the ψ (3770) decays only to D^+D^- or $D^0\bar{D}^0$ pairs, making very clean "tagged" measurements possible. In tagged measurements pioneered by the MARK III collaboration, if one D meson, D^- for example, is reconstructed in an event, then the rest of the particles in that event must be from the decay of a D^+ meson. Coupled with the excellent resolution and large acceptance of the CLEO-c detector, tagging provides a very clean sample of D^+ meson decays, which is an ideal arena for searching for rare decays such as $D^+ \rightarrow \mu^+\nu$.

The CLEO collaboration found eight $D^+ \rightarrow \mu^+\nu$ events (with an estimated background of one event) in the first 60 pb^{-1} of CLEO-c data. This provided a rough measurement of f_{D^+} to an accuracy of 20%, which has now been published (Bonvicini 2004). The larger data sample and improvements in selection criteria produced a yield of 50 candidates for $D^+ \rightarrow \mu^+\nu$ decay with an estimated background of 2.9 ± 0.5, enough candidates to yield an error in f_{D^+} below 10%.

While the CLEO collaboration, with the help of their CESR colleagues, was accumulating and analysing these data, a group of LQCD theorists was also hard at work calculating f_{D^+}. It became clear that both groups could have substantial results just in time for the Lepton-Photon Symposium in Uppsala at the end of June. Since both communities felt that it was very important for the LQCD result to be a real prediction, they agreed to embargo both of their results until the conference. On the second day of the symposium, Marina Artuso of Syracuse University reported the preliminary CLEO-c result $f_{D^+} = 223 \pm 16 ^{+7}_{-9}$ MeV (CLEO-c 2005), and Iain Stewart of MIT reported the LQCD result from the Fermilab, MIMD Lattice Calculation (MILC) and High Precision QCD (HPQCD) collaborations, $f_{D^+} = 201 \pm 3 \pm 17$ MeV (Aubin *et al.* 2005). For both results the errors are statistical and systematic, respectively. The two results agree well within the errors of about 8% for each.

The agreement between the results motivates both communities to continue comparing LQCD calculations with experiments. On the LQCD side, important next steps include improvements in algorithms that can reduce systematic errors and precision calculations of the "form factors" involved in semileptonic decays of D and B mesons. The CLEO collaboration plans to utilize its data sample to measure form factors in semileptonic D decay and take more data to reduce errors. The LQCD theorists and the CLEO collaboration both aim to reduce errors to below 5%. The CLEO collaboration is also planning to explore the threshold region for $D_s\bar{D}_s$ production to search for an energy at which the tagging techniques can be applied to make the first accurate measurements of D_s meson decay, including f_{D_s} and D_s semileptonic decay form factors. The Fermilab, MILC and HPQCD group has already predicted the value of f_{D_s}.

Further reading

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Résumé

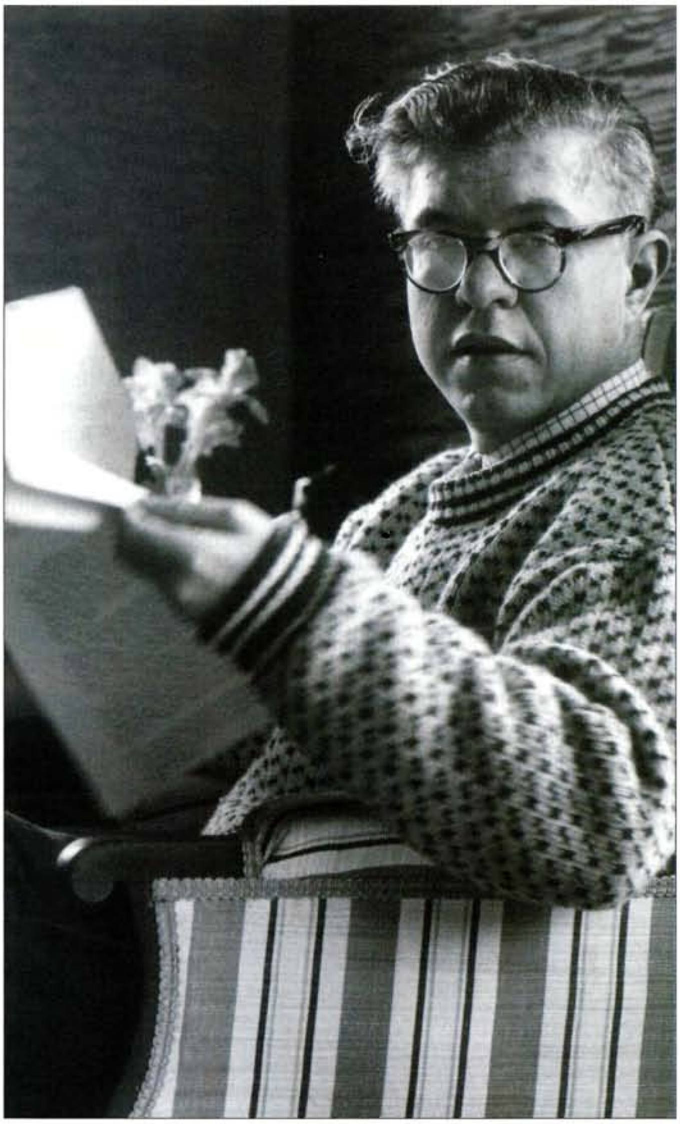
La CDQ sur réseau et CLEO-c relèvent le défi de la CP

Les nouveaux résultats présentés à la conférence Lepton-Photon 2005 ont permis d'éprouver la valeur prédictive des calculs de chromodynamique quantique sur réseau dans le cadre de la violation de CP. Le paramètre F_{D^+} a notamment été mesuré par la collaboration CLEO-c à Cornell et comparé aux prédictions des calculs sur réseau. Les résultats concordent bien avec des marges d'erreur d'environ 8% dans chaque cas.

David Cassel, *Laboratory for Elementary-Particle Physics, Cornell.*

Fred Hoyle: pioneer in nuclear astrophysics

Fred Hoyle, who died in 2001, is best known as a cosmologist. But, as **Simon Mitton** relates, his career in physics began with the weak interaction and moved on to a crucial discovery in nuclear physics.



Later in life Hoyle seldom worked at a desk in a faculty building, preferring a comfortable armchair at home. (St John's College.)

Fred Hoyle, the great cosmologist, nuclear astrophysicist and controversialist, was born 90 years ago in the beautiful county of Yorkshire in the north of England. Hoyle's first science teacher was his father, who supplied the boy with books and apparatus for chemistry experiments. By the age of 15 he was making highly toxic phosphine (PH_3) in his mother's kitchen, and terrifying his young sister with explosions. In high school he excelled in mathematics, chemistry and physics, and in 1933 won a place at Cambridge to study physics.

On arrival at Cambridge he immediately demonstrated his fierce independence by telling his astonished tutor that he was switching from physics to applied mathematics. The future nuclear astrophysicist foresaw that Cambridge mathematics rather than laboratory physics would give him the right start as a theorist. The country boy displayed an astonishing talent at mathematics, even by the highest standards of the university. He skipped the second year completely, yet graduated with the highest marks in his year. That soaring achievement won him a position as a research student in the Cavendish Laboratory, where Ernest Rutherford held the chair of experimental physics. By the 1930s Rutherford had created for Cambridge the greatest nuclear physics laboratory in the world.

Hoyle identified Rudolph Peierls as a supervisor. Peierls, a German citizen and son of a Jewish banker, had studied quantum theory under the pioneer Werner Heisenberg. In 1933 Peierls and his young wife had escaped the anti-Jewish practices of the Nazi regime; they arrived in Cambridge via Stalin's Russia. Peierls won a one-year fellowship from the Rockefeller Foundation, and by the time Hoyle tracked him down he had just returned from spending six months in Rome with Enrico Fermi. Peierls immediately set Hoyle the task of improving Fermi's theory of beta decay, published in 1934. This led, in 1937, to Hoyle's first research paper, "The generalised Fermi interaction".

In 1938 Paul Dirac, who had won the Nobel prize in 1933, became Hoyle's supervisor because Peierls had left Cambridge for a permanent position in nuclear physics at the University of Birmingham. Just one year under Dirac's silent tutelage enabled Hoyle to produce two papers in quantum electrodynamics, both of them masterpieces.

The impending 1939–1945 war curtailed Hoyle's career as a theoretical nuclear physicist. In January 1939 he read of Irène and Frédérick Joliot-Curies' discovery that the fission of uranium by neutron bombardment produced a fresh flood of neutrons. The nuclear physicists in the Cavendish Laboratory immediately realized that a chain reaction could be used to create a nuclear bomb. Hoyle foresaw that war research would drain the UK universities of scientists and mathematicians. Wishing to avoid ▷

B^2FH – Margaret and Geoffrey Burbidge, Willy Fowler and Hoyle – admire a steam engine presented to Fowler on his 60th birthday in 1971. (Donald D Clayton.)

being drafted for weapons research, he changed his research interest to theoretical astronomy and offered his services to the nation as a weather forecaster. The British authorities declined this suggestion. Instead he found himself engaged in radar countermeasures for the war at sea, a field in which he worked with great distinction that was never publicly recognized.

In late 1944 the US Navy convened a secret meeting in Washington for the US and UK to share knowledge of radar research. Hoyle was one of two UK delegates. Outside of the meeting he used his time productively. He flew out to the US west coast to meet Walter Baade, one of the greatest observational astrophysicists of the 20th century. Baade introduced Hoyle to papers that he had missed during his war work, about the extremely high temperatures in supernovae. Baade taught him that a supernova is a nuclear explosion triggered by stellar collapse: "Maybe a star is like a nuclear weapon!" was how Baade put it.

Hoyle returned to England via Montreal, his itinerary allowing him to visit the Chalk River Laboratories. This Canadian facility had played host to British research on nuclear weapons since 1942. From a former Cavendish Laboratory contact, Hoyle learned some of Britain's nuclear secrets first-hand. What particularly amazed him was how far the measurements of energy levels in nuclei had progressed. Hoyle now made an important connection: what would the nuclear chain reactions look like in an exploding star?

The post-war period

At the conclusion of the war in Europe, Hoyle walked out of his job as a radar scientist (he could have continued if he had wished), and returned to Cambridge as a lecturer. He immediately turned his mind to nuclear reactions in massive stars with central temperatures of around 3×10^9 K. Astrophysicists had long known of the two stellar reactions that synthesize helium from hydrogen. Hoyle, following suggestions by his hero, Arthur Eddington, now asked himself if helium could be processed to the heavier elements via chain reactions. He studied tables giving the natural abundances of the chemical elements, picking up an important clue from the marked increase in abundances around iron, the so-called iron peak. From his solid grasp of nuclear physics and statistical mechanics he convinced himself that the iron nuclei were synthesized in stars at very high temperatures. He set himself the task of working out how stars do it.

He quickly became frustrated at the lack of data on nuclear masses and energy levels. Then, one afternoon in the spring of 1946, he bumped into Otto Frisch. Frisch had recently returned to the UK from Los Alamos, where he had worked on nuclear fission aspects of the Manhattan Project. Frisch directed Hoyle to a declassified compilation on nuclear masses that the British authorities had found in occupied Berlin. Drawing on these data from the wartime atomic-weapons programmes, he now worked alone in St John's College (rather than the Cavendish Laboratory), searching for the answers to the origin of the elements from beryllium to iron.

A single page in a notebook he had first started in 1945 captures the moment when Hoyle cracked this problem. The notebook has a series of reactions, commencing with ^{12}C capturing ^4He, and concluding with Fe. Hoyle treated the problem as one of statistical equilibrium. For example, he wrote down a chain reaction connecting ^{16}O and ^{20}Ne in the following manner: $^{16}O + {}^4He \rightleftarrows {}^{19}F + {}^1H$, $^{19}F + {}^1H \rightleftarrows {}^{20}Ne + h\nu$. The double arrow symbol he used $\rightleftarrows$ is to indicate that these reactions are occurring in equilibrium, with the action being read from right to left as well as left to right.

Using statistical mechanics, Hoyle calculated the proportions of each isotope that would arise under equilibrium conditions. This is not explosive nucleosynthesis, but a more mundane steady-state alchemy in the cores of red giant stars. Hoyle assumed, correctly as it turned out, that rotational instability and stellar explosions would release the heavier elements inside the star back to the interstellar medium. His scheme neatly matched reality, as its predicted distribution of the different elements corresponded well with their abundance in the natural environment. But there was barely a ripple of interest from the scientific community when Hoyle published his findings in 1946. At that stage he was far ahead of his time in applying nuclear physics to stellar interiors. In the 10 years following publication the paper received just three citations.

One spring afternoon in 1953 a young postdoc, Geoffrey Burbidge, gave a seminar in Cambridge that changed nuclear astrophysics forever. He described the proportions of chemical elements in a peculiar star (γ Gem) that his wife Margaret had just observed. The composition of this star seemed bizarrely different from that of the Sun. The rare earths, from ^{57}La to ^{71}Lu, were spectacularly over-represented: in γ Gem ^{57}La has an abundance 830 times greater than in the Sun. The Burbidges appeared to have discovered a star with nuclear reactions taking place on the surface.

The results greatly excited Willy Fowler of Caltech who was in Cambridge as a Fulbright professor. He already knew of Hoyle's work on synthesis through the iron peak. Now he introduced himself to the Burbidges saying that his particle accelerator in the Kellogg Radiation Lab could accelerate protons to the energies found in solar flares. He exclaimed: "Geoff, the four of us should attack the problems of nucleosynthesis together."

Soon after the seminar Fowler and Hoyle joined up again at Caltech. Hoyle had a problem on his mind. His synthesis through to the iron peak started with ^{12}C. Where had the ^{12}C come from? Not from the Big Bang – that made only hydrogen and helium. The synthesis of elements with atomic masses 5 and 8 in stellar interiors was already known to be impossible because there are no stable isotopes with those masses. In the absence of these light isotopes to form a stepping-stone, how could three ^4He become ^{12}C? Calculations suggested that anything synthesized from three alpha particles (^4He) would be absurdly short-lived. And there the matter rested until Hoyle goaded a reluctant Fowler into action.

One of Fowler's associates, Edwin Salpeter, had found an enhanced energy level in ^8Be that lasted just long enough to react with an alpha particle and make the prized ^{12}C. However, when

Hoyle looked at the nuclear physics more closely, he realized that the ^{12}C resulting from Salpeter's scheme would immediately react to ^{16}O. However, in a flash of inspiration Hoyle tried to make Salpeter's triple-alpha process work with an enhanced level in ^{12}C. To his amazement he found that if the newly made ^{12}C had a resonance at 7.65 MeV the reaction would proceed at just the correct rate.

Hoyle crashed into Fowler's office without so much as a "by your leave" and urged him to measure the resonance levels in carbon. The experimentalist wasn't going to embark on a quest that would take many weeks just because an exotic theorist from England asked him to. But Hoyle persisted and Fowler eventually relented. Hoyle had already returned to his teaching in Cambridge by the time Fowler's group completed the experiment. They did find the resonance at 7.65 MeV, a discovery that Fowler found absolutely amazing. "From that moment we took Hoyle very seriously indeed," he later said, because Hoyle had predicted a nuclear-energy level entirely on the basis of an anthropic argument.

The Burbidges, Fowler and Hoyle – "B^2FH" – now embarked on an enormous research programme to account for the origin of the elements in the entire Periodic Table. The Burbidges brought the observations to the collaboration, Fowler the nuclear data, and Hoyle and Geoff Burbidge many of the calculations (on hand-cranked machines). Their encyclopaedic paper, always referred to as B^2FH, ran to 108 pages, appearing in *Reviews of Modern Physics* in 1957 (B^2FH 1957). It has received 1400 citations, which is very high for a paper in astrophysics. It remains a key paper, which set out the physics of several different mechanisms of nucleosynthesis, including the explosive pathways in which supernovae build the elements beyond the iron peak. The paper led to a lifelong friendship between Fowler and Hoyle, both of whom made many further contributions to nucleosynthesis. Fowler was deeply disturbed and disappointed when Hoyle did not get a share of the 1983 Nobel prize, which went to Chandrasekhar and Fowler.

Fowler strongly supported Hoyle's plans for an Institute of Theoretical Astronomy in Cambridge. This opened in 1968, with nuclear astrophysics at the heart of the programme. Hoyle used the institute as a platform to re-establish British expertise in all branches of theoretical astronomy. By example he pulled the subject out of the doldrums, inspiring a string of distinguished visitors and a legion of graduate students. His research papers (there are more than 500) show he was wrong more often than he was right. That did not trouble him at all. Among the papers in the "right" class, those on nuclear astrophysics still stand as a towering achievement of central importance to astrophysics.

