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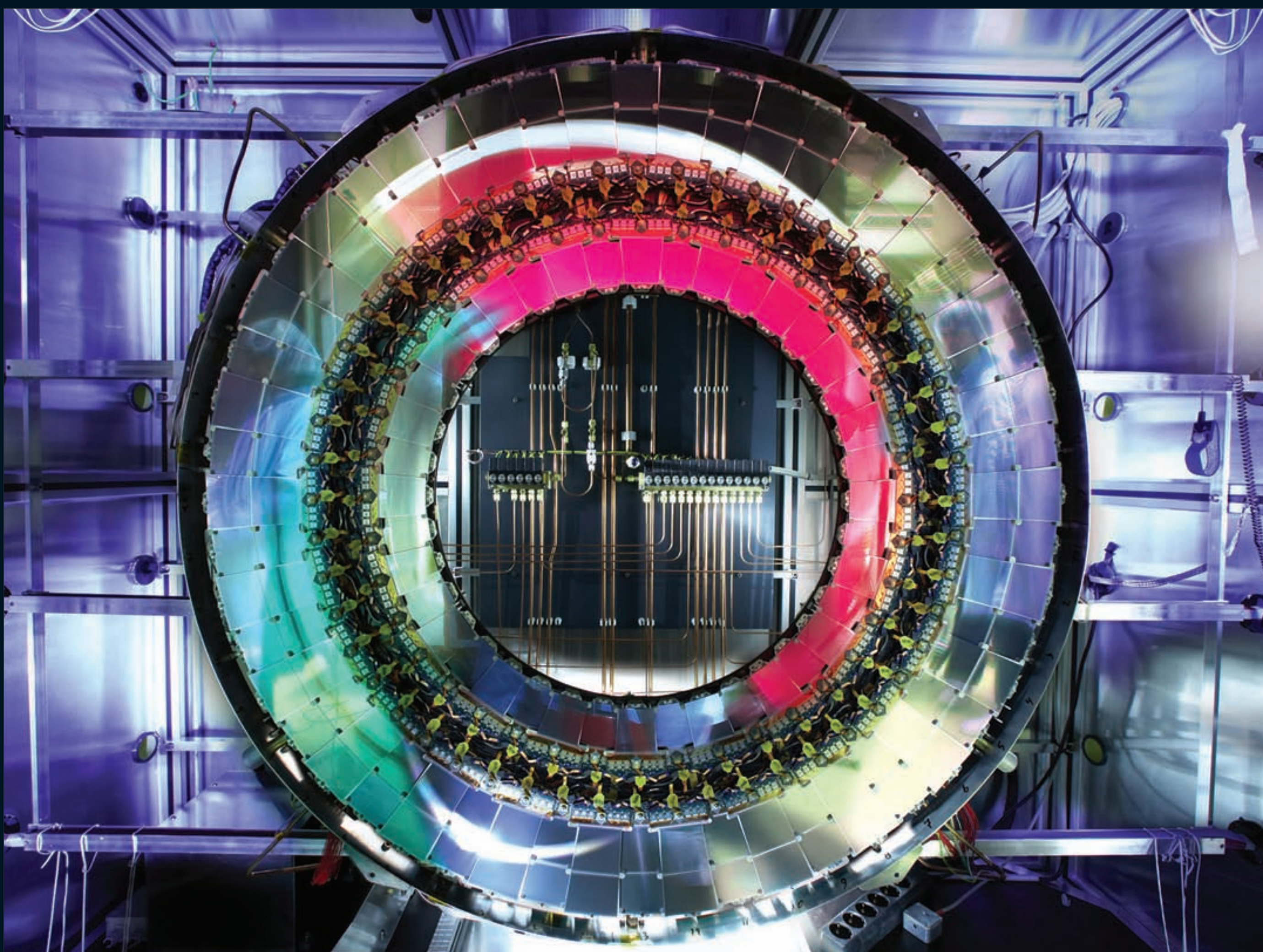

The heart of ATLAS takes shape

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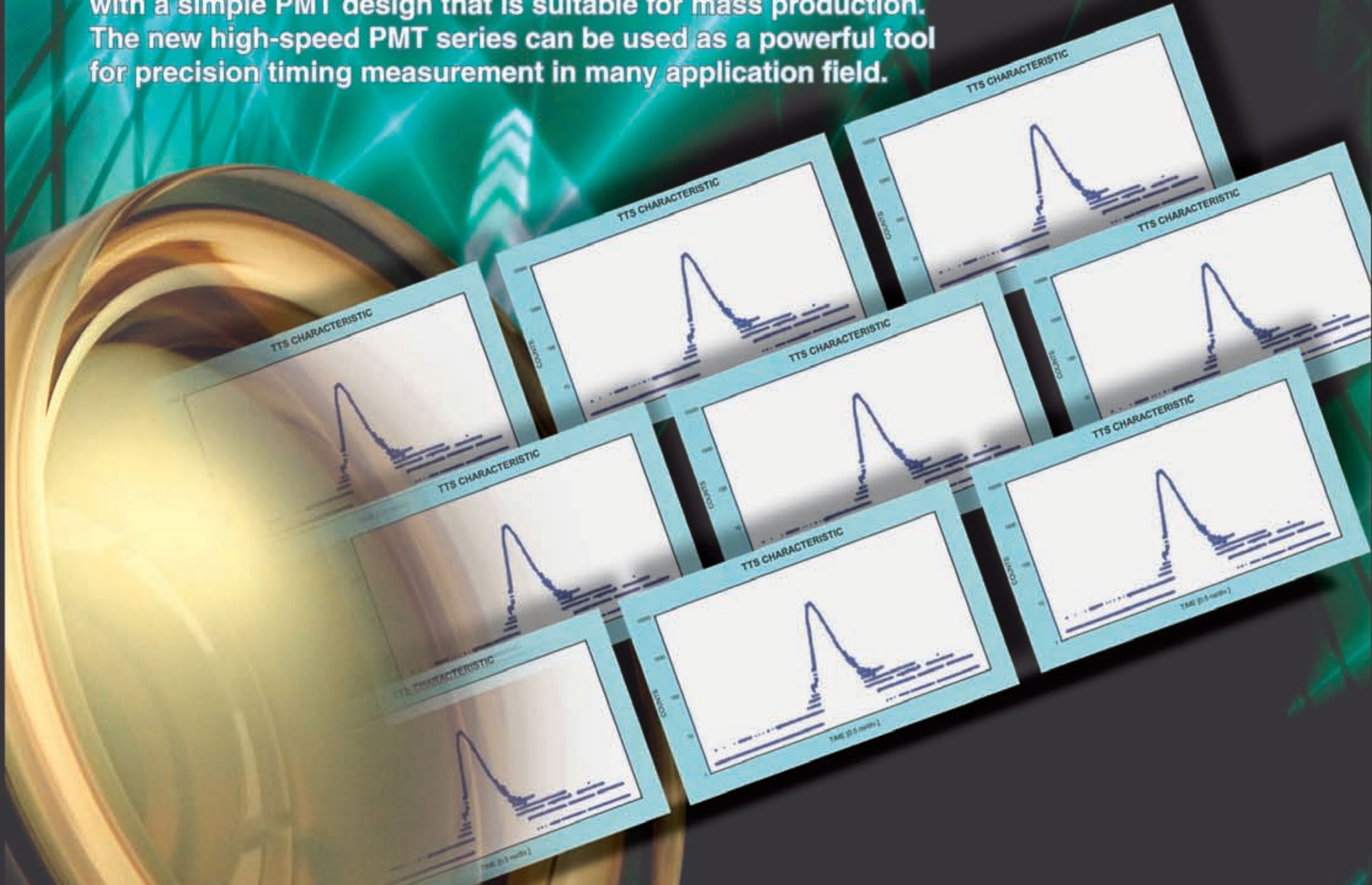
New light source for Southern Hemisphere p7

