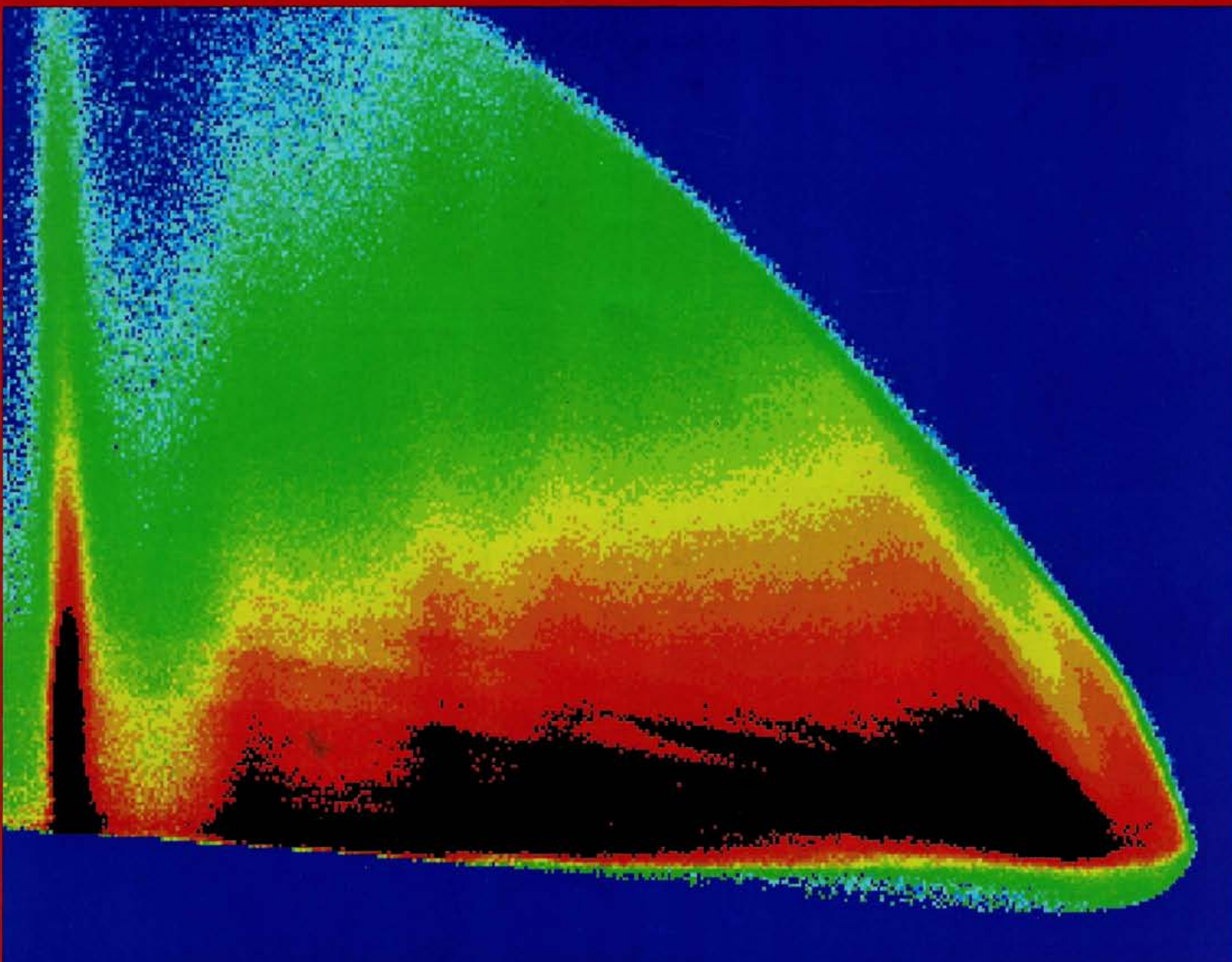
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 44 NUMBER 10 DECEMBER 2004



JLab's portrait of the nucleus

ISOLTRAP
High-precision masses test Standard Model p9

BOOKSHELF
A seasonal selection of easy reading p39

Electron and Ion Guns / Systems
UHV Components, Vacuum Chambers


UHV Electron Guns/Systems
UHV Ion Guns/Systems

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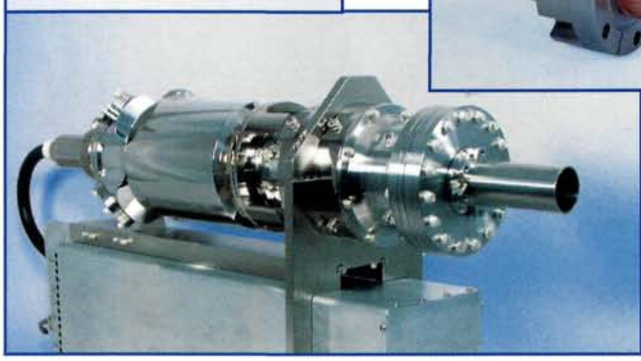


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Covering current developments in high-energy physics and related fields worldwide

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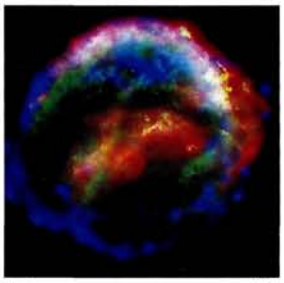
Dignitaries celebrate at CERN p4



Telescopes snap a supernova p15

ISOLDE makes light work p16

Cover: Experiments at Jefferson Lab cover the boundary between nuclear and particle physics (p22). In this plot of electron–proton scattering data from the CLAS experiment the horizontal axis is the invariant mass (i.e. the mass of the resonance) and the vertical axis represents the amount of energy transferred to the system. Darker colours indicate more events. Elastic events are visible in the peak at the left (around 0.94 GeV), with the delta resonance just to the right (around 1.2 GeV). At higher invariant masses, towards the deep inelastic scattering region, individual resonance peaks become washed out. (CLAS/JLab.)

50 YEARS OF CERN

Lab rolls out the red carpet for prestigious official ceremony

In honour of 50 years of CERN, more than 800 invitees, including 28 delegations of member and observer states, attended the official anniversary ceremony in October.

François de Rose at the anniversary ceremony – one of CERN's founding fathers.

Left to right: Jacques Chirac, President of France; Joseph Deiss, President of the Swiss Confederation; Juan Carlos, King of Spain.

Heads of state, representatives from many countries, and scientists and engineers from CERN's past, present and future research in particle physics attended the laboratory's official 50th anniversary ceremony on 19 October. The speakers praised the organization for its advancement of science and for fostering international collaboration, both among scientists and between countries, across Europe and beyond.

Juan Carlos, the King of Spain, Jacques Chirac, President of the Republic of France, and Joseph Deiss, President of the Swiss Confederation, were joined by delegations from member and observer states. Before the ceremony, Jacques Chirac visited the construction site for the CMS experiment in Cessy, France, and later he joined Joseph Deiss and Juan Carlos on a tour of the ATLAS cavern. Juan Carlos also took the time to meet many of CERN's Spanish scientists.

Immediately before the ceremony, the heads of state and the delegations gathered in the recently erected Globe of Science and Innovation. This large, spherical building made entirely of wood was donated by the Swiss Confederation in honour of the 50th anniversary. In the Globe, which is as big as the dome of St Peter's Cathedral at the Vatican, a multimedia presentation tailored to each country played while the representatives entered and signed the gilded visitor's book.

Robert Aymar, director-general of CERN, began the series of speeches at the event. François de Rose, the sole surviving founder of the organization, gave a first-hand account of how CERN arose from the ashes of the Second World War (*CERN Courier* October 2004 p74). Also speaking were Federico Mayor, former director of UNESCO; Maria van der Hoeven, minister of education, culture and science of the Kingdom of the Netherlands (speaking on behalf of the president of the European Council, who was recovering from a severe illness); Robert Cramer, president of the Geneva State Council; and the heads of state, Joseph Deiss, Jacques Chirac and Juan Carlos. Enzo Iarocci, president of the CERN Council, closed the ceremony.

A common theme in the speeches was how CERN should continue to serve as a model of scientific rigour and international co-operation. Speakers pointed to how scientists at CERN have deepened our knowledge of nature, while also creating technologies of practical importance, such as new types of medical imaging equipment and the World Wide Web.

POLARIZED PROTONS

Spin-flipping crosses the Atlantic

Fig. 1. The 3.5 GeV/c COSY (Cooler Synchrotron) storage ring without shielding.

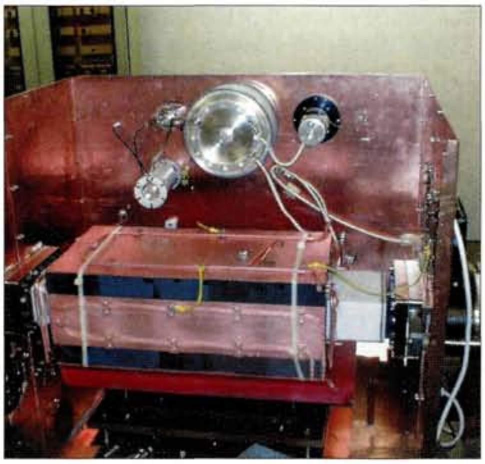


Fig. 2. The ferrite-core water-cooled RF-dipole, with a transverse RF magnetic-field integral of 1.5 Tmm peak-to-peak.

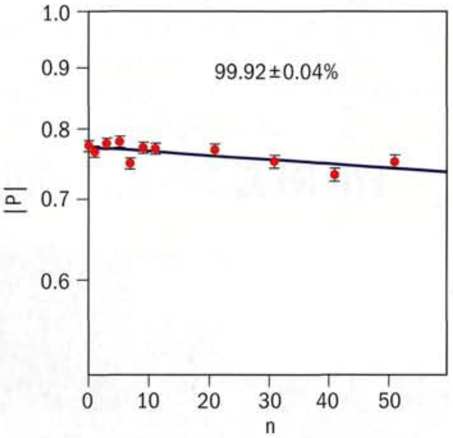


Fig. 3. The polarization (P) of 2.1 GeV/c stored protons plotted against the number of times (n) that they have flipped; the fit gives a measured spin-flip efficiency of 99.92%. The protons remain highly polarized after 51 flips.

After the venerable Cooler Ring at the Indiana University Cyclotron Facility (IUCF) passed on to accelerator heaven in autumn 2002, the polarized beam team, led by Alan Krisch, crossed the Atlantic to continue their spin-manipulation work at COSY, the cooler synchrotron at the Forschungszentrum in Jülich (figure 1). As part of the SPIN@COSY collaboration, they have been improving the polarization capabilities of the 3.5 GeV/c proton and deuteron storage ring.

Recently, the collaboration – from Michigan and Brookhaven in America, COSY, Bonn and Hamburg in Germany, and KEK and J-PARC in Japan – has used a new ferrite RF-dipole magnet to flip the spins of stored 2.1 GeV/c protons with almost no polarization loss.

The ferrite-core water-cooled RF-dipole (figure 2) was designed and built by Maria Leonova, a graduate student at Michigan, and Alexander Schnase, a COSY/J-PARC electrical engineer. It was coupled to a sophisticated RF high-voltage supply to form a highly tuned L-C circuit, which produced a transverse RF magnetic-field integral of about 1.5 Tmm peak-to-peak. This gave a higher spin flip efficiency (99.92 ± 0.04%) than the air-core RF-dipole used for the spin-flipping of polarized deuterons and protons during SPIN@COSY's first runs in February and April 2003. The total polarization loss was only about 3% after 51 spin flips (figure 3), which allows many spin-flips of polarized proton or electron beams while they are stored for billions of turns.

This spin-flipping would greatly reduce almost all systematic errors in spin asymmetry experiments, which is very important for scattering experiments in storage rings with stored polarized beams, such as Brookhaven's Relativistic Heavy Ion Collider (RHIC), HERA at DESY, COSY and the MIT-Bates facility in Massachusetts.

Combining an earlier IUCF spin-flipping experiment at 489 MeV/c (*CERN Courier* April 2003 p6) with this higher-energy 2.1 GeV/c experiment at COSY leads to a "prediction" that a slightly stronger RF-dipole magnet – only about 35% stronger than the small RF dipole used already – should give at least the same 99.92% spin-flip efficiency to the polarized protons stored in the 100–250 GeV RHIC and perhaps someday in Japan's 50 GeV J-PARC facility and CERN's 7 TeV Large Hadron Collider. This is because the spin-flipping strength of a transverse RF-dipole is almost invariant under the Lorentz transformation from an accelerator's stationary frame to the highly relativistic rest frame of each beam proton, where each proton's spin observes the RF-dipole's strength, which controls the efficiency of the spin-flips.

Further reading

M A Leonova *et al.* 2004 submitted to *Phys. Rev. Lett.*
V S Morozov *et al.* 2004 *Phys. Rev. ST-Accel. Beams* **7** 024002.

ELECTRONICS

Indian chips on track for ALICE

As an observer state of CERN, India is collaborating in many aspects of the Large Hadron Collider (LHC) project – building components of the accelerator as well as constructing detectors for various experiments. In the ALICE experiment, India is participating in the forward di-muon spectrometer (FMS) and in particular has responsibility for the design, fabrication and supply of the custom VLSI chip required for the spectrometer's front-end electronics.

ALICE will study lead ion collisions at the LHC, where the production of the heavy quarkonia, such as the upsilon and its excited states, is expected to be suppressed. This is regarded as one of the strongest signals for the formation of a quark–gluon plasma.

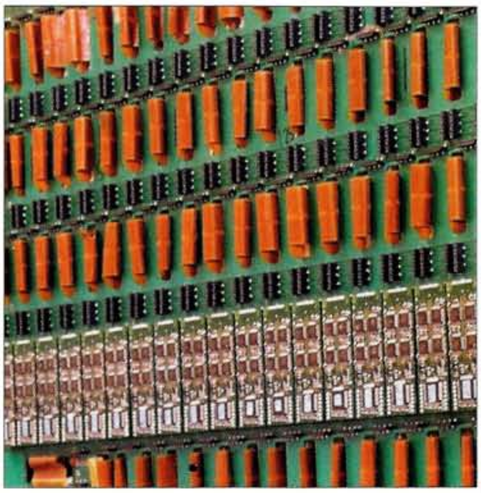
Here, the yields of the upsilons will be measured by detecting their decays to two muons and determining the momenta of the muons though their bending in the field of ▷

a dipole magnet. The upsilon resonances will show up as "peaks" in the reconstructed invariant mass spectrum over a background of various other sources.

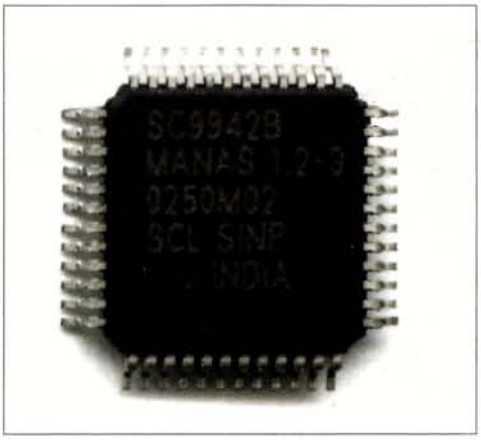
The tracks of the muons through the magnetic field will be measured in the FMS by a set of multiwire proportional chambers with finely segmented cathode pads. Muons passing through the detectors will produce signals on these pads, and their tracks will be reconstructed from a measurement by the front-end electronics of the charges deposited on the pads. Because of the high packing density and low noise required of the electronics readout, it is essential that the front-end electronics is realized in form of a custom-designed VLSI chip – the MANAS (Multiple Analog Signal processor).

The design of the MANAS chip, based on the GASSIPLEX chip developed by Jean Claude Santiard at CERN, started in late 1997 at the Saha Institute of Nuclear Physics (SINP), Kolkata, and a memorandum of understanding was signed between SINP and Semiconductor Complex Ltd (SCL), Chandigarh, for the fabrication of the chip. Inside this chip, the signal from the detector is amplified by a charge-sensitive amplifier, processed by a deconvolution filter and shaping amplifier, tracked and stored, then finally read out via a multiplexer.

The final set of masks for fabrication of the MANAS-1.2-1 prototype was released by Bikash Sinha, SINP, in October 1999 and the first prototype ceramic packaged chips were



Readout cards, developed by INP Orsay, with four MANAS chips each.



The final plastic-packaged chip.

delivered by SCL in March 2000. Extensive bench tests at SINP and CERN on the prototype chips were performed, followed by a beam test of the chip, mounted on a prototype detector for the second of the tracking stations (developed and fabricated at SINP) and exposed to a 7 GeV proton beam.

The results of these bench tests showed that the first prototype satisfied most of the design criteria. Two modified iterations of the design then corrected the problems found in the first prototype.

By January 2002, 1500 pre-production chips, MANAS-1.2-3, were sent to several institutes collaborating in the ALICE FMS for more extensive tests, both in the lab and in test beams. The main features of this state-of-the-art chip are the low noise level (640 electrons rms), small gain fluctuations, large dynamic range (500 to −275 fC), radiation tolerance and the low sensitivity of parameters to temperature variations.

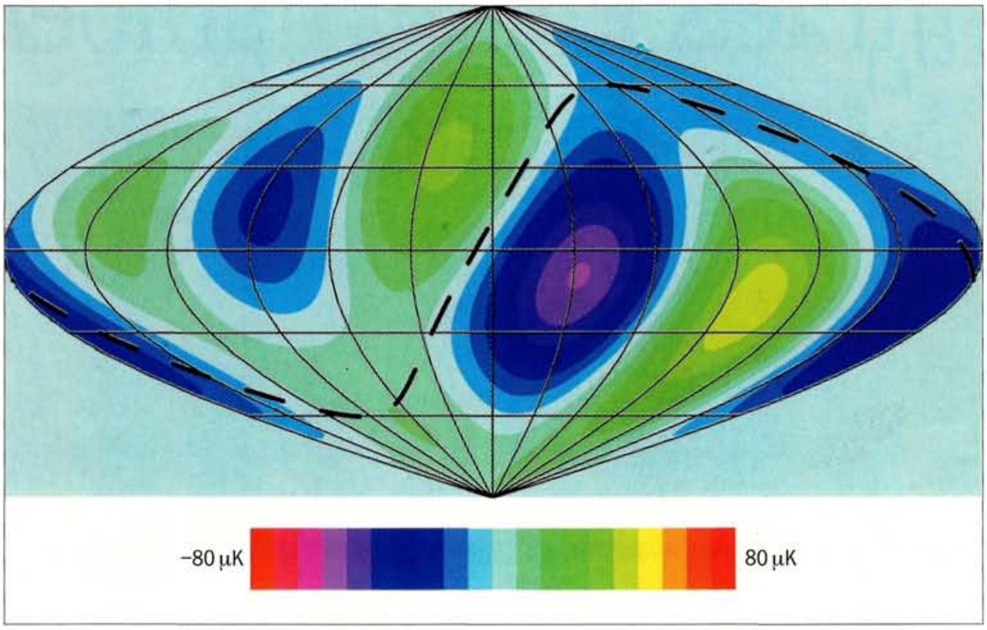
The production readiness review for the MANAS chip was held in October 2003, and was based on results from various laboratories. More than 100 000 chips will be delivered by January 2005, after stringent quality and performance tests by the foundry, SCL in Chandigarh.

The MANAS chip is a definite success story for R&D and fabrication for high-technology VLSI development in India. It has already initiated more R&D activity in VLSI technology in India, and a large number of useful applications are being planned, including accurate image processing.

COSMOLOGY

Does the motion of the solar system affect the microwave sky?

The cosmic microwave background (CMB) radiation provides the most precise probe of the largest structures of the universe. Now, however, a team from Case Western Reserve University in Cleveland, Ohio, and CERN has discovered surprising evidence that the largest-scale features of the microwave sky seem to be correlated with both the motion and the orientation of the solar system (D J Schwarz *et al.* 2004).



Pictured here is a combined quadrupole plus octopole map of the WMAP microwave sky in galactic co-ordinates, after subtracting the Milky Way. The ecliptic (dashed line) threads its way along the node line, separating one of the hot spots from one of the cold spots, tracking the node over a third of the sky. Extrema in the south are more extreme than those in the north ecliptic hemisphere; indications for such an anisotropy have also been noticed at higher multipoles (Eriksen et al. *2004).*

The tiny temperature variations of the CMB were discovered by the Cosmic Background Explorer (COBE) satellite more than a decade ago. Then, in February 2003, the Wilkinson Microwave Anisotropy Probe (WMAP) team published the analysis of their first year of high-resolution observations of the full sky.