Further reading

B^2FH: E M Burbidge, G R Burbidge, W A Fowler and F Hoyle 1957 *Rev. Mod. Phys.* **29** 547.

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Résumé

Fred Hoyle: pionnier de l'astrophysique nucléaire

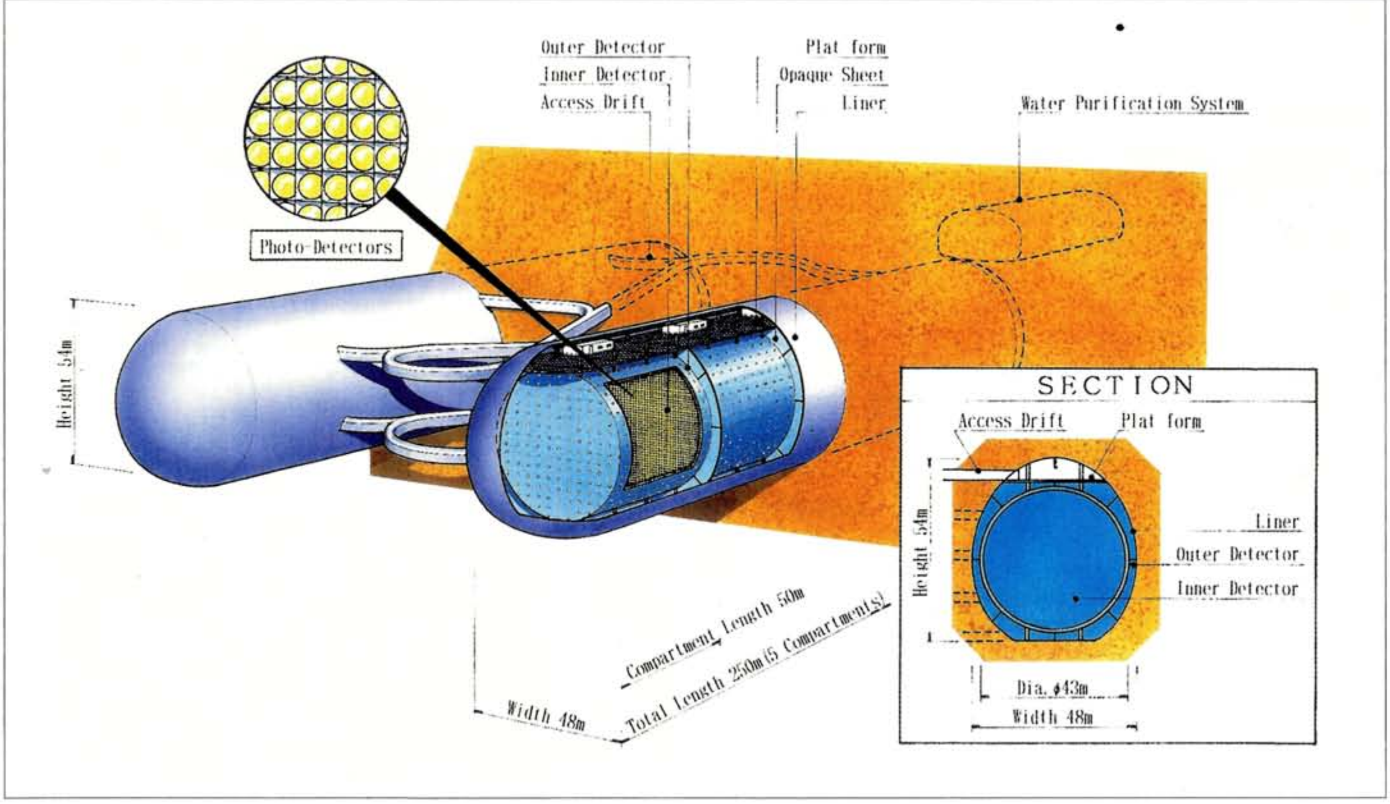
Sir Fred Hoyle (1915–2001) est mieux connu en tant que cosmologiste, Simon Mitton nous rappelle toutefois qu'il a fait ses premiers pas de physicien dans le domaine de l'interaction faible, avant d'être à l'origine d'une découverte décisive en physique nucléaire. Alors qu'il était étudiant à Cambridge, Hoyle a travaillé sous la direction de Rudolph Peierls et de Paul Dirac, avant de se consacrer à la recherche sur les radars pendant la Seconde Guerre mondiale. De retour à Cambridge après la guerre, il a participé avec Geoffrey et Margaret Burbidge et Willy Fowler à des travaux décisifs sur la nucléosynthèse stellaire.

Left to right: R V Wagoner, Fowler, Hoyle and D D Clayton at Caltech in 1967 shortly before a move to Cambridge and Hoyle's Institute of Theoretical Astronomy. (Donald D Clayton.)

Simon Mitton, *St Edmund's College, Cambridge. He is author of* Fred Hoyle: A Life in Science, *Aurum Press, London, also published as* Conflict in the Cosmos, *Joseph Henry Press, Washington. The book is reviewed on p44.*

Thinking big: the next generation of detectors

The conference on the Next Generation of Nucleon Decay and Neutrino Detectors looked at the development of new, large-scale detectors. **Alain de Bellefon** reports.



Detailed schematic of a second-generation detector. Hyper-Kamiokande, a megatonne water Cherenkov detector, is proposed as a successor to Super-Kamiokande, to be located at Tochibora, a few kilometres from the Kamioka site.

This time last year, it became clear at the Neutrino 2004 conference that results from experiments on solar and atmospheric neutrinos are converging with those from accelerators (in particular, KEK to Kamioka, or K2K, in Japan) and reactors (as in KamLAND, also in Japan) in pointing to a definite neutrino deficit due to an oscillation mechanism (*CERN Courier* January/February 2005 p33). However, further understanding will require new experiments, aimed at making precision measurements of all the parameters of the Pontecorvo–Maki–Nakagawa–Sakata (PMNS or MNSP) leptonic mixing matrix that describes the oscillation mechanism.

The major challenge will be to detect a potential violation of charge–parity (CP) invariance in the leptonic sector, which might in turn make a crucial contribution to explaining the matter–antimatter asymmetry in our universe. Such experiments will require the use of huge "mega-detectors".

The first generation of large-volume detectors was initially designed to measure proton decay. By pushing up the limits on the lifetime of the proton by two orders of magnitude, these experiments made it possible to exclude a minimal SU5 theory as the theory for grand unification. A new, second generation of experiments would make it possible to increase the sensitivity to the proton lifetime by two further orders of magnitude, and check the validity of a significant number of supersymmetry theories. The kind of detector required would also be well suited to the study of those major events in the history of the universe that we know as supernovae.

It is therefore quite appropriate for the same conference to address the detection of neutrinos, the measurement of the proton lifetime and issues relating to cosmology, as in this year's meeting on the Next Generation of Nucleon Decay and Neutrino Detectors (NNN), held near the Laboratoire Souterrain de Modane (LSM). Originally the site of a detector to study proton instability, the LSM is now a potential site for hosting a mega-detector, capable of receiving a low-energy neutrino beam from CERN, 130 km away. Thus, on 7–9 April 2005, around 100 participants, mainly from Europe, Japan and the US, came together for a conference at the CNRS's Paul Langevin Centre at nearby Aussois organized by IN2P3 (CNRS) and Dapnia (DSM/CEA), with financial support from photomultiplier manufacturers Hamamatsu, Photonis and Electron Tubes Ltd (ETL).

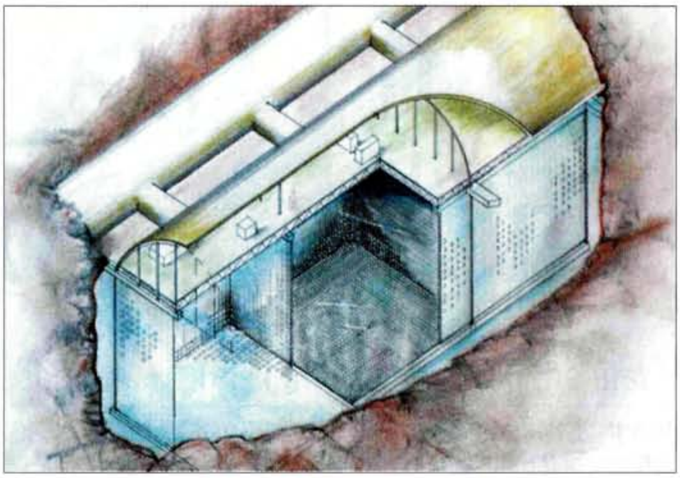
The first day of the meeting was dedicated to theory, physics motivations and future experimental projects to be pursued at underground sites. John Ellis from CERN opened the conference with a striking plea in favour of this type of physics; he insisted that it complemented collider physics, and emphasized the potential discoveries to be made with a mega-detector.

Specialists in the field explained that proton decay, which has not yet been discovered, is still the key to grand unified theories. Recalling that the detectors built to measure the proton lifetime had made it possible to detect neutrinos from supernovae for the first time, subsequent presentations addressed potential approaches to supernova physics, about which little is known, through the high-statistics detection of the neutrinos from these stellar explosions. As Gianluigi Fogli of Bari and Sin'ichiro Ando of Tokyo explained, such a detector would make it possible to extend to neighbouring galaxies the study of these major events in the evolution of the universe, be they in the future or in the distant past.

The afternoon sessions moved on to consider future detectors that could be sited at locations where the detection of neutrino beams, at some distance from an accelerator, could be combined with the observation of proton decay and astrophysical neutrinos. These presentations took stock of the progress of large-scale detector projects in the US, Asia and Europe.

On the face of it, the most accessible technology (the best known and simplest to implement) uses the Cherenkov effect in water, as proposed for the Hyper-Kamiokande project in Japan and the Underground Nucleon Decay and Neutrino Observatory (UNO) project in the US. The most ambitious technology is without doubt that for a large liquid-argon time-projection chamber (100 kt), a bold derivative of the ICARUS detector currently under preparation in the Gran Sasso Laboratory. Further promising alternatives look to organic scintillating liquids, as in the Low Energy Neutrino Astronomy project (LENA), and even a magnetized iron calorimeter as in the India-based Neutrino Observatory (INO).

Precision measurements of the θ_{13} mixing angle in the PMNS matrix, with a value that conditions the possibility of obtaining a measurement of CP violation, require high-intensity neutrino beams. The following day, the conference heard presentations on the worldwide status of experiments using a beam to verify the results obtained with solar or atmospheric neutrinos. For Japan – in addition to the K2K experiment, which has already successfully launched such a programme – the opportunities offered by a successor, Tokai to Kamioka (T2K), at the new Japan Proton Accelerator Research Complex (J-PARC) were reviewed. For the US, following the report of the first results after the successful launch of the Main Injector



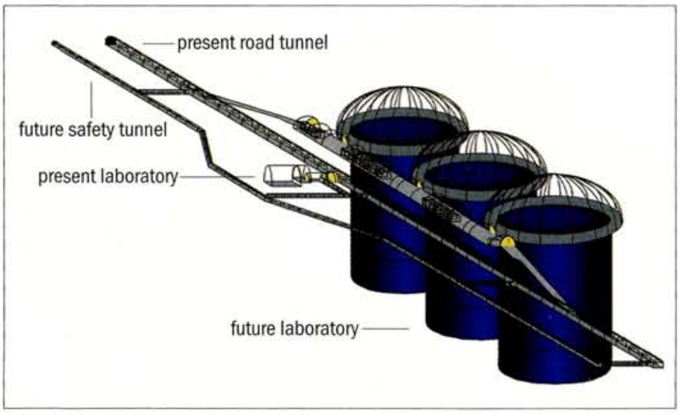
Conceptual design for the Underground Nucleon decay and Neutrino Observatory (UNO) project in the US. This would be a water Cherenkov detector with a total volume of 650 kt – 20 times that of the Super-Kamiokande detector.

Neutrino Oscillation Search (MINOS), presentations highlighted the opportunities for measuring θ_{13} at Fermilab with experiments using off-axis beams to the Soudan mine, as well as the very-long-distance projects from Brookhaven towards several prospective sites.

Moving on to CERN, and Europe more generally, the opportunities for beams to the Gran Sasso Laboratory, which hosts the OPERA and ICARUS experiments, were defined. A series of contributions also demonstrated the validity and physics potential of longer-term projects that are likely to be of direct interest to the CERN community. These are based on the superbeams and neutrino beta-beams produced by the beta-decays of certain light nuclei, such as helium or neon, and even by the decay of dysprosium, which has been met with enthusiasm since the recent discovery of this possibility.

The afternoon session of the second day was mainly devoted to the complex but encouraging R&D efforts in fields as varied as the study of the different physics and instrumental backgrounds, and photo detection. In particular, the presence and support from principal actors in the field of photomultiplier manufacture led to a series of promising technical presentations, in addition to those by physicists on the efforts underway in laboratories in the field of photo detection. The clear objective is to build photomultipliers able to cover large surface areas. The synergies with other fields of research, such as geophysics and rock mechanics, were also underlined.

On one hand, the conference sought to follow in the footsteps of its predecessors; on the other it aimed to ensure that such meetings were held on a more regular basis, and to rationalize their agendas. With this in mind, the day concluded with a round-table discussion, where the participants included Alain Blondel (Geneva), Jacques Bouchez (Saclay), Gianluigi Fogli (Bari), Chang Kee Jung (Stony Brook), Kenzo Nakamura (Tsukuba), André Rubbia (Zurich) and Bernard Sadoulet (Berkeley). It was moderated by Michel Spiro (IN2P3), who proposed making the NNN an annual event and improving coordination of the community's R&D efforts. This would be done by setting up an inter-regional committee, consisting of several members for each region (Europe, North America, Japan and so on), with a view to validating the construction of a very large detector in around 2010. The committee would also maintain contacts ▷



An artistic view of MEMPHYS, a proposed megatonne-scale detector at the site of the existing laboratory, LSM, at Fréjus.

with the steering group for ECFA Studies of a European Neutrino Factory and Future Neutrino Beams, which is chaired by Blondel.

On the last day, before the organized visit to the LSM, an entire session was devoted to a series of presentations from Japan, the US and France. Taking an engineering point of view, this session examined the potential caverns for housing a megatonne detector. Several possible sites are being considered in the US, and the Japanese are presenting the results of their studies for the Kamioka sites. In Europe, the Fréjus site on the Franco-Italian border could host a megatonne detector, so long as the preliminary studies, which have already begun, yield positive results.

The various presentations given throughout the NNN05 conference clearly highlighted the possible areas for exchanges between the different regions and communities, which until now have tended to pursue distinct paths. The next NNN conference will be held in the US in 2006, and the following meeting has already been scheduled to take place on 2 October 2007 at Hamamatsu in Japan, the Japanese "shrine" for photomultipliers.

Further reading

For further information, and to find out more about the events of NNN05, visit www.nnn05.in2p3.fr.

Résumé

Mega-détecteurs pour grands enjeux

La conférence de la série NNN (Next Nucleon decay and Neutrino detector) s'est tenue cette année à proximité du laboratoire souterrain de Modane. Après une introduction sur les motivations de physique, ces journées ont fait le point de la situation mondiale en matière de projets expérimentaux visant à repousser les limites sur la durée de vie du proton, à augmenter significativement la statistique des neutrinos d'origine extraterrestres et enfin à détecter une possible violation de CP dans le secteur leptonique.

Alain de Bellefon, *Astroparticule et Cosmologie-Paris (APC).*

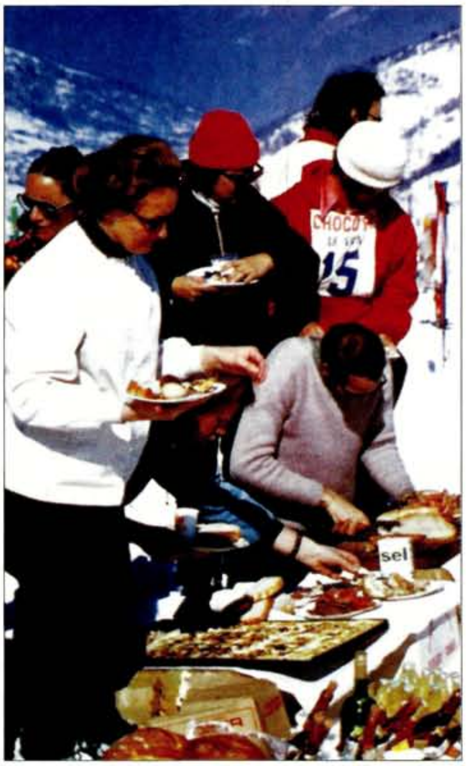
40 great years of the Rencontres de Moriond

"Theorists and experimenters must listen to each other." This leitmotif inspired the first Rencontres de Moriond in 1966, and it was just as relevant at this year's event.