COMPUTING NEWS
Behind the headlines on quantum computing p22

SPIN PHYSICS
HERMES tackles puzzle of nucleon spin p26

New high-speed PMT series

A new series of high-speed photomultiplier tubes (PMT) from Hamamatsu has now appeared on the market. These offer an incredibly small transit time spread that is uniform across the entire effective area. The 2-inch PMT (R9779), for example, yields a TTS of 250 picoseconds. This excellent time resolution has been achieved with a simple PMT design that is suitable for mass production. The new high-speed PMT series can be used as a powerful tool for precision timing measurement in many application field.



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WEB SITE www.hamamatsu.com

United Kingdom: Hamamatsu Photonics UK Limited Telephone: 44-(0)1707-294888, Fax: 44(0)1707-325777
North Europe: Hamamatsu Photonics Norden AB Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01
Italy: Hamamatsu Photonics Italia: S.R.L. Telephone: (39)02-935 81 733, Fax: (39)02-935 81 741
U.S.A.: Hamamatsu Corporation Telephone: (1)908-231-0960, Fax: (1)908-231-1218
Germany: Hamamatsu Photonics Deutschland GmbH: Telephone: (49)8152-375-0, Fax: (49)8152-2658
France: Hamamatsu Photonics France S.A.R.L. Telephone: (33)1 69 53 71 00, Fax: (33)1 69 53 71 10

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Editor Christine Sutton
CERN, 1211 Geneva 23, Switzerland
E-mail: cern.courier@cern.ch
Fax: +41 (0) 22 785 0247
Web: cerncourier.com

Advisory board James Gillies, Rolf Landua and Maximilian Metzger

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Institute of Physics Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK
Tel: +44 (0)117 929 7481; E-mail: jo.nicholas@iop.org; Web: iop.org

Publishing director Richard Roe
Publisher Jo Nicholas
Art director Andrew Giaquinto
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Technical illustrator Alison Tovey
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Product manager Claire Webber

Advertising
Tel: +44 (0)117 930 1026 (for UK/Europe display advertising), +1 215 627 0880 (for North American display advertising), or +44 (0)117 930 1196 (for recruitment advertising);
E-mail: sales@cerncourier.com; Fax: +44 (0)117 930 1178

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Italy Loredana Rum or Anna Pennacchietti, INFN, Casella Postale 56, 00044 Frascati, Rome, Italy. E-mail: loredana.rum@lnf.infn.it
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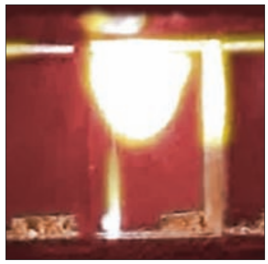
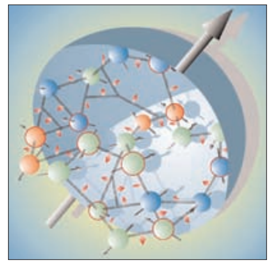


Ball lightning made in the lab p9



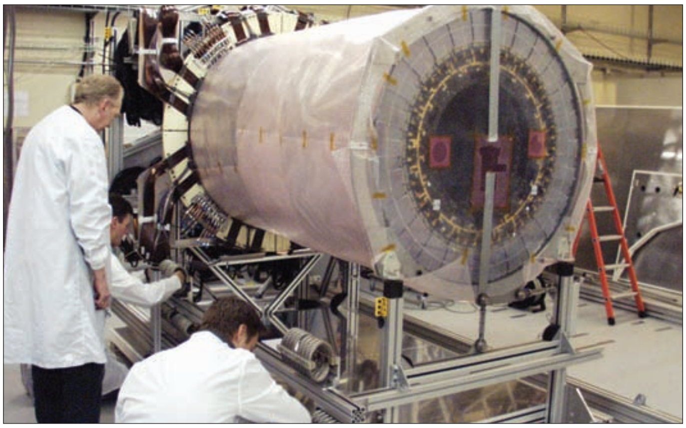
Nucleon spin examined p26

New director-general for KEK p36

Cover: At the heart of the ATLAS experiment at the Large Hadron Collider lies the Semiconductor Tracker, which comprises silicon microstrip sensors in a central part of four concentric barrels around the beam pipe, and endcaps of nine discs. This photo shows one endcap being assembled at NIKHEF; the other endcap, assembled in Liverpool, arrived at CERN in February (see p5). (Photo by Peter Ginter.)

LHC EXPERIMENTS

ATLAS tracker takes major strides



The first Semiconductor Tracker endcap, still in its wrapping, arrives at CERN from Liverpool. (Courtesy Steve Haywood, RAL.)

Checking clearances before the ATLAS Semiconductor Tracker barrel, in the background, is inserted into the Transition Radiation Tracker.