In a stunning manner, the results from WMAP confirmed the Standard Model of modern cosmology, with its key elements of a period of cosmological inflation and a composition of 5% baryons, 25% cold dark matter and 70% dark energy. One real surprise, however, was how WMAP showed that the optical depth for microwave photons is high, which implies an unexpected early onset for star formation.

A second look at the publicly available WMAP data reveals anomalies at the largest angular scales (> 60°). For example, the angular two-point correlation function vanishes at scales larger than 60° (as already seen by COBE, but largely forgotten). In Fourier space, the vanishing of the two-point correlation function at large scales is reflected by the smallness of the quadrupole and octopole moments. As we observe only one universe, it is possible to attribute these findings to bad luck (cosmic variance), although – taken at face value – the measurement does not agree with the expectation from inflation.

In fact, the WMAP measurements contain more information. Angélica de Oliveira-Costa and colleagues studied the cosmic quadrupole and octopole and realized that both are very planar and aligned, i.e. all minima and maxima happen to fall on a great circle on the sky – another unexpected feature (de Oliveira-Costa *et al.* 2004).

Craig Copi, Dragan Huterer and Glenn Starkman of Case Western Reserve University then developed a method to assign *1* directions to the *1*-th multipole (multipole vectors). While Starkman was on sabbatical at CERN, the team was joined by Dominik Schwarz, also at CERN at the time, to test the claims of de Oliveira-Costa *et al.* by means of multipole vectors.

To their surprise, the new method revealed at high statistical significance (99.9% CL) that the observed quadrupole and octopole are inconsistent with a Gaussian random, statistically isotropic sky (the generic prediction of inflation). They also looked ▷

for correlations with any known directions on the sky. No significant correlation with the Milky Way was found, but a strong correlation with the orientation of the solar system (ecliptic plane) and with its motion (measured as the CMB dipole) showed up.

A comparison with 100 000 skies generated by Monte Carlo shows that each of those correlations alone is unlikely at more than 99% CL. Therefore, there is strong evidence either of some systematic error in the WMAP pipeline (although in a preliminary analysis, the team is now discovering similar features in COBE maps), or that the largest scales of the microwave sky are dominated by a local foreground.

This finding has vast implications. It casts doubts on the cosmological interpretation of the lowest-*1* multipoles from the temperature–temperature correlation and from the temperature–polarization correlation, and in turn on the claim that the first stars formed very early in the history of the universe.

Further reading

H K Eriksen *et al*. 2004 *Astrophys. J*. **605** 14.
A de Oliveira-Costa *et al*. 2004 *Phys. Rev. D* **69** 063516.
D J Schwarz *et al*. 2004 *Phys. Rev. Lett*. (in press), arXiv:astro-ph/0403353.

50 YEARS OF CERN

CERN's 50th anniversary open day attracts record number of visitors

The normal main entrance was crowded with visitors from 8.30 a.m. onwards.

Orange jackets made the demonstrators and guides easy to find during the open day.

Posing for a photograph in the ATLAS cavern was a popular choice with visitors.

When CERN opened its doors to the public for its open day on 16 October, the laboratory took on the air of a county fair. Children took rides around the site in a big lorry, visitors ate ice cream that had been handmade in a flash using liquid nitrogen, and crowds strolled the lanes as they visited more than 50 events across various sites in Switzerland and France.

An estimated 32 000 visitors, from across Europe and beyond, flocked to the laboratory for a day of tours, displays and presentations. The majority of events were in experiment halls and workshops that are normally closed to the public. The last open day was in 1998, and this one attracted so many people that visitors had to wait in long lines at the main events.

Some of the biggest attractions were the huge detectors under construction for the Large Hadron Collider. Such tours helped the visitors gain a sense of the scale of CERN's work – and even those who already had some notion of CERN were awed by the gigantic detectors, caverns, and tunnels.

Some of the attractions gave visitors a more direct feel for the science and technology behind research at CERN. In one hall, volunteers revealed the strange properties of matter at low temperatures with a miniature train levitated by a superconducting magnet, and demonstrated superfluidity in liquid helium. At the GridCafé, visitors could surf the Web and learn about the networks of computer centres that CERN is helping to organize. At another site, visitors gained hands-on experience assembling their own working cosmic-ray detectors.

NUCLEAR PHYSICS

High-precision masses test the Standard Model at ISOLTRAP

The atomic mass of a nucleus is important in a wide range of physics, as it conveys information on the nuclear binding energy. It is a unique property of each of the more than 3000 known nuclides. Now, experiments at ISOLTRAP at CERN's ISOLDE facility have reached a level of precision where the mass measurements for extremely short-lived radionuclides are significant for fundamental studies that touch upon the very foundations of the Standard Model. Two recently published sets of measurements on neutron-deficient magnesium and rubidium nuclides concern the conserved-vector-current hypothesis of the weak interaction and the unitarity of the Cabibbo–Kobayashi–Maskawa (CKM) quark-mixing matrix.

The ISOLTRAP Penning trap spectrometer at CERN's online isotope separator, ISOLDE, is providing precision mass measurements. (Photo: Alban Kellerbauer.)

According to the quantum-field theory of the electroweak interaction, the weak interaction has two components, a vector and an axial-vector part. In a manner analogous to electromagnetism, currents can be associated with each of these components, and the vector current is exactly conserved. This postulate is equivalent to the statement that the weak force is not influenced by the strong force and that the weak vector coupling constant is thus truly constant.

By careful choice of a particular weak decay whose initial and final states respect certain selection rules (so-called superallowed decays), the vector part of the interaction can be studied selectively. Within this subclass of decays, the nuclear matrix element depends only on the isospin, so a comparison of the *Ft* values (also called comparative half-lives) allows a direct comparison of the vector coupling constant.

An experimental value for the comparative half-life of a decay can be deduced from high-precision measurements of its atomic mass and its partial half-life. In order to obtain truly comparable quantities, two small calculated corrections must also be taken into account. These describe radiative and spin flip effects, as well as a lack of overlap between the decaying nucleon and its daughter.

The mean of the *Ft* values of all decay pairs with the same isospin, together with the fundamental vector coupling constant from muon decay, can furthermore be used to calculate the first element V_{ud} of the CKM matrix. Using this value, the most precise determination of V_{ud} available today, the unitarity test of the quark mixing matrix currently fails by two standard deviations.

The ISOLTRAP experiment at ISOLDE (see p16) is at the forefront of a new class of experiments that perform mass measurements on trapped exotic nuclides using the time-of-flight cyclotron resonance technique. For this purpose, a beam of radionuclides produced and mass-separated with ISOLDE is first accumulated and bunched. The ions are then mass-selectively cooled, before the mass of the radionuclides is measured via the cyclotron frequency in a precision Penning trap.

Now a team from Germany, France, the US and Canada has measured the masses of ^{74}Rb and ^{74}Kr as well as ^{22}Mg and ^{22}Na with unprecedented precision, ranging from 6×10^{-8} for the very short-lived ^{74}Rb ($T_{1/2} = 65$ ms) to 1×10^{-8} for ^{22}Na ($T_{1/2} = 2.6$ y) (Kellerbauer *et al.* 2004, Mukherjee *et al.* 2004). ^{74}Rb is the shortest-lived radionuclide that has ever been studied in a Penning trap. The comparative half-lives obtained for the superallowed decays of ^{74}Rb and ^{22}Mg agree well with the previously known *Ft* values, thus confirming the CVC hypothesis in this new mass region and for isospin projection $T_z = -1$, respectively. However, improved calculations of one of the theoretical corrections (^{74}Rb) and more precise measurements of the partial half-life (^{22}Mg) are required before these data can have an impact on the test of CKM unitarity.

Further reading

A Kellerbauer *et al.* 2004 *Phys. Rev. Lett.* **93** 072502.

M Mukherjee *et al.* 2004 *Phys. Rev. Lett.* **93** 150801.

To celebrate the 50th anniversary of CERN, we look back at some of the items in the early issues of *CERN Courier*

THE PS

The proton synchrotron leads the news in *CERN Courier* again

It seems to be getting quite a habit for the proton synchrotron to provide the most important CERN news every month.

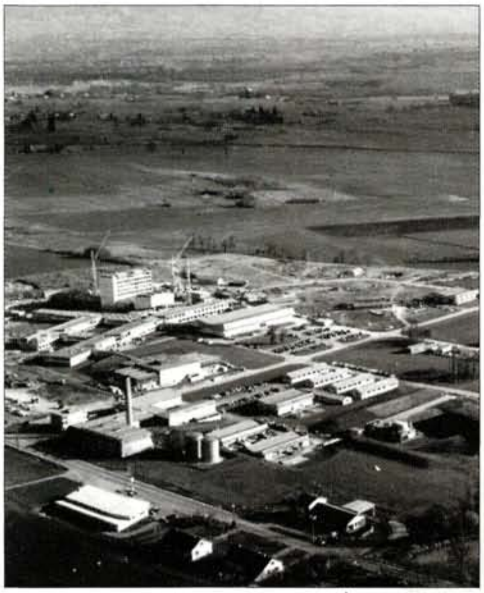
On 24 August, a 50 MeV particle beam was obtained at the output end of the last of the three LINAC cavities. Final energy of the LINAC was thus reached.

That evening, the accelerated proton current reached half a milliampere. Tests made at night – maximum energy is only produced at night so as to avoid unnecessary radiation hazards for the staff – have since made it possible to increase this figure to nearly 5 milliamperes. This is almost the maximum beam intensity for this part of the machine. The beam then passed through a port in the radiation shielding wall at the end of the linear accelerator room.

Further on, the proton beam entered the inflector, which should be completely installed by the middle of September. The purpose of this device is to bend the beam emerging from the linear accelerators into the 100 m radius orbit of the proton synchrotron ring. The inflector gives the 50 MeV beam the optimum shape and characteristics for use in the big circular accelerator.

After the final adjustments have been made on the inflector, the beam will enter the synchrotron vacuum chamber for a distance of about 15–20 magnet units. This distance corresponds to what is known by scientists as a "betatron wavelength", and will allow careful study of the behaviour of the beam after it has been properly injected into the proton synchrotron. Simultaneously, the beam may be directed into the circular vacuum chamber to make one or more complete revolutions. During this preliminary test, the beam will not be accelerated.

All this is scheduled to happen in September. In October, all the components of the radiofrequency accelerating system will have been assembled. The beam will probably be accelerated for the first time at the end of that month.



Part of an aerial photo of CERN and the PS ring, taken in April 1959 and used on the cover of early issues of the CERN Courier.

The running-in period will follow. This may perhaps end with the announcement of a high-energy beam before the end of 1959. In the opinion of those concerned, this will be the critical period. Although it may be relatively easy to design the components of a machine, test them separately and assemble them, it is the perfect running of the machine as a whole that always gives the most trouble.

Of course, there is a precedent – the energizing of the electromagnet – when a whole system was brought into regular operation without any major snags. A magnetic field corresponding to the maximum energy of the accelerator, 25 GeV, was obtained. Apart from some details needing adjustment, only one addition will be necessary: in the interphase transformer assembly.

Putting things right

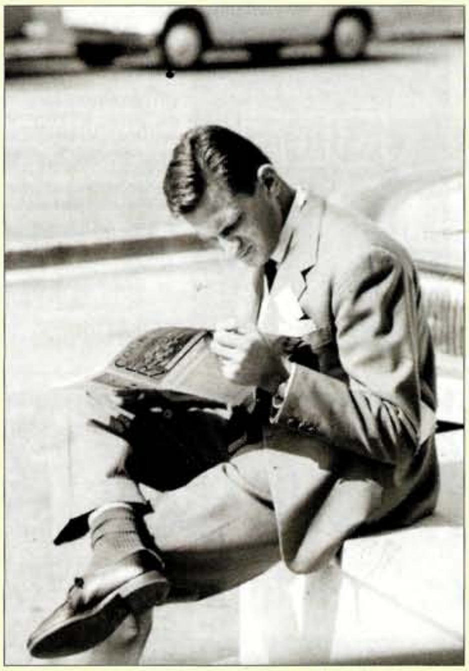
On the subject of corrections, readers have been kind enough to assist an absent-minded proof-reader. Thanks to their eagle eye, two misprints have been spotted in the French edition of our first issue. It is certainly rather incongruous to have reduced the CERN site to a tenth of its actual area. The organization will run much better if it is restored to its original size of about 41 hectares.

Also – and the reader will probably have corrected this himself from the context – the final energy of the proton synchrotron should have read 25 000 million electron-volts and not 25 million.

To err is human, as they say.

• From *CERN Courier* September 1959 p1.

EDITOR'S NOTE



Since it first appeared in 1959, the *CERN Courier* has featured many articles on the accelerators at CERN. The image above shows Franco Bonaudi, who was a leading figure in the design and construction of the laboratory's main machines from the very beginning. He is seen reading the second edition of the *CERN Courier*, the leading article of which is reproduced here.

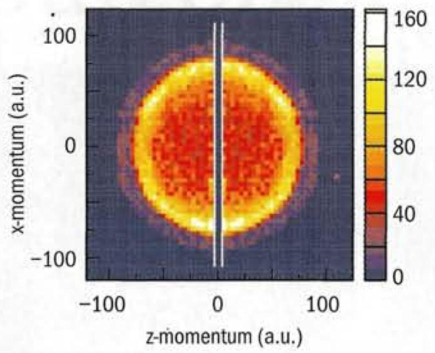
Compiled by Steve Reucroft and John Swain, Northeastern University

Electrons jump atoms to dispose of excess energy

A novel means by which atoms can lose excess energy has recently been observed. This development may have considerable implications for many fields.

Predicted in 1997, the idea of interatomic Coulombic decay, or ICD, is best seen through the example in which it has just been measured. Consider two neon atoms, sitting about six atomic radii apart (34 nm), weakly bound by van der Waals interactions. A tightly bound electron is knocked loose from one of them. As might be expected, a less tightly bound electron drops down to fill its place, but the energy released is transferred to the neighbouring neon atom where it kicks out a low-energy electron. The resulting two adjacent, singly charged Ne^{1+} ions repel each other and are emitted back-to-back. Together with the coincident electron, they provide a unique fingerprint for ICD.

Recent work by T Jahnke and colleagues, conducted at the J W Goethe-Universität Frankfurt am Main and the Max-Planck-Institut für Plasmaphysik in Garching, shows the effect unambiguously. The experiment used a beam line at the BESSY synchrotron radiation facility in Berlin, in single bunch operation, together with the COLTRIMS (cold target recoil ion momentum spectroscopy) technique. The researchers detected the energy of two Ne^{1+} fragments in coincidence with the ICD electron, yielding a clean, background-free experimental spectral distribution of the ICD electrons.



This plot of the measured Ne^{1+} ion momenta, parallel to the spectrometer's axis and perpendicular to that axis, shows that the detected ions are located on a sphere in momentum space, as expected for their back-to-back emission in interatomic Coulomb decay.

The observation of this process is currently generating a great deal of interest. ICD is expected to occur most commonly in hydrogen-bonded systems such as water, and could explain the hitherto mysterious presence of low-energy electrons in irradiated solutions of biomolecules.

Further reading

T Jahnke *et al.* 2004 *Phys. Rev. Lett.* **93** 163401.

The substance that freezes with heat

Normally you have to add heat to a solid to make it melt, but now a French group has made an astounding discovery: it has found the first example of a substance that is liquid at low temperatures, but which freezes when heated! Hans-Peter Trommsdorff of Joseph Fourier University in Grenoble and his colleagues mixed alpha-cyclodextrine – which is basically rings of six glucose molecules – with 4-methylpyridine and water to make the strange substance.

At room temperature, the mixture is a clear liquid, but on being heated to temperatures between 45 and 75 °C it turns into a white solid. It is important to note that this is not some sort of gelling, but a genuine phase transition to a solid.

The underlying physics is based on hydrogen bonds: some that would normally help to hold the cyclodextrine together are broken at modest temperatures. This allows new hydrogen bonds to form, making a solid. At higher temperatures, around 95 °C, the bizarre material reliquifies.

Further reading

M Plazanet *et al.* 2004 *J. Chem. Phys.* **121** 5031.

Electrical spray makes ion source

A new way of making ions could revolutionize mass spectroscopy.

Zoltán Takáts, Justin M Wiseman, Bogdan Gologan and R Graham Cooks of Purdue University have shown that using a spray of electrically charged solvent droplets to strike a sample can replace the more cumbersome technique of dissolving a sample in solvent and then using high voltage to pull out charged droplets.

The new method, known as desorption electrospray ionization (DESI), looks rather like techniques that use ion beams (a vacuum is needed) or laser beams (surface preparation is generally needed) to produce ions, but it works on just about anything. In principle, mass spectrometers could now be made into portable, easy-to-use devices.

Further reading

Zoltán Takáts *et al.* 2004 *Science* **306** 471.

Entanglement allows for precise timing

A new use for entanglement allows incredibly precise synchronization of widely separated clocks. Alejandra Valencia, Giuliano Scarcelli and Yanhua Shih of the University of Maryland have managed to use pairs of entangled photons to synchronize clocks separated by 3 km to an accuracy of 1 ps.

The technique works by splitting an ultraviolet photon in a nonlinear crystal to produce two red ones. Detection of one photon makes detection of the other happen only at a sharply determined time, and this correlation can be used to match up the clocks amazingly well.

The tests were done over long optical fibres. Some accuracy may be lost if this is attempted over open-air channels, but it is an exciting new approach to an old problem, with a great deal of potential applications for both fundamental and applied physics.

Further reading

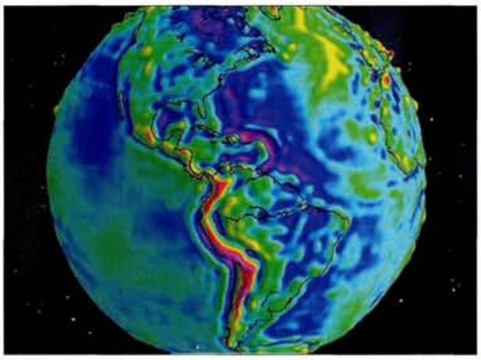
Alejandra Valencia, Giuliano Scarcelli and Yanhua Shih 2004 *App. Phys. Lett.* **85** 2655.

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

Two dedicated satellites reveal the Earth's pull on space–time

The general relativistic prediction of the Lense–Thirring effect has been confirmed to a precision of less than 10%. The result was obtained by measurements of the position of two satellites over a period of more than 10 years.

In 1918, soon after Einstein published his general theory of relativity, Austrian physicists Joseph Lense and Hans Thirring predicted that a rotating massive body would pull on the surrounding space–time. This frame-dragging or Lense–Thirring effect is one of the "gravitomagnetic" phenomena that are absent in Newtonian gravity. They result from the motion of matter (matter currents) and are the gravitational analogues of magnetic fields arising from moving charges (electric currents). The spinning Earth, containing a large amount of matter in motion, is the source of a very weak gravitomagnetic force.



The relief on this map (left) indicates the deviation of the true gravitational field from that of a perfect spheroid with uniform mass distribution. Red illustrates higher deviation, while blue illustrates lower deviation. This map obtained by the GRACE mission was used to detect frame-dragging in the data of the LAGEOS satellites (right). (Artwork by F Ricci [Roma "La Sapienza"] and I Ciufolini [Lecce]; Earth model courtesy of GFZ-Potsdam.)

The Moon is too far away to be significantly affected by frame-dragging due to the Earth's spin, so it fell to artificial satellites LAGEOS and LAGEOS 2 (for Laser Geodynamics Satellites) to detect the Lense–Thirring effect. They were launched, respectively, in 1976 by NASA and in 1992 from the space shuttle as a joint project of NASA and the Italian Space Agency (ASI). Their instantaneous position can be ascertained by measuring the time it takes light to travel between a point on Earth and the satellite. This is achieved by sending short laser pulses from 50 Earth-based stations, and detecting them as they are sent back by retro-reflectors that cover the spherical satellites.

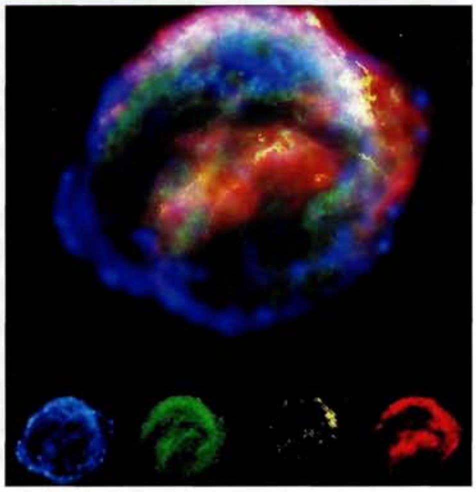
The analysis of millions of these laser-ranging measurements over a period of nearly 11 years has been published in *Nature* by I Ciufolini of INFN/Lecce and E C Pavlis of Maryland. The frame-dragging effect of the Earth causes the orbit of the satellites to precess by just 33 ms of arc per year, corresponding to less than 2 m per year at a distance of about 12 000 km, the semi-major axis of the LAGEOS satellites' orbit. The difficulty of measuring this tiny effect is complicated by the non-spherical gravitational field of the Earth, which has to be corrected for. Indeed, the Lense–Thirring effect could only be detected thanks to the precise knowledge of the ripples in the Earth's gravity field, measured in particular by the two satellites of NASA's Gravity Recovery and Climate Experiment (GRACE).