From 5 to 19 March, 400 scientists from the four corners of the world gathered in La Thuile to discuss fundamental questions in high-energy physics and astrophysics, during four distinct one-week meetings. This was the 40th Rencontres de Moriond – an event that has grown from being a gathering of around 20 friends in 1966 to an annual institution for scientists everywhere.

In the early 1960s, scientific meetings in which theorists and experimenters discussed questions of mutual interest were rare. Even rarer were meetings in which participants of all ages talked to each other on an equal footing, in a climate insulated from day-to-day problems and far removed from the usual laboratory environment.

In 1965, Jean Tran Thanh Van, a young researcher at Orsay, decided to organize an unusual scientific meeting for January 1966. The subject itself – electromagnetic interactions – was not particularly unusual, but the organization was. The meeting was held in the French Alps in a group of chalets, with no catering help or assistance, few of the visual aids one associates with such meetings and, most importantly, without any telephone contact with the outside world. Tran Thanh Van was helped in this groundbreaking initiative by five colleagues: Bernard Grossetête, Fernand Renard, Michel Gourdin, Jean Perez Y Jorba and Pierre Lehmann.



Méribel 1974. It was traditional at the Rencontres de Moriond for participants to enjoy an afternoon picnic on the ski slope.

This was not a conference or a school, but a gathering ("rencontre") of minds. The name of what became a series of meetings reflects this original motivation. Held in Moriond village, the very first of the Rencontres de Moriond was a resounding success. The 20 participants included theorists and experimenters of all ages, from France, Italy (Frascati) and Germany (DESY). The time was well filled with fruitful but relaxed discussions, culinary experiments, skiing, and evenings spent listening to music performed by the scientists themselves.

The Rencontre was unusual in another respect. Half of the participants and organizers were young researchers, but their views and contributions were as significant as those of the senior members. At Moriond, all participants were equal, and none were more equal than others. Happily this tradition persists today.

For the past 39 years the meetings have not been held in Moriond, but they still take place in the mountains! The content has changed continuously, but the underlying Moriond spirit has taken on a life of its own, much to the surprise of Tran Thanh Van. Those original chalets used in 1966 soon became too small and the Rencontres moved to Courchevel, at the Hotel des Neiges, then wandered from hotel to hotel before finding a temporary home in Meribel in 1970, at the Lac Bleu hotel. Gradually, the Rencontres de Moriond became known as the annual fair of the high-energy physics community. Participants would go their separate ways, conduct their own research, then return to the annual Rencontres to show their latest work, find new collaborators and exchange ideas – and then continue their trek to new horizons. A core membership of more than 80 physicists began to meet annually.

In 1969, Tran Thanh Van felt that it was time to apply the idea of bridges within his discipline to bridges between disciplines. As a result, 1970 saw the addition of a biology meeting (founded by cell biologist Kim Tran Thanh Van) to the particle-physics meetings.

An evolving institution

During the decades that followed, the Rencontres gradually changed in character. From a one-week meeting, devoted essentially to one subject in high-energy physics, it expanded into a two-week conference with two basic topics in particle physics – electroweak and hadronic interactions – and a topic in biology. It became an annual "happening", followed by physicists and biologists worldwide. It was a place to announce new discoveries, to discover the new directions that researchers were taking, ▷

and to forge new friendships and collaborations.

The Rencontres de Moriond became an institution, but the underlying motivation remained intact. Theorists mingled with experimenters; young researchers (postdocs and PhD students) were encouraged to present their work and talk with senior researchers as with colleagues and friends; even the most outrageous ideas had their place. The Rencontres were often the place for young scientists to present their first serious papers before a prestigious international audience, and a place to meet and listen to individuals before there was even a hint that they would one day win a Nobel prize.


A packed Les Arcs conference room (La Coupole) in 1981.

Times changed, the pressure to publish rose and the number of participants grew, but the original convivial spirit of the Rencontres was an invariant from year to year. The early afternoon breaks were invariably devoted to skiing (for beginners and experts alike), but this never stopped the science. Tourists would often wonder who those strange people were, stopping on the pistes to talk about some recondite subject using an esoteric vocabulary, pausing to draw diagrams in the snow, and getting so involved in an arcane discussion on a ski lift that they would almost forget to get off.

Although science was always on our minds, on or off the snow, there was time to talk of other matters, to change the world, to make and listen to music. The scientific community includes a large number of excellent amateur musicians of all kinds, from singers to pianists and violinists, who would often show their skills after dinner around the bar. Sometimes a popular science talk would be organized for the general public of the resort, and these talks were always well received.

Science knows no barriers: a proton is a proton, in Switzerland, America or Russia. But the post-war world was a labyrinth of frontiers and walls, and the Rencontres de Moriond played a part in changing this stifling climate of political confrontation between the East and the West. Every effort was made to help and encourage Russian (and more generally Eastern European) scientists to come to the Rencontres, both to display their considerable scientific expertise – often unrecognised – and to learn about the latest advances in the West. This was a new and different kind of multidisciplinary work, which many years later would find an echo in the Rencontres du Vietnam. The annual Rencontres in the Alps was a peaceful haven where the best minds of hostile, inward-looking nations could meet, talk, exchange ideas, push back the frontiers of their discipline and dream of a happier future.

Changing times

As the 1970s drew to a close, participants at the Rencontres found themselves increasingly attracted by subjects such as atomic physics and astrophysics, which were beginning to encroach on the domain of high-energy physics. The Rencontres had begun as a forum for exchanging ideas in frontier science, and now, true to this spirit, Tran Thanh Van recognized that it was once again time to broaden the scope of the meetings.

In 1981 the Rencontres de Moriond Astrophysique was born. It ran in parallel with the now traditional high-energy and biology meetings, and was an annual event devoted to the study of the infinitely large. The Rencontres de Moriond had become a true interdisciplinary institution, where specialists in distinct disciplines could confront their very different views of the universe. There were accelerator experimenters, observers, theorists in particle physics, cosmologists and even experts in galactic evolution.

The Rencontres was thus restructured around three major centres of interest: biology, high-energy physics and astrophysics. But the rest of science was not neglected. As the 1980s gave way to the 1990s, new subjects, sometimes only marginally related to the regular topics, would start to make an appearance. Among these topics were gravitational physics, mesoscopic physics, the search for the fifth force and for new laws in physics, and tests of the limits of existing laws.

As with all successful enterprises, Moriond has evolved. There are now more subjects, more meetings, more participants and more administration! But the spirit and excitement of those early days remain unabated. No discipline is an island unto itself, and the programme of each meeting, whatever its nominal subject, emphasizes the essential unity of the scientific endeavour.

During its 40 year lifetime, the Rencontres de Moriond has welcomed more than 10 000 scientists of all ages and statures from across the world. The meetings represent an important date in the scientist's calendar. Since 1993 they have been sponsored by the European Union under the euroconference system, and thanks to this financial help, many young researchers have been able to participate – helping to maintain the youth and vigour of the meetings.

Spin-off events

The Rencontres de Moriond has stimulated the creation of other meetings organized in the same spirit: the Aspen Winter Conferences (US) and the Rencontres de Physique de la Valée d'Aoste (La Thuile, Italy) are flourishing examples, where frontier science is conducted in a warm and convivial atmosphere. The Rencontres de Blois, in existence for 17 years, represents another development of the Moriond spirit; these meetings are explicitly multidisciplinary in character, the subject changing from year to year, and culture replaces skiing during the break time.

Most recently, the Rencontres du Vietnam, which started in 1993, has taken this idea even further, with the explicit aim of helping Vietnam, still a developing country, realize its great potential. These meetings offer a forum in which scientists from Asia and the West can meet, present their work and forge new collaborations (*CERN Courier* May 2005 p42).

Which brings us to the present day, and to this year's Rencontres de Moriond. In March it welcomed 20 times as many participants as the first meeting, incorporated audiovisual techniques that were unheard of 40 years ago, and enjoyed instantaneous contact with the world through the Internet. On the programme was research into fundamental questions that had not even been asked in 1966. The impressive set of proceedings, covering several decades, emphasized that we are in the golden age of physics, and that science is more vigorous than ever.

Toasting the top quark discovery after presentations by both the CDF and D0 collaborations in 1995.

But the unique spirit of those early meetings lives on. Of the 400 participants at the 2005 meeting, 57% were younger than 35; of the 350 papers presented, 80% were read by young researchers; 60% of the participants were experimenters or observers and 40% were theorists. Sandwiched between three hours of morning talks and another three hours of hard work in the late afternoon was that traditional break, in which science, snow and sky combine to create new and ever-changing patterns.

What has the Moriond spirit brought to the scientific community? Nobel laureate James Cronin had this to say at the 20th anniversary of the Rencontres: "The Rencontres de Moriond has had a profound effect on the way we communicate in particle physics. It is a format which is extensively copied. The first Rencontres I attended was in 1971. There I learned for the first time about the GIM mechanism from Glashow and Iliopoulos. By having informal conversation on the ski slopes and in the bar at night, one could really understand why charm is necessary... I shall remember... the opportunity to discern the genuine humanity of our colleagues from all over the world."

Résumé

Rencontres de Moriond: 40 ans déjà, mais plus jeunes que jamais

En 1965, Jean Tran Thanh Van, un jeune chercheur d'Orsay, décidait d'organiser des réunions scientifiques plutôt inhabituelles à Moriond, dans les Alpes françaises. Ce ne fut, dans son esprit, ni une conférence, ni un colloque, il a dû créer le terme "Rencontres". Son idée était que les expérimentateurs et théoriciens de tous âges pourraient discuter sur un pied d'égalité, dans un environnement éloigné de leur laboratoire et de leurs problèmes quotidiens. C'est ainsi que naquirent les rencontres de Moriond, précurseurs d'autres Rencontres organisées dans le même esprit.

Ludwik Celnikier, *Observatoire de Paris-Meudon.*

Telescope takes next ste

In April, while Lake Baikal in Siberia was iced ove was successfully upgraded with three additional for diffuse fluxes of cosmic neutrin

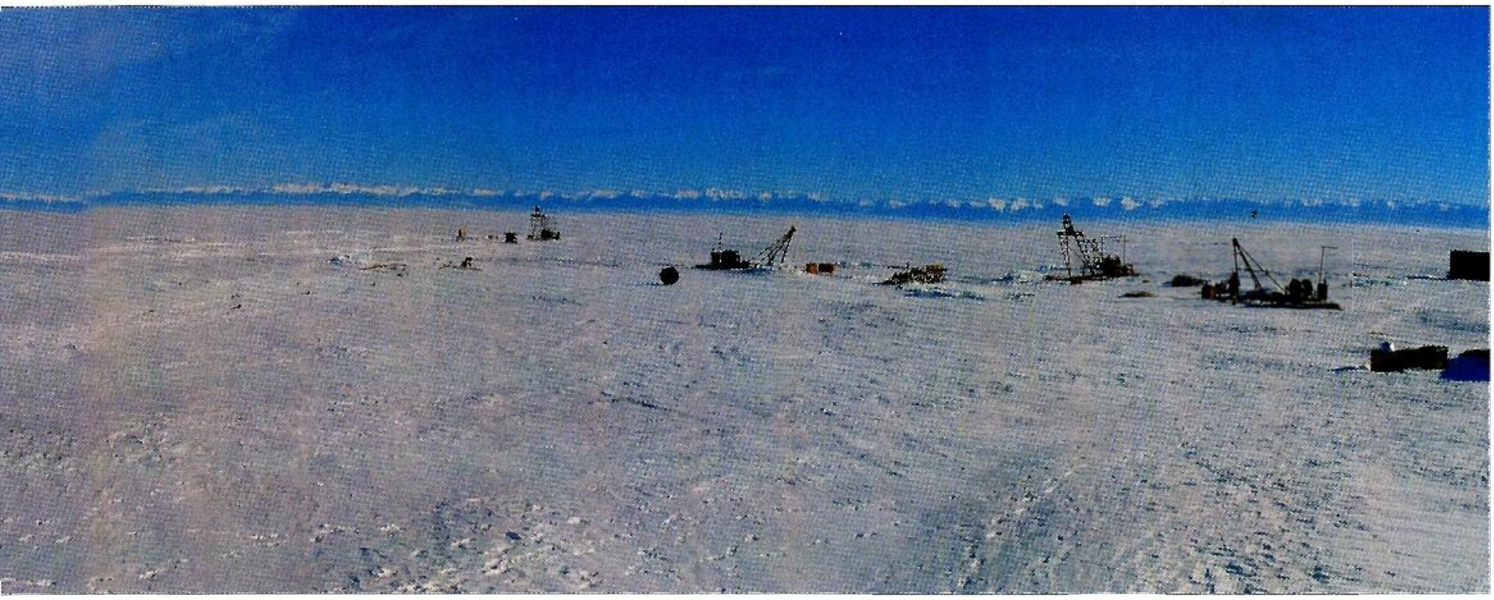
Top: the central trigger electronics in its pressure glass spheres, ready to descend into Lake Baikal. Bottom: a pair of light sensors in water about 10 m below the ice cover of the lake, before deployment to a depth of 1.1 km.

On 9 April 2005, another sunny and bitterly cold day on the south-west shore of Lake Baikal in Siberia, NT200+ was commissioned as the successor to the neutrino telescope NT200. With an effective volume of 10 million tonnes, NT200+ forms one of a trio of large high-energy neutrino telescopes currently in operation, together with Super-Kamiokande in Japan and the Antarctic Muon and Neutrino Detector Array (AMANDA) at the South Pole.

Every year in February and March, the Baikal Neutrino Telescope is hauled up close to the surface of the thick layer of ice that covers the lake in winter for routine maintenance. Then, in early April, in a race against the steadily warming environment, the ice camp with all its containers and winches is dismantled and stored on shore. The telescope is re-deployed to its operational depth of 1.1 km below the surface and switched back on for another year of operation. With a stable ice cover on the lake lasting well into April, nature has been kind this year to the 50 physicists and technicians, who have struggled over two Siberian winters to accomplish their ambitious programme to upgrade NT200.

The existing NT200 telescope consists of 192 glass spheres, 40 cm in diameter, each housing a 37 cm phototube. The first, smaller stage of the telescope was commissioned in 1993, and became the first stationary underwater Cherenkov telescope for high-energy neutrinos in a natural environment (*CERN Courier* September 1996 p24). The full array was completed in 1998 and has been taking data ever since.

The glass spheres are arranged in pairs along eight vertical strings



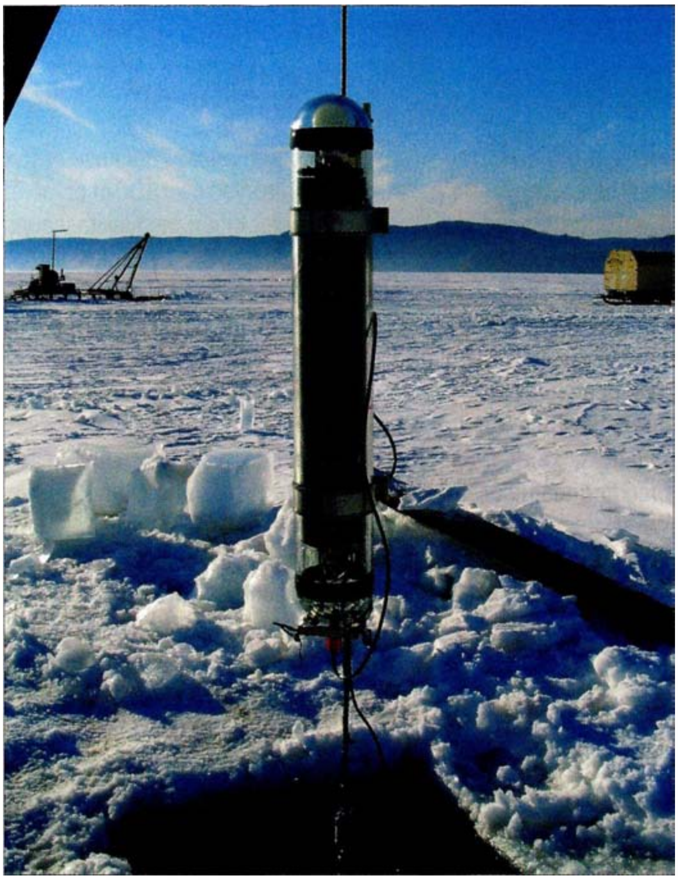
ɔ to high-energy frontier

', the neutrino telescope 1.1 km below the surface strings. Renamed NT200+ it is tailored to search ›s at energies of peta-electron-volts.

that are attached to an umbrella-like frame at a depth of 1.1 km. The phototubes record the Cherenkov light emitted by charged particles as they pass through the water. Three electrical cables, 5 km long with seven wires each, connect NT200 to the shore 3.5 km away and enable the array to be operated throughout the year. Two of these cables were changed in 2004 and 2005. The reliability and performance of the telescope were also improved during this period, with embedded high-performance PCs installed underwater. In addition, new modems operating at 1 Mbit/s have increased the transfer rate to shore by two orders of magnitude.