At the heart of the ATLAS experiment at the Large Hadron Collider (LHC), silicon sensors will provide accurate detection of charged particles produced in the collisions. The Semiconductor Tracker (SCT) consists of silicon microstrip sensors located 25–55 cm from the LHC beams, subdivided in a central part of four concentric barrels around the beam pipe, and endcaps of nine discs on either side. February saw two major milestones for the ATLAS tracker within a week – the first stage of the integration of the barrels with other parts of the tracking system and the arrival of the endcap silicon tracker that has been assembled in Liverpool.

The ATLAS tracker project was conceived in 1993 at a meeting in the UK where a small international group of physicists and engineers sketched out plans for a tracking system for the LHC. After four years of development, 40 institutes around the world agreed to start the construction of the SCT. Eight years later the tracker is now a reality at CERN and is being integrated into ATLAS ready for physics.

The central barrels and two endcaps of the SCT together hold 4088 silicon modules (60 m^2 of silicon), which can record the trajectory of charged particles with 20 μm precision (less than the diameter of a human hair). The complete system comprises 6 million detector elements, each with its own amplifier and memory. It is larger than any existing silicon tracking system. Careful work at each stage of the project has ensured that more than 99.5% of the channels are working.

The modules for the SCT barrels were produced by four collaborations centred in Japan, Scandinavia, the UK and the US, and sent to the UK for precision assembly on cylindrical structures at Oxford University. The fourth and final barrel arrived at CERN in September 2005 and was integrated into the full barrel assembly shortly afterwards (*CERN Courier* November 2005 p6). In the latest integration stage, on 17 February, dozens of physicists and engineers from the collaboration gathered to witness the insertion of the barrel SCT into the Transition Radiation Tracker (TRT). The SCT and the TRT are two of the three major parts of the ATLAS inner detector – the third and final part is the pixel detector, which will be added in the very centre of the tracker.

While the SCT central detector is already complete at CERN, the two endcaps are making good progress as well. More than 2000 modules with sensors and readout electronics have been produced in laboratories in the UK, Spain, Germany, the Czech Republic, the Netherlands, Switzerland and Australia, and were then sent to the two endcap assembly sites at the University of Liverpool, and NIKHEF in Amsterdam.

Each endcap is a 2 m long, light and strong carbon-fibre cylinder containing a series of nine discs on which the modules are mounted in rings, so as to surround the LHC beams. Each disc contains cooling circuits to take away the excess heat produced by the electronics, to maintain an operating temperature of −7 °C, which is chosen to minimize radiation damage in the harsh LHC environment. Control signals and data are sent through optical fibres to and from each sensor, minimizing noise and heavy cabling. On 23 February the first endcap arrived safely at CERN from Liverpool and the second is nearing completion at NIKHEF.

Sommaire

ULTRACOLD NEUTRONS

Team at ILL sets new limit on neutron's EDM

An experiment at the Institut Laue Langevin (ILL), Grenoble, has produced a new, tighter limit on the electric-dipole moment (EDM) of the neutron. This result has a high potential impact for theories beyond the Standard Model that attempt to explain the origin of CP violation and hence the baryon asymmetry of the universe.

One way to test theories likely to explain the matter–antimatter asymmetry that characterizes our universe is to study the corresponding asymmetry in sub-atomic particles, by looking for slight distortions in their charge distributions. The existence of such an EDM in the neutron, and in other particles, would violate time-reversal and hence CP symmetry. While the Standard Model predicts an immeasurably small neutron EDM and a baryon asymmetry that is far too modest, theories that go beyond it almost invariably predict values for both that are many orders of magnitude larger. Accurate measurements of EDMs thus provide strong constraints on such theories.

The neutron EDM has been sought for more than 50 years, and many candidate theories have been eliminated along the way.

Members of the EDM experiment team at ILL.

Experiments are now sensitive enough to test currently popular theories such as supersymmetry. The experiment that has recently been carried out at ILL by a collaboration from the University of Sussex, the Rutherford Appleton Laboratory and ILL, has produced an upper limit on the absolute value of the neutron EDM of 3×10^{-26} ecm (Baker *et al.* 2006). This represents an improvement of a factor of two over its intermediate result and almost a factor of four with respect to earlier measurements (Harris *et al.* 1999).

The experiment used ultracold neutrons produced at the high-flux ILL reactor. These neutrons were stored in batches in a trap permeated by uniform electric and magnetic fields. Spurious signals from magnetic-field fluctuations were reduced to insignificance by the use of a cohabiting atomic-mercury magnetometer (Green *et al.* 1998). The ratios of neutron to mercury-atom precession frequencies were measured; shifts in this ratio that are proportional to the applied electric field may in principle be interpreted as EDM signals.

The collaboration, which has now expanded to include Oxford University and the University of Kure in Japan, is constructing a new version of the experiment in which the neutron trap will be submerged in a bath of liquid helium, half a degree above absolute zero. The increase in neutron density and electric field strength that this will allow should yield a hundredfold increase in sensitivity.

Further reading

C A Baker *et al.* 2006 http://arXiv.org/abs/hep-ex/0602020, submitted to *Phys. Rev. Lett.*
P G Harris *et al.* 1999 *Phys. Rev. Lett.* **82** 904.
K Green *et al.* 1998 *Nuc. Instr. Meth. A* **404** 381.

COLLABORATION

Co-operation agreement strengthens CERN's links with Cyprus

On 14 February, the minister of finance of the Republic of Cyprus, Michalis Sarris, visited CERN, accompanied by a distinguished delegation, including Christos Schizas, the vice-rector of the University of Cyprus, Costas Kounnas of Ecole Normale and Panos Razis of the University of Cyprus. During the visit, Sarris and CERN's director-general, Robert Aymar, signed a co-operation agreement.

The new agreement provides the framework for strengthening the scientific and technical co-operation between CERN and Cyprus, giving the opportunity for scientists from Cypriot institutes to participate in CERN's scientific programme in experimental high-energy physics, theoretical physics, information technology and accelerator development. In addition, university students and professionals will be able to take part in training and educational programmes, as well as in jointly organized workshops and conferences.

The high-energy physics team of the University of Cyprus, with head of the group, Panos Razis, standing second from left.

Cyprus was already an active member of the L3 experiment at the Large Electron–Positron collider, when it joined the CMS collaboration in 1995, preparing for the Large Hadron Collider (LHC). A memorandum of understanding was signed in 1999.