This first accurate measurement of frame-dragging confirms Einstein's predictions to within 10%. What remains for NASA's Gravity Probe B spacecraft launched this year is to confirm and refine this measurement to a precision of 1% using its orbiting gyroscopes (*CERN Courier* June 2004 p13). The confirmation of this effect is important, because it is one of the last predictions of general relativity to be measured, and plays an important role in the accretion disc around compact spinning objects such as neutron stars and black holes. In particular, the Lense–Thirring effect may contribute to the alignment of jets in active galactic nuclei and quasars.

Further reading

I Ciufolini and E C Pavlis 2004 *Nature* **431** 958.

Picture of the month



In 1604, the astronomer Johannes Kepler watched a bright, apparently new star in the Ophiuchus constellation. Almost 400 years later, NASA's three orbiting observatories – the Hubble Space Telescope, the Spitzer Space Telescope and the Chandra X-ray Observatory – provided a composite image showing the expanding remains of this supernova in our galaxy. Pictured here, blue and green colours show the emission of high- and low-energy X-rays as observed by Chandra, the optical emission detected by Hubble is in yellow and the infrared image of Spitzer is overlayed in red. (NASA/ESA/JHU/R Sankrit and W Blair.)

ISOLDE goes from strength to strength

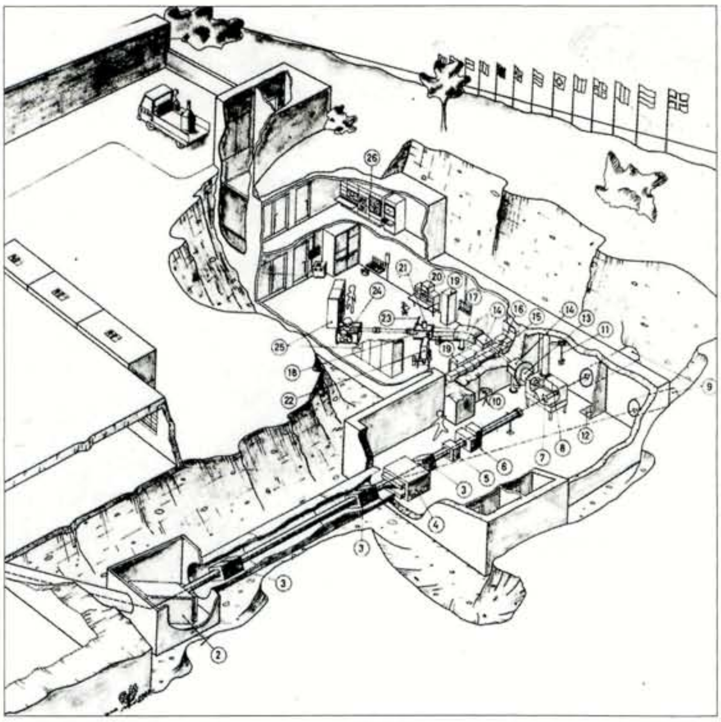
In 1964 CERN took the initiative to develop the means for studying short-lived nuclei. Forty years on, ISOLDE continues to be a world-leading facility for research with radioactive beams.

If you can look into the seeds of time,
And say which grain will grow and which will not...
Macbeth I, 3

Experiments with radioactive beams are attracting a great deal of interest these days. In the US, a radioactive-beam facility – the Rare Isotope Accelerator (RIA) – has been approved as one of the top-priority projects in physics for new construction. In Europe, there are several new projects that are well advanced in securing funding, such as SPIRAL 2 in France and the Facility for Antiproton and Ion Research (FAIR) in Germany. In the next decade, a high-intensity installation called EURISOL could become a powerful successor to CERN's ISOLDE (Isotope Separator On Line).

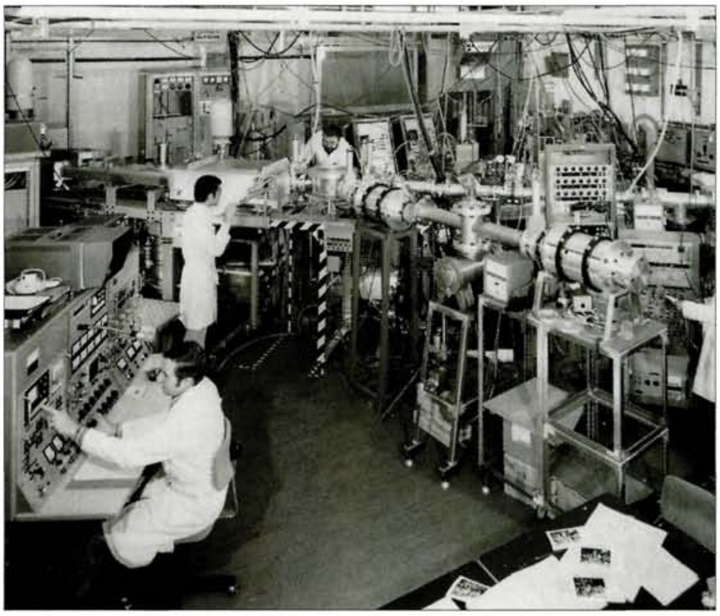
In the year of CERN's 50th anniversary, it is interesting that the field had its beginnings at the organization 40 years ago. Even earlier, an experiment carried out at Niels Bohr's Institute in Copenhagen in 1951 had proved the feasibility of connecting an electromagnetic isotope separator to a cyclotron. Its scientific aims lay primarily with neutrino physics, but a decade later it was becoming clear that the same technique would allow an attack on the problem of unstable nuclei with very short lifetimes, which were predicted theoretically. It was also clear that this would require a major effort. During 1963–64, CERN's director-general, Victor Weisskopf, consulted leading European nuclear physicists, and early in 1964 he issued a call for proposals for nuclear experiments at CERN's 600 MeV Synchrocyclotron (SC).

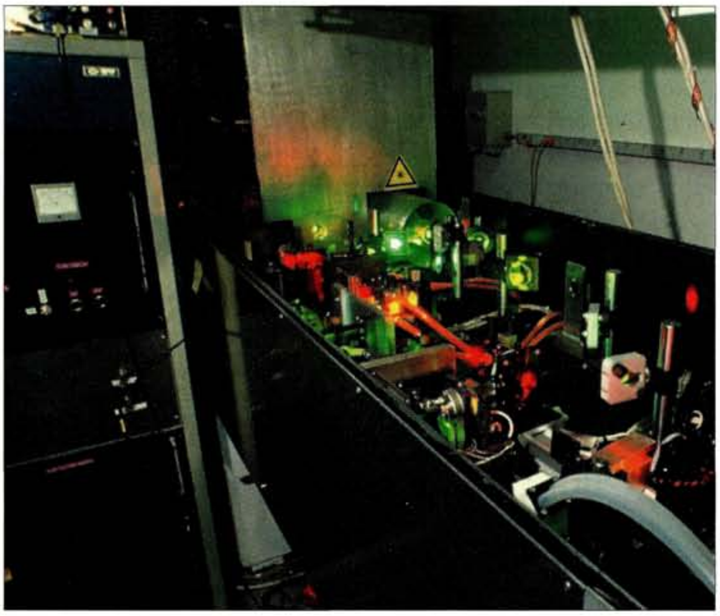
There was already an informal European network active in the areas of isotope separators and nuclear structure, and within this a collaboration emerged to prepare a proposal for studying unstable nuclei. Among its prominent members in the early phase were René Bernas (Orsay), Wolfgang Gentner (Heidelberg), Karl Ove Nielsen (Aarhus), Alexis C Pappas (Oslo) and Goesta Rudstam (Uppsala). Later the same year, a proposal prepared by the collaboration was presented to Weisskopf, and on 17 December 1964 he invited the groups to go forward with the proposed programme.



Cutaway view of ISOLDE, 1967. An underground beam tunnel (left) connects to a target area (right), which is separated by 3 m of shielding from the experimental hall and the electronics area (above).

On 16 October 1967, the first experiments were carried out at ISOLDE. The experimental arrangement that had emerged from the collaboration's interactions with the leaders of the SC Division, Giorgio Brianti and Ernst Michaelis, is shown in figure 1. An important and far-sighted feature of the design was that the extracted proton beam was taken to a shielded area approximately 6 m below ground in order to reduce the external radiation levels, although this increased the construction costs considerably. Without this feature, it would have been impossible for ISOLDE to make use of the 100 times stronger beam that became available after the SC





Left: the ISOLDE experimental hall in 1969, with the isotope separator in the upper left corner and, from left to right, Rudi Stoeckli at the separator control panel, Gilbert Droz and Henri Bersinger. Beam tubes branch out from a switchyard, which uses electrostatic deflectors to direct beams of short-lived isotopes to various spectroscopic apparatus. Right: the ISOLDE Laser Ion Source in 1998.

Improvement Programme (SCIP) in 1973–74.

The SC closed in the early 1990s, and the ISOLDE facility moved to the PS Booster where, at the time, there was sufficient capacity to enable operation with an average of 2 μA of protons at 1 and 1.4 GeV. The pulsed proton beam from the PS Booster initially caused major concerns, as many target types deteriorated quickly owing to the high instantaneous beam power. Technical improvements and inventions would eventually help to overcome these problems, turning the pulsed beam into a unique feature for release measurements of radioactive species from the targets and for physics that could benefit from a semi-pulsed radioactive beam.

Technical development to keep CERN at the leading edge in this field has always been important at ISOLDE. The development of a Resonant Ionization Laser Ion Source (RILIS) in collaboration with the Institute of Spectroscopy in Troitsk (Russian Academy of Sciences) had already started while ISOLDE was still at the SC, and the decision to continue this work has proved essential for the facility's competitiveness. Today the RILIS system can be used to selectively ionize 25 elements, and it is now employed in more than half of the physics shifts that the facility delivers. The development of a two-stage target with a durable primary target directly hit by the proton beam – resulting in a shower of neutrons irradiating UC and ThC secondary targets – has also been essential. With this type of target, the total yield of secondary radioactive ions is smaller, but the suppression of many reaction channels in the secondary target results in a pure beam of fission fragments. The technique was first proposed by Jerry Nolen of Argonne National Laboratory, and is the leading principle for at least two proposals for future radioactive beam facilities, SPIRAL 2 in France and SPES in Italy.

The fundamental understanding of the nucleus requires precision measurements of its properties at the edge of stability, and this requires that the radioactive beams are accelerated to energies of several million electron-volts per nucleon. In the 1990s, a collaboration between several European institutes proposed a compact linear accelerator for radioactive ions at ISOLDE, the Radioactive Beam Experiment (REX). This system, in particular the low-energy part, is highly innovative. The radioactive ions from ISOLDE are delivered at 60 keV predominantly in charge state 1^+. At REX the ions are captured in one of the world's largest Penning traps (REX trap) and subsequently undergo cooling and side-band cooling; both techniques have been developed at the ISOLDE ISOLTRAP experiment. In the next stage, the ions are injected into an Electron Beam Ion Source (EBIS) for charge-state multiplication. This is an ultra-high vacuum system with an intense electron beam guided by a strong magnetic field. The ions are trapped in the electron beam and will lose electrons through collisions. The fact that the EBIS system operates at a very good vacuum results in a pure and highly charged radioactive ion beam in which only isobaric contaminants from the previous stages can potentially cause pollution of the beam.

A mass separator after the trap-EBIS system permits the selection of a charge state for further acceleration in a linear accelerator. This device is very compact thanks to the high charge states used, and consists of a radiofrequency quadrupole (RFQ) followed by an interdigital H-type (IH) structure and multi-gap resonators. It is very similar to LINAC 3 at CERN, which is used for the heavy-ion programme, the main differences being that at REX-ISOLDE the isotopes accelerated are frequently changed and the beam intensities are very low. The main experimental device operating at REX is MINIBALL, a compact and highly efficient array of segmented germanium detectors. In recent experiments the pure beams have permitted precise measurements of the shape of nuclei that are very rich in neutrons, such as ^{32}Mg, ^{78}Zn and ^{126}Cd. The results are very encouraging and show that the full REX system is unique and provides a powerful tool for the investigation of the structure of exotic nuclei.

ISOLDE's success has two main ingredients. First, CERN provides the infrastructure and manpower that make it possible to operate ▷

a large facility serving many users, and second, the collaboration of many European physics institutes leads to a broad programme of a high scientific quality that justifies the effort. ISOLDE is today delivering some 350 eight-hour shifts of radioactive ion beams per year. The variety and availability of such beams far exceeds that of any other low-energy facility in the world.

The ISOLDE collaboration remains a major driving force behind the evolution of the facility, and it makes an important contribution to both its operation and its development. The large amount of knowledge in target and ion-source chemistry and technologies that has accumulated over many years has resulted in 700 isotopes from 70 elements being available at ISOLDE. Combined with important technical developments such as the RILIS and REX, this makes ISOLDE a unique facility at the forefront of research in nuclear physics and allied fields. ISOLDE is also well integrated in the European research structure through the EURONS infrastructure initiative.

The future of ISOLDE and REX-ISOLDE will be determined by the proposed upgrades of the injector accelerators at CERN to provide a primary proton beam of much higher intensity. The ISOLDE hall is currently being extended, and CERN is undertaking a major consolidation of the facility itself, including a new laboratory for target handling. In addition, plans are under way to increase the energy of the REX post-accelerator and make highly charged and cooled beams available for other experiments. ISOLDE also plays a central role in the European Union design study for the third-generation radioactive ion-beam project EURISOL. CERN would be an ideal site for this facility, with unique synergies with other areas of research through the multi-megawatt proton driver that is required (*CERN Courier* July/August 2004 p30). The link to neutrino physics within EURISOL (the beta-beam concept) makes an interesting connection to where it all began in Copenhagen – the study of neutrinos through nuclear methods that demonstrates the close alliance between nuclear and particle physics.

In this view of the REX-ISOLDE system, the last nine-gap resonator of the linear accelerator is clearly visible, open. In the background is the large Faraday cage containing the Electron Beam Ion Source (EBIS) on top of the REX trap.

In 1981, D Allan Bromley of Yale University, later science advisor to President George H Bush, wrote in an external assessment requested by the CERN Directorate: "The question sometimes arises as to why other major activities of the scope of ISOLDE have not been mounted in the US and elsewhere. I believe that the answer is rather simple. The ISOLDE group got such a head start on the rest of the world activity in this field that people were very reluctant to attempt to mount a competitive operation." Since then the field of radioactive ion-beam physics has expanded enormously, and ISOLDE's lead has been followed by major investment in new facilities in three continents.

Further reading

P G Hansen 1996 "The SC: ISOLDE and Nuclear Structure" in *History of CERN* vol. III ed. John Krige (Elsevier) 327.

Peter Butler, *CERN*, **P Gregers Hansen**, *National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, and* **Mats Lindroos**, *CERN.*

CEBAF set to double energy

Jefferson Lab is aiming to further studies of strongly interacting matter by upgrading the Continuous Electron Beam Accelerator Facility to 12 GeV and adding a fourth experimental hall. **Steven Corneliussen** reports.

The US Department of Energy (DOE) has placed Jefferson Lab in Newport News, Virginia, on a path towards a major upgrade of the Continuous Electron Beam Accelerator Facility (CEBAF). In April, the DOE announced "critical decision zero" (CD-0) for the laboratory's proposal to double the superconducting accelerator's energy from 6 to 12 GeV, add a fourth experimental hall and upgrade equipment in the three existing halls. This step establishes the "mission need" and moves the upgrade into a formal project-definition phase.

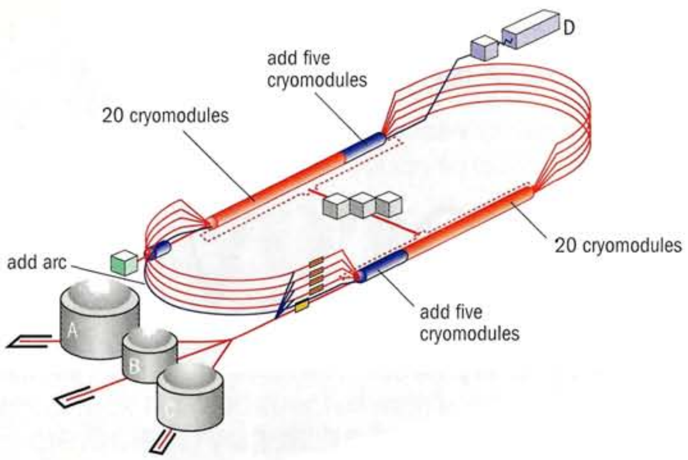
CEBAF already offers unique capabilities for investigating the quark–gluon structure of hadrons, particles that interact via the nuclear strong force. The accelerator's scientific users number in excess of 2000, and more than half of these users are currently active on experiments. Because user demand far exceeds available beam time, the backlog for each experimental hall is at least three years. Since operations began nearly a decade ago, more than 100 experiments have been completed, deepening understanding of strongly interacting matter.

In this aerial photograph of the Continuous Electron Beam Accelerator Facility (CEBAF), the dashed line indicates the location of the accelerator and the circles indicate the positions of the three existing experimental halls.

Nevertheless, careful study by users and by the US Nuclear Science Advisory Committee has shown that a straightforward, comparatively inexpensive upgrade of CEBAF offers tantalizing prospects for achieving still deeper understanding. Accordingly, *Facilities for the Future of Science: A Twenty-Year Outlook*, published by the DOE in November 2003, recommended the 12 GeV upgrade as a near-term priority (*CERN Courier* January/February 2004 p13). In plain language, the 20 year plan explained why: "Quarks are the particles that unite to form protons and neutrons, which, with electrons, combine to form the atoms that make up all the matter that we are familiar with. As yet, scientists are unable to explain the properties of these entities – why, for example, we do not seem to be able to see individual quarks in isolation (they change their natures when separated from each other) or understand the full range of possibilities of how quarks can combine together to make up matter."

The physics reach

Experiments at CEBAF have already led to a better understanding of a variety of aspects of the structure of nucleons and nuclei and the nature of the strong force. These include the distributions of charge and magnetization in the proton and neutron; the distance scale where the underlying quark and gluon structure of strongly interacting matter emerges; the evolution of the spin structure of the nucleon with distance; the transition between strong and perturbative quantum chromodynamics (QCD, the field theory of quarks and gluons); the size of the constituent quarks; and possible new states of strongly interacting matter (*CERN Courier* April 2004 p29). The upgrade will allow important new thrusts in these areas, generally involving the extension of measurements to substantially higher values of momentum transfer, probing correspondingly smaller dis- ▷



To upgrade the CEBAF superconducting, recirculating accelerator, Jefferson Lab will add Hall D, 10 higher-performing cryomodules and an extra recirculation beamline, and will upgrade equipment in the three original experimental halls and the helium refrigeration plant at the centre of the "racetrack".

tance scales. Moreover, many experiments that can run at a currently accessible momentum transfer will run more efficiently at higher energy, consuming less beam time.

The higher energy of 12 GeV will also mean qualitative changes for CEBAF's physics reach in two areas in particular. First, the upgrade will cross the threshold above which the origins of quark confinement can be investigated. Specifically, 12 GeV will enable the production of certain "exotic" mesons, the discovery and spectrum of which will establish the origin of quark confinement as being due to the formation of QCD flux tubes, and the spectrum of which encodes information about the mechanism within QCD that is responsible for their formation. If these exotic mesons are not found, their absence will seriously challenge our present understanding of "strong" QCD, and the meson spectra that will be accumulated with unprecedented statistics (including spectra of mesons containing strange quarks and antiquarks) will provide essential information for revising that theory.

A second important area will be the direct exploration of the quark–gluon structure of hadrons and nuclei. It is known that inclu-

Physics opportunities with the CEBAF 12 GeV upgrade

• **The experimental study of gluonic excitations to understand the fundamentally new dynamics that underpins all nuclear physics: the confinement of quarks.** Theoretical conjectures, which have now been strengthened by lattice QCD simulations, indicate that quark confinement – the most spectacular new prediction of QCD – occurs through the formation of a string-like "flux tube" between quarks. This conclusion (and proposed mechanisms of flux-tube formation) can be tested by determining the spectrum of the gluonic excitations of mesons.