NT200 looks at the sky for sources of high-energy cosmic neutrinos. Galactic candidates for high-energy sources include supernova remnants and micro-quasars, while extragalactic sources include active galactic nuclei and gamma-ray bursts. If individual sources are too weak to produce an unambiguous directional signal, the integrated neutrino flux from all sources might still produce a detectable "diffuse signal". This flux could be identified by an excess of particles at high energies above the background – which is dominantly muons produced in the atmosphere above the detector, with a small contribution from muons generated in the interactions of atmospheric neutrinos.

The most important result of the first four years of NT200 comes from a search for such a diffuse neutrino flux. It is based on a principle that works only in media with small light scattering, such as water. The idea is not only to watch the geometrical volume of the detector, but also to look for bright events in the large volume ▷



A glass cylinder housing a powerful nitrogen laser, the light of which – shifted to the blue – illuminates all photomultipliers and allows a time synchronization of about 2 ns. The light flash also mimics high-energy particle cascades in an energy range from 20 TeV to 10 PeV.

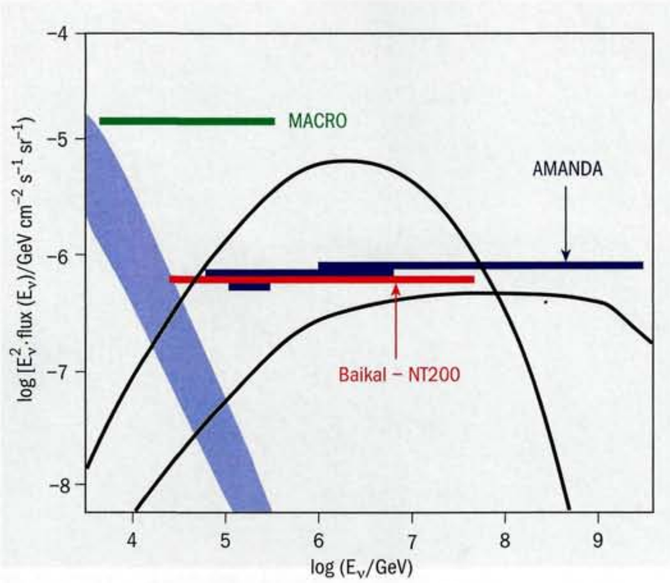


Fig. 1. The best current experimental limits on the flux of diffuse high-energy cosmic neutrinos of all three types. The limit from the Baikal experiment (1998–2002) covers an energy range of 20 TeV to 50 PeV. The various AMANDA limits are for one year. The upper curve denotes a model for neutrino production in active galactic nuclei, which is excluded by the new limits since it predicts a fourfold higher flux; the lower curve represents another model that can be tested only with more and better data. The band at the left side denotes the known flux of neutrinos generated in the atmosphere.

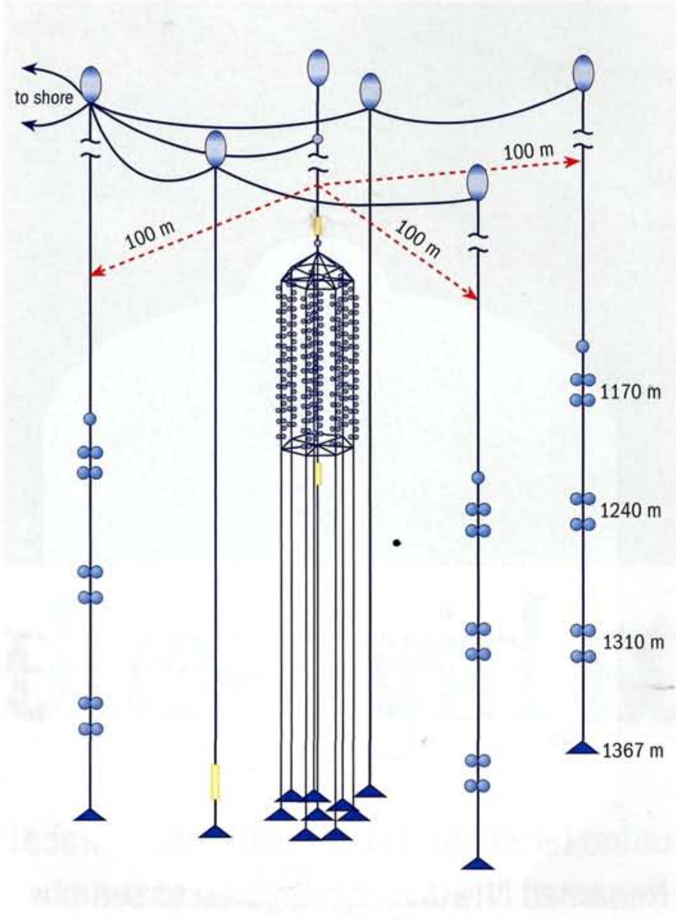


Fig. 2. The new NT200+ adds three outer strings to NT200, which has operated since 1998. Each string carries 12 light sensors. Calibration lasers are shown in yellow.

between the detector and the bottom of the lake. Because of the small light scattering, wave fronts are preserved over 100 m or more. This results in good pattern recognition for bright particle cascades occurring far outside the geometrical volume, and it enables distant high-energy cascades generated by neutrinos to be distinguished from bright bremsstrahlung showers along the much more frequent downward-going muons. No such events in excess of background have been found.

This result can be transformed into a limit on the flux of cosmic neutrinos, for a given spectral distribution. Assuming a reference spectrum that falls with the inverse square of the neutrino energy, four years of Baikal data yield the flux limit shown in figure 1. For comparison, the limits obtained in one year with the much larger AMANDA telescope are shown. Both experiments have entered new territory and exclude several models for sources of cosmic neutrinos.

It is this success that motivated the upgrade to NT200+. In the new configuration, three 140 m strings with 12 photomultipliers each are arranged at a radius of 100 m from NT200, so that they surround most of the sensitive volume (figure 2). This enables a much better determination of the shower vertex and dramatically improves the energy resolution. As a result, the upgrade, which adds only 36 photomultipliers to the existing 192, yields a fourfold rise of the sensitivity at 10 PeV – certainly a cost-effective way to do better physics.

The results from NT200 have demonstrated that a deep underwater detector with an instrumented volume of 80 kt can reach an effective volume of a few megatonnes at peta-electron-volt energies. NT200+, with its moderate but cleverly arranged additional instrumentation, will boost the effective volume to more than 10 Mt. If successful, this could become the prototype for an even larger, sparsely instrumented detector for high energies.

• The Baikal Telescope is a joint Russian-German project, with the Institute for Nuclear Research (INR) in Moscow, the Moscow State University, the Joint Institute for Nuclear Research, Dubna, the Irkutsk State University (all Russia) and DESY (Germany).

Résumé

Le télescope du Baïkal va explorer de nouveaux territoires

Le télescope à neutrinos du lac Baïkal est un détecteur immergé par environ 1.1 km de fond. Les opérations de maintenance et d'amélioration ont lieu en février et mars, époque où le lac est recouvert d'une épaisse couche de glace. Cette année, le télescope existant, NT200, a été doté de trois lignes supplémentaires de tubes photomultiplicateurs. Rebaptisé NT200+, le détecteur ainsi amélioré recherchera des flux diffus de neutrinos cosmiques à des énergies de l'ordre du péta-électron-volt.

Grigorij Vladimirovitch Domogatsky, *INR Moscow, and*
Ralf Wischnewski, *DESY.*

ClearPET offers improved insight into animal brains

An efficient new PET scanner for the small animal brain, developed by the Crystal Clear collaboration, is now in production.

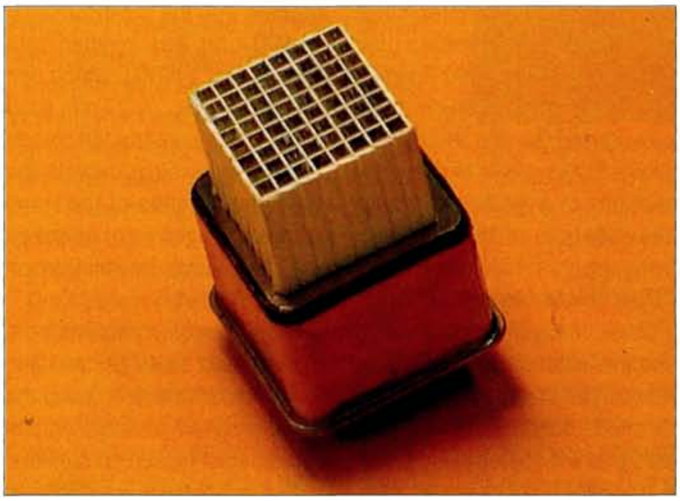


Fig. 1. A detector head based on a LYSO-LuYAP crystal matrix, mounted on a multi-anode photomultiplier tube.

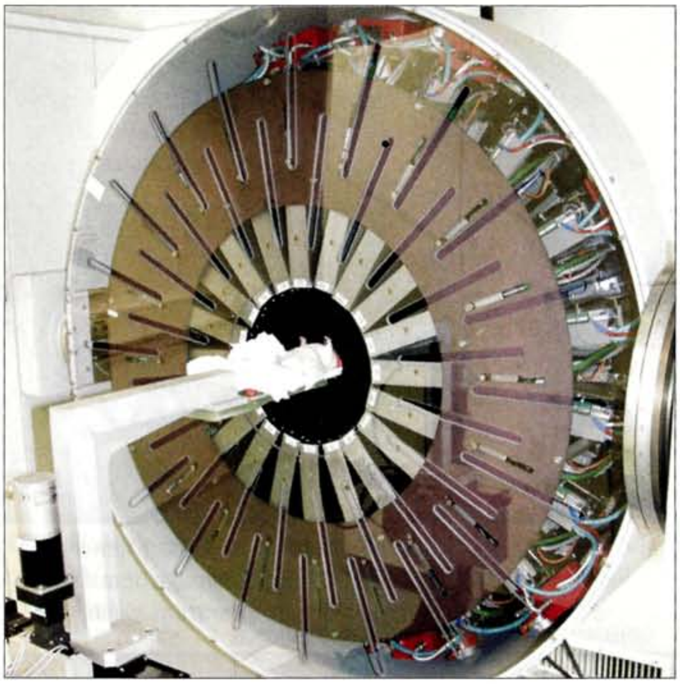


Fig. 2. The ClearPETNeuro system at the Forschungszentrum Jülich. Here it is being used to image a rat's brain.

Crystal Clear is an international collaboration of research institutes, working to develop new generations of scanners for positron emission tomography (PET). The members are CERN, Forschungszentrum Jülich, the Institute of Nuclear Problems in Minsk, the Institute for Physical Research in Ashtarak, the Laboratório de Instrumentação e Física Experimental de Partículas (LIP) in Lisbon, Sungkyunkwan University School of Medicine in Seoul, the Université Claude Bernard in Lyon, the Université de Lausanne and the Vrije Universiteit Brussel (VUB).

Together with a number of guest laboratories, the institutes provide expertise in different domains of physics instrumentation, biology and medicine. Their research activities have led to the design and construction of three prototypes of a new generation of PET scanners for small animals, which provide depth-of-interaction (DOI) information. This machine has now been commercialized by the German company Raytest GmbH under the name ClearPET.

In PET, a molecule involved in a metabolic function of an organ or tumour is labelled by a positron-emitting radioisotope. Once injected, it is taken up by the cells or organs under study. The emitted positrons annihilate with electrons in the surrounding atoms to produce a back-to-back pair of gamma rays. Detecting this gamma radiation reveals the detailed distribution of the isotope.

In the prototype scanners developed by the Crystal Clear collaboration, the detector heads are based on an 8×8 matrix of scintillation crystal elements, read out by a multi-anode photomultiplier tube (figure 1). Each element consists of a phosphor sandwich, or phoswich, made up of two layers of crystals with different decay times. One layer is formed from cerium-doped lutetium yttrium orthosilicate (LYSO) scintillator material; the other contains cerium-doped lutetium yttrium aluminate perovskite (LuYAP) scintillator, specially developed by the Crystal Clear collaboration and now commercially available from several companies.

The phoswich arrangement yields DOI information that can be used to correct parallax errors, resulting in a more uniform spatial resolution across the field of view. The crystal elements have an area of 2×2 mm and are 8 or 10 mm long; they are separated by 300 μm Tyvek, a highly reflecting material.

The detector modules, which are installed on a rotating gantry, consist of four detector heads mounted in line together with readout electronics. A complete ring system contains 20 detector modules. Because the gantry rotates during a scan, not all of the 20 need to be present. This allows the option of designing a cost- ▷

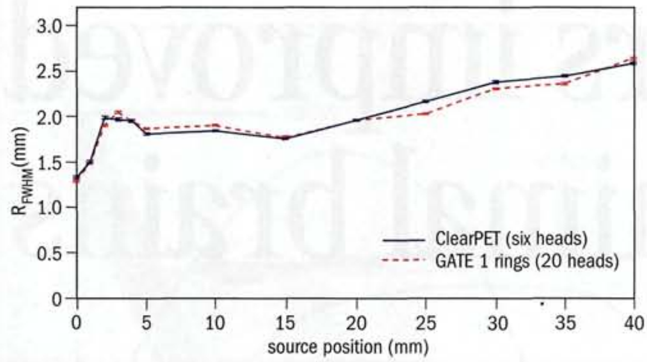


Fig. 3. Radial resolution as a function of the radial distance to the scanner axis. The red curve shows the prediction from a Monte Carlo simulation, while the blue curve is the measured resolution in the reconstructed image of a point source. These were performed on the Lausanne ClearPET demonstrator.

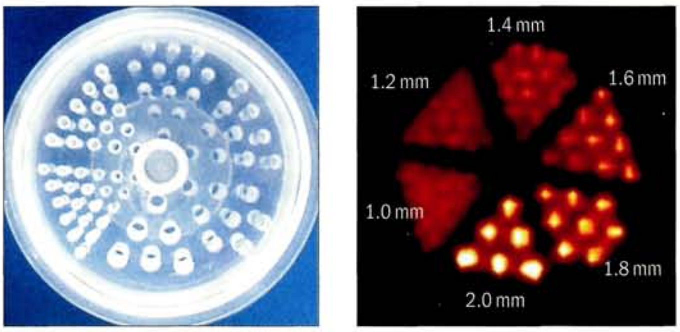
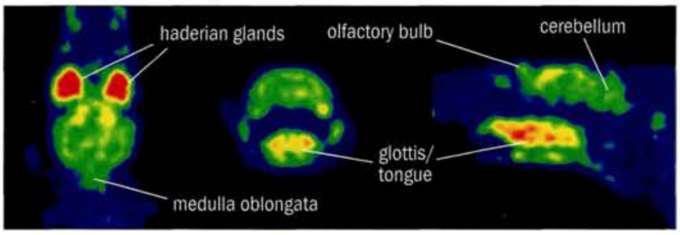


Fig. 4 (a). Left, the Derenzo phantom, with capillary tubes of various diameters. (b) Right, reconstructed image obtained with the ClearPETNeuro of the Forschungzentrum Jülich.



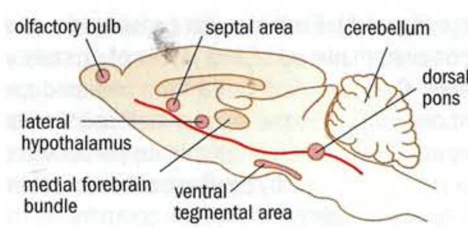


Fig. 5 (a). Above, PET image showing uptake in a rat brain labelled with ^{18}F. (b) Right, anatomy of a rat brain.

effective system based on a partial ring configuration. Two versions of the scanner are being produced, differing only in the mechanics of the gantry. ClearPETNeuro is optimized for small primates and features a gantry that can be tilted to allow the animal to be imaged in a sitting position, while ClearPET Rodent is optimized for rats and mice.

The performance of the ClearPET prototypes has been studied in various tests. The spatial resolution was measured by imaging a point source of the positron emitter ^{22}Na. Figure 3 shows that the spatial resolution is close to the predictions made in detailed Monte Carlo simulations using GATE, the Geant4 Application for Tomographic Emission (*CERN Courier* January/February 2005 p27). At the centre of the field of view the resolution is 1.35 mm FWHM, and it remains constant around 1.8 mm FWHM for objects within 20 mm of the scanner axis.