In work for CMS, the Cypriot high-energy physics group joined a consortium with responsibility for manufacturing the barrel yoke and the vacuum tank of the CMS solenoid. Construction of both systems is now complete. In addition, members of the Cypriot team have also developed specialized equipment for performing control and calibration tests of the "very front-end" electronic boards of the CMS calorimeter. The groups from Cyprus are also currently seeking an upgrade of their high-performance computer clusters for Monte Carlo simulation and analysis of LHC data, as a valuable component of the Grid initiative.

The co-operation agreement between CERN and Cyprus will soon be followed by the signing of the corresponding protocols, upgrading the scientific and technical links in the areas of experimental and theoretical particle physics, high-performance computing and applications, and other projects subject to prior formal agreement between Cyprus and CERN.

SYNCHROTRONS

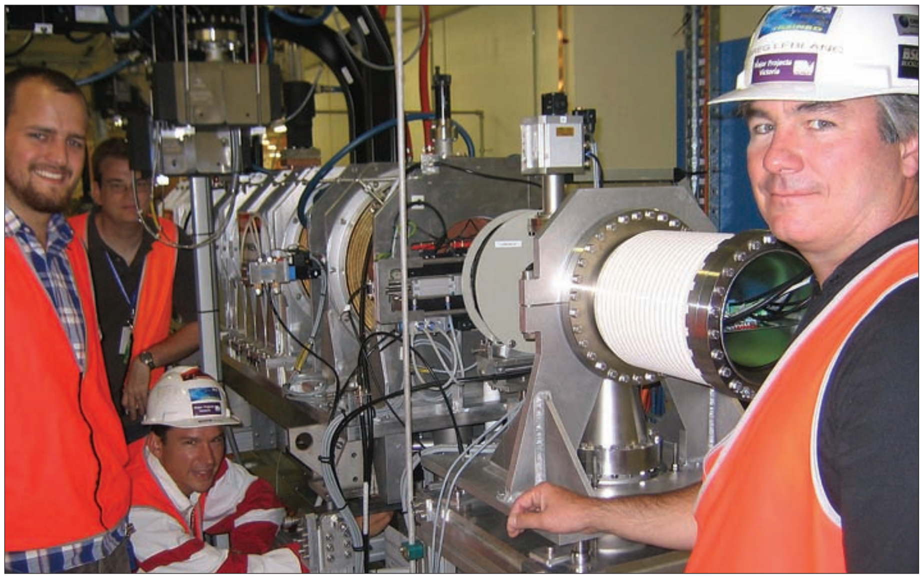
Australian synchrotron shines new light in the Southern Hemisphere

The Australian Synchrotron under construction in Melbourne is due to begin operation in April 2007. This third-generation light source is an electron-accelerator laboratory comprising a full-energy injection system (linac plus booster synchrotron) and a 3 GeV storage ring. It has the capacity for more than 30 beamlines, with nine to be built in the first phase of facility development.

Although Australia has a long and distinguished history in nuclear and particle physics, the Australian Synchrotron is the largest accelerator in the country and the only one of its type in the Antipodes. The storage ring has a circumference of 216 m and is housed in a building with office and laboratory space for more than 100 staff and beamline users.

Commissioning of the injection system is well under way, with the 100 MeV linac now in routine operation. The first turn in the booster was achieved in February, rapidly followed by hundreds of thousands of turns. The beam has been stored at 100 MeV for 1 s from one injection to the next. The injection system ramps at a rate of 1 Hz to accelerate the beam from 100 MeV to 3 GeV in a few hundred milliseconds. Conditioning of the booster RF system is under way and the electron beam will soon be accelerated to full energy.

Installation of the storage ring is almost complete, with only a few of the magnets and vacuum chambers left to assemble. The klystrons that will provide the RF power to the storage-ring accelerating cavities are being commissioned on site during March and will be ready for the first injected beam, which is scheduled for June. The front ends that interface the beamlines to the storage ring are being installed, while beamline installation is due to start in December. Beamline commissioning with photons on sample is expected to be well under way by March 2007.



Australian Synchrotron Accelerator Physics, from right to left: Greg LeBlanc (lead), Mark Boland, Rohan Dowd, Martin Spencer and Eugene Tan (not pictured), with the 100 MeV linac.

The Australian science community recommended consideration of an initial suite of 13 beamlines to cover almost the whole range of research being done in Australia, aiming to meet 95% of the anticipated needs of the Australian Synchrotron research community. Nine of these are being developed now, and others will be developed as funding allows. Contracts have been awarded for beamlines for powder diffraction, protein crystallography, X-ray absorption spectroscopy, infrared spectroscopy and soft X-ray spectroscopy beamlines, and the infrared spectroscopy beamline contract is imminent. Designs are well advanced for small- and wide-angle scattering, microspectroscopy and imaging, and medical therapy beamlines, as is design of a second protein-crystallography beamline that will also cater for small-molecule research.

The accelerator systems and building were funded entirely by the Victorian State government at a cost of AU$157 m. The beamlines are being funded through a partnership to which state governments, leading universities, research institutions and the New Zealand government have already committed AU$40 m.

Further reading

J W Boldeman and D Einfeld 2004 *Nucl. Instr. and Meth. A* **521** 306.

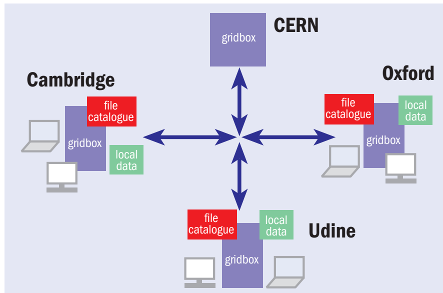
MEDICAL APPLICATIONS

Mammography database targets breast cancer

There would be great benefits if clinicians around the world could gain access to a common support resource in diagnosing breast cancer. MammoGrid, a three-year project under the Fifth Framework Programme (FP5) of the European Community was completed in 2005 and its partners are now exploring the possibilities for developing a commercial product based on the project's results.

Led by CERN, MammoGrid involves the universities of Oxford, Cambridge and the West of England in the UK, together with Mirada Solutions of Oxford, and the universities of Pisa and Sassari and hospitals in Udine and Torino in Italy. The project was conceived within the Technology Transfer Group and the Physics Department at CERN, and an FP5 project was established with total resources of €1.9 m.