• **The determination of the quark and gluon wavefunctions of the nuclear building blocks.** A vast improvement in our knowledge of the fundamental structure of the proton and neutron can be achieved. Not only can existing "deep inelastic scattering" cross-sections be extended for the first time to cover the critical region where their basic three-quark structure dominates, but also measurements of new "deep exclusive scattering" cross-sections will open the door to a comprehensive characterization of these wavefunctions using the framework of the generalized parton distributions. These data will provide access to information on the correlations among the quarks. These studies will be complemented by detailed measurements of elastic and transition form factors, determining the dynamics underlying the quark–gluon wavefunctions through measurements of their behaviour at high-momentum transfer and providing essential constraints on the wavefunctions.

• **Exploring the limits of our understanding of atomic nuclei.** A broad and diversified programme of measurements that (taken together with the hadron studies outlined above) aims to provide a firm intellectual underpinning for all nuclear physics by answering the question "How does the phenomenological description of nuclei as nucleons interacting via an effective interaction parameterized using meson exchange arise from the underlying dynamics of quarks and gluons?" It has two main components:

The short-range behaviour of the nucleon–nucleon (N–N) interaction and its QCD basis involves experiments aimed at identifying the physics of strong QCD that gives rise to the N–N force and exploring the short-range behaviour of the N–N force through a novel programme of deep inelastic scattering.

The second component of the programme consists of **identifying and exploring the transition from the nucleon/meson description of nuclei to the underlying quark and gluon description.** This programme aims to explore and determine the limits of applicability of the nucleon/meson description of nuclei, identifying the distance and energy scales at which it fails and the physics of nuclei is better described directly using strong QCD.

• **Tests of the Standard Model of electroweak interactions and the determination of fundamental parameters of this model.** Precision, parity-violating electron scattering experiments made feasible by the upgrade have the sensitivity to search for deviations from the Standard Model that could signal the presence of new physics. Proposed studies of the three neutral pseudoscalar mesons, the π^0, η and η', will provide fundamental information about low-energy QCD, characterizing the strengths of the chiral anomalies.

Extracted from the *12 GeV Upgrade Pre-Conceptual Design Report,* 11 June 2004.

sive electron scattering at the high momentum and energy transfers available at 12 GeV is governed by elementary interactions with quarks and gluons. CEBAF's original design energy was adequate for entering the deep inelastic scattering regime (see p22), but continuous 12 GeV beams will provide clean access to hadron structure throughout the entire "valence quark region". This will allow exploitation of the generalized parton distributions so as to experimentally access both the correlations in the quark wavefunctions of the hadrons and their transverse momentum distributions. The higher-energy beams will also allow precise identification of the limits of the long-standing nucleon- and meson-based description of nuclei, as well as full access to and characterization of the transition from this description to the underlying quark–gluon description.

The experimental environment

The CEBAF accelerator consists of a pair of superconducting radiofrequency linacs linked by recirculation arcs for up to five acceleration passes. It serves three experimental halls with simultaneous, continuous-wave beams, originally with a final energy of up to 4 GeV but now with one of up to 6 GeV thanks to incremental improvements in cryomodule technology. The complex experimental programme often requires independent beams to the three halls, each with fully independent current, a dynamic range of 10^5, high beam polarization and "parity quality" constraints on energy and position. To meet these varied demands, the machine undergoes about one change in configuration per week and must routinely operate at 5.5 GeV or higher.

For the upgrade, a new hall (Hall D) will be built at the end of the accelerator opposite the present Halls A, B and C. There, experimenters will use collimated beams of linearly polarized photons at 8–9 GeV, produced by coherent bremsstrahlung from 12.1 GeV electrons. To send a beam of that energy to that location requires a sixth acceleration pass through one of the linacs. This means adding a recirculation beamline to one of the arcs, and also requires augmenting the accelerator's present 20 cryomodules with 10 new, higher-performing ones. Maximum energy for five passes will rise to 11 GeV for the three original halls, with experimental equipment upgraded in each. The 2 K helium refrigeration plant will be upgraded to 10.1 kW from the present 4.8 kW.

In December 2002, the DOE Office of Science asked the Ad-hoc Facilities Subcommittee of the US Nuclear Science Advisory Committee (NSAC) to review all proposed projects once again. The report declared the science programme of the 12 GeV upgrade "absolutely central" to progress in the field, and the project "ready for construction". The remaining R&D will be focused on optimizing cost and increasing technical contingency. With this year's CD-0 decision, Jefferson Lab is moving the project forward with enthusiasm.

For the more distant future, research needs beyond the 12 GeV upgrade are also being considered. That science would require high luminosity and still higher energies. Essential concepts and technology advances are under study.

● For more information see the "CEBAF @ 12 GeV" link at the website www.jlab.org.

Steven Corneliussen, *Thomas Jefferson National Laboratory.*

Jefferson Lab's journ

Experiments at the boundary of nuclear physics and particle physics are providing a clearer view

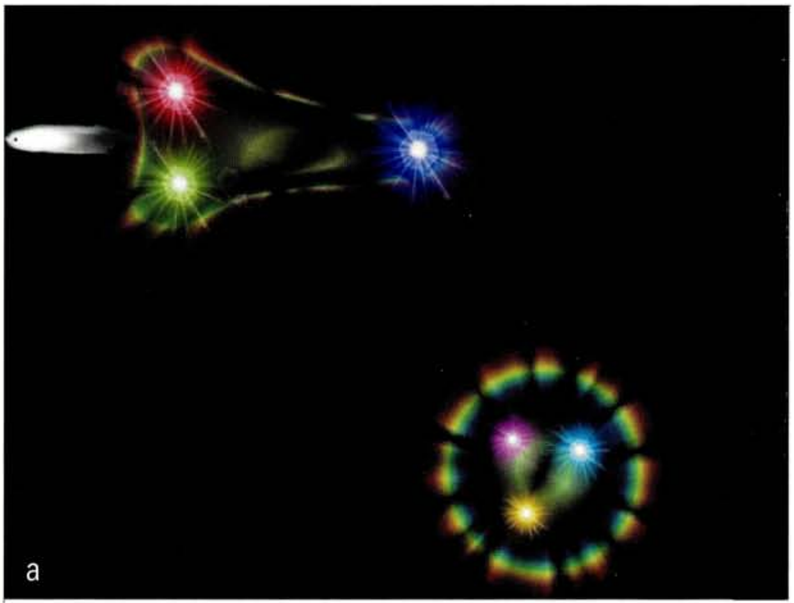
The year 1969 saw the publication of the first results indicating that hard scattering centres exist deep inside protons. A collaboration between the Stanford Linear Accelerator Center (SLAC) and the Massachusetts Institute of Technology was using SLAC's new high-energy electron linac to pioneer a rich new field in the study of the nucleus – deep inelastic scattering. Their measurements revealed that nucleons are made up of point-like particles, which Richard Feynman dubbed "partons". Thirty-five years on, studies of the parton-nature of the nucleus continue, not only at the traditional high-energy centres, but also at lower-energy laboratories, and in particular at the Thomas Jefferson National National Accelerator Facility (Jefferson Lab) in Virginia.

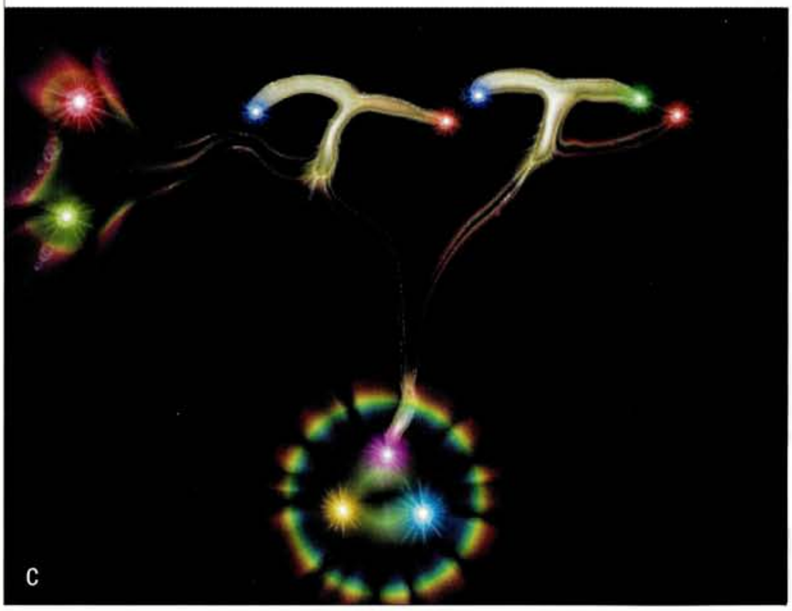
Jefferson Lab is home to the Continuous Electron Beam Accelerator Facility (CEBAF). Its main mission is to explore the atomic nucleus and the fundamental building-blocks of matter (see p19). As part of this mission, researchers there study the transition from the picture of the nucleus as a bound state of neutrons and protons to its deeper structure in terms of quarks and gluons – in other words, the transition from the hadronic degrees of freedom of nuclear physics to the quark–gluon degrees of freedom of high-energy physics. In exploring this transition, a wide range of experiments has been performed, from measurements of elastic form factors at large momentum transfers to studies of deep inelastic scattering.

An array of spectrometers together with electron-beam energies of up to 5.7 GeV has allowed the laboratory to make significant contributions to this field. This article describes three experiments, each aimed at improving our understanding of a different aspect of the partonic nature of matter. The first, a classic deep inelastic scattering experiment, seeks to further our understanding of the composition of nucleon spin. The second experiment studies the concept of quark–hadron duality – a link between the deep inelastic region and the resonance region. The third experiment uses the atomic nucleus as a laboratory to improve understanding of the propagation and hadronization of quarks. Jefferson Lab's ability to perform this range of measurements is illustrated by the plot from the CEBAF Large Acceptance Spectrometer (CLAS) shown on the cover of this magazine, where the hadronic resonance peaks are seen to be washed out as one goes from the delta resonance around 1.2 GeV to higher invariant masses and into the deep inelastic scattering realm of quarks and gluons

The spin of the nucleon

In the 1980s, experiments at CERN and SLAC showed that only a small fraction of the nucleon spin is carried by the quarks. Since then, many experiments have been done to solve this "spin crisis". Our current understanding of nucleon spin is that it is the sum of the





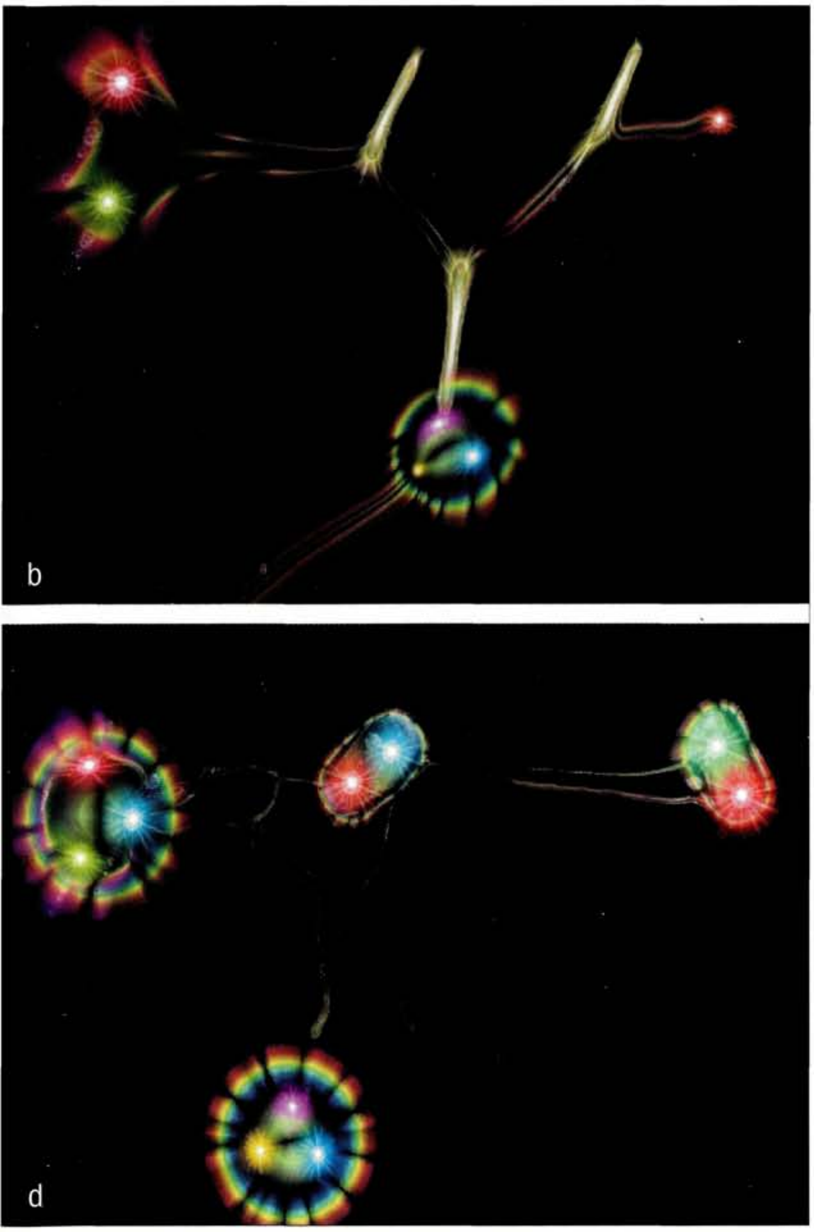
An artist's impression of a quark being struck by a virtual photon (a). As the (
gluons (b) and creating pairs of quarks and anti-quarks (c). As the system be

spins of the valence quarks and the q and the $\bar{q}$ sea quarks, the orbital angular momenta of quarks and the spins of gluons. While many experiments have been performed in the region of low Bjorken *x*, where sea quarks and gluons dominate, it has been experimentally challenging to make measurements in regions of higher Bjorken *x*, where the valence quarks are predicted to dominate.

Using the high-resolution spectrometers in Hall A with a polarized

ney into the nucleus

v of the nucleus in terms of the basic quarks and gluons, as **Douglas Higinbotham** describes.



quark propagates through nuclear matter, it loses energy by emitting
egins to return to equilibrium, two-quark systems (pions) are formed (d).

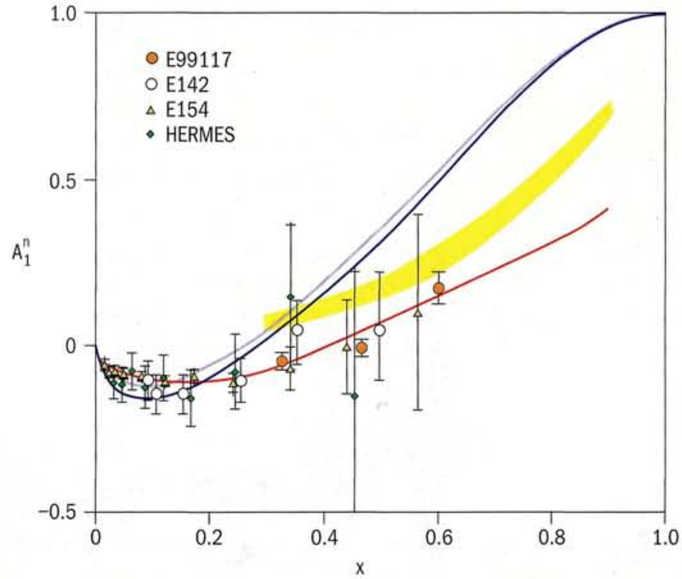


Fig. 1. The recent result from E99-117 on A_1^n, plotted with world data taken with polarized ^{3}He targets, shows for the first time that the A_1^n asymmetry becomes positive at large Bjorken x as predicted by the constituent quark model (yellow band) and perturbative QCD fits (shades of blue). The best fit of the data is the parameterization shown in red, for which hadron helicity conservation is broken, suggesting, along with the constituent quark model, that the orbital angular momentum of quarks is important in this region (Zheng et al. 2004).

^{3}He target, Jefferson Lab has recently completed a measurement in the valence-quark region of the neutron spin asymmetry A_1^n. At large momentum-transfer squared (Q^2) this asymmetry is approximately the ratio of the polarized and unpolarized structure functions: g_1/F_1. Perturbative quantum chromodynamics (QCD) as well as constituent quark models predict that this ratio should tend towards unity as Bjorken *x* goes to unity, while simple calculations based on SU(6) symmetry predict that A_1^n should be zero. Previously, the A_1^n data in the range of *x* from 0.4 to 0.6 were consistent with zero. However, the new high-precision data from experiment E99-117 at Jefferson Lab, shown in figure 1, indicate that the A_1^n asymmetry is becoming positive and hints that it may indeed approach unity (Zheng *et al.* 2004). This result reveals strong SU(6) symmetry-breaking and agrees best with calculations that include quark orbital angular momenta.

Quark–hadron duality

In the early 1970s, Elliott Bloom and Fred Gilman proposed that resonances created in electroproduction are a "substantial part of the observed scaling behaviour of inelastic electron–proton scattering". They showed that by appropriately averaging data in the resonance region, the resonance data could be smoothly linked with deep inelastic data. The authors were careful to state that they had not predicted the scaling behaviour of deep inelastic scattering, but that they had pointed out a phenomenological correlation that

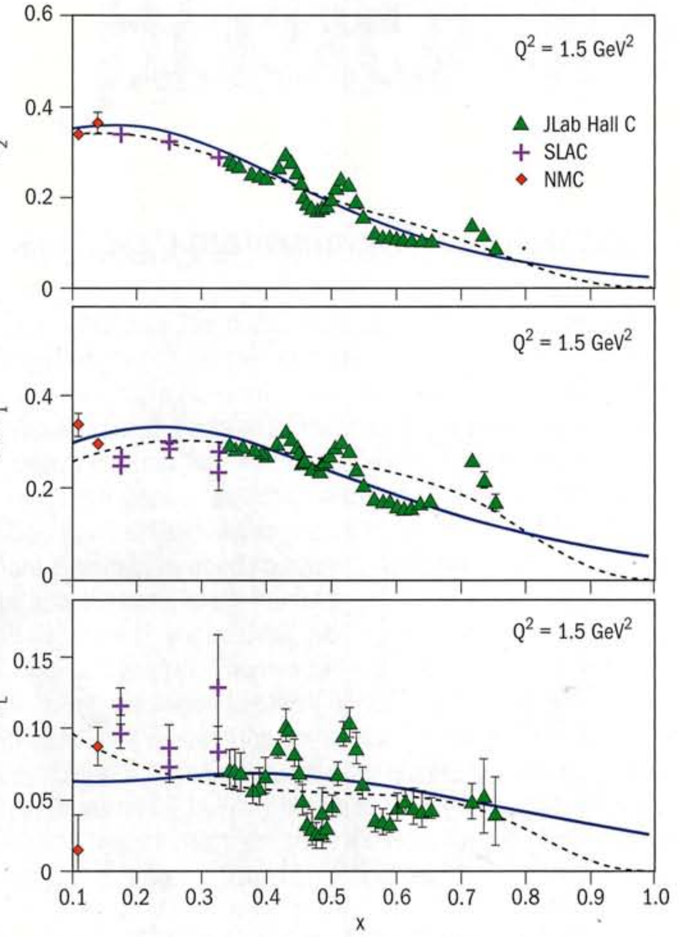


Fig. 2. Results of the E94-110 experiment are shown for the mixed longitudinal and transverse F_2 structure function (top), the purely transverse $2 x F_1$ structure function (middle) and the longitudinal F_L structure function (bottom), at $Q^2 = 1.5$ GeV^2 (Liang et al. 2004). Data from previous CERN and SLAC experiments are also indicated. The solid curve is a QCD calculation in next-to-next-to-leading order, while the dashed curve is the result of fits to deep inelastic scattering data by the SLAC group.

hinted at a common origin. This phenomenon has become commonly known as quark–hadron duality.

Recent results from Jefferson Lab's Hall C have shown that duality works quantifiably better and over a larger Q^2 range than previously thought (Niculescu *et al.* 2000, Ent *et al.* 2000). Using data in the nucleon-resonance region, it has been shown that it is possible to use the idea of duality to extract the proton's magnetic form factor as well as the ratio of longitudinal to transverse deep inelastic electron–proton scattering cross-sections. Recent structure function data in the resonance region from Hall C are shown in figure 2. These data show that even for the different structure functions, the resonance data oscillate about curves generated from fits to deep inelastic scattering.

The successful application of duality to extract known quantities suggests that it should also be possible to use it to extract quantities that are otherwise kinematically inaccessible. For example, analysis is now under way on data from experiment E01-012 at Jefferson Lab, which is using duality to determine the A_1^n asymmetry to higher Bjorken x values than are kinematically accessible through deep inelastic scattering. As a check of its validity, this extraction will partially overlap the deep inelastic scattering A_1^n data.