A general feeling for the ClearPET's performance was obtained by imaging a phantom – a model that measures the characteristics of a medical imaging system. An ad hoc Derenzo phantom was used, consisting of capillary tubes with diameters varying between 1.0 and 2.0 mm, arranged like slices in a pie. Rods of the phantom were filled with 0.5 mCi ^{18}F, a positron emitter regularly used, for example, in PET scans of the brain. It was scanned for 6 min. Figure 4 shows a picture of the phantom and a reconstruction using the ordered-subsets expectation maximization (OSEM) method. Tubes with diameters as small as 1.6 mm are still clearly distinguishable.

The prototypes have also been tested with real subjects. Figure 5 (a) shows one of the rat images obtained with the ClearPETNeuro of the Forschungszentrum Jülich. A 400 g rat was injected with 0.5 mCi of ^{18}F-labelled fluorodeoxyglucose ([^{18}F]FDG), which can be used to observe sugar metabolism in the brain. A 24 min scan was started 30 min after the injection. The reconstructed image shows FDG uptake in the head of a rat. Figure 5 (b) depicts the anatomy of a rat brain. Note the good identification of the small olfactory bulb in front of the brain. These images were obtained using the library of Software for Tomographic Image Reconstruction (STIR) at Hammersmith Hospital, London.

These measurements meet the ClearPET design specifications, and the first images obtained with a rat support these encouraging results. The ClearPETNeuro of the Forschungszentrum Jülich and the ClearPETRodent at the Vrije Universiteit Brussel are nearing completion, and will soon be used in several biomedical research projects.

● "ClearPET" has been registered as a trademark and the technology is licensed to Germany's Raytest GmbH, which is commercializing a small animal PET system based on the ClearPET Rodent developed by Crystal Clear. See www.raytest.de/index2.html.

Further reading

For more on Crystal Clear, GATE or the STIR library, visit http://crystalclear.web.cern.ch/crystalclear, www.opengatecollaboration.org or http://stir.hammersmithimanet.com respectively.

Résumé

Le ClearPET, un nouvel outil pour l'imagerie cérébrale du petit animal

Crystal Clear est une collaboration internationale regroupant des instituts de recherche afin de développer de nouvelles technologies pour les prochaines générations de scanners pour la tomographie par émission de positons (TEP). Leur recherche les a menés à la conception et à la fabrication de prototypes pour une nouvelle génération de scanners TEP pour de petits animaux. L'image d'un cerveau de rat révèle le potentiel des nouveaux scanners.

Stefaan Tavernier, *Vrije Universiteit Brussel, spokesman of the Crystal Clear collaboration.*

CERN

India strengthens links with CERN

On 25 May the president of India, Avul Pakir Jainulabdeen Abdul Kalam, came to CERN between state visits to Russia and the Swiss Federation. Anil Kakodkar, the chairman of India's Atomic Energy Commission, accompanied the president, who is a physicist and supporter of CERN. The visit included the tunnel of the Large Hadron Collider (LHC), the ATLAS experimental cavern and the test facility for the LHC magnets, where the president had the chance to meet Indian scientists working at CERN.

India has been an active partner of CERN for many years and was one of the first non-member states to make significant contributions to the LHC. In 1991 India and CERN first signed a formal collaboration agreement. In 2002 CERN granted the country observer status.

Left to right: Anil Kakodkar, chairman of India's Atomic Energy Commission, Robert Aymar, director-general of CERN, Avul Pakir Jainulabdeen Abdul Kalam, president of India, and Philippe Lebrun, head of the Accelerator Technology department at CERN, during their visit to the LHC magnet test facility at CERN in May.

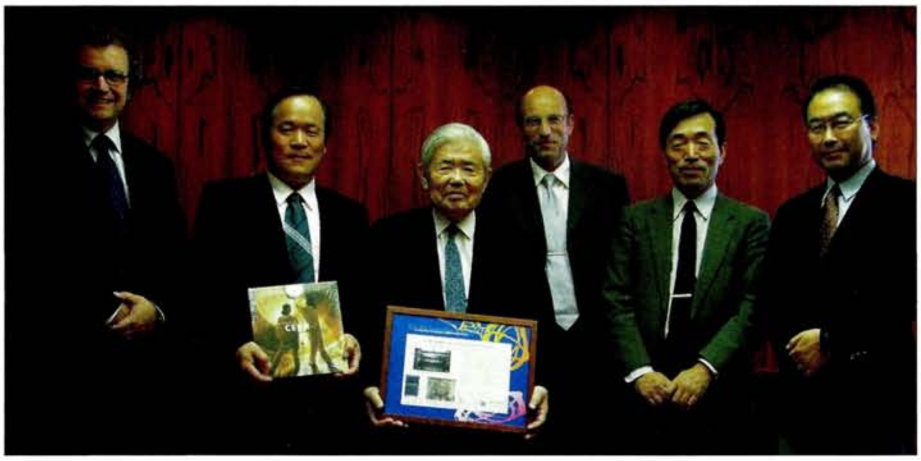
During the visit Kakodkar and CERN's director-general, Robert Aymar, signed a statement of intent. The purpose is "to encourage extending the existing scientific and technical co-operation between India and CERN, in particular in the field of novel accelerator and information technologies, as well as through training and educating scientists and technical experts". The aim is to draft a protocol to the co-operation agreement, for India and CERN to sign in the near future, extending the existing collaboration into the long term.

India's collaboration with CERN currently involves some 130 people, with scientists participating in the CMS and ALICE experiments for the LHC. In addition, many Indian universities and R&D organizations, as well as Indian industry, have contributed to the LHC project, delivering state-of-the-art equipment. India is also helping to establish a regional Tier-2 computing centre using GRID technology to provide a platform for their scientists to analyse the LHC data.

KEK

ATLAS spokesman visits Hamamatsu and KEK in Japan

On 16 May Peter Jenni, spokesperson for the ATLAS experiment, and Jos Engelen, chief scientific officer at CERN, visited Hamamatsu Photonics, Japan, which has produced silicon microstrip sensors for the ATLAS silicon-tracking detector, on which the ATLAS–Japan group works. While there, Jenni presented the ATLAS Supplier Award to the company's president, Teruo Hiruma, in recognition of its production of very-high-quality sensors.



Left to right: Jos Engelen, CERN's chief scientific officer; Koei Yamamoto, senior managing director of Hamamatsu Photonics; Teruo Hiruma, chairman of the board and CEO of Hamamatsu Photonics; Peter Jenni, ATLAS spokesman; Takahiko Kondo, ATLAS–Japan co-spokesperson, KEK; and Yoshinobu Unno, ATLAS–Japan silicon project leader, KEK.

Two days later, Jenni delivered a presentation on the Large Hadron Collider and the ATLAS experiment at the Japanese national high-energy physics laboratory (KEK), and had in-depth discussions with members of the ATLAS experiment in Japan. Working in collaboration with Japanese universities and companies, KEK is producing a significant part of the ATLAS detector, including silicon-tracking detectors, muon-trigger chambers and the superconducting solenoid.

APPOINTMENTS

GSI names new head of Accelerator Division

GSI have named Hartmut Eickhoff as the new head of its Accelerator Division, after almost a year of interim leadership by Bernhard Franzke following Norbert Angert's retirement.

Eickhoff, who joined the division in 1980, was in charge of injection/extraction systems during the construction phase of the Schwerlonen-Synchrotron/Experimental Storage Ring (SIS/ESR) and led the Accelerator Development Group for the synchrotron development and operation. He also moved into heavy-ion therapy, first preparing the GSI facility for patient treatment and later becoming project leader for the Heidelberg cancer-therapy accelerator facility currently under construction. He will now oversee the development of the Facility for Antiproton and Ion Research (FAIR), the challenging new project of GSI and its international partners.

Hartmut Eickhoff, the new permanent head of the Accelerator Division at GSI.

HONOURS

Oelert nominated to Polish academy

Oelert at CERN in 1996, with the experiment that detected the first atoms of antihydrogen.

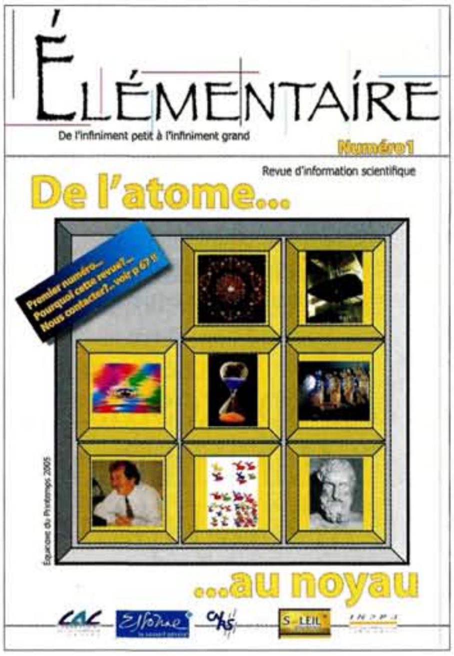
On 20 April, at Berlin's Polish embassy, Walter Oelert from the Forschungszentrum Jülich (FZJ), Germany, was nominated as a member of the Polish Academy of Sciences to honour his longtime co-operation with Polish scientists.

Even before the collapse of the iron curtain, Oelert maintained close links with Polish physicists at the University of Krakow, and strengthened them during the construction and operation of the Cooler Synchrotron (COSY) accelerator at the FZJ in the 1990s. Oelert helped to set up a laboratory in Krakow for the further development of particle detectors and to organize symposia in Poland.

PUBLICATIONS

Elémentaire, mon cher Rutherford!

Comme son nom l'indique, la revue *Elémentaire* s'est donnée pour objectif d'expliquer de manière simple l'univers des particules élémentaires. Soutenue par le Laboratoire de l'Accélérateur Linéaire (LAL), l'IN2P3, le Synchrotron SOLEIL et le Conseil général de l'Essone, cette revue d'information scientifique est bi-annuelle. Le comité de rédaction *d'Elémentaire* entend "suivre, tel un fil rouge, l'évolution de la construction de la machine LHC et des expériences qui y seront installées". Se faisant, l'idée est de donner les clés de base de la physique des particules pour qu'un tel projet soit compris par le plus grand nombre.



En l'occurrence, le premier numéro laisse la part belle aux notions de bases de la physique subatomique, relatant 2500 ans d'histoire de l'atome de Démocrite à Rutherford. D'autres pages sont dédiées à l'actualité du LHC à CERN mais aussi à des explications sur les techniques d'accélération, de détection, avec un reportage plus spécifique sur l'installation de physique nucléaire GANIL à Caen et le multi-détecteur de particules chargées INDRA.

- Voir http://elementaire.web.lal.in2p3.fr.

AWARDS

Russian Academy awards gold medals

The presidium of the Russian Academy of Sciences has awarded the 2004 Bogoliubov Gold Medal to Dmitry Shirkov, honorary director of the Bogoliubov Laboratory of Theoretical Physics at the Joint Institute for Nuclear Research, Dubna. The presidium has also awarded the 2004 Skobeltsin Gold Medal to Georgi Zatsepin of the Institute of Nuclear Physics, Moscow.

Shirkov was a student of Nikolai N Bogoliubov, and in the 1950s they co-wrote papers on quantum-field theory (QFT), superconductivity theory and the renormalization group method (*CERN Courier* September 2001 p19). Their book *Introduction to the Theory of Quantized Fields* has served for many years in the final part of education in modern theoretical physics.

Dmitry Shirkov (left) and Georgi Zatsepin (right): Russian Academy gold medal winners .

Shirkov transferred the formalism of the Bogoliubov renormalization group from QFT to mathematical physics, introducing the notion of "functional self-similarity" in the early 1980s. More recently, he developed an algorithm to apply it to various mathematical problems, work for which he received the medal from the Russian Academy.

Zatsepin received the Skobeltzin medal for his outstanding contribution to cosmic-ray physics, elementary-particle physics and astrophysics; and for the creation of a first-class scientific school on cosmic-ray physics, neutrino physics and astrophysics. He is a pioneer of many aspects of cosmic-ray physics and neutrino astrophysics, and is well known for the prediction of the cosmic-ray cut-off – the Greisen–Kuzmin–Zatsepin effect.

He helped to create the Baksan Neutrino Observatory and the gallium–germanium neutrino telescope, and participates in the Russia–US solar-neutrino experiment, SAGE.

AWARDS

Theorists win prize of some gravity

Left to right: winners Dimitri Nanopoulos, John Ellis and Nick Mavromatos in earlier days.

The Gravity Research Foundation has awarded its 2005 prize to John Ellis of CERN, Nick Mavromatos of King's College, London, and Dimitri Nanopoulos of Texas A&M University. The foundation holds an annual essay contest on gravitation, its theory, applications or effects.

They wrote about their time-dependent string approach to cosmology, in which string provides the universe with vacuum energy, making its expansion accelerate at a rate equal to the square of the string-coupling strength. Recent measurements of the expansion of the universe indeed indicate acceleration that can be interpreted as vacuum energy. Moreover, the latest measurement yields a good value for the string-coupling strength. The trio previously won in 1999, and join theorist Gary T Horowitz as the only authors to win the prize twice.

Further reading

For the prize-winning paper, see http://arXiv.org/abs/gr-qc/0503120.

DESY accelerator physicists honoured

The US Particle Accelerator School has awarded its Prize for Achievement in Accelerator Physics and Technology to Anton Piwinski from DESY, for his "fundamental contribution to the understanding of charged particle beams in circular accelerators, in particular of intra-beam scattering, beam–beam effects and synchro-betatron resonances". During his 34 year career at DESY and his time as a scientific associate at CERN (1984–1986), Piwinsky played a leading role in the successful commissioning and improvements of accelerators such as DORIS, PETRA, HERA and LEP.

Lutz Lilje from DESY has received the German laboratory's Bjørn H Wiik Prize 2005 for his outstanding contributions to the development of superconducting resonators with very high gradients. In 2002 Lilje and colleagues from KEK used electrolytic polishing to achieve a 35 MV/m accelerating gradient in a nine-cell niobium resonator. After the technique had been introduced at DESY, the team was able to reach 35–40 MV/m with a quality factor of 10^{10}, first in one-cell resonators and now in nine-cell resonators.

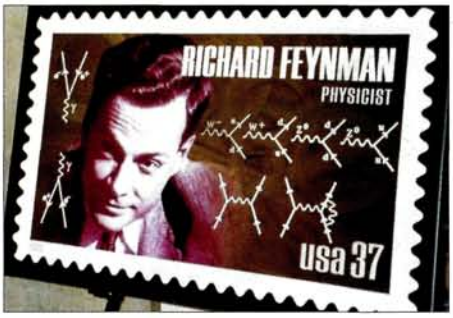
Prizes reward QCD and proteins studies

Particle physicist Iwona Grabowska-Bold and molecular biologist Oliver Schilling have won the annual PhD Thesis Prize of the Association of the Friends and Sponsors of DESY. Grabowska-Bold's work, carried out in the ZEUS collaboration, explored virtual Compton scattering, thereby providing a new test of quantum chromodynamics. Schilling used X-ray absorption spectroscopy at the European Molecular Biology Laboratory to investigate proteins that play a role, for instance, in resistance against antibiotics and the origin of prostate cancer.

DEDICATION

Stamp and street named for Feynman

On 11 May, the late Richard Feynman's birthday, a stamp was dedicated to Feynman at the Far Rockaway Post Office in Queens, the borough of New York City where he grew up. In addition, a street on which he lived as a boy was named "Richard Feynman Way". Among the attendees at the ceremony were many of Feynman's relatives, including his daughter Michelle and son Carl. His sister Joan and cousin Frances Lewine were also there and spoke about Feynman as a budding scientist in his early teens.



The Richard Feynman stamp, with various Feynman diagrams. (Text and photo courtesy Samuel Marateck, Courant Institute, New York University.)

The Feynman diagrams on the stamp show, among other things, how his work originally applicable to quantum electrodynamics, for which he won the Nobel prize, was later used to elucidate the electroweak force. The stamp shows flavour-changing transitions, e.g. $d \rightarrow W^- + u$, and flavour-conserving transitions, e.g. $d \rightarrow Z^0 + d$, of the electroweak force, where d represents the down quark, u the up quark, and W and Z represent the intermediate vector bosons.

Michelle Feynman was sent a provisional version of the stamp by the US Postal Service and was advised on the design by, among others, Ralph Leighton, co-author with Richard Feynman of two popular books, as well as Steven Frautschi and Kip Thorne from Caltech. Frautschi and Leighton edited the Feynman diagrams, and Frautschi rearranged them and composed the final design. The person who chose the original Feynman diagrams that form the basis of the stamp is a mystery.