Breast cancer is the most common cancer in women, and mammograms as images are extremely complex with many degrees of variability across the population. Breast-cancer screening procedures suffer from several complications with a relatively high error rate. It is estimated that around 30% of mammograms give false results. Early and unequivocal diagnosis is therefore a fundamental requirement for early diagnosis and reduced cancer mortality.



Distributed database system for the consultation of reference mammograms.

One effective way to manage disparate sources of mammogram data is through a federation of autonomous multi-centre sites spanning national boundaries. Such collaboration is now being facilitated by Grid-based technologies, which are emerging as open-source standards-based solutions for managing distributed resources. In the light of these new computing solutions, the goal of the MammoGrid project was to develop a Grid-aware medical application to manage a Europe-wide database of mammograms.

The MammoGrid solution utilizes Grid technologies in seamlessly linking distributed data sets and allowing effective co-working among mammogram analysts throughout Europe. Thanks to the Grid infrastructure it is possible to exchange data and images, and carry out remote and more accurate radiological diagnosis. This in turn should lead to decreasing biopsies, standardization of quality-control procedures, improvements in the training of radiologists and provision of sufficient statistics for complex epidemiological studies.

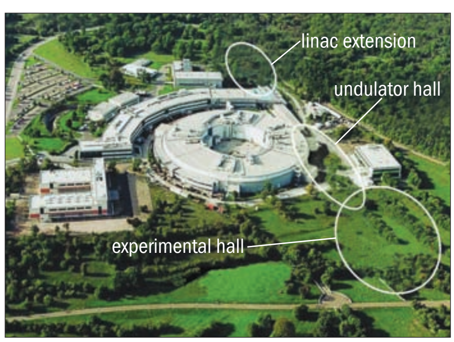
One of the aims of the project was to build a demonstrator for testing in hospitals in Cambridge and Udine. Since the project reached its completion in 2005, the MammoGrid partners have been negotiating a licence and a partnership agreement with an industrial company. Commercialization is still at an early stage, however, and CERN's Technology Transfer Group is exploring opportunities to disseminate the project results further, both to hospitals and industry. A non-exclusive licence based on the results of the MammoGrid project has been made available and a few companies are interested in using the demonstrator to build a fully functioning operational tool for oncological studies and cancer screening.

ACCELERATOR APPLICATIONS

Trieste seeks participants for new fourth-generation light source

Sincrotrone Trieste has announced a call for letters of intent to participate in developing and using a new fourth-generation light source, FERMI@Elettra, operating alongside the present ELETTRA source near Trieste. The FERMI@Elettra source will be added to the existing 2.0–2.4 GeV synchrotron and will be one of the first single-pass free-electron laser (FEL) facilities in the world.

FERMI@Elettra will operate in harmonic generation mode at wavelengths in the UV to soft X-ray range. It will initially have two FELs covering the wavelength ranges of 100–40 nm and 40–10 nm. The existing ELETTRA linac will be extended with a new 70 m long klystron gallery; a 65 m shielded undulator hall and a new experimental hall with eight beamlines will also be added.



The ELETTRA laboratory, indicating the proposed extensions for FERMI@Elettra.

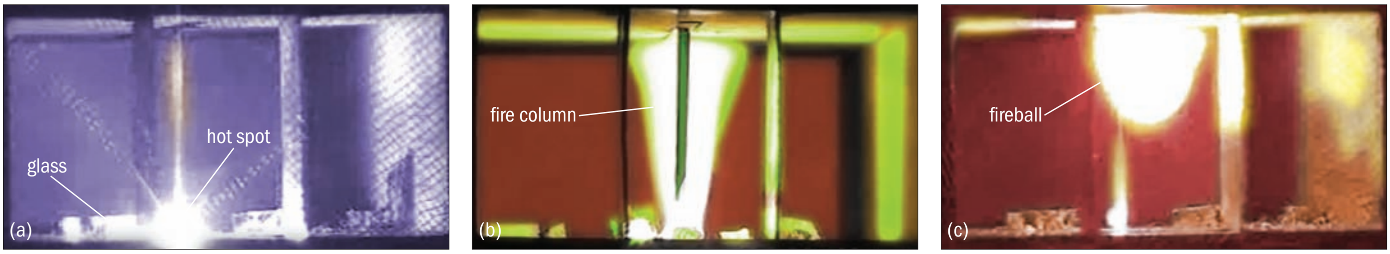
Support laboratories will be built at the end of the chain. The technical design study has been completed, the commissioning of the new booster is planned for summer 2007 and the two FELs are expected to be operational by the end of 2009.

ELETTRA, which is managed by the non-profit organization Sincrotrone Trieste, currently has more than 800 users a year; 86% are from European countries, working on research in physics, chemistry, earth science, material and life science. Proposals for FERMI@Elettra should be submitted before 30 April. Proponents selected by the international advisors will be involved in developing the scientific-exploitation programme (beam lines, end stations and R&D projects), to be defined by the end of 2006.

● Further information and the procedure to follow to participate in the call for letters of intent are available at www.elettra.trieste.it/index.php.

Compiled by Steve Reucroft and John Swain, Northeastern University

Microwaves create ball lightning



The fireball initiation process in a microwave cavity. (a) A molten hot spot is created by the microwave drill in the substrate material. (b) A fire column is ejected from the hot spot. (c) The fireball detaches from the hot spot and floats near the cavity ceiling.

Ball lightning remains a mysterious phenomenon, but now there is something similar that is reproducible in the lab. Vladimir Dikhtyar and Eli Jerby of Tel Aviv University have shown that microwaves can “drill” into silica and eject “fireballs” a few centimetres across. They need a supply of microwaves to keep them going and wink out about 40 ms after the power is switched off. However they do look rather like ball lightning, and can melt through glass as some ball lightning has been reputed to do.

For a more radical recent theory, Vladimir K Ignatovich of JINR in Dubna has proposed that lightning can trigger laser action in the air. In this way, ball lightning is a ball in which laser light is trapped by internal reflection. This adds to the many explanations proposed over the years; but with no clear leading contender, research in the field is likely to continue for some time.

Further reading

Vladimir Dikhtyar and Eli Jerby 2006 *Phys. Rev. Lett.* **96** 045002.
Vladimir K Ignatovich 2006 http://xxx.lanl.gov/abs/physics/0601127.