The successful application of duality to extract known quantities suggests that it should also be possible to use it to extract quantities that are otherwise kinematically inaccessible.

Propagation of quarks

A recent experiment in Hall B at Jefferson Lab using CLAS has made measurements to improve our understanding of quark propagation through cold QCD matter. The data from this experiment, which are now being analysed, should shed light on two topics: quark hadronization and quark energy loss (as shown schematically in the artist's impression on pp22–23).

Owing to confinement, a quark struck with sufficient energy will produce multiple hadrons through a process known as hadronization. This process is uniquely described by QCD. While the evolution of quarks into hadrons cannot be seen directly, the attenuation of the leading particles emerging from deep inelastic scattering can be determined and used to gain insight into the hadronization process.

Before the quark hadronizes, it can be considered to be travelling through the colour field of the nucleus. QCD predicts that as the quark traverses the nucleus, it will lose energy by emitting gluons. This is similar to how in quantum electrodynamics a charged particle moving through matter loses energy by emitting photons. The energy loss of the quark in the QCD process can be studied by observing the properties of the leading particles in deep inelastic scattering from different nuclei. Preliminary analysis of these data has shown that a majority of the lightest particles (pions) with the largest relative energy are strongly attenuated as one goes from light nuclei to heavy nuclei. This observation is in sharp contrast to the naive view that the nucleus is a benign spectator. The quantitative results of this experiment will be forthcoming.

In summary, three experiments from Jefferson Lab, one from each experimental hall, illustrate a different aspect of the partonic nature of matter. These experiments, along with others being performed around the world, are refining our understanding of the fundamental building-blocks of matter. With the proposed upgrade of its accelerator to 12 GeV (see p19), the laboratory will be able to cover an even greater kinematic range as it continues to map out the transition from hadronic degrees of freedom to quark–gluon degrees of freedom, providing an increasingly accurate portrait of the nucleus.

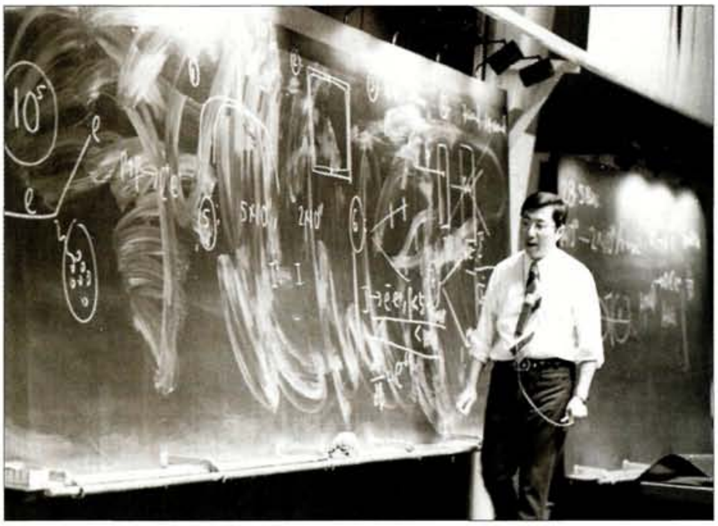
Further reading

R Ent *et al.* 2000 *Phys. Rev. D* **62** 073008.
Y Liang *et al.* 2004 www.arxiv.org/abs/nucl-ex/0410027; submitted to *Phys. Rev. Lett.*
I Niculescu *et al.* 2000 *Phys. Rev. Lett.* **85** 1182, 1186.
X Zheng *et al.* 2004 *Phys. Rev. Lett.* **92** 012004.

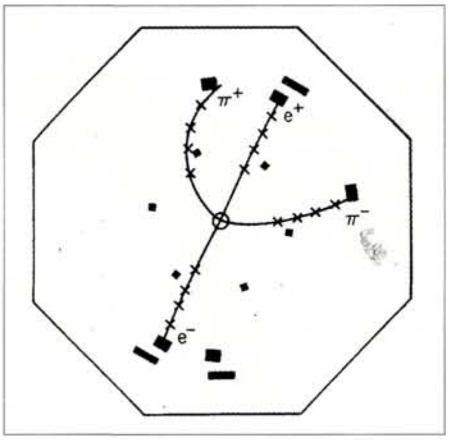
Douglas Higinbotham, *Thomas Jefferson National Laboratory.*

A November revolution: the birth of a new particle

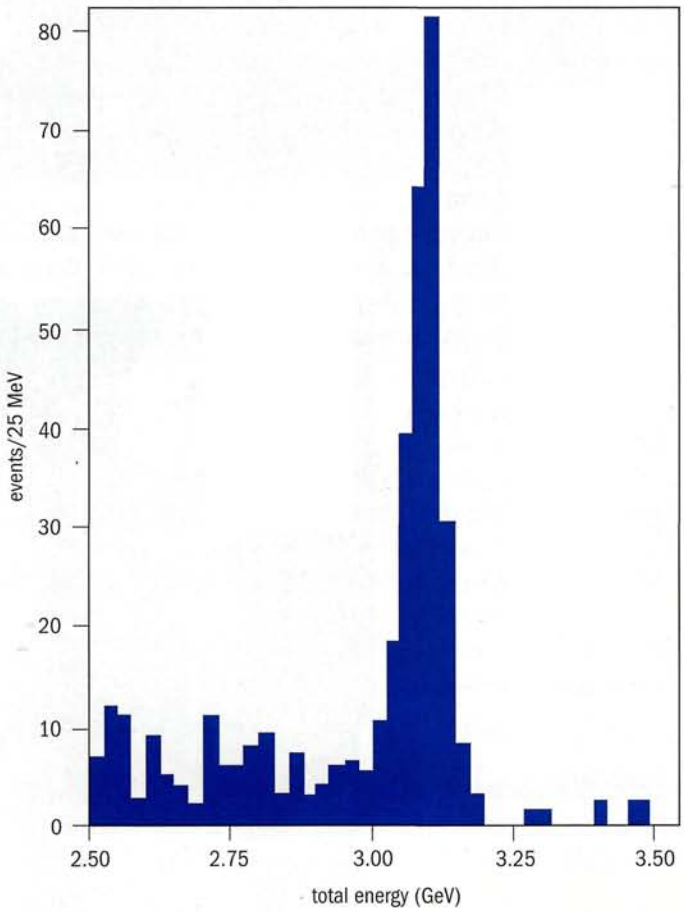
Frank Close goes back 30 years to when he first heard of the remarkable results from Brookhaven and SLAC that heralded the discovery of the fourth quark, charm.



Sam Ting describes his team's discovery of the new particle at Brookhaven to a packed auditorium at CERN.



SPEAR's Mark I detector reveals the decay of the heavier Ψ' into a J/Ψ plus two charged pions. The J/Ψ itself decays into an electron (e^-) and a positron (e^+); the four charged particles together write out a Greek Ψ in the detector.



At Brookhaven, this dramatic spike in the number of electron–positron pairs produced in collisions of a proton beam with a beryllium target revealed the existence of the J/Ψ.

I first heard about the J, or J/Ψ as it would become, in Jacques Prentki's office at CERN, immediately after lunch on an unforgettable afternoon in November 1974. At that time I was in the theory group at CERN, and responsible for organizing the phenomenology seminars. That day the speaker was Yair Zarmi from the Weizmann Institute, and his topic was inclusive hadron production in the quark parton model, on which he had written a much quoted paper with Michael Gronau and Finn Ravndal. Up to lunchtime that day it seemed extremely interesting.

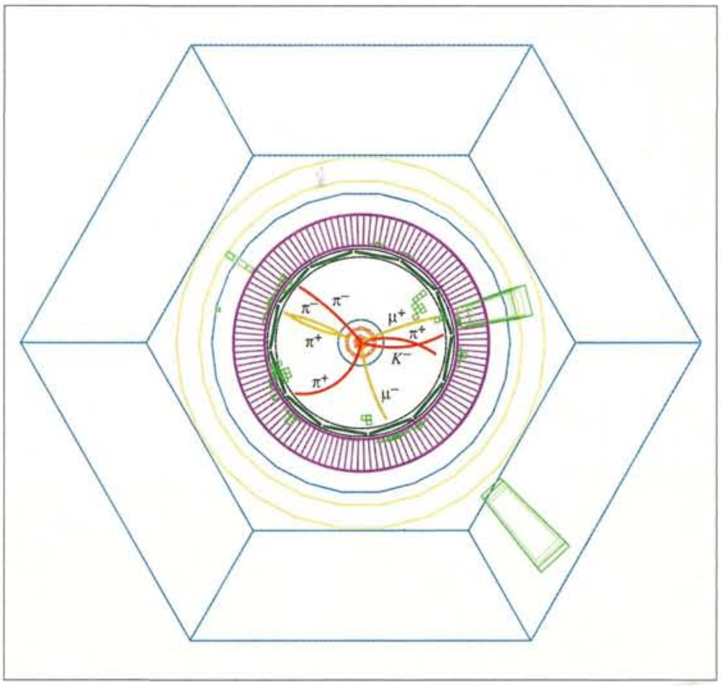
Walking back to my office after lunch I noticed three people in Jacques Prentki's office, and Jacques himself was looking agitated. I heard the words: "Hey, Frank, come look at this!" I cannot recall who the third person was, but the central character was a French experimentalist named Jean-Jacques Aubert. He was a member of Sam Ting's group at the Brookhaven National Laboratory, and there in Prentki's office, for the very first time, I saw the famous plot of their "J" particle. It was sharp, tall and narrow, and 3 GeV in mass, which in those days was heavy. It was astonishing. ▷

Zarmi gave his seminar, but I don't remember anything about it – all I can recall is that afterwards the questions weren't about his talk; they were all about the rumours that a new particle had been found. Then hot news arrived: Aubert would give a special seminar later that afternoon in the Theory Discussion Room.

I arrived early, but it was almost too late – it was already standing room only. News spread fast around CERN, even in the days before Tim Berners-Lee invented the Web. Jack Steinberger opened the proceedings with this statement: "It is good to hear of something that we can really believe in." He briefly explained the circumstances, then introduced "Professor Aubert".

Jean-Jacques began by saying, somewhat apologetically, "I am not a professor", to which Steinberger instantly retorted, "You will be!" Of course, Steinberger was right, and in 1982 Aubert became professor at the Université de la Méditerranée in Marseilles, where he later created the Centre for Particle Physics.

Somewhere in all of this we learned that SLAC had seen it too. And then we heard that Ting was en route from the US to give an official presentation at CERN in the auditorium.



Nowadays, the J/Ψ particle provides an important "signature" for other kinds of events. This display from the BaBar experiment at SLAC shows the decay of a B and an anti-B meson. One decays into a J/Ψ and a neutral kaon, the J/Ψ itself decays into a pair of muons (μ).

The search for charm

Ting gave his talk and wrote an enormous "J" on the board at CERN. On that occasion, the J was also in honour of J-J Aubert. The auditorium was overflowing and there was prolonged applause.

Soon afterwards, details reached CERN of the discovery of the same particle by Burton Richter and colleagues working on the Mark I detector at SLAC, where they called it the "psi" (Ψ). Then, a week later, Sacha Dolgov stopped me in the corridor: "SPEAR has found another one." This was the Ψ′. This too was narrow.

John Bell soon organized a special session where the data would be presented and three theorists would review the ideas. Mary Gaillard, who with Ben Lee and Jonathan Rosner had already drafted a seminal paper, "The search for charm", naturally reviewed charm; Dolgov reviewed the possibility that this (these!) could be the long-sought Z boson (the discovery of the real one was still a decade in the future), and I was given the task of discussing colour. I was enthusiastic about this because, according to rumour, Richard Feynman had said that a new quantum number must be involved to make it narrow, and Jacques Prentki had said "It's not charm." What we were not up to speed with was the phenomenon of asymptotic freedom, which proved to be so vital for understanding the bizarre properties of these particles (and which has this year been recognized with the award of a Nobel prize – see *CERN Courier* November 2004 p5).

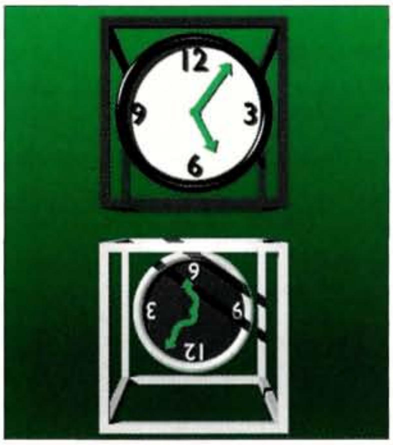
The impact of the news we all heard on that November day 30 years ago was such that Yair Zarmi's talk, and the whole area in which it fell and on which I had been devoting my effort, lay dormant in my notebook. We dropped everything and turned to the only problem in town. Two years later, after it had become undisputedly clear that the J/Ψ was the first example of a new type of quark – charm – bound with its antiquark, Ting and Richter shared the Nobel prize for their discovery, a vital step in building the current Standard Model of particles and interactions.

Frank Close, *University of Oxford.*

Framing Lorentz symmetry

Experimentalists and theorists from around the world recently gathered at Indiana University to exchange the latest findings from their experiments in the search for the violation of Lorentz symmetry.

Kurt Gibble (left) of Penn State talks with Ron Walsworth of Harvard-Smithsonian and Alan Kostelecky of Indiana University.



The two clocks depicted in the official logo for the CPT '04 meeting are related by the parity transformation (P). The inversion of black and white represents charge conservation (C), while time reversal (T) is represented by the movement of the hands of the clock in opposite directions.

Efforts to test Lorentz symmetry at ever-increasing sensitivities have opened up new perspectives in theoretical and experimental physics. While high-energy accelerators have traditionally been designed to probe fundamental particles at ever-smaller microscopic scales, it has been known for some time that data from many such experiments could contain information about weak Lorentz-violating background fields that exist in space on scales the size of the solar system and greater. Among the basic signals being sought are sidereal variations arising due to the rotation of the Earth relative to the fixed background stars. Measurements of these effects at CERN and similar facilities can potentially also be confirmed in other experiments, such as those involving atomic clocks, masers, torsion pendulums, optical and microwave cavities, astronomical polarization data and Penning traps, to name some examples. The triennial Meeting on Lorentz and CPT Symmetry (CPT '04), held at Indiana University on 4–7 August 2004, provided a forum for researchers in the field to compare results and new ideas.

Lorentz symmetry, the feature of nature that says experimental results are independent of the orientation or the boost velocity of the laboratory through space, has survived a century of tests since Albert Einstein introduced the special theory of relativity. CPT, the combination of charge reversal (C), parity inversion (P) and time reversal (T), is a closely related symmetry of nature that also appears to be exact. The general theory of Lorentz and CPT violation, known as the Standard Model Extension (SME), was developed by Alan Kostelecky and collaborators at Indiana University as part of the effort to unify the theories of quantum mechanics and gravity by investigating the full range of possible violations of Lorentz and CPT symmetries. The violations appear in the SME as minuscule coefficients, which are estimated to be observable in experiments that are sensitive at the Planck scale, where quantum mechanics and gravitation are merged. Numerous experiments are able to reach these sensitivity levels and have explored the coefficient space of the SME for almost 10 years.

The opening session of CPT '04 featured theorist Yoichiro Nambu from Chicago University and experimentalist Ron Walsworth from Harvard. Nambu outlined several interesting and counterintuitive features of physics that could be observed in a Lorentz-violating world. In efforts to study such a world, many experiments employ, or plan to employ, rotating turntables and highly controlled laboratory environments. Walsworth spoke about the idea of a dedicated facility to provide these technical services. He also discussed an experiment using co-located helium and xenon masers to place the first bounds on 11 combinations of SME coefficients for the neutron.

Tests with neutrinos and photons

Carlos Peña-Garay of the Institute for Advanced Study at Princeton presented the theoretical arguments for massive neutrinos based on observations from solar neutrinos, atmospheric neutrinos and the KamLAND experiment in Japan. The SME offers a general framework for Lorentz and CPT violation in the neutrino sector, and in particular a general analysis of neutrino oscillations exists. The full range of effects involves dozens of coefficients, but a simple two-coefficient model with no neutrino masses has been devised by Kostelecky and Matt Mewes at Indiana University. Mark Messier of the SuperKamiokande collaboration showed in his talk that this rudimentary model, dubbed the "bicycle" model, fits the atmospheric neutrino data from SuperKamiokande just as well as the fit with models involving neutrino mass differences. The MINOS experi- ▷

Ryugo Hayano (left) of the ASACUSA collaboration discussing prospects for antihydrogen symmetry tests with Alan Kostelecky and Alban Kellerbauer (behind) of the ATHENA collaboration.

ment, due to become fully operational in December, may be able to resolve sidereal effects as predicted by the SME. This experiment will take data in the Soudan mine in northern Minnesota from a neutrino beam originating at Fermilab near Chicago.

Data from the Liquid Scintillating Neutrino Device (LSND) experiment at Los Alamos can be interpreted as showing that there is a 0.26% probability that a muon antineutrino will decay into an electron antineutrino over a distance of about 30 m. Rex Tayloe from the LSND collaboration presented a discussion of efforts that are under way to investigate whether the SME coefficients can successfully account for both the LSND data and the atmospheric and solar-neutrino data.

The SME shows that 19 independent components control Lorentz-violating effects on photons. The absence of any observed frequency dependence in the polarization of light from distant quasars places a bound of parts in 10^{32} on several of these coefficients. Birefringence observations cannot access the remaining ones, but modern Michelson–Morley and Kennedy–Thorndike experiments are doing so using cavity oscillators. Michael Tobar of Western Australia presented the sharpest measurements to date on several combinations of the coefficients, obtained using microwave oscillators. He hopes to improve on them soon with the aid of a rotating platform. Achim Peters, from Humboldt University in Berlin, reported on another experiment using optical resonators created from a single sapphire crystal. He outlined various plans for improving the sensitivity, including better cryogenics and a turntable mount to aid in searching for sidereal variations.

Claus Lämmerzahl of Bremen discussed theoretical approaches to Lorentz violation in the context of electromagnetism. His approach modifies the field equations without requiring a Lagrangian, and the resulting effects include charge non-conservation. An analysis accounting for the changes in length of an optical cavity as it interacts with the SME background was presented by Holger Müller of Stanford University. The approach highlights the interconnectivity

The plethora of experiments aimed at identifying violations of Lorentz symmetry bear testimony to the continued relevance of Einstein's achievements.

of the photon sector in the SME with the fermion sector involving atoms and molecules.

Lämmerzahl also described the OPTIS project, a mission of the European Space Agency, which plans to place optical resonators and masers on a dedicated satellite. The mission will offer a number of advantages over ground-based tests of Lorentz symmetry. The status of programmes that are funded through NASA for other space tests was outlined by Joel Nissen of Stanford. He pointed out that the Superconducting Microwave Oscillator (SUMO) mission could be adapted to fly independently of the International Space Station.

Tests in atomic physics

Various Lorentz tests have been done or are planned in atomic systems, and include three experiments at CERN that involve antiprotons. Ryugo Hayano of the ASACUSA collaboration reported on efforts to study the spectrum of antiprotonic helium (*CERN Courier* January/February 2003 p27). Another test involves comparison of the antihydrogen spectrum with that of conventional hydrogen. Alban Kellerbauer of the ATHENA collaboration reported on the status of the effort to create, cool and trap antihydrogen. Together with the ATRAP antihydrogen collaboration, ATHENA and ASACUSA utilize CERN's Antiproton Decelerator facility to supply antiprotons. In terms of the SME, comparison of the hyperfine levels of the atomic spectra could test CPT symmetry for the proton. Whereas searches for sidereal variations using only one species of atom access complicated combinations of SME coefficients, the test involving hydrogen atoms and anti-atoms is clean and would be difficult to duplicate in other experiments.

Penning traps are other devices that allow comparisons of properties of particles and their corresponding antiparticles. Brian Odom reported on the progress of Gerald Gabrielse's group at Harvard working on a new measurement of g-2 for the electron and positron. It is expected that the researchers will be able to improve significantly on existing resolutions.

Atomic clocks operating on transitions involving a change in the spin state have the potential to test Lorentz coefficients in the SME with great precision. Mike Romalis from Princeton discussed the status of his potassium–helium comagnetometer, involving a mixture of these two atoms in a single bulb. The experiment, which has the potential to achieve record sensitivities, is currently taking data. Atomic clocks have been planned to fly on the International Space Station or other space platforms, providing increased speeds and rotation rates and hence improved sensitivities for tests of Lorentz symmetry. Kurt Gibble of Penn State reviewed the status of his two-arm rubidium clock, which may eventually be used to perform Lorentz tests in space.