WORLD YEAR OF PHYSICS

Physics stories inspire

Stories are a compelling way to reach students and adults, and stories about physics can do much to make physicists and their work better understood, and to convey the excitement of real scientific research. This is the concept behind the Physics Stories project, set up during World Year of Physics by an international committee and project leader Fred Hartline, from Argonne National Laboratory. The aim is to challenge scientists and science educators worldwide to share their best stories with students and teachers of all cultures and nationalities.

Authors from any country are invited to submit their science stories, which may be about scientists, scientific research, phenomena, discoveries, how things work, and so on. The intention is to spark an interest in and an appreciation of scientists and their work – especially physicists, who contribute in so many ways to so many disciplines. Articles are submitted in the author's preferred language and in English, and volunteers from other countries translate the stories into their own languages.

Eventually, entries will be judged by students from around the world who visit the website, and the students' 10 favourite stories will receive special recognition.

- For further information about the Physics Stories project see http://wyp.dep.anl.gov/.

New Zealand student tour reaches CERN

Pictured with their teacher Noema Watene (far left) are the three prize-winners Katrina Hamblin, Jordan Roach and Ellen Clarkson, in front of the CMS magnet.

Three high-school students from Fairfield College in Hamilton, New Zealand, visited CERN on 6 June after winning first prize in a scientific-film competition promoted by the Royal Society of New Zealand for World Year of Physics. The reward for their documentary on physicist and winner of the Nobel Prize for Medicine, Maurice Wilkins, was a trip to Italy and Switzerland, including a stop at CERN. After breakfast with the director-general, Robert Aymar, the students were shown around the antiproton decelerator and the CMS experiment, accompanied by one of their teachers and a science journalist.

- For more about the project see www.rsnz.org/events/emc2/video.php.

NEW PRODUCTS

Bede has launched a digital X-ray inspection tool for the high-speed identification and quantification of structural defects in semiconductor wafers up to 300 mm in diameter. The BedescanT is ideal for high-volume manufacturing and uses X-ray diffraction to identify anomalies in substrates and epilayers. For more details see www.bede.co.uk.

Burle Electro-Optics Inc has released a new line of Spiraltron electron-multipliers for mass-spectrometry applications. These compact detectors offer higher performance, improved linearity over a wider current range, higher-pressure operation and lower noise. For further information call +1 508 347 4000 or e-mail sales@burle-eo.com.

Optical Surfaces Ltd has launched a new range of motorized optical mounts. Offering high resolution (to 0.1 arcsec) and uni-directional repeatability (0.5 arcsec), they are designed for positioning large precision optics where stability of pointing is important. The range covers apertures from 305 mm to 550 mm. For further information tel +44 208 668 6126, e-mail sales@optisurf.com or see www.optisurf.com.

Physik Instrumente says that its model E-480 is the most powerful four-quadrant DC piezo amplifier currently available. The bipolar high-voltage driver provides 200 W of dynamic power in an output range of 1000 V or ± 500 V. Based on a novel design employing energy-recovery technology, it can be operated in inverting and noninverting modes. For further information call +1 508 832 3456 or see www.physikinstrumente.de/products/.

Pulse Power & Measurement has announced new fibre-optic-link products for test and instrumentation, particularly in electrically noisy environments. The DC-coupled point2point system now offers DC-to-10 MHz operation, and the AC-coupled system offers a bandwidth as high as 3 GHz. There are also new Sentinel IIsc and Sentry IIsc systems, with bandwidths exceeding 1 GHz and performance at lower operating frequencies respectively, both managed by a new system controller. For more information e-mail apps@ppm.co.uk or see www.ppm.co.uk.

LETTERS

CERN Courier welcomes letters from readers. Please e-mail cern.courier@cern.ch. We reserve the right to edit letters.

Open access in accelerator physics

It pleases me that the *CERN Courier*, itself an open-access journal, has put the debate of scientific publishing on the agenda. Ken Peach's "Viewpoint" (*CERN Courier* June 2005 p50) is an excellent contribution to the discussion and should be carefully read by everyone in the publication chain.

In the field of accelerator physics a major fraction of our literature is nowadays made available through open-access publications. Our main conference series, i.e. PAC, EPAC, and APAC, are all published as open-access through JACoW (http://accelconf.web.cern.ch/AccelConf/). Our scientific articles are to a large extent submitted to *Physical Review Special Topics – Accelerators and Beams (PRST-AB)*, a peer-reviewed, all-electronic journal published by the American Physical Society. The journal is available to everyone without subscription or pay-per-view fees and even without author charges, all thanks to the support of sponsors.

PRST-AB has quickly become the primary means of communicating new results in accelerator physics, but so far, unfortunately, no European institutions are among its sponsors. I hope that this situation will soon change to ensure the continuity of open-access publishing in accelerator physics.
Frank Zimmermann, CERN.

A question of sponsorship

Ken Peach's article on open access was met, on my part, with a combination of a grain of salt and wry amusement. The American Physical Society started an all-electronic open-access journal called *Physical Review Special Topics – Accelerators and Beams* that has been successfully published since 1998. The journal has been endorsed by the Division of the Physics of Beams of the APS and the Accelerators Group of the European Physical Society. It has been supported by sponsorship contributions from large accelerator laboratories in the US and Canada, with no charges either to authors or to readers. This only partially covers its costs, and the shortfall has to be made up by the APS. This is sustainable in the short term, but becomes an increasing burden as more articles than the current 10 per month are published.

Periodically I hear of endorsement by one or another part of CERN for open-access journals, but in spite of occasional requests CERN has declined to become a sponsor of *PRST-AB*. To date 52 articles have been published with one or more CERN authors, and more have been based on results from CERN accelerators. Isn't it time that CERN – one of, if not the, largest accelerator laboratories in the world – came forward?
Martin Blume, editor-in-chief, APS.

SLAC has honoured its first director, W K H "Pief" Panofsky, with a Chinese lion dance for his 86th birthday. The ritual reflects his significant scientific and governmental affinities with China. Lion dances and dragon dances are performed on auspicious occasions as a way to confer best wishes for the honouree. Lions are considered peaceful and divine animals symbolizing strength, courage and wisdom.

On 28 May Les Houches Summer School unveiled a sculpture dedicated to Yves Rocard (see obituary in *CERN Courier* May 1992 p25), benefactor of the school. Seen here, from left to right, are Vincent Barré, the sculptor, Cecile Morette-Dewitt, founder of the school in 1951, and Francis Rocard, astrophysicist and Yves' grandson. The sculpture can be seen in the background and consists of structures that vibrate in the wind, recalling Yves' interest in vibrational phenomena. (Courtesy André Martin.)

MEETINGS

The **IVth SNOLAB Workshop** takes place at the facility's new surface building on 15–17 August. The main goals of the workshop are to update the scientific community on SNOLAB construction and the development of the scientific programme; to establish an initial suite of experiments for SNOLAB; to develop further the longer-term scientific strategy for SNOLAB; and to begin the development of a users group for the new facility. For further details see http://snolab2005.snolab.ca/.

The **DESY Theory Workshop on Quantum Chromodynamics from the MeV to the TeV Scale**, organized by Johann Kuehn of Karlsruhe University, will be held at DESY, Hamburg, on 27–30 September. For more information see www.desy.de/desy-th/workshop2005.

The **2nd Vienna Central European Seminar on Particle Physics and Quantum Field Theory** is to be held in Vienna on 25–27 November. This year's subject is "Frontiers in Astroparticle Physics". Invited speakers from major research centres will cover recent developments, both experimental and theoretical. Special grants will be available for younger scientists to participate. For further details see www.univie.ac.at/vienna.seminar/index05.html.

OBITUARIES

Hubert Curien (1924–2005)

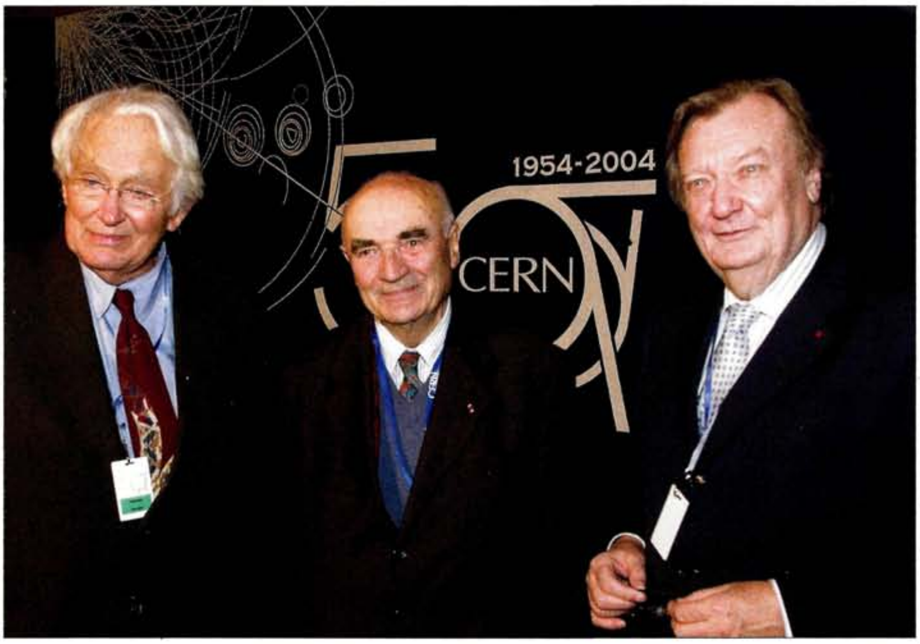
Le 6 février 2005, le français Hubert Curien, l'un des grands artisans de l'Europe scientifique, s'éteignait à l'âge de 80 ans. Des personnalités de toute l'Europe, de tous les domaines scientifiques et de toutes les sensibilités politiques lui ont rendu hommage. "S'il existe aujourd'hui un semblant d'Europe scientifique, nous le devons en grande partie à M. Curien. Il a joué un rôle clé dans l'histoire de la coopération scientifique européenne", déclarait Janez Potocnik, commissaire européen en charge de la science et de la recherche.

Né le 30 octobre 1924, Hubert Curien étudie la physique à l'Ecole normale supérieure à Paris. Il s'oriente vers la cristallographie, domaine dans lequel il se fait remarquer par la découverte d'une nouvelle forme cristalline du gallium.

Professeur à l'Ecole Normale supérieure, puis à l'Université de Paris VI, il entre en 1966 au Centre national de la recherche scientifique (CNRS) comme Directeur scientifique. Il en devient le Directeur général de 1969 à 1973, avant d'être nommé en 1976 Président du Centre national d'études spatiales, CNES.

A ce poste, il mettra toute son énergie pour la réussite du projet de lanceur spatial européen, Ariane. La première fusée européenne s'élance à la veille de Noël 1979. L'Europe tient depuis un rôle majeur dans la politique spatiale mondiale. Parallèlement, Hubert Curien préside de 1981 à 1984 le Conseil de l'Agence spatiale européenne. Considéré depuis lors comme le père de la politique spatiale européenne, Hubert Curien est nommé Ministre de la recherche du gouvernement français en 1984. Le portefeuille lui sera confié à nouveau en 1988 et il le conservera jusqu'en 1993.

Il est élu Président du Conseil du CERN en



Hubert Curien au centre, entouré de deux lauréats du Prix Nobel du CERN, Georges Charpak, à gauche, et Carlo Rubbia, à droite, lors de la célébration des 50 ans du CERN en octobre 2004. Ce devait être sa dernière visite au Laboratoire.

1994, l'année de la décision de construire le grand collisionneur de hadrons, LHC. Hubert Curien use de son talent d'habile négociateur pour convaincre les Etats Membres du CERN de s'engager dans cette ambitieuse entreprise. Fin 1994, le Conseil du CERN parvient ainsi à un consensus pour construire le LHC en deux étapes, avec les ressources disponibles.

Avec la Direction du CERN, il contribue à rallier les Etats non-membres au projet, afin d'en accélérer la réalisation. Il s'agit notamment de convaincre les Etats-Unis qui viennent d'abandonner leur projet de Super collisionneur, mais également le Japon, le Canada, l'Inde et la Russie.

Au cours des trois années qui suivent, tous ces Etats font leur entrée dans le projet LHC, apportant des contributions significatives. Si bien qu'au terme du mandat d'Hubert Curien, fin 1996, un accord est trouvé entre les Etats membres pour construire le LHC en une seule étape, grâce aux contributions d'autres pays.

Hubert Curien restera l'un des grands amis du CERN qu'il considérait comme une référence pour les organisations scientifiques européennes. En 2001, il devient Président de l'Académie des sciences en France dont il était membre depuis 1993.

Hubert Curien a marqué la science par ses contributions exceptionnelles. Tous ceux qui l'ont côtoyé témoignent de surcroît de ses remarquables qualités humaines. Sa stature allait de pair avec une grande simplicité et une modestie désarmante.

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

The Faculty of Physics

invites applications for a

W3-Professorship "Experimental Physics" with special emphasis on Particle Physics

at II. Physikalisches Institut (Previous holder of this position: Prof. K.-P. Lieb)

to be filled by April 1, 2006

The successful applicant must be able to document excellent scientific work in the field of **particle physics**. We seek an individual with substantial experience in planning and carrying out experiments within international collaborations. Possible branches of research are, for example, as follows: physics of the Higgs particles, weak interaction and neutrino physics, supersymmetry and unification of forces, dark matter, characteristics of hadronic matter. We expect strong commitment to establishing a research focus area with a promising future in the field of astrophysics and particle physics in cooperation with the Göttingen Institutes of Theoretical Physics and Astrophysics.

The successful candidate should be able to teach the whole range of subjects of experimental physics. The Faculty of Physics with its new building offers a very good scientific and technical infrastructure.

Göttingen University is a foundation of public law. The offer of this position is based on §25 of the Law on Higher Education of Lower Saxony (Nds.GVBl.2002, p. 286). Details can be given on request. Part-time employment may possibly be offered. If equally qualified, severely handicapped persons are given preference. Göttingen University endeavours to increase the proportion of female professors. Thus, qualified female scientists are expressly encouraged to apply.

Interested candidates should send their application, including a curriculum vitae, description of their teaching career, publication list and certificates no later than August 31, 2005.

Please send your application to:
Dekan der Fakultät für Physik
Georg-August-Universität Göttingen
Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany

HadronPhysics I3

Study of Strongly Interacting Matter

HadronPhysics I3
Study of Strongly Interacting Matter

European Commission

Transnational Access to Research Infrastructures

The Integrated Initiative "HadronPhysics I3", financed by the European Commission and coordinated by the Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, Italy, combines in a single contract several activities, Networking, Research Projects and Transnational Access. The Transnational Access activity involves 9 infrastructures among those operated by the participants in HadronPhysics I3. Its objective is to offer the opportunity for European research teams, performing or planning a research project at these infrastructures, to

APPLY FOR EC FUNDED ACCESS

to these infrastructures, to cover subsistence and travel expenses.
The only eligible teams (made of one or more researchers) are those that conduct their research activity in the EU Member States or in the Associated States. Information about the modalities of application and the **Calls for Proposals** can be obtained by visiting the web site of each infrastructure:

A1. INFN-LNF, http://www.lnf.infn.it/cee/tarifp6/
A2. DESY-HERMES, http://www-hermes.desy.de/I3HP-TA-HERMES/
A3. FZJ-COSY, http://www.fz-juelich.de/ikp/tmr-life.html
A4. FZJ-NIC/ZAM, http://www.fz-juelich.de/nic/i3hp-nic-ta/
A5. GSI-SIS, http://www.gsi.de/informationen/users/EC-funding/I3/SIM_e.html
A6. U Mainz-MAMI, http://www.kph.uni-mainz.de/en/eu/
A7. ZIB, http://www.zib.de/i3hp
A8. LU-MAXLAB, http://www2.maxlab.lu.se/members/proposal_nucl/index.html
A9. UU-TSL, http://www4.tsl.uu.se/tsl/tsl/infrastr.htm

This announcement can also be found at the following URL: http://www.infn.it/eu/i3hp

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

PAUL SCHERRER INSTITUT

Head of the Department of Large Research Facilities

at the Paul Scherrer Institute (PSI) and

Professor of Particle Accelerator Physics

at Ecole Polytechnique Fédérale de Lausanne (EPFL)

PSI is a centre for multi-disciplinary research and one of the world's leading user laboratories. In this function it develops and operates complex research installations that demand exceptionally high standards of know-how, experience and professionalism. With its 1200 employees it belongs as an autonomous institution to the Swiss ETH domain.
EPFL is a leading university with strong emphasis on basic, engineering and life sciences. Research and teaching within its School of Basic Sciences includes high-energy physics, particle accelerator physics (in close collaboration with CERN) and plasma physics.
We are looking for a strategic thinking and communicative person for the joint position of Head of the Department for Large Research Facilities at PSI and Professor of Particle Accelerator Physics at EPFL.