Modifying Einsteinian gravity casts light on the dark side

Tweaking Einstein’s general theory of relativity could have important implications for dark matter and dark energy. The existence of both is inferred from observations together with the assumption that we understand gravity at cosmic distance scales. Philip Mannheim of the University of Connecticut has long argued for a change in the behaviour of gravity at large distances, working from a Lagrangian that is the square of the Weyl tensor in place of the curvature scalar. Now he has some recent company in the belief that gravity may not be what we think it is at scales beyond the solar system.

Hong Sheng Zhao of the University of St Andrews in the UK and Benoit Famaey of the Free University of Brussels have suggested a modification of Einsteinian gravity at large distances building on Moti Milgrom’s “modified Newtonian dynamics”, which Jacob Bekenstein has linked to a scalar field not present in normal general relativity. The resulting theory has gravity behaving differently at large distances – something that would look like dark matter if the data were interpreted with general relativity.

In the meantime, Olga Mena and José Santiago of Fermilab and Jochen Weller of University College London have argued for a modified Lagrangian for gravity with inverse powers of the curvature. This would explain the acceleration of the universe’s expansion without the need for dark energy, although dark matter would still be needed with this theory. It remains to be seen whether any of these ideas stand the test of time, but modifications to gravity seem likely to continue to give theorists food for thought.

Further reading

Philip D Mannheim 2006 *Prog. Part. Nucl. Phys.* **56** 340.
Olga Mena *et al.* 2006 *Phys. Rev. Lett.* **96** 041103.
H S Zhao and B Famaey 2006 *The Astrophysical Journal* **638** L9.

Lab grows spiky ice

Most forms of ice can be made in the lab, but one has been experimentally inaccessible until now. Penitentes are tall spikes of ice that can grow in high-altitude glaciers, and can reach heights of 4 m. The physics is based on sublimation, with the ice going directly into the gas phase. Initial depressions are subjected to increased sunlight reflected from nearby curved ice surfaces, which speeds up the sublimation leading to these exotic structures.

Vance Bergeron of the Ecole Normale Superieure in Paris and colleagues have duplicated these structures with a horizontal freezer, liquid-nitrogen-cooled air, controlled humidity and a flood lamp in place of the Sun. Aside from showing how penitentes form, the work could help to unravel the effects of global warming. When temperatures rose above −4 °C the growth rate slowed dramatically, and because penitentes cast shadows on glaciers, a reduction in their numbers and or sizes could accelerate glacial melting.

Further reading

Vance Bergeron *et al.* 2006 http://arXiv.org/pdf/physics/0601184; to be published in *Phys. Rev. Lett.*

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

Astronomers find new class of neutron star

An international team of astronomers using the Parkes radio telescope in Australia has detected very short radio flashes from 11 sources distributed in the plane of our galaxy. The isolated flashes last typically no more than 10 ms and are separated by relatively long periods of quiescence of several minutes. The detection of periodicities in the signal suggests that these new sources are rotating neutron stars, but of a different class to pulsars and magnetars.

The 11 sources were detected in data recorded between January 1998 and February 2002 as part of a pulsar survey by the 64 m Parkes radio telescope in New South Wales, operated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). This survey found more than 800 pulsars and is the most successful in history. Rather than searching only for the periodic trains of pulses, the astronomers, led by a team from the University of Manchester's Jodrell Bank Observatory in the UK, developed new techniques for detecting single short bursts of radiation.

CSIRO's Parkes radio telescope in New South Wales detected the new class of neutron star by picking up brief radio flashes distributed over our galaxy's plane. (Courtesy Shaun Amy.)

After confirmation of their celestial origin, all sources have been re-observed several times since August 2003 and they all showed repeated bursts, from four to more than 200 bursts in total for each source. The pulses last for 2–30 ms and occur with an average rate of one every 4 minutes to one every 3 hours. For all but one source it was possible to identify periodicities in the arrival times of the bursts. The period range from 0.4 to 7 s suggests that the new sources are likely to be rotating neutron stars. Half of the sources have periods exceeding 4 s, which is very unusual for radio pulsars, but is similar to the periods measured for magnetars: neutron stars with a very strong magnetic field, which can produce recurrent flashes of soft gamma-rays (*CERN Courier* June 2005 p12).

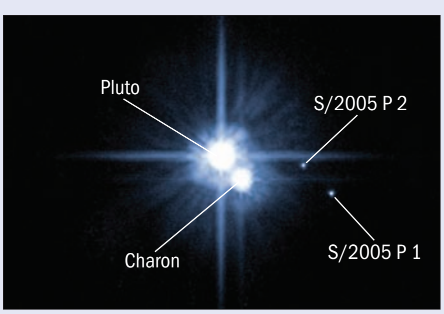
The relatively high periodicities and the transient nature of the pulses suggest that these neutron stars are of a new class, which the team has named rotating radio transients, (RRATs). These sources seem to need several hundred of rotations to gather enough energy for a flash. The properties of RRATs resemble those of magnetars, so it is possible that they are neutron stars evolving to or from magnetars.

The new objects appear to be distributed preferentially along the galactic plane and they might even be several times more numerous than radio pulsars. This estimate is based on their ephemeral nature, which makes them shine in total for only about 0.1 s each day. This also explains why these sources, which are among the brightest radio sources when flaring, remained unnoticed until now, and it opens a new field of investigation for the emerging generation of wide-field radio telescopes.

Further reading

M A McLaughlin *et al.* 2006 *Nature* **439** 817.

Picture of the month



This Hubble Space Telescope image confirms the presence of two new moons around the distant planet Pluto. The moons were first detected by Hubble in May 2005, but this image from 15 February 2006 confirms that the faint sources, provisionally designated S/2005 P 1 and S/2005 P 2, are indeed orbiting the ninth planet. Pluto's previously known moon, Charon, was detected in 1978, nearly half a century after the discovery of Pluto in 1930. According to a study published in *Nature*, along with the discovery paper, the two small moons are very likely to have been born in the same giant impact that gave birth to Charon. The newly discovered moons are two additional targets for NASA's *New Horizons* spacecraft, which was launched on 19 January 2006 and will fly past Pluto in July 2015. (Courtesy NASA, ESA, H Weaver [JHU/APL], A Stern [SwRI] and the HST Pluto Companion Search Team.)