Blayne Heckel and Eric Adelberger of the "Eöt-Wash" torsion pendulum group at the University of Washington in Seattle discussed progress in several experiments. One type of pendulum employs a bob with a net electronic spin but no net magnetic field, and oscillates torsionally from a thin thread. The group is trying to eliminate systematic effects possibly due to swing, bounce and wobble of the thread in their most recent version. Preliminary results show that they already have significant improvements in sensitivity to Lorentz-violation coefficients in the electron sector.

Violations in theory

The SME has enjoyed broad interest because it encompasses Lorentz-violation experiments from all areas of physics. It is a step in the quest to produce a single theory that unites the quantum world with the theory of gravitation. In the absence of a fundamental theory that achieves this goal, the SME provides a full set of possible Lorentz- and CPT-violating effects that could reasonably occur in the low-energy limit of such a theory.

At the fundamental level, theorists are currently considering various ideas, including string theory and several forms of quantum gravity. Daniel Sudarsky of the National University of Mexico (UNAM) gave a review of some approaches, particularly loop quantum gravity. Ralf Lehnert of Vanderbilt University discussed how Lorentz violation can be associated with space–time-varying couplings in a scenario with a cosmological scalar field. Lorentz tests in atomic experiments have a variety of generic features, and Robert Bluhm of Colby College gave a comprehensive overview of these and the related theory. Some of these features are also common in Lorentz tests in other experimental sectors.

The past 10 years have seen a first generation of Lorentz experiments probing SME coefficients in the theoretical context of a flat space–time. A second generation of tests has the potential to probe the SME with gravity. Kostelecky presented some of the myriad of features of the SME in a curved space–time. Particles with spin are incorporated into the space–time structure using the "vierbein" formalism, rather like a mathematical four-legged spider placed in a smoothly varying manner at each point in the manifold. The coefficients for Lorentz violation acquire additional dependence on features such as the space–time metric and on associated properties like torsion and curvature.

The plethora of experiments aimed at identifying violations of Lorentz symmetry bear testimony to the continued relevance of Einstein's achievements. The ever-increasing sensitivity to SME coefficients continues to strengthen this legacy. Remarkably, much of the SME coefficient space is still unexplored. Should Lorentz violation be found soon, it would be a fitting time to build on the foundations laid by Einstein a century ago.

Neil Russell, *Northern Michigan University.*

APS AWARDS

APS announces winners for 2005

The American Physical Society has announced many of its awards for 2005, with recipients who work in particle physics and related fields, from the physics of supernovae to accelerator techniques.

Stan Woosley of the University of California at Santa Cruz has been awarded the Hans A Bethe Prize, which recognizes outstanding work in the areas of astrophysics, nuclear physics, nuclear astrophysics or closely related fields. Woosley receives the prize "for his significant and wide-ranging contributions in the areas of stellar evolution, element synthesis, the theory of core collapse and type Ia supernovae, and the interpretation of gamma-ray bursts – most notably, the collapsar model of gamma-ray bursts".

Nuclear physics is also recognized in the award of the Tom W Bonner Prize for outstanding experimental research in nuclear physics, given to Roy Holt of Argonne National Laboratory. Holt has been recognized for "his pioneering role in experimental studies of the structure of the deuteron, and especially for his innovative use of polarization techniques in these experiments".

The 2005 Dannie Heineman Prize for mathematical physics goes to Giorgio Parisi of INFN-Seigone, "for fundamental theoretical discoveries in broad areas of elementary particle physics, quantum field theory, and statistical mechanics; especially for work on spin glasses and disordered systems".

CP violation figures in the citations for two of the 2005 prizes awarded for particle physics. Pier Oddone of the Lawrence Berkeley National Laboratory receives the W K H Panofsky Prize in experimental particle physics, "for his insightful proposal to use an asymmetric B-Factory to carry out precision measurements of CP violation in B-meson decays, and for his energetic leadership of the first conceptual design studies that demonstrated the feasibility of this approach".

Pier Oddone of LBNL is one of several people working in particle physics who have been awarded APS Prizes for 2005.

On the theoretical side, the J J Sakurai Prize for outstanding achievement in particle theory is awarded to Susumu Okubo of the University of Rochester. Okubo receives this prize for his "groundbreaking investigations into the pattern of hadronic masses and decay rates, which provided essential clues into the development of the quark model, and for demonstrating that CP violation permits partial decay rate asymmetries".

Tests of CPT symmetry (see p27) feature in the 2005 Francis M Pipkin Award. It honours exceptional research accomplishments by a young scientist in the interdisciplinary area of precision measurement and fundamental constants, and aims to encourage the wide dissemination of the results of that research. For 2005, the award goes to Ronald Walsworth of the Harvard-Smithsonian Center for Astrophysics "for broad investigation in precision measurements involving masers; in particular, for using hydrogen and noble-gas masers in achieving record sensitivities to violations of Lorentz and CPT symmetry in neutrons and protons, and for innovative applications of masers to imaging".

A third particle physics award is the Robert R Wilson Prize for achievement in the physics of particle accelerators. For 2005 this is awarded to Keith R Symon of the University of Wisconsin "for fundamental contributions to accelerator science, including the FFAG concept and the invention of the RF phase manipulation technique that was essential to the success of the ISR and all subsequent hadron colliders".

Particle physics also features in the Dissertation Award in Nuclear Physics to Andriy Kurlov. He receives the award "for his theoretical work on electroweak radiative corrections to precision low-energy processes, including calculations of neutrino-deuterium scattering needed to interpret solar neutrino data and other calculations to constrain limits for physics beyond the Standard Model".

Lastly, the Einstein Prize, which recognizes outstanding accomplishments in the field of gravitational physics, has been awarded to Bryce DeWitt of the University of Texas. DeWitt receives this "for a broad range of original contributions to gravitational physics, especially in quantum gravity, gauge field theories, radiation reaction in curved space–time, and numerical relativity; and for inspiring a generation of students." Sadly, DeWitt died on 23 September 2004, aged 81. A tribute to this exceptional physicist will be published in a forthcoming issue.

GROSSMAN AWARD

Black hole expert receives the prestigious Grossman Award

Roy Kerr, emeritus professor of the University of Canterbury in Christchurch, New Zealand, has been honoured with the Marcel Grossman Award, which recognizes outstanding work in general relativity, gravitation and relativistic theories. Kerr receives the award for his discovery in 1963 of a solution to the equations of general relativity, describing space–time around rotating black holes – which have since become known as "Kerr black holes".

Kerr heard the news at the Kerr Fest Black Hole Symposium, held at Canterbury in honour of his 70th birthday. He will receive the award at the next Marcel Grossman Meeting in St Petersburg in 2006.

ALICE AWARDS

Industrial collaborators honoured by ALICE

The ALICE collaboration has presented its second round of awards to three companies for their novel and remarkable contributions to major detector systems: Advance Technology and Materials (ATM), Fischer Advanced Composite Components (FACC) and North Crystals. The awards presented to these three leaders in advanced, modern materials were beautifully sculpted from one of the oldest materials used by mankind to manufacture tools – Mexican Obsidian.

ATM is a young, private Chinese company with headquarters in Beijing. An offspring of a previously state-supported network of research institutes, ATM has emerged as a leader in advanced materials, such as tungsten alloys and refractive metals. The company won the contract with ALICE to produce complex absorber parts fabricated from a high-density tungsten alloy. These parts, totalling more than 50 t, are the heart of the experiment's finely tuned muon filter. Located in the centre of the 15 m long muon spectrometer, they had to be built with sub-millimetre precision, in complex, interlocking shapes to surround the delicate beam pipe of the collider.

The winners gather after the ALICE Award ceremony (from left to right): Yuri Saveliev, Stanislav Burachas and Sergei Beloglovsky of North Crystals; Maximilian Metzger, CERN's secretary-general; Rang Cai of ATM; Jürgen Schukraft, ALICE spokesperson; Erich Pamminger and Daniel Gattinger of FACC; and Tiejun Wang of ATM.

FACC is another young company, located in Upper Austria, which has become a major manufacturer of composite parts for some of the biggest aircraft builders. It won the contract to develop and manufacture the panels that form the cylindrical field cage of the time projection chamber for ALICE; with a volume close to 100 m^3, it is the largest device of this nature in the world. FACC developed and constructed the panels, not much thicker than thin card, which form cylinders 5 m long and 5 m in diameter, capable of supporting tonnes of force with essentially no deformation.

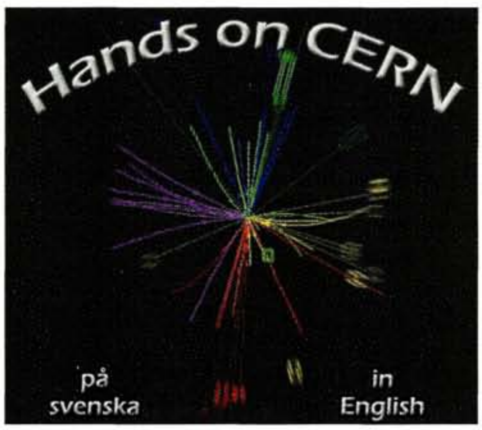
North Crystals, located in Apatity near Murmansk, Russia, has made the transition from a state-owned institute – this time in the former Soviet Union – to a world leader. As well as the spectrum of crystals developed and produced for telecommunications, medical imagery and consumer electronics, North Crystals has developed crystals for state-of-the-art electromagnetic calorimeters – in close collaboration with the Kurtchatov Institute, Moscow. The company was honoured for its remarkably successful collaboration and development of these crystals, currently being assembled into the Photon Spectrometer for ALICE.

WEB AWARDS

Scientific American accolade for Hands-on-CERN website

"2004 will go down in history as the year the rovers *Spirit* and *Opportunity* landed on Mars, the year the Cassini–Huygens spacecraft entered Saturn's orbit, the election year in which the issue of stem-cell research loomed large, and the year predicted to contain the costliest hurricane season ever recorded in the US", reads the website that describes *Scientific American's* Science & Technology Web Awards 2004. So it is a pleasure to find that Hands-on-CERN (http://hands-on-cern.physto.se) is among the 50 sites honoured this year. Developed by Stockholm's Erik Johansson, it uses events from the DELPHI experiment at CERN's Large Electron Positron collider to explore the smallest components of matter (*CERN Courier* March 2002 p18).

According to the citation, "the site does a brave job of making the business of elementary particles, accelerators, detectors and collision exercises comprehensible to a general audience. The crowning jewel of the site is WIRED, or World Wide Web Interactive Remote Event Display, where students can study actual particle collisions... The site represents quite a feat in ultimately making this branch of physics more accessible for all."



The homepage of the award-winning site.

SYMPOSIUM

Siberia provides setting for collider anniversary

Earlier this year, the Budker Institute of Nuclear Physics in Novosibirsk hosted an international symposium celebrating the 40th anniversary of the first experiments with lepton colliders. On 19 May 1964 the first events of Moeller scattering were detected at the VEP-1 collider in Novosibirsk. At about the same time, similar experiments began at Stanford. These activities opened a new era in high-energy and accelerator physics, demonstrating the feasibility of experiments often considered unachievable at the time. Today, particle colliders are the main source of precise information in high-energy physics.

The symposium was organized by SLAC and the Budker Institute, and attracted 150 physicists. Among its guests were two patriarchs of collider experiments, Wolfgang Panofsky from the US and Carlo Bernardini from Italy, as well as many young physicists just starting their careers.

During the three days of the symposium the participants heard various talks on the history of lepton colliders, their current status and possible future developments, as well as numerous applications in other fields, including synchrotron radiation and free electron lasers.

Carlo Bernadini (left) and Wolfgang Panofsky during the symposium. (Courtesy of V V Petrov.)

The first day was devoted to the history of lepton colliders. After a brief greeting by the co-chairman Alexander Skrinsky, Wolfgang Panofsky gave a talk about his meetings with Gersh Budker. Their friendship and fruitful discussions greatly helped to develop the collider method. Comprehensive reviews of the history of electron-positron colliders were then presented, from the first experiments at Ada in Frascati and VEPP-2 in Novosibirsk to the Large Electron Positron (LEP) collider at CERN and the B factories.

Linear and photon colliders formed the main topic of the second day, and the last day of the symposium was devoted to detectors and applications. Unusually hot weather (over 35 °C) changed the opinion of many guests about Siberia, and did little to spoil the friendly atmosphere. The high-energy physics community is looking forward to the discussion of new achievements with colliders on the next major anniversary in 2014.

PUBLICATIONS

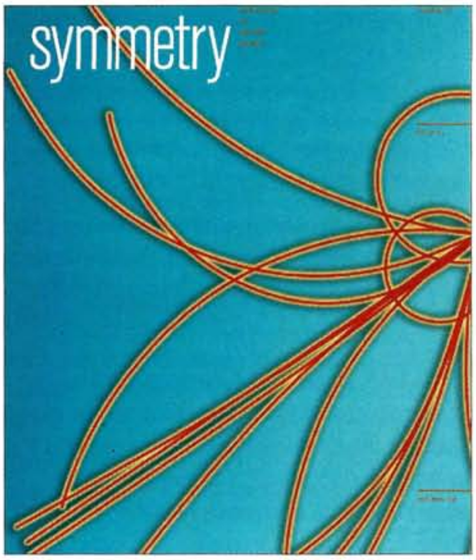
Fermilab and SLAC launch new magazine

A new particle physics magazine, *symmetry*, was launched in October by Fermilab and SLAC. It replaces Fermilab's *Fermi News* and SLAC's *Beam Line*. The magazine will be published 10 times per year in print and electronic formats, and is funded by the US Department of Energy's Office of Science through Fermilab and SLAC.

According to the magazine's editor-in-chief, David Harris, *symmetry* will discuss the connections between particle physics and other aspects of science, policy and culture. "Particle physics has discovered stronger connections to other fields of science, such as cosmology, in recent years," explains Harris. "The magazine looks at these connections and also how particle physics fits into people's lives. We hope to capture and share the new excitement that has arisen in particle physics in a way that is accessible to physicists and non-physicists alike."

The inaugural October/November issue of *symmetry* includes features on the process by which the International Technology Recommendation Panel (ITRP) came to its decision recommending a "cold" technology for a future International Linear Collider, the problems and opportunities faced by families due to the increasingly international nature of particle physics, and the challenges of conducting neutrino-observation experiments under Antarctic ice and the Mediterranean Sea. Other parts of the publication include commentaries, essays, reviews, and the graphical explorations of ideas, devices and history in particle physics.

The December issue of *symmetry* will feature an analysis of the first 25 years of inflationary cosmological theories, a gallery of paintings inspired by particle physics, and an examination of SESAME, the synchrotron facility being constructed in Jordan.



The inaugural issue of the new magazine.

The magazine represents the first time that two US national laboratories have collaborated on a publication on this scale. Harris says that he hopes this reflects the increasing co-operation in the particle-physics communications community.

To read the magazine online or to subscribe, visit www.symmetrymagazine.org.

OUTREACH

Stockholm hosts Europe's first Open Science Forum

From 25 to 28 August, the first European Open Science Forum (ESOF) was held at the Stockholm City Conference Centre in Sweden's capital city. More than 1800 people participated in this first pan-European scientific meeting, coming from a total of 68 countries and including 350 journalists. The aim was to provide an interdisciplinary forum for open dialogue, debate and discussion on science and technology in society, and the meeting took the form of a variety of exhibitions and seminars.

Particle physics made its appearance at ESOF in two sessions and several exhibits. The "From quarks to galaxies" session was supported by the European Committee for Future Accelerators (ECFA), and organized in particular by Michael Kobel of Bonn, who is an active member of both the European Particle Physics Outreach Group and the International Linear Collider Communication Group. The five speakers – Gerard 't Hooft (Utrecht), Licia Verde (Pennsylvania), Ugo Amaldi (Milano Bicocca), Ulf Danielsson (Uppsala) and Albrecht Wagner (DESY) – covered a wide range of topics, from string theory to hadron therapy.

In another session, "The top 10 mysteries of the early universe", devised by Rolf Landua (CERN), the audience discovered the results of a survey among leading scientists, presented in reverse order as in the "top 10" music charts on television. John Ellis (CERN) and Licia Verde also had to answer questions, but could turn to the audience for help.

Three exhibitions at the conference centre also contained particle-physics themes: the ECFA exhibition, the CERN and Swedish exhibition, and the exhibition by EIROforum, the collaboration of seven European inter-governmental research organizations. Outside the conference, in open spaces and in universities in Stockholm, "Science in the city" attracted the general public.

"Science in the city" offered hands-on activities, including INFN's "Physics on the road" (top) and Stockholm's "House of science" (centre). Below, Micheal Kobel (centre) and Albrecht Wagner (right).

JINR

Alexei Sissakian celebrates his 60th birthday

On 14 October, Alexei Sissakian, vice-director of the Joint Institute for Nuclear Research (JINR) in Dubna and full member of the National Academy of Sciences of Armenia, celebrated turning 60 years of age.

Born in Moscow, Sissakian graduated from the Physics faculty of Moscow University in 1968, and started work at the Laboratory of Theoretical Physics, JINR, under the guidance of Nikolai Bogoliubov. Beginning as a junior scientist, he progressed to become vice-director in 1989. Since then he has contributed greatly to the improvement of the JINR scientific base, the renovation of the institute as an open international centre, the development of wide co-operation with national and world research centres, and the training of qualified scientific personnel.

Sissakian's main scientific activities concern the physics of elementary particle interactions, approximation methods and quantum-field-theory equations, the quantization problem of systems with non-trivial geometry, symmetry and topology. He is an acknowledged specialist in the phenomenology of multiple particle production, and is an active participant in the preparation of scientific programmes and the realization of experiments at the Institute of High-Energy Physics' U-70 accelerator (2 m propane chamber collaboration, "thermalization", etc), at the JINR Nuclotron at CERN (DELPHI, ATLAS) and at Fermilab (CDF).

Sissakian is professor at Moscow State University, and scientific leader of the chamber of high-energy particle physics at the Moscow Physics and Technology Institute. He was one of the initiators of the idea to open the International "Dubna" University for Nature, Society and Man. Alongside all this, he is also a member of the Commission on Particles and Fields of the International Union of Pure and Applied Physics (IUPAP), the European Committee for Future Accelerators (ECFA) and a number of special councils and editorial boards of scientific publications.

COLLABORATION

High-energy physics gets accelerated in Turkey


Participants at the UPHUK-2 conference.

Turkey has been a CERN Observer State since 1986, and Turkish high-energy physicists have been active in many experiments at CERN. A notable example has been CHORUS, for which Turkish high-energy physicists made several important contributions to the analysis. Now they are involved in preparing the CMS and ATLAS experiments for the Large Hadron Collider, and in parallel a group of nuclear physicists plans to participate in the ALICE experiment.

These were among the topics discussed at the second Turkish National Accelerators and Applications Conference (UPHUK-2), organized in Ankara this year by the Chamber of Commerce of Ankara and the Turkish Atomic Energy Authority. The meeting also discussed the prospects for a Turkish Accelerator Complex (TAC), as well as medical and industrial applications of accelerators. Subsequently a TAC group from Ankara visited CERN with a view to participating in R&D on the Compact Linear Collider project, CLIC.

The Turkish high-energy physics community is now formulating proposals for developing the relationship between Turkey and CERN. This was discussed during a visit to CERN by the acting president of the Scientific and Technical Research Council of Turkey (TUBITAK), Nuket Yetis, and its vice-president, Omer Cebeci, on CERN's 50th anniversary.

LETTERS

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

Joint visits to CERN with SESAME

I was pleased to learn about the visit of five UAE Students to CERN (*CERN Courier* October 2004 p58). This first visit by a member country of the GCC (Gulf Cooperation Council: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE) is of great significance for the Middle East. We need many more such visits by students and teachers.

In future it would be more meaningful to have joint visits together with SESAME, the first international science centre in the Middle East. With formal ties between CERN and SESAME (*CERN Courier* July/August 2003 p8), such joint visits appear very feasible. Participants would acquire the motivation to contribute to SESAME – a "mini CERN" in the Middle East. We also need to start schools on physics and the technology of particle accelerators, a subject often not covered in the university curriculum in the Middle East region.

With the successful example of SESAME, it is time to address the need for a regional facility in Africa. The question is not whether Africa needs synchrotrons, but rather how to acquire them. The first step would be to launch an African Synchrotron Radiation Programme (AfSRP), which could assist in coordinating African participation in SESAME and other synchrotron facilities worldwide, and could also play a pivotal role in creating synchrotron radiation facilities in Africa.
Sameen Ahmed Khan, Middle East College of Information Technology, Oman.