The Challenge

As Head of the Department for Large Research Facilities you will have the scientific and technical responsibility for providing an excellent research environment to Swiss and foreign research groups using the high intensity proton accelerator complex, the Synchrotron Light source (SLS) and the medical cyclotron for proton therapy. This department cares for the running, maintenance and enhancement of all accelerator complexes and the design and development of new accelerator concepts.
As Professor of Particle Accelerator Physics, you will promote collaboration in your field with other Laboratories and Centers at EPFL. The education of scientists in the field of particle accelerator physics and technology is an important investment in the future. We are looking for a person with interests and abilities to teach at the master and graduate level and direct PhD students in their research.
For this extremely demanding task we are seeking a person of international standing in the field of particle accelerators. Proven leadership and the ability to motivate people are essential requirements.
Applications including a curriculum vitae, publications list, concise statement of research and teaching interests as well as the names and addresses (including email) of at least five references should be submitted as a single PDF file via the website http://sb.epfl.ch/apsearch **by 31st August 2005.**
Questions should be addressed to Prof. Ralph Eichler: Tel. +41 (0)56 310 3216; e-mail: ralph.eichler@psi.ch
For additional information on PSI, please consult: http://www.psi.ch
For additional information on EPFL, please consult: http://www.epfl.ch
EPFL and PSI are equal opportunity employers.

Postdoctoral Research Associate Position

Experimental High Energy Physics University of Toronto

Applications are invited for a postdoctoral Research Associate position in the University of Toronto Experimental High Energy Physics group. The group has active participation in the ATLAS, ZEUS and CDF experiments. The currently advertised position is exclusively associated with ATLAS. Our group is a major participant in the construction, installation and commissioning of the hadronic sections of the ATLAS forward calorimeter. In the coming years the focus will be on the understanding of the performance of the calorimeter system, and preparations for the turn on of the LHC in 2007. The position is initially for two years with the possibility of extension. For the initial two-year period the successful candidate will be based in Toronto with frequent travel to CERN. Relocation to CERN at some point during the initial phase of LHC running is possible, subject to funding. Candidates should supply a resume, a description of research interests and three letters of reference, to

Ms. Winnie Kam, Department of Physics,
University of Toronto, 60 St. George Street,
Toronto, Ontario M5S 1A7, Canada.

For further information send email to **krieger@physics.utoronto.ca**. The review of applications will begin September 30, but applications will be accepted until the position is filled.

In accordance with Canadian immigration regulations, this advertisement is directed in the first instance to Canadian citizens or permanent residents. Nonetheless, all qualified applicants are encouraged to apply. The University of Toronto strongly encourages applications by women and members of minority and aboriginal groups.

UCL

UNIVERSITY COLLEGE LONDON

Department of Physics & Astronomy

High Energy Particle Physics Group

Lecturer in Physics

Applications are invited for the above position to commence during the 2005/2006 academic year.

We are looking for an outstanding particle physicist who will contribute to the research and teaching of the high energy physics group.

The group has a broad experimental program spanning neutrino physics (MINOS, NEMO III, SuperNEMO, ACORNE) and current and future collider experiments (ZEUS, CDF, ATLAS, International Linear Collider). We also have an interest in particle phenomenology, including a collaboration with the IPPP on the CEDAR project. Full details are available at http://www.hep.ucl.ac.uk.

The successful candidate will be an experimentalist, or a theorist with an interest in close collaboration with experiment. They will be expected to enhance this challenging and exciting programme.

The successful applicant will have an established record of significant research and the potential to become a leader in the field. They will also be expected to show evidence of competence in teaching at undergraduate and postgraduate level. Candidates wishing to transfer a long-term fellowship are welcome to apply. Salary scale in the Lecturer range: £23,643 to £35,883 plus £2,330 London Allowance and relocation benefits.

Further details about the post are available at: www.hep.ucl.ac.uk/positions Application forms can be downloaded from: http://www.ucl.ac.uk/hr/docs/download_forms/job_app.doc Applications forms, accompanied by a full CV, including a statement of research interests and plans, plus contact details of three referees, should be sent to Professor J Tennyson, (hod.physast@ucl.ac.uk), Head of Department of Physics and Astronomy, University College London, Gower St, London WC1E 6BT, to arrive not later than Wednesday, 20th July 2005. Informal enquiries may be made to the HEP Group Leader, Dr Jonathan Butterworth, (j.butterworth@hep.ucl.ac.uk).

The closing date for applications is **Wednesday, 20th July 2005**.

UCL Taking Action For Equality

Grid System Administrator for US CMS Tier-2 Site at UNL

The US CMS Tier-2 Team at the University of Nebraska-Lincoln, composed of Physicists and Research Computing Facility staff, has two openings. The first position will support the UNL Tier-2 site in areas 1) and 3) listed below. The second will support the UNL Tier-2 site in areas 2) and 3) below.

1) Grid Computing: Globus, CONDOR, and other grid protocols will be used. Mastery of VDT and other software to be implemented in the Open Science Grid will be required.

2) High Capacity Storage: This project will require on the order of 200 TB of storage to be uniformly accessed by multiple nodes in a large cluster. Implementation and testing of suitable file systems and transfer protocols and selection of hardware solutions will be necessary.

3) Linux Cluster System Administration: Experience in cluster building, hardware maintenance, software and distribution management, scheduling, and other general system monitoring and maintenance is required. Familiarity with Perl and/or other scripting languages, installation and compiling issues is required. Applicant will provide general user support via email, web pages, and phone.

The successful applicant will make his/her areas of expertise clear. A Bachelor's Degree in Computer Science, Physics, or other related field is required; expertise (PhD) in High Energy Physics is preferred. Starting salary commensurate with experience and expertise.
Review of applications will begin August 15. For more information see **http://rcf.unl.edu/employment**.
UNL is committed to AA/EEO and ADA/504.
If you require an accommodation, call +1 402 472 1039.

University of Nebraska Lincoln

SLAC
STANFORD LINEAR ACCELERATOR CENTER

The Wolfgang Panofsky Fellowship
Call for nominations

The Panofsky Fellowship was created in 1989 to honor SLAC's founder and first Director, Wolfgang K. H. Panofsky. It is designed to recognize those exceptional and promising young individuals who would most benefit from the unique opportunity to conduct their research at SLAC. The fellowship carries a five year term with salary and benefits comparable to an Assistant Professorship at SLAC. Panofsky Fellows may carry out research in one or more areas of the SLAC program: elementary particle physics, accelerator physics, beam physics, particle astrophysics, and/or cosmology.

Nominations may be submitted by Façulty or Senior Staff of any institution conducting research related to SLAC's program. Candidates for the Fellowship should be early in their postdoctoral careers yet widely recognized as having exhibited the potential for exceptional scholarship, breadth, innovation and leadership.

The candidate's curriculum vitae, publication list, and a brief research plan should accompany the nomination letter. The nominator should arrange for three additional reference letters to be sent. All supporting documentation should be sent to: **Panofsky Fellowship Chair, SLAC MS 43, 2575 Sand Hill Rd., Menlo Park, CA 94025 USA**. All material must be received by November 1, 2005 for consideration.

For further information, contact lilian@slac.stanford.edu, or see www2.slac.stanford.edu/panofsky_fellow.

SLAC is an equal opportunity, affirmative action employer.

INDEX TO DISPLAY ADVERTISERS

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DIRECTOR

Laser Interferometer Gravitational Wave Observatory

The California Institute of Technology (Caltech) and Massachusetts Institute of Technology (MIT) have initiated a search for a new Director of the Laser Interferometer Gravitational Wave Observatory (LIGO). LIGO is a major scientific endeavor, funded by the National Science Foundation, and devoted to furthering our understanding of the universe through the observation of gravitational waves. The position will be for a term of five years, with the possibility of extension, beginning in 2006. The LIGO Oversight Committee welcomes applications and nominations for this position. It is recommended that applications be accompanied by curriculum vitae and other information bearing on the candidates' qualifications for the Directorship. Relevant qualifications include scientific stature, leadership capability and management skills. *The California Institute of Technology and Massachusetts Institute of Technology are affirmative action/equal opportunity employers, and encourage applications from women, minorities, veterans and disabled persons.* Communication should be sent as soon as possible, preferably before **August 15, 2005** and should be addressed to:

Emlyn Hughes
Chair, LIGO Oversight Committee
Kellogg Radiation Laboratory, MS 304-38
California Institute of Technology
Pasadena, CA 91125

e-mail: emlyn@caltech.edu

POSTDOCTORAL POSITION IN EXPERIMENTAL HIGH ENERGY PHYSICS

TEXAS A&M UNIVERSITY

The experimental high energy physics group at Texas A&M University has a postdoctoral position available to participate on both the CDF and CMS experiments. Our group, led by Profs. Kamon and Toback, concentrates on searches for Supersymmetry with final state leptons (including taus) and/or photons. We have both hardware and software responsibilities for both the calorimeter and TDC systems at CDF, and on the trigger at CMS. **More details can be found at http://hepr8.physics.tamu.edu/postdoc**. Candidates must possess a Ph.D. in Physics and have demonstrated ability pertinent to the above activities. While we anticipate the successful candidate beginning in January 2006, the actual start date is negotiable; salary will be commensurate with experience.

An application consisting of a CV, a short statement of physics interests, and three letters of recommendation should be sent via e-mail to **hee_postdoc@physics.tamu.edu**, followed by a paper copy to be mailed to **HEE Postdoc Search Committee, Department of Physics, MS 4242, Texas A&M University, College Station, TX 77843-4242**. For full consideration applications must be received by August 15th, 2005, however late applications will be considered until the position is filled; for more information see the above website.

Texas A&M University is an Affirmative Action/Equal Opportunity Employer, committed to excellence through diversity.

Texas A&M University particularly invites applications from minorities, women, veterans and persons with disabilities.

Postdoctoral Research Associate:

Theoretical physics with ultra-intense laser fields: MPI Heidelberg

Max-Planck Institut for Nuclear Physics

A BATIIa/IB position is available starting any time in the near future in the recently established division 'theoretical physics with ultra-intense laser fields' at the Max-Planck Institute for nuclear physics in Heidelberg.

Activities of the division are currently focused in the theory of ultra-intense laser-matter interaction, quantum electrodynamics, high-energy processes and many-particle quantum dynamics. For an overview see Physik Journal 2, 61 (2003) or best our web page. Applicants are encouraged to apply in particular with a strong background in theoretical high-energy physics or alternatively also in nuclear physics or computational physics. A successful doctoral degree is expected and favorably a short postdoctoral stay or good experience in helping with supervising students. A later employment as a group leader is not excluded.

Please address questions or send applications with CV and reprints to

Prof. Dr. Christoph H. Keitel at Max-Planck Institut for Nuclear Physics
Saupfercheckweg 1 69117 Heidelberg Tel. (+49) 6221 516 150

Email: keitel@mpi-k.de

web (group) : http://www.mpi-hd.mpg.de/keitel/

Learning About Particles – 50 Privileged Years by Jack Steinberger, Springer. Hardback ISBN 3540213295, €39.95 (£30.50, $49.95).

Learning About Particles is an interesting excursion for the reader through the past 50 years of particle physics – 50 privileged years, as one is aptly reminded by the subtitle. Our guide is Jack Steinberger, undoubtedly one of the protagonists of those years, who offers a personal account of the historical and scientific evolution of the field, interspersed with autobiographical notes. He also makes sociological comments and expresses political views, but always gracefully, even when it is obvious that they must bring to memory particularly sad events.

The book follows a chronological order, which at times is slightly violated in favour of more logical organization by topic to improve readability. It unfolds at two paces: pleasantly accurate with generous detail of experiments from the early years, and slightly rushed by the time experiments at the Large Electron Positron (LEP) collider are reached.

Particularly enjoyable are the first four chapters, which recount his years as graduate student, post-doc and young faculty in various prestigious institutions. Descriptions of early experiments and of the theoretical interests of the time are wisely mixed with personal recollections and anecdotes about the "gurus" of physics, and about the author's young colleagues who later became very famous. The history is a little more difficult to follow into the next chapter, however, when dealing with strange particles.

Two chapters are dedicated to neutrinos, marking two moments of their "interaction" with Steinberger. After the first, the reader feels disappointed – more details of the conception of the fundamental "two-neutrino experiment" would have been expected, as would some "inside stories". Perhaps the disappointment stems from anticipation created earlier in the book when a future collaboration between the then Captain Lederman and the then Private Steinberger is mentioned. As for inside stories, Steinberger confesses that initially he did not believe in neutral currents and this (quite rightly!) cost him a few bottles of good wine.

In the second of the two neutrino chapters, the steps towards the present understanding of the nucleon structure are retraced clearly – although with some haste – and the author brings the reader to present times with neutrino masses and oscillations. The intervening chapter on CP violation is an authoritative account of the achievements in the field since its beginning in 1957. Here Steinberger enumerates the spectacular accomplishments of the Standard Model within the context of the LEP experiments, perhaps with a tinge of nostalgia for earlier times.

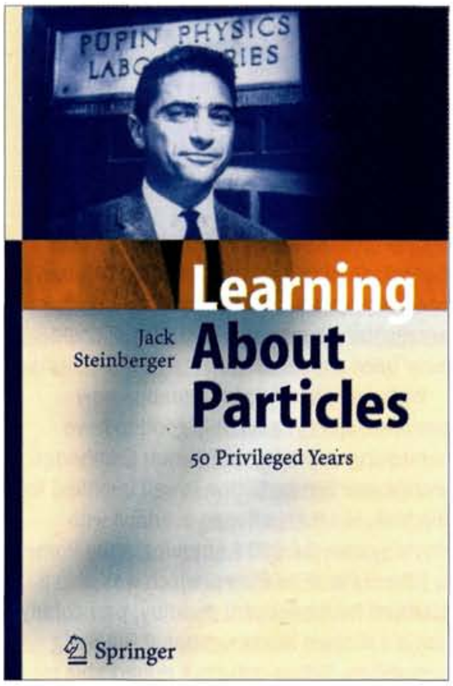
It is difficult to identify precisely the intended audience for this book. It seems to be aimed at a variety of readers, not all necessarily from a scientific background, as the explanations given from time to time in the footnotes imply. This is, however, not done consistently and the result is often unsatisfactory. Furthermore, the occurrence of a few misprints at unfortunate places might prove disconcerting for the untrained reader.

Regardless of the audience, however, the book touches clearly upon the building blocks of the Standard Model and communicates 50 years of passion for physics and its intricacies – a lesson for young researchers. It also speaks of a passion for other, and far more common, sources of enjoyment in life such as music and mountains – a lesson for physicists in general!

Biagio Saitta, Universita' di Cagliari.

Summer Bookshelf

Summer for physicists is traditionally the season of conferences as well as (or instead of!) well earned holidays. In this issue Bookshelf presents a selection of less technical books for reading in quieter moments, whether on the beach or on long plane journeys – or indeed for family and friends to read to learn more about the world of particle physics.



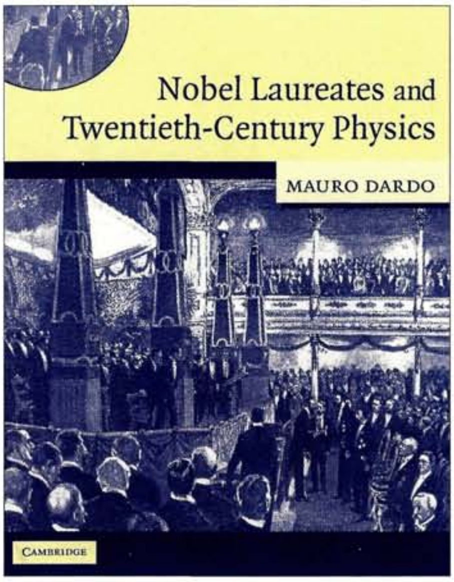
Nobel Laureates and Twentieth-Century Physics by Mauro Dardo, Cambridge University Press. Hardback ISBN 0521832470, £70.00 ($110). Paperback ISBN 0521540089, £24.99 ($39.99).

Few would argue that the Nobel prize is an honour accorded to the greatest minds for outstanding discoveries. While I would not go quite as far as Mauro Dardo in the introduction ("these prizes are considered everywhere to be the most prestigious honours of our times, far outstripping... all others"), this statement sets the reverential tone maintained throughout this useful volume.