CERN COURIER ARCHIVE: 1963

A look back to CERN Courier vol. 2, April 1963

LOOKING AHEAD

Physics using future accelerators

At the first meeting of the European Committee on Future Accelerators, in January 1963 at CERN, Prof. L Van Hove, CERN's Theory Division leader (and later director-general, 1976–1980) gave a paper on "Physics that could be done with future high-energy accelerators". The following is extracted from his write-up.

In discussing the general significance of physics as a whole it is convenient to distinguish the "practical" significance and what might be called its "philosophical" or "epistemological" significance for human knowledge in general.

Consider, for instance, electromagnetism. Understanding this branch of physics is very closely connected with the understanding and controlling of electricity and of electromagnetic radiation in all forms: radio-waves, light, radar. The practical applications are only so complete and diversified because the basic understanding is so good. As for the epistemological significance of electromagnetism, its main contribution has been the theory of relativity. Maxwell's equations probably did not excite the layman very much, but certainly relativity has been a striking development for philosophy and human knowledge. Yet there could have been no relativity without electromagnetism. Relativity was born from the clash between Maxwell and Newton, and both were necessary for Einstein.

Then there is atomic physics. Understanding atomic and molecular structure through quantum theory has led to the detailed understanding and controlling of all the forces at the atomic level, forces that dominate chemistry, solid-state physics, etc. The epistemological consequences arise from quantum theory itself, particularly statistical interpretation and the concept of complementarity, which are striking examples of how important the implications of physics can be in philosophy.

In the field of elementary-particle and high-energy physics, included in the broader one of nuclear physics, the general significance is largely for the future to determine. On the practical side, nuclear forces have already found very spectacular applications, but these resemble the practical uses of chemistry before atomic and molecular phenomena were really understood. It is known how nuclei stick together, but nobody at present claims to understand nuclear forces. It has also been learnt that the understanding of these forces will not come from low-energy nuclear physics, but will only be reached by looking deeper into the properties of fundamental particles, towards higher energies.

The fundamental discoveries and concepts of high-energy physics appear to be of interest mainly to physicists. The existence of antimatter, the violation of parity, the existence of fundamental variables outside space and time (like baryon number, lepton number and isospin), the hierarchy of interactions (strong, electromagnetic, weak), and the strangely parallel one of symmetry properties. Although these are overwhelmingly important to the specialist, none of them seem to hold much interest for the layman.

At the moment, physicists have discovered a forest of particles and interactions. The very fact that the variety of unexpected findings is so puzzling is a promise that new fundamental discoveries may very well be in store. Through these discoveries, the nature of the basic forces may eventually be grasped. In so doing, new consequences may arise, which may be as significant as the two mentioned above, relativity and complementarity. Both of these arose at the end of many years of very thorough experimental work, at a detailed level where the layman could find little intellectual excitement. A look back to the past produces an extremely strong motivation for the vigorous continuation and extension of this work.

● Extracted from a four-page article (pp48–51).

WHO'S WHO AT CERN

The Accelerator Research Division

Many people will be surprised to learn that one of the Organization's twelve Divisions is run by three men who take turns to assume the official title and functions of Division Leader. This is, however, true of the Accelerator Research Division, where K Johnsen, having replaced A Schoch in January 1962, this year handed on the title to C J Zilverschoon.

Following the successful completion and operation of the proton synchrotron, many of the physicists and engineers who had built it migrated into the Accelerator Research group. When the AR Division was constituted in 1961 the senior staff were already thinking of new, bigger projects. It seemed to them that their responsibilities should be, more than in any other Division, towards CERN as a whole. It was agreed that all policy decisions – which projects to recommend, which fields to explore – would be taken jointly. Since the normal day-to-day administrative responsibilities of a Division Leader cannot easily be divided, it was decided that this post would be held in turn. A strong argument for rotation was that no one would face an inescapable decision to give up most of his time to routine administration rather than to more interesting scientific work.

● Extracted from an account of life in CERN's AR Division (pp.52–54).

C J Zilverschoon (left), K Johnsen and A Schoch discuss the layout of a 300 GeV proton synchrotron surrounded by a pair of storage rings for colliding-beam experiments.

COMPUTING NEWS

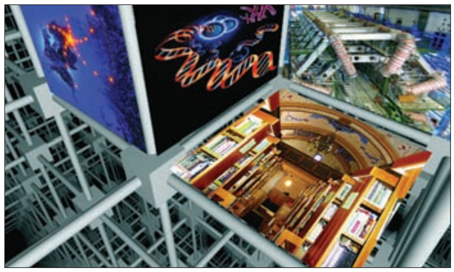
Compiled by Hannelore Hämmerle and Nicole Crémel

EUROPEAN GRID PROJECTS

BIG GRID gets grant for e-science

In the Netherlands, the government has recently awarded the BIG GRID consortium a four-year, €29 million grant to build the new national e-science infrastructure. BIG GRID combines many scientific disciplines that face a common challenge: managing a huge growth in distributed data. Detectors, medical imaging instruments, micro-arrays and multisensor instruments produce amounts of data that are rapidly exceeding the capacity of their local data storage and computing environments. Also, combining such datasets in new ways opens up the opportunity for novel forms of research. What these data have in common is that they all need reliable storage, comprehensive archiving, secure access and sharing.

The scientific disciplines concerned with BIG GRID include the life sciences, astronomy, particle physics, meteorology, climate research and water management, to name just a few. However, the very nature of the new infrastructure – a multidimensional collaboration enabler and accelerator – allows also for direct participation of the social sciences and the humanities, and even addresses communities in administrative domains, through applications such as digital academic repositories.



Dutch consortium BIG GRID is to build the new national e-science infrastructure.

BIG GRID aims to realize the necessary multiscience national grid infrastructure and to put the Netherlands at the forefront of Grid developments. For example, it will enhance the excellent position of Dutch academic hospitals in patient data collection, enable the use of the Grid for applications that combine biometrics with banking, and enable major advances in drug discovery. Industrial research laboratories both contribute to and benefit from the available resources for engineering sciences. Last but not least, this consortium enables the Netherlands to be one of the Tier-1 sites for experiments at CERN's Large Hadron Collider.

The new award to BIG GRID is in recognition of the active Dutch participation in international Grid developments, including European flagship projects such as Enabling Grids for E-science and the Distributed European Infrastructure for Supercomputing Applications, as well as acknowledgment of the success on a national scale of the Virtual Laboratory for e-science projects.