CORRECTION

In the October 2004 issue of *CERN Courier*, the caption of the photograph illustrating the article "How nature can carve out a fractal" in Physicswatch (p17) wrongly identifies the coastline shown as Portugal. It is the coastline of Spain's Galicia region.

NEW PRODUCTS

CEDIP Infrared Systems has implemented a new feature on its JADE range of cameras that increases the dynamic range by a factor or four and provides the equivalent to a 16-bit dynamic range. The new feature, called Multiple Exposure, combines several subframes taken with a variable integration time. Using Composer, a new software module, users can now recombine subframes and rescale them in an appropriate manner so that the overall dynamic range is greatly increased. The new technique is particularly appropriate for demanding applications, such as measuring transient thermal phenomena over a large temperature range. For further information, call +33 160 370100, e-mail cedip@cedip-infrared.com or visit the website www.cedip-infrared.com.

Integrated Engineering Software (IES) has announced the release of IES IMPORT version 6.2, an import utility for IES users with CAD and CAE programs on separate computers from their IES program. IES programs link directly to CAD programs such as I-DEAS, SolidWorks, ProEngineer, Inventor and Solid Edge, to allow true representation of complex geometric shapes. IES IMPORT enables the user to first import a 3D model from other solid modelling applications, then zoom in and out and fully rotate the model to ensure that it is accurate. For more details, call +1 204 632 5636 633 7780. Alternatively, e-mail info@integratedsoft.com, or get further information online at the IES website: www.integratedsoft.com.

Sundance, a provider of high-performance signal processing and reconfigurable computing solutions for communication original equipment manufacturers (OEMs), has introduced the SMT145. This is a fully configurable signal carrier board that addresses OEM's requirements for extended network and communications high throughputs. With its add-on module and interface architecture, compatible with Sundance's family of signal processing and FPGA-based systems, the SMT145 can handle high-speed data streams through its fibre interface or its InfiniBand architecture. For further information on the SMT145, e-mail SALES@sundance.com or visit the company's website at www.sundance.com.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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EARTH

DIRECTIONAL SENSITIVE, LOW-ENERGY ANTINEUTRINO DETECTOR DEVELOPMENT

The Kernfysisch Versneller Instituut, Rijksuniversiteit Groningen, the Netherlands is leading an international consortium (EARTH) of research institutes and industry in developing a global network of antineutrino antennas to produce a tomographic image of the Earth's radiogenic heat sources. These heat sources could be due to natural radioactive decay or maybe a nuclear georeactor. Each antenna will consist of a vertical main shaft up to a depth where the cosmic background is acceptable. From a central point about twenty to thirty, one kilometre long shafts will be drilled and filled with a chain of detectors. The nature, location and strength of these sources will be derived from antineutrinos to be detected in an array of many, small volume, TL-tube like detectors which by their design are mainly sensitive in their axial direction. For the optimisation of the design, the construction and test of these detectors as well as the design of a chip carrying all coincidence and pulse-shape decisions and data transfer to the surface station, the KVI is searching on behalf of the consortium for a

POST-DOCTORAL FELLOW

The candidate should have a strong background in the development and application of nuclear detection techniques and associated electronics. An important aspect of the candidate's interest is the investigation of extremely low-power consuming integrated electronics, which can operate under demanding environments. Candidates should have a PhD in physics or a closely related area. In view of the international and multi-disciplinary setting of the programme, excellent communication skills are required. The post-doc position is offered for a period of two years. It is expected that the candidate will qualify and apply for a VENI scholarship as offered by the Dutch National Research Foundation NWO in 2005/2006. Such a scholarship will give the applicant additional status and will increase the chances to obtain a more permanent position. (See **www.nwo.nl/vernieuwingsimpuls**). Information on the project can be obtained from **www.kvi.nl/~earth/main.htm** and from **Prof.dr. Rob de Meijer, Head Nuclear Geophysics Division, KVI, email demeijer@kvi.nl**. Application: Please send your application, together with three references to the following address before 1 January, 2005 to
Ms. A.M. van der Woude, Personnel Manager, KVI, Zernikelaan 25, 9747 AA Groningen, The Netherlands, email pa@kvi.nl

UNIVERSITY OF OXFORD

Mathematical and Physical Sciences Division
Department of Physics
in association with Jesus College

University Lecturership in Experimental Particle Physics

Applications are invited for a University Lecturership in Experimental Particle Physics. The successful candidate will be offered a Tutorial Fellowship at Jesus College, under arrangements described in the further particulars. The combined University and College salary will be according to age on a scale up to £45,707 p.a. plus allowances.

The successful candidate will be expected to lead the Oxford effort on the development of a silicon vertex detector for an experiment at the International Linear Collider (ILC), planned for completion in 2015. The Oxford Group is a major contributor to the Linear Collider Flavour Identification (LCFI) collaboration, developing techniques based on silicon pixel technology. The candidate will be expected to play a leadership role in the LCFI collaboration and in the longer term to develop physics studies and initiatives in the ILC experimental programme. The postholder will undertake tutorial teaching at Jesus College.

Further particulars of this post and information on how to apply are available on http://www.physics.ox.ac.uk/pnp/jobs/lect04-fp.htm or from Mrs Sue Geddes, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, UK, e-mail: s.geddes@physics.ox.ac.uk or fax: 00 44 1865 273417. Informal enquiries about this post may be made to Professor Brian Foster, e-mail: b.foster@physics.ox.ac.uk The application deadline is 22nd January 2005.

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A $2^1/_2$ year fixed-term lectureship is available from early 2005 for a suitably qualified applicant to contribute to undergraduate teaching in the Lancaster University Physics Department and to participate in its research programme, rated 5*A in the last Research Assessment Exercise (RAE). We would, in particular, welcome applicants wishing to work on the T2K neutrino oscillation experiment. Candidates should have a PhD in physics, at least 3 years postdoctoral experience, an interest and commitment to physics teaching and the ability to teach introductory Java programming.

Initial salary: £24,820. Closing date: 31st December 2004. Job ref: A394

For further information online, please visit http://www.hep.lancs.ac.uk/jobs

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(Werner Heisenberg Institute)

MAX-PLANCK-GESELLSCHAFT

We invite applications for a research position at the postdoctoral level in the H1 group at the Max-Planck-Institute for Physics, Munich.

Postdoctoral position

The physics analysis of our group is centered around inclusive deep-inelastic scattering at large Q2 (neutral and charged current reactions), and heavy flavour physics. On the hardware side, our group is engaged in the Liquid Argon calorimeter electronics and trigger of the H1 Experiment at HERA and is presently upgrading the first level calorimeter trigger ("Jet Trigger").

We are looking for an individual who is willing to contribute strongly to the jet trigger project and to a physics subject making use of this new trigger. The applicant should hold a PhD in High Energy Physics.

The post is available immediately for an initial period of two years, with a possible extension for another year. Salary and benefits are commensurate with public service organizations (BAT IIa). The Max Planck Society wishes to increase the participation of women in its research activities. Therefore applications by women are particularly welcome. The Max Planck Society is committed to employing more handicapped individuals and especially encourages them to apply.

Applications should contain a letter of introduction, a full curriculum vitae, and a list of publications. The applicant should request three referees to provide letters of reference. The applications should be sent to

Max Planck Institute for Physics
Prof. Allen Caldwell
Föhringer Ring 6
D-80805 München

Or online to caldwell@mppmu.mpg.de. Further information and details on the job profile may be obtained from Prof. Christian Kiesling at cmk@mppmu.mpg.de.

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Experimental Particle or Accelerator Physics

The Fermi National Accelerator Laboratory (Fermilab) has an opening for a postdoctoral Lederman Fellow in experimental particle physics or accelerator physics. The successful candidate must have demonstrated outstanding ability in research. In recognition of Leon Lederman's commitment to the teaching of physics at all levels, he or she will be expected to participate, for a small fraction of the time, in physics outreach. The successful candidate will have a choice among experiments, which include Tevatron and LHC collider experiments, neutrino experiments, other fixed target experiments and astroparticle physics experiments, or research on accelerators. See **http://www.fnal.gov/** for more information.

Candidates should have obtained a Ph.D. in experimental particle or accelerator physics after August 31st 2003. The appointment is normally for three years with an extension possible. To apply write to **Dr. Michael Albrow (Chair of Lederman Fellowship Committee), Fermi National Accelerator Laboratory, MS 122, P.O.Box 500, Batavia, IL 60510-0500**. Applicants should send a letter including their research experience and noting any experience or interest in teaching and outreach, a curriculum vita, publication list and the names of at least four references. The deadline for applications is **December 10, 2004**.

Fermilab

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DESY is world-wide one of the leading accelerator centres exploring the structure of matter. The main research areas range from elementary particle physics over various applications of synchrotron radiation to the construction and use of X-ray lasers.

DESY is playing a major role in the world-wide development of the TeV e+e- International Linear Collider (ILC). Within the EU funded Design Study EUROTeV DESY invites applications for

6 Physicists for R&D on the International Linear Collider

The scope of the proposed programme covers: Simulations of the luminosity performance of the ILC, focusing on beam dynamics issues pertaining to the damping rings, and the tuning and preservation of ultra-low emittances; design and performance evaluation of an undulator-based polarised positron source, including spin transport and tuning issues; studies of ground motion and vibration spectra, and possible stabilisation techniques; development of control system hardware and software for demonstration of remote operation.
We expect you to have a PhD in Accelerator or Particle Physics and a good working knowledge of English. Experience in the development of sophisticated software models, or experience with electronics development in conjunction with an experimental physics background is desirable. If you are interested in one of these positions, please send your complete application papers by indicating 3 references to our personnel department. For further information please contact Mr. Elsen (+49 40/8998-2565, eckhard.elsen@desy.de) or Mr. Walker (+49 40/8998-4570, nicholas.walker@desy.de).

The positions are limited to 3 years.
Salary and benefits are commensurate with public service organisations (BAT IIa or BAT-O IIa). DESY operates flexible work schemes, such as flexitime or part-time work. DESY is an equal opportunity, affirmative action employer and encourages applications from women. DESY has a Betriebskindergarten.

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Deadline for applicants: January 2, 2005

ASSOCIATE DIRECTOR

The Center for Advanced Microstructures and Devices (CAMD) at Louisiana State University (LSU) in Baton Rouge, Louisiana, invites applications for the position **Associate Director "Machine Physics"** (head of the machine group). CAMD (http://lsu.camd.edu) is one of eight US synchrotron radiation facilities. Currently, synchrotron radiation is produced for 14 beamlines by bending magnets of a 1.3 GeV storage ring providing a characteristic energy of 1.7 keV and a 7 Tesla wiggler insertion device. Seeking a scientist to:

- Supervise in close collaboration with ring manager daily operation of machine
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- Write proposal to secure necessary support for realization of new plans

Candidates are required to have:

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- Professional experience in the operation of electron accelerators for production of synchrotron radiation
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Offering a salary in accordance with the requirements of job and individual experience of candidate. Application deadline is December 15, 2004, or until candidate is selected. Candidates should submit application letter with C.V. (including e-mail address), publication list, and the names and contact information of at least three references to: Craig Stevens, CAMD, 6980 Jefferson Hwy., Louisiana State University, Ref: Log #0217, Baton Rouge, LA 70806. For further information contact the CAMD Director, Prof. Dr. Josef Hormes (e-mail: hormes@lsu.edu) or Dr. V. Suller (e-mail Suller@lsu.edu)

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POSTE ACADEMIQUE EN PHYSIQUE THEORIQUE DES PARTICULES ELEMENTAIRES ET DES INTERACTIONS FONDAMENTALES

Le Recteur de l'Université catholique de Louvain (UCL) à Louvain-la-Neuve, Belgique, annonce la vacance d'un poste académique à temps plein à partir de septembre 2005. Les candidats seront titulaires d'un diplôme de doctorat en sciences (physique) ou équivalent et auront une expérience postdoctorale en physique théorique des particules élémentaires et des interactions fondamentales.

Le/La candidat(e) retenu(e) assurera des enseignements de physique à l'université (1er, 2e et/ou 3e cycles) et participera activement au programme de recherche en physique théorique des particules élémentaires et des interactions fondamentales. Ce programme inclut actuellement la phénoménologie associée au modèle standard des interactions électrofaibles et fortes, les tests de la relativité générale ainsi que l'interface entre physique des particules et cosmologie.

Seule une bonne connaissance de la langue anglaise est requise au début. Toutefois, étant donné que le titulaire du poste sera amené à enseigner en français, il/elle sera tenu(e) d'acquérir la maîtrise de la langue française parlée et écrite dans les deux ans de sa prise de fonction. Le grade et le salaire dépendront de la qualification et de l'expérience du (de la) candidat(e).

Le/La candidat(e) retenu(e) développera un programme de recherche significatif et sera progressivement impliqué(e) dans les différents cycles d'enseignement. Ses activités seront menées entre autres au sein du « Centre de recherches en Physique des Particules et Phénoménologie des interactions fondamentales » (CP3). Elles impliqueront par conséquent une interaction avec le groupe expérimental de physique des particules élémentaires, dont l'activité principale est actuellement centrée sur l'expérience CMS du futur collisionneur LHC au CERN.

La date limite pour l'introduction des candidatures est fixée au **15 janvier 2005**.

Les formulaires d'inscriptions et les instructions peuvent être obtenus sur le site web de l'université **http://www.crct.ucl.ac.be/vacancies.html (anglais)** ou **http://www.crct.ucl.ac.be/postes_vacants.html (français)**.

Pour de plus amples informations, veuillez consulter le **Prof. J-P. Antoine, président du Département de physique, chemin du Cyclotron 2, B-1348 Louvain-la-Neuve, Belgium.** Tel. **+32-10-473283**, Fax **+32-10-472414**, E-mail: **antoine@fyma.ucl.ac.be**, ou le **Prof. J-M. Gérard, FYMA, chemin du Cyclotron 2, B-1348 Louvain-la-Neuve, Belgium.** Tel. **+32-10-473305**, Fax **+32-10-472414**, E-mail: **gerard@fyma.ucl.ac.be**

For an English version of this advertisement please go to www.cerncourier.com

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The Institute conducts basic experimental and theoretical research in the fields of particle physics and astrophysics, atomic and molecular quantum dynamics as well as atmospheric and laser physics.

A next-generation cryogenic, electrostatic storage ring for molecular ions and atomic ions in extreme charge states is under development in a joint project of the Max-Planck-Institut für Kernphysik, Heidelberg, the Weizmann Institute of Science, Rehovot, Israel, and the Université Louvain la Neuve, Belgium. The facility will work at internal wall temperatures down to 2 Kelvin under extremely high vacuum conditions. It will be set up at the site of the Max-Planck-Institut für Kernphysik in Heidelberg, Germany, which pursues active research programs with cold molecular ion beams, highly charged ions and intense laser sources.

Two positions are open for young researchers in physics (Post-Doc) with expertise in

Accelerator Physics, Cryogenic Physics, and/or Atomic and Molecular Physics

for a period of 3 years immediately, to take an essential role in setting up the new facility and to explore new physical methods in the are of cryogenic ion storage under extreme vacuum conditions (10^{-15} mbar).

For one of the positions, we expect theoretical and practical experience in the design of cryogenic systems. A strong background in the field of low temperature experiments is of advantage. The main task for this position will be the design of the cryogenic cooling system including the system integration of the cryo-plant.

For the second position, the focus will be the development of beam diagnostic techniques, the layout of beam optical components, beam dynamics studies and the integration of experimental equipment. A solid background in vacuum and/or cryogenic technology is expected.

Interested candidates with qualified PhD degree and suitable research experience are asked to apply, sending CV, publication list and addresses of 3 references under the **reference no. 21** one month after publication in this journal.

The Max Planck Society wishes to increase the proportion of female academic staff and therefore, especially welcomes applications from women. Handicapped persons with the same qualifications will be preferred.

Interested candidates on the level of a completed Diploma or Masters degree with relevant experience are encouraged to apply for PhD grants available within this project.

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Jacquard's Web by James Essinger, Oxford University Press. Hardback ISBN 0192805770, £14.99.

When invited to review *Jacquard's Web*, I admit that I had to google (v.t., *Macmillan English Dictionary*) James Essinger. I discovered, with some misgivings, that he has published more than 25 management books with titles such as *The Investment Manager's Handbook* and *Virtual Financial Services*. However, I also found a claim that he is good at making technical issues accessible, and indeed he is. Better still, Essinger turns out to be an accomplished storyteller.

Jacquard's Web is an intricate tale of inventors and inventions, starting almost three centuries ago among the silk-weavers of Lyons, France, and ending today, or rather tomorrow, among computer users worldwide. Well researched, the narrative traces a chain of links between Jacquard's silk-weaving loom and modern computers. Most of the techniques involved are adequately explained, even if occasionally with fuzzy accuracy (a pixel, whether on a screen or in woven cloth, has more than two possible states), but Essinger presents this particular technological evolution from a socio-economical standpoint, and here his familiarity with the business world and its denizens clearly adds value.

The story tells of the achievements and frustrations of a motley collection of characters, who between them took the punched card about as far as it could go. We find out about Joseph-Marie Jacquard, son of a Lyons master weaver, who cunningly avoided execution as a counter-revolutionary and went on to benefit from Napoleon's imperial boost to science and technology; Charles Babbage, a Victorian gentleman of private means, who outlived the largesse of a government that funded his developments of some of the most complicated unbuilt machines ever imagined; Ada, Countess of Lovelace, daughter of Lord Byron and steadfast believer in Babbage, a scientifically minded lady born long before her time; Herman Hollerith, a mechanical engineer more at ease with cogs than commerce, who nonetheless became successful and wealthy thanks to his exploitation of Jacquard's concepts; and finally Thomas Watson, businessman *par excellence*, patron saint of salesmen and father of IBM.

The automated loom technology patented by Jacquard in 1804 was born of a need to increase production of the exquisite silk fabrics so coveted by France's aristocracy, and to create whatever pattern the customer desired – roses today, lilies tomorrow. The breakthrough came with the use of punched cards to store instructions for controlling the "pick" – the number and position of warp threads to be lifted for each row woven. The result was an astonishing 24-fold increase over the inch of cloth per day that a weaver and draw-boy could produce.

Thereafter, the humble punched card was pivotal to most of the inventions described, controlling the cogwheels of Babbage's would-be Analytical Engine, storing data for Hollerith's automatic information processing of US and Russian census returns, and governing the operation of tabulators, comptometers and early computers. Indeed, IBM's very last punched card was produced as late as 1984.

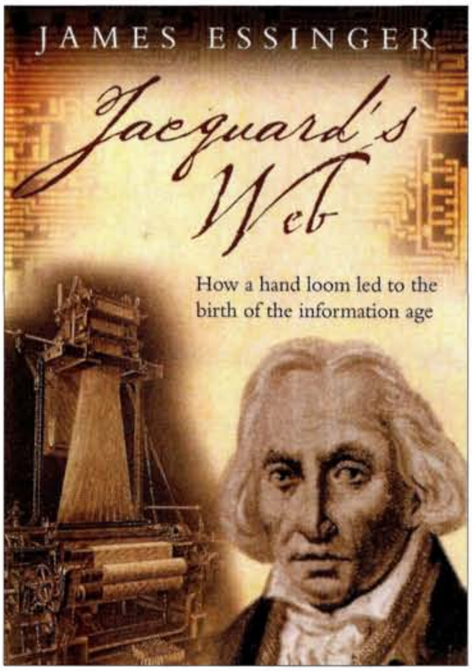
Instead of *Jacquard's Web*, this book could aptly have been titled *Pieces of Cardboard that Changed the World*. As well as looms and computers, the author recalls the notorious "hanging chads" of Florida, those parts of the stiff cards that didn't always fall away from holes punched by voters in the 2000 presidential election.

With the advent of electronics, magnetic tapes and disks, Essinger has increasing difficulty arguing for one-to-one associations between looms and modern computers; Tim Berners-Lee might take umbrage, were that his nature, at the suggestion that "it is not stretching credibility too far to describe the internet itself [sic] as Jacquard's Web".

The final chapter, speculating on the future, is rather untidy, unnecessary and much weaker than the others. But never mind – the others are all good, packed with facts and anecdotes, agreeably illustrated, highly informative and subtly amusing.
Peggie Rimmer.

Christmas Bookshelf

In this festive season, Bookshelf looks beyond the usual specializations in particle physics, to books that are intended for the general public and which deal with a broader range of topics. Here, several people who have been involved with education and communication at CERN review books they would consider buying as presents for family or friends.



Faster Than The Speed of Light – The Story of a Scientific Speculation by João Magueijo, Arrow Books. Paperback ISBN 0099428083, £8.99.