The book presents a straightforward chronology of the major themes that have shaped 20th-century physics in the context of the Nobel prizes awarded. The first chapter gives a brief introduction to the foundation of the prizes themselves, as well as some interesting tallies of the number of physics prizes awarded to particular nations and institutions. It is well known, for example, that the US has dominated the physics awards since the Second World War, but I was surprised to learn that it can boast a total of 77 laureates, with the UK in distant second place with 22 laureates.

Chapters two and three, in a mere 20 pages, cover physics up to the end of the 19th century, starting with Copernicus and ending with Maxwell. The level of detail is necessarily brief, and in an attempt to keep the book accessible to a wide audience Dardo avoids equations almost entirely – I noticed only a handful throughout the whole book. He also avoids technical diagrams, which could have helped to illustrate the experiments and observations. A simple diagram, for example, could help non-experts – who form part of the intended readership – to understand the interference of light rays from two slits.

Chapter three ends with an outline of the "vexing problems" that set the stage for the great discoveries of the early 20th century: the non-observation of the "ether", cathode ▷



rays, the black-body radiation spectrum, X-rays and radioactivity. Here, and throughout the book, Dardo adds useful paragraphs on the technology and inventions that form a vital context for the discoveries themselves.

The bulk of the book – some 430 pages in 10 chapters – is a straightforward and highly readable chronological account of the Nobel prize awards (and "near misses") between 1901 (Roentgen) and 2003 (Abrikosov, Ginzburg, Leggett). Most of the material will be very familiar to physics graduates, but it is useful to have it well laid out and clearly presented in a single volume.

My main disappointment is that only the briefest of biographical details are given about the laureates, and there are rather few "human" details to illustrate their personalities. However, these would lengthen the book further, and an extensive bibliography is supplied.

Paradoxically, the lack of equations and diagrams could make the narrative harder to follow for non-physicists, but the plain language and clear descriptions of (in some cases) complex phenomena render this book an excellent read for a long journey.

Philip Burrows, Queen Mary, University London.

Fred Hoyle – A Life in Science by Simon Mitton, Aurum Press. Hardback ISBN 1854109618, £18.99. (In the US, **Conflict in the Cosmos: Fred Hoyle's Life in Science**, Joseph Henry Press. Hardback ISBN 030909313, $27.95.)

Fred Hoyle (1915–2001) was something of a British counterpart to Richard Feynman. They both came from modest backgrounds, with fathers in the garment trade; both had supreme ability that propelled them to the top of the student ladder; and both had their research careers interrupted by the Second World War. Their work during the war – Feynman at Los Alamos, Hoyle in UK naval radar – also established important contacts for their future careers.

Both brandished fierce accents (Feynman's from New York City, Hoyle's from Yorkshire) as their personal trademarks. Both made important contributions in several areas of physics; both were gifted communicators and popularizers of science; and both could be irreverent of authority, a trait possibly inherited from their fathers.

While Feynman largely sidestepped administrative responsibilities to concentrate on research, Hoyle did not, and an otherwise distinguished career was sometimes marred by acrimony, his unconventional opinions often antagonizing contemporaries. (Frank could have been a more suitable name than Fred!)

With a wealth of documentation now available on Feynman, it is good to have something on Hoyle, and former Cambridge astronomer Simon Mitton is well qualified for the task. His lively offering overlaps with Hoyle's colourful 1994 autobiography *Home is Where the Wind Blows*, which was also a platform for flamboyant punditry, particularly Hoyle's disdain for conventional Big Bang cosmology. Mitton depicts a remarkable man who never stopped striving – if not doing science or writing, he was climbing mountains.

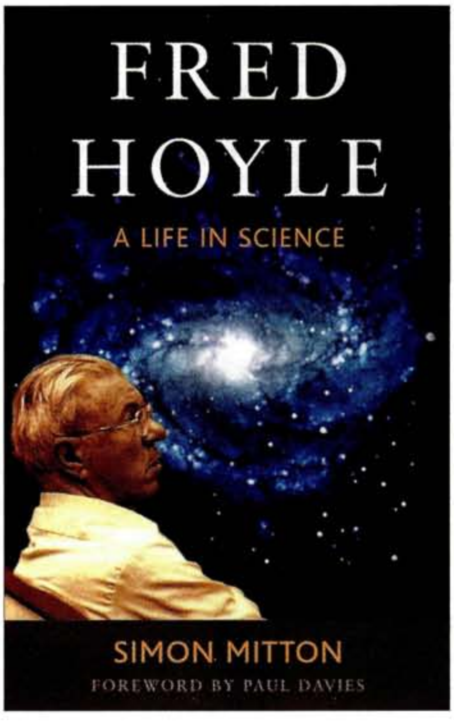
Hoyle began his research career at Cambridge as a theoretical physicist under Peierls, but after the latter's departure to Birmingham he switched to the nascent fields of astrophysics and cosmology. His major contributions went on to cover three areas – stellar accretion (with Lyttleton and Bondi), steady-state cosmology (with Bondi and Gold) and the classic work on nuclear evolution in stars (with the Burbidges and Fowler).

Steady-state cosmology has now fallen by the wayside, but paradoxically Hoyle will long be remembered for his continual staunch support of a dying cause. Mitton's book contains an extensive transcript of the 1949 radio broadcast in which Hoyle facetiously described the rival theory as a "Big Bang". Already at loggerheads with the astronomy community, Hoyle created more friction in these broadcasts. He was also a prolific producer of science fiction, an offbeat activity that annoyed some of his academic contemporaries.

Mitton's chapter "Clash of Titans" depicts the long battle at Cambridge between the hot-headed Hoyle and the tempestuous Martin Ryle. Entertaining though it may have been, this bitter personality clash poisoned the atmosphere at Cambridge and embarrassed the university. Nevertheless modern astronomy owes much to these men.

The outspoken Hoyle had run-ins with many sectors of the establishment. Mitton points out that these continual antics, including criticism of the 1974 Nobel award to Ryle and Antony Hewish for their pioneering contributions to radioastronomy, could have affected the Nobel decision in 1983: a prize with the theme of stellar evolution went to Subrahmanyan Chandrasekhar and Hoyle's long-time collaborator William Fowler, the news of which "completely devastated Fowler as he realized Fred had been passed over".

Furious at other decisions, Hoyle threatened several times to resign from Cambridge, and finally departed in 1972 after being overlooked again for a new appointment. Mitton suggests that Hoyle, then 57, could have stepped back and remained in a cosy Cambridge niche. Characteristically he chose to walk out in a final thunderclap of frustration.

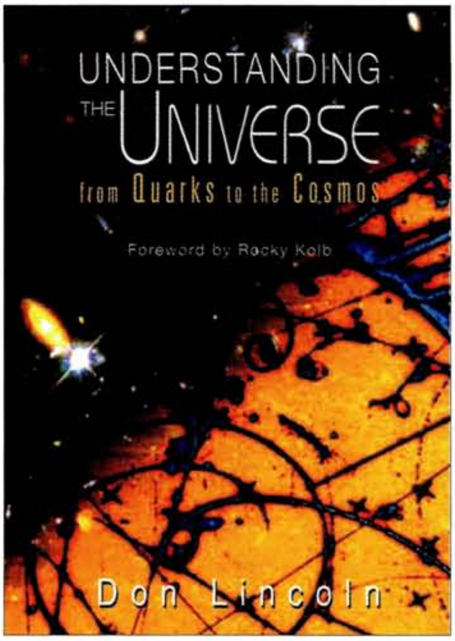


This valuable book paints a detailed picture of an important but enigmatic character who will long be studied. Hoyle's dramatic prediction of an overlooked energy level in carbon-12 – vital for the existence of life – will remain a saga of science (see p15).

Mitton is at his best writing about subjects he knows well, such as astrophysics and the arcane politics of Cambridge University. The driving influence of Eddington is well described, but perhaps more could have been made of the pioneering role of Bethe in the development of nuclear theory – Bethe was awarded the 1967 Nobel prize for his work on nuclear reactions and their role in the stars. There are other criticisms too: Rutherford was hardly "at the height of his intellectual powers" when he died after, not before, surgery, and the names Cockcroft and Feynman are systematically misspelled. But none of this detracts from the value of the book.

Gordon Fraser, Divonne-les-Bains.

Understanding the Universe: from Quarks to the Cosmos by Don Lincoln, World Scientific. Hardback ISBN 981238703X £65 ($88). Paperback ISBN 9812387056 £17 ($28).



Do not let the over-ambitious title put you off. Don Lincoln's *Understanding the Universe* is a recent book about particle physics written by an experimental particle physicist of the Standard Model generation. Here it has a clear advantage over similar but older books that rely on appendices or additions to keep up to date. The book is addressed to the curious layman, with only a murky recollection of school physics, who wants to know how far mankind has gone in understanding the world around us. High-school students with an interest in physics will also find the book exciting and accessible. It is an excellent reference for any scientist who is occasionally unsure how best to explain a particular physics concept to a non-specialist audience.

In the whole book there are few mathematical equations and everything, from the principle of energy conservation to the Higgs mechanism, is explained in plain English. Lincoln does not distract his readers by trying to explain quantum mechanics in any depth. He warns simply that it is a bizarre theory in parts and presents its predictions in a matter-of-fact way.

Lincoln is enthusiastic, even passionate, and a man of some allegiance. Foremost he is a physicist, and in the first sentence of his book states that, in his opinion, physics is the most interesting science. He is an experimentalist, and throughout the book makes good-humoured jokes about his theoretical-physics colleagues. He is an American, often bringing baseball into his many examples. He is a Fermilab boy, from the lab that houses "the highest-energy particle accelerator in the world as of 1971 and probably through 2007, or even beyond". Finally, he is a member of the D0 collaboration with a detector "in some ways significantly superior" to rival CDF. If like most of us you are not from D0, you could forgive Lincoln, as his understanding and explanations of complex phenomena are excellent and the book strikes a balance between depth and accessibility.

The first two chapters provide an historical overview of particle physics from the Greek philosophers to the discovery of the muon neutrino at the beginning of the 1960s. Chapters three and four deal with the Standard Model. Chapter five is devoted to the search for the Higgs particle, and chapter six discusses the basic concepts behind particle acceleration (ignoring focusing and accelerator cavities, however) and detection.

The next two chapters deal with important unanswered questions: chapter seven presents hot research topics such as neutrino physics and charge–parity (CP) violation and chapter eight discusses grander but more speculative ideas including unification, extra dimensions and string theory. Finally, chapter nine covers cosmology – although the book could benefit from a longer discussion of dark energy – and chapter 10 approaches particle physics from the perspective of its benefits to mankind.

The book includes informative, but rather bland, figures. Although Lincoln is too young to include personal recollections of the personalities that shaped particle physics in the 20th century, his second-hand anecdotes and his first-hand account of the discovery of the top quark make interesting reading.

Lincoln cleverly includes an appendix that discusses issues further for the interested reader without obstructing the body of the book. However, it seems unnecessary to include a detailed account of Higgs production and an appendix on the pronunciation of Greek letters (where the reader finds out that alpha is pronounced "al-fuh"). The book also contains an extensive "further reading" section, which lists books and magazine articles (mostly from *Scientific American*) alongside Lincoln's assessment of them.

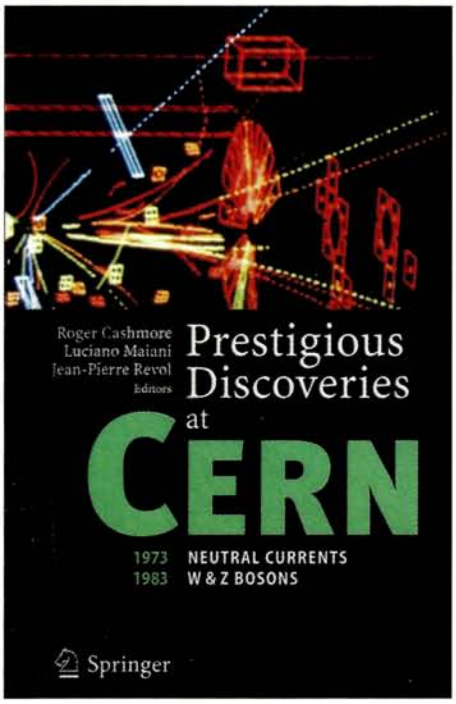
Understanding the Universe is recent, informative and accessible. If you come from the US (or, even better, from Illinois), you will enjoy it even more.

Mike Koratzinos, CERN.

Prestigious Discoveries at CERN: 1973 Neutral Currents, 1983 W & Z Bosons by Roger Cashmore, Luciano Maiani and Jean-Pierre Revol (eds), Springer. Hardback ISBN 3540207503, €39.95 (£30.50, $59.95).

In 1973 CERN physicists found indirect evidence for the existence of the Z boson in so-called "neutral currents". Ten years later, CERN announced the discovery of both the W and Z bosons, which in 1984 brought the laboratory its first Nobel prize, awarded to Carlo Rubbia and Simon van der Meer. These discoveries together provided convincing evidence for the electroweak theory, a cornerstone of the modern Standard Model.

In a double-anniversary celebration, CERN held a special symposium on 16 September 2003 (*CERN Courier* December 2003 p25). This book contains the beautifully illustrated proceedings of that symposium, which covered more than the title suggests, as it encompassed more recent physics at the Large Electron Positron (LEP) collider and looked at the challenges that the Large Hadron Collider (LHC) project presents. ▷



Steven Weinberg, a leading architect of the Standard Model, gave the opening talk, "The Making of the Standard Model", in which he spoke of his own contributions to the electroweak theory. The experimental progress that subsequently established the Standard Model came about courtesy of important developments in accelerators. Giorgio Brianti described CERN's various contributions to accelerators and beams, including van der Meer's invention of the magnetic horn and of stochastic cooling, which was crucial to the discovery of the W and Z particles.

Dieter Haidt, a member of the Gargamelle collaboration, described the search for the neutral currents predicted by the electroweak theory, and the difficulties in convincing people that they had been observed in Gargamelle. By the beginning of the 1980s the search was on for the predicted W and Z particles. Pierre Darriulat, one-time spokesman of the UA2 experiment, recalled the decision to convert CERN's Super Proton Synchrotron to a proton–antiproton collider, and the subsequent discovery of the bosons by both UA1, led by Rubbia, and UA2. Peter Zerwas then looked back on the era of LEP and its many tests of the current Standard Model.

The second part of the symposium looked to the future, in particular to the LHC. John Ellis considered the physics possibilities; Lyn Evans presented the problems involved in constructing and operating the collider; Jos Engelen described the building of the detectors; and Paul Messina talked of the challenges in collecting and analysing the vast amounts of data that will be produced.

Many experiments in particle physics over the past 20–30 years owe much to the development of detector techniques, in particular by Georges Charpak at CERN, who was rewarded with a Nobel prize in 1992. In his talk, Charpak recalled many years of work with detectors, and spoke of the opportunities for spreading enthusiasm for physics to the younger generations.

In the final presentation Luciano Maiani, then director-general of CERN, looked to the organization's future. A panel discussion followed, chaired by Rubbia, which considered the future of particle physics. Together these talks present a fascinating record of past discoveries and a look to the future, where more discoveries must surely lie.
Christine Sutton, CERN.

Qu'est-ce que la relativité? par François Vannucci, Les Petites Pommes du Savoir, Editions Le Pommier. Broché ISBN 2746502161, €4,5.

C'est la troisième contribution de François Vannucci pour les "Petites pommes du savoir". Chercheur en physique des particules et professeur à l'université de Paris VII, François Vannucci est un féru de vulgarisation scientifique. Il est notamment l'auteur d'un roman policier autour des neutrinos et d'une pièce de théâtre traitant de la relativité et des neutrinos. Pas étonnant donc que cette collection, qui entend mettre à portée de tous des concepts parfois compliqués, ait fait appel à ses talents de vulgarisateur.

Après *Combien de particules dans un petit pois?* et *L'homme est-il au centre de l'Univers?*, François Vannucci apporte une réponse brève et claire à la question de la relativité. En remontant aux prédictions de Galilée, il rappelle les principes décrivant le mouvement et la notion de repère, admis à la fin du XIXe siècle. Il raconte l'énigme soulevée alors par la constance de la vitesse de la lumière, se dérobant aux lois connues. Einstein entre alors en scène avec sa théorie froissant le sens commun.

François Vannucci en explique tous les ressorts, de la dilatation du temps à la fameuse équation $E=mc^2$, les illustrant par des exemples concrets. Il dévoile les implications et les étonnantes observations qui validèrent de façon spectaculaire cette théorie. Le ton est parfois un peu didactique, mais au final ce petit livre est un outil bien pratique pour se familiariser avec la relativité en cette année Einstein.
Corinne Ménard, CERN.