Cosmologist João Magueijo certainly believes in rocking the boat. This is his first book, but he is happy to propose theories that challenge the fundamentals of physics. He also challenges the institution of science itself – so much so, that a long-time collaborator had to point out that a reference letter for a PhD student was not an appropriate forum for insulting the establishment.

So what is Magueijo's theory? Simply, that the speed of light, one of the fundamental constants in our model of the universe, may not be as constant as we have assumed. Working through explanations of relativity and modern cosmology – often featuring a cow called Cornelia – he introduces the science of his Variable Speed of Light (VSL) theories, but it is the personal element that makes the book unusual. Here, Magueijo really brings us two books: one is popular science, and the other is about the day-to-day process of science, a human drama full of dreams, allegiances and betrayals. This section is likely to surprise members of the public as much as it makes scientists chuckle (or grimace) in sympathy with the story Magueijo has to tell.

In an unusual display of emotion, Magueijo attacks everything from the management of his university (which he suggests blowing up ▷

for the good of science) to journal reviewers (whose reports, he claims, often contain only 1% science). He avoids sounding bitter only because he compliments the same groups he criticises, remarking that his university has "perhaps the best scientific environment in the world", despite his views on how it is run.

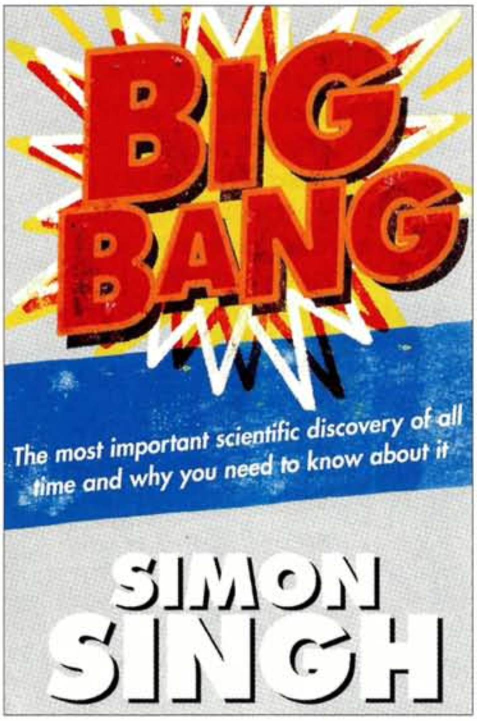
The book ends on an uncertain note, its VSL theories widely discussed but as yet unproven. Magueijo is not precious about his creation, or worried about humiliation if he is proved wrong. He believes that trying out new ideas is crucial to science. This aside, it is Magueijo's unsanitized portrayal of science that will surprise and entertain his readers.
Owen Appleton.

Big Bang – The Most Important Scientific Discovery of All Time and Why You Need to Know About It by Simon Singh, Fourth Estate. Hardback ISBN 0007152515, £20.

Ex-particle physicist Simon Singh is now in the literary big time. After gaining his PhD at Cambridge University and helping to build a detector for the UA2 experiment at CERN's proton–antiproton collider, he became a BBC TV producer and director. His 1996 documentary led to the highly successful book *Fermat's Last Theorem*, which was soon followed by *The Code Book* in 1999.

His latest offering goes deep into fundamental physics and back a long time in the history of science. The first three chapters of *Big Bang* trace the histories of cosmology, gravity and astronomy; that's already 260 pages. Chapter 4 explains how cosmology and nuclear and particle physics became entangled, and Chapter 5 goes on to show how the conflict between two opposing cosmological pictures – the expanding Big Bang universe and a steady-state universe – was finally resolved after the discovery of the cosmic microwave background radiation. With such difficult and complex subject matter, the two-page summaries at the end of each chapter are helpful.

Its main aim is to explain physics and cosmology, but the book is packed with interesting anecdotes and biographical details. Some of these figures – Einstein, Newton, Rutherford – need no introduction, but others are less familiar, such as Fritz Houtermans, one of the first scientists to consider the role of nuclear transformations in the Sun, and Henrietta Leavitt, an unpaid volunteer who went on to show how variable



stars can be used as accurate gauges of astronomical distances.

I enjoyed Singh's coverage of the colourful George Gamow and the controversial Fred Hoyle, two devout non-conformists who duly ruined their own careers. Hoyle makes two major appearances: first for his role in developing steady-state cosmology, where we read the transcript of the 1950 BBC radio broadcast in which he sceptically introduced the term "Big Bang" for the rival theory; and then for his key contributions to stellar nucleosynthesis, where he was snubbed by the Nobel committee. Nevertheless, it is surely for carbon-12 that Hoyle will ultimately be best remembered in science, so his portrait caption "most famous for his steady-state model of the universe" is off-target.

The book goes way back in history, for example with several pages on Eratosthenes' pioneering third-century BC measurements of the size of the Earth. However, the book reads as if most of it was written 10 years ago, when the measurement of the cosmic microwave background by the COBE satellite in 1992 confirmed the Big Bang picture. Some crucial topics and recent developments are compressed into a brief epilogue.

In this postscript-like final chapter, Singh whistles past the key mechanism of inflation that powered the Big Bang, and resolves the flatness and horizon problems of the universe. He gives scant attention there to the need for the universe to be mostly made up of mysterious dark matter (a pity, because the topic is briefly introduced earlier with the colourful character of Fritz Zwicky).

Also skimmed over are the recent measurements from high-redshift supernovae, revealing the need for a mysterious repulsive force which acts against gravity and modulates the basic Hubble expansion. This "dark energy" is redolent of Einstein's cosmological constant which, as Singh does explain at length earlier in the book, was painfully conceived by the great man before he was forced to abandon it in 1931 in the face of then-overwhelming evidence. Einstein could have been right all along and this abdication premature.
Gordon Fraser.

Computers Ltd – What They REALLY Can't Do by David Harel, Oxford University Press. Paperback ISBN 0198604424, £8.99 ($14.95).

Yes, computers can't do the mathematically impossible, which is what this book is all about, but they also seem to be unable even to do spelling/grammar checking. The phrase in the preamble "You don't go looking for triangles whose angels add up to 150° or 200°" passes easily, though it is an early point in the book at which to invoke the supernatural. I counted no fewer than 24 typos before I gave up. The use of non-metric units in a science book on maths is also not quite what I expect.

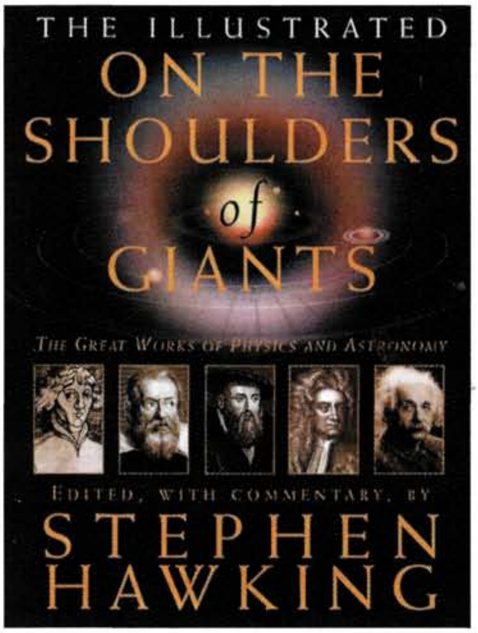
These mistakes and the split infinitives apart, *Computers Ltd* is a gripping book. It is enthusiastically written with excellent examples. It builds pleasingly from easy stuff up to a range of difficult-to-understand NP problems. After each individual topic, I felt delighted to have been given a refreshing view of a subject with which I'm not entirely unfamiliar. Yet each following chapter surprised again with the clarity that Harel achieves in introducing the next "bad news" – the apt term he uses for impossible computing tasks. Also amazing is the book's ability to build on the examples given before. This in itself is highly useful, giving a good view of where the author will ultimately lead the reader.

There is an interesting chapter on whether or not humans can do better than computers, rightly concluding that machines still lack the embryonic ability to deal with the vast amounts of context that we humans obtain through all our senses all the time. And context is certainly needed before one can even start to discuss understanding.

All along I was wondering whether there would be something about "almost possible" solutions. The fact that some task has been proved impossible in the general case does not mean that we can't get acceptably good solutions for everyday use. And yes, there is a short chapter on these issues, but it does not go very far and is a little too purist for my tastes. That said, *Computers Ltd* is a very entertaining book that anyone with an interest in computers should read.
Robert Cailliau.

The Illustrated On the Shoulders of Giants – The Great Works of Physics and Astronomy by Stephen Hawking (ed.), Running Press. Hardback ISBN 0762418982, £18.99 ($35.00)

Copernicus, Galileo, Kepler, Newton, Einstein... everybody has heard of these people who shaped our understanding of the universe – and of mankind's role in it. Copernicus removed the Earth from the centre of the universe and put the Sun there instead; Galileo put observation and experiments above beliefs; Kepler made the Sun-centred model more accurate and Newton gave it laws



of motion, establishing a nature in which mankind plays no role (except to inhabit the third planet in the solar system); and Einstein developed the general theory of relativity, in which space and time itself are curved and become dynamic, making our universe only one of many.

Stephen Hawking had already shown how these major figures changed the course of science, with extracts from their master works in *On the Shoulders of Giants* (Running Press 2002). For those (like me) who found the 1200 pages of that volume a little too daunting, this new edition, with lovely illustrations and wonderful photographs, is a very nice alternative. Excerpts from the original publications are given, with introductory essays about the lives and times of the scientists, including the difficulties they had to overcome both on a personal and a political (or religious) level. With just the right balance between being informative and being entertaining, the book was a real pleasure to read.
Hannelore Hämmerle.

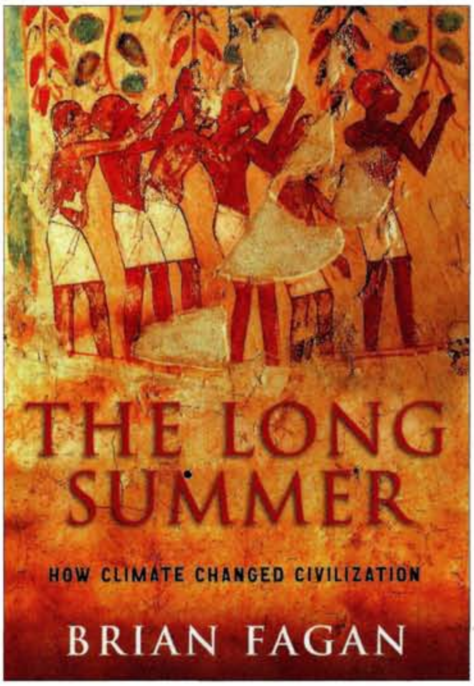
The Long Summer – How Climate Changed Civilization by Brian Fagan, Granta. Hardback ISBN 1862076448, £20.

1816 was widely known as the year without a summer. A massive volcanic eruption in Java, one of the biggest since the last great ice age 20 000 years ago, cast a pall over the Earth. Temperatures plummeted and storms battered crops. Across the world in Geneva, the cold weather kept Mary Shelley indoors, where she entertained her husband and a friend with the now-classic story *Frankenstein*, a cautionary tale of the dangers of science.

Anthropologist Brian Fagan's *The Long Summer* is a cautionary tale, too. Modern agriculture and technology help buffer much of humanity from short-term climate shifts, such as the odd drought or flood, volcanic eruption or ocean-current shift. (The summer of 1816 seems to have been merely an inconvenience for the Shelleys.) But, Fagan argues, this buffer is illusory. We are actually more vulnerable than ever to long-term climate change.

Fagan's book takes the long view, covering the migrations and development of human societies over the past 20 000 years. He shows how human societies have risen to great heights when the climate was cooperative – but also suffered spectacular crashes when the climate shifted. Archaeologists have long known about these ups and downs of civilization, but many make sense only in the light of relatively recent data on the history of climate change.

From cores from glaciers, lake beds, and the ocean, combined with studies of tree rings and pockets of preserved pollen grains,



climatologists have assembled a remarkably detailed record of the climate since the last ice age. Fagan focuses on the picture these records paint, while piecing together a parallel narrative of human societies from the much more scant written records and artefacts people left behind, which give a sense of their lifestyles and movements.

In shifting from mobile to settled life, from diets based on a wide variety of plants and animals to those reliant on a few staples, populations have soared. But in going through this process, which Fagan calls "trading up", people exchanged flexibility and mobility for some measure of stability and prosperity.

But what will happen if there is another major climate shift? Atlantic ocean currents warm Europe, but a few thousand years ago those currents probably shut down when North American glaciers melted, plunging Europe into a mini ice age. Humanity has flourished through the past 15 000 years, a rare stretch of warm, stable climate that Fagan calls the "long summer". Today we do not have the options open to our ancient forebears of shifting back to herder or hunter-gatherer lifestyles. But another major climate change is bound to come, and no doubt sooner rather than later because of human-influenced climate change. When it does, humanity will face tougher decisions and greater chaos than ever before. This book is an attempt to get people thinking about it now.
Mason Inman.

Particle physics in 2054

Luciano Maiani, former director-general of CERN, looks into a "very cloudy" crystal ball and argues the case for a future global accelerator network.

In a letter to the European Cultural Conference in Lausanne, Switzerland, in December 1949, Louis de Broglie advocated "the creation of a laboratory or institution where it would be possible to do scientific work, but somehow beyond the framework of the different participating states". Endowed with more resources than national facilities, such a laboratory could "undertake tasks, which, by virtue of their size and cost, were beyond the scope of individual countries".

CERN, the European Organization for Nuclear Research, came into being five years later in 1954. Today, 50 years after its foundation, it is reassuring to see that CERN is building the largest and most powerful particle accelerator ever: the Large Hadron Collider (LHC). This 14 TeV proton–proton collider is at the cutting edge of technology, and is a heartening sign of both the public's support for basic science in Europe and beyond, and of the determination of European countries to stay at the forefront of particle physics.

I have been asked to imagine what the next 50 years might hold for CERN and for particle physics. I shall take this opportunity to look into a very cloudy crystal ball, with the deep conviction that particle physics will continue to enrich culture and produce knowledge and technology as it has done for a large part of the last century.

In the medium term, CERN's activities will be dominated by the LHC. By modifying the magnetic fields of the collider around the proton-interaction points, we can envisage a luminosity upgrade that would prolong the working life of the accelerator and extend the mass range for discovery. At a much higher cost we can even imagine doubling the collision energy by replacing the present LHC dipoles with higher-field magnets. Indeed, fully exploiting the LHC could easily take us to 2020 or 2025. As a result, there is little chance of CERN being involved in the construction of a 0.5–1 TeV linear electron–positron collider (*CERN Courier* October 2004 p5).

But what can we say about the more distant future of CERN, say from 2020 onwards, once the results from the LHC and, possibly, the linear collider are known? A linear collider with a length of several tens of kilometres could conceivably be built underground alongside the Jura mountains next to CERN. On the other hand, a big circular tunnel, such as that required by a Very Large Hadron Collider, would have to go below Lake Geneva or below the Jura (or both). Either option would be simply too expensive to consider. This is why a 3–5 TeV Compact Linear Collider (CLIC) would be the project of choice for the CERN site. A CLIC project could be launched in about 2015, when the LHC will be operating smoothly at its design luminosity, and data-taking could begin as soon as the early 2020s.

CLIC or a VLHC are enormous projects that will have to be undertaken through worldwide collaboration. But does this mean we should make a further step along the lines advocated 50 years ago by de Broglie and promote a world laboratory? This issue has been widely discussed, but in my view concentrating high-energy particle physics in a single laboratory with worldwide support is not a good idea. It would be too vulnerable to fluctuations in policy and mistakes in management. Moreover, it would not stimulate competition. My preference would be a coordinated global network that includes universities, national laboratories and regional laboratories like CERN and Fermilab.

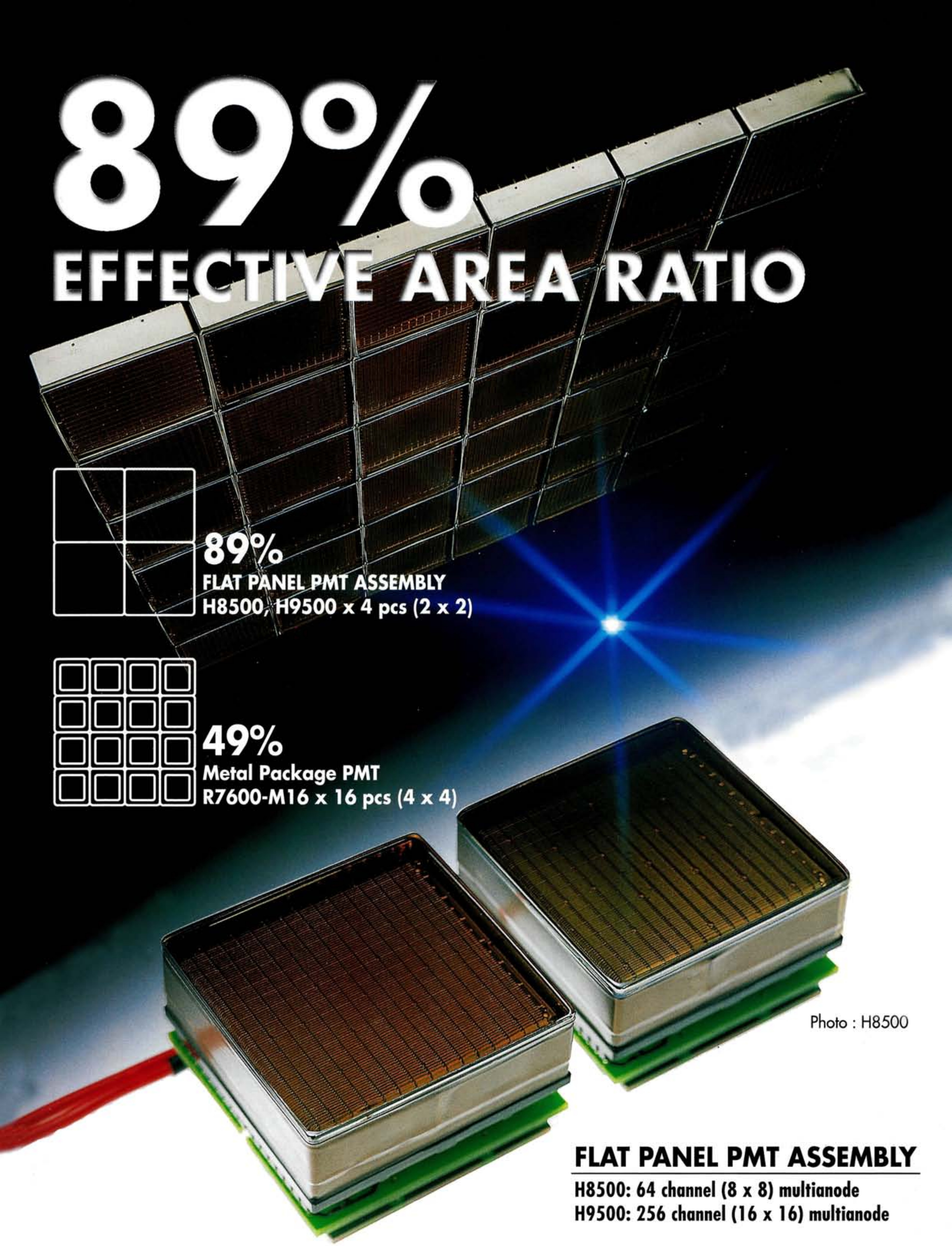
The International Committee for Future Accelerators has considered the concept of a global accelerator network, although there is no consensus on what such a network might actually be or what it could do for us. As I see it, a global network would essentially be a new way of organizing existing particle-physics centres across the world, and focusing them on projects with a global dimension. For example, it would perform "diffuse" R&D on accelerators and detectors, co-operating on a single project at any one time and providing components for the machines and detectors.

Multinational companies are supposed to do what national companies cannot. Similarly, a global accelerator network only makes sense if it can achieve something that individual regions cannot do by themselves and, moreover, something that is essential to make real progress in particle physics. CLIC at CERN and the VLHC at Fermilab could be among the long-term goals of the global accelerator network, which would keep the world's particle physicists busy until 2050. The transition to such a new organization would probably be similar to the shift in Europe from national laboratories to CERN – it would be difficult but worth trying.

Whatever the next 50 years hold for CERN and particle physics in general, it will almost certainly require countries to pool their resources and work together closely. Some 54 years since de Broglie's letter inspired European scientists to build a single laboratory, his vision of basic science is still as relevant: "The universal and very often disinterested nature of scientific research seems to have predestined it for reciprocal and fruitful collaboration."

● Extracted with permission from "CERN: the next 50 years" in *Physics World* September 2004 p42.

Luciano Maiani, Universita' di Roma "La Sapienza" and INFN. He was director-general of CERN from 1999 to 2003.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