● BIG GRID is an initiative of the National Computer Facilities Foundation, the Netherlands Bio-Informatics Centre and the National Institute for Nuclear Physics and High Energy Physics.

SUPERCOMPUTING

apeNEXT computers take up residence in La Sapienza

A new home for apeNEXT supercomputers was inaugurated on 8 February in the Citicord machines hall of La Sapienza University in Rome. The development of apeNEXT, a new generation of machines for lattice quantum chromodynamics, began in 2001. Today, the apeNEXT supercomputers are among the most powerful computing machines in the world, developed by an international collaboration guided by the National Italian Institute for Nuclear Physics and including DESY, CNRS and the Université Paris-Sud.

The new computing laboratory, set up with the support of the Interuniversity Centre for Information Technology and Communication in Research and Teaching (Citicord), is the result of the collaboration of a network of research centres and European universities. The apeNEXT system installed in Rome has been built by the Italian company Eurotech and includes more than 6000 processors, with 8 Tflops total computing power and a memory of 1.5 TB. This latest laboratory will be dedicated to fundamental research, but the apeNEXT technology will also have consequences for economics and industry.

So far the apeNEXT infrastructure in Europe includes another apeNEXT system with 1500 processors installed at DESY in Germany, and 3000 processors supplied to Bielefeld University. Furthermore, 1000 processors of the French national research centre CNRS will soon be installed in Rome, to be used by French researchers through the network.

Around the world there are fewer than 10 computers with computing power comparable to the new apeNEXT system in Rome. Furthermore, apeNEXT boasts a series of innovative architectural solutions, combining high computing performance with a drastic reduction of development and construction costs, energy consumption and overall dimensions. The system is also highly reliable, permitting difficult calculations to be carried out over several weeks without interruption.

Les gros titres de l'actualité informatique

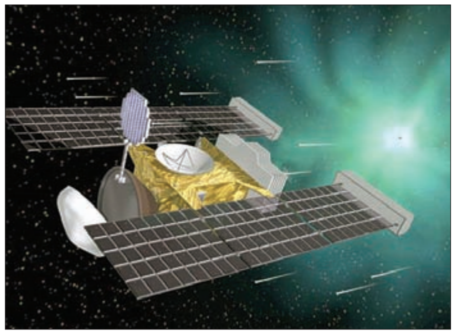
DISTRIBUTED COMPUTING

Volunteers use own PCs to analyse cosmic dust

Many sciences are discovering the tremendous amount of computing power available from volunteer PCs all over the world. For example, LHC@home, which was launched in 2004, has had more than 25 000 volunteers provide more than 1300 CPU years for beam studies at CERN's Large Hadron Collider. The Stardust@home project, launched in January, takes volunteer computing in a new and ambitious direction by getting the volunteers not only to donate spare PC time, but to participate actively in the search for interstellar dust in the samples collected by NASA's Stardust mission.

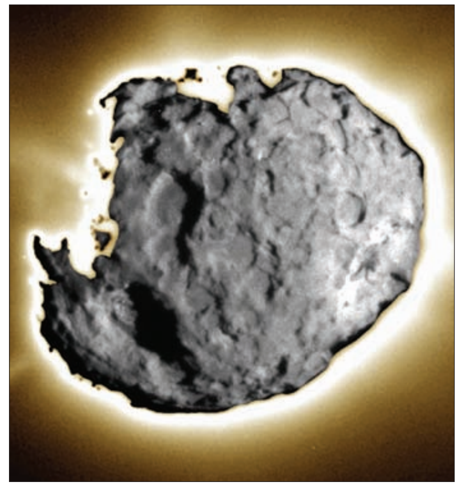
The Stardust capsule returned to Earth in January, after a 4.6 bn km round trip to bring comet and interstellar dust particles back to Earth. Scientists believe the cargo will help provide answers to fundamental questions about comets and the origins of the solar system. The dust samples were collected in a special aerogel used as a capture medium.

Finding the tiny interstellar dust particles in the Stardust Interstellar Dust Collector will be extremely difficult. The impacts created by interstellar dust can only be found using a high-magnification microscope with a field of view smaller than a grain of salt. The aerogel collector, however, is about 0.1 m^2. More than 1.6 million fields of view will have to be searched to locate the interstellar dust grains.



Artist's impression of the Stardust spacecraft. (Courtesy NASA/JPL.)

Stardust@home enables public volunteers to help in this task, which is done more accurately by humans than by any pattern recognition software. After a web-based training session, passing a test and registering, volunteers download a virtual microscope (VM). The VM automatically connects to the Stardust@home server and downloads stacks of images created by an automated microscope at the Cosmic Dust Lab at the Johnson Space Center. Each field can then be searched for interstellar dust impacts by focusing up and down with a focus control. The first images for scanning should become available in April and the project should be completed by October.



Composite image taken by the navigation camera during the close approach phase of Stardust's flyby of comet Wild 2 on 2 January 2004. Comet Wild 2 is about 5 km in diameter. (Courtesy NASA/JPL.)

● For more information about the Stardust mission visit www.nasa.gov/stardust. For more information about Stardust@home, go to http://stardustathome.ssl.berkeley.edu/.

CNL ARCHIVE

CNL celebrates at 40

After CERN's 50th anniversary in 2004, this year there is another anniversary: the first CERN Computer Newsletter (CNL) was circulated in 1966. As CNL celebrates its 40th year, we will take a look back at some of the highlights – and historical curiosities – of the early years of computing at CERN, seen through its pages. Below is a brief look at previous issues of the CNL. For an extended retrospection read the January–March issue of CNL, which is also available online at www.cerncourier.com.

Ferranti EP140 Microfilm Plotter

For the first time as far as we know, the EP140 at CERN has been used to make a motion film. A description is given in a paper by P Lapostolle and R Le Bail entitled Two-Dimensional Computer Simulation of High Intensity Proton Beams, which was presented at the First European Conference on Computational Physics, Geneva, 10–14 April 1972. (May 1972).

Who uses the computer time?

With the intention of matching some real numbers against people's guesses as to who uses the time on central computers, the attached figure [not reproduced] shows the CP time used by each division of CERN in 1974 up to 1 December. (...) 80% of the used time goes to the two physics divisions, NP (46%) and TC (33%). (...) The Theory division have used only 1.8%. Clearly the theorists are thinking rather than computing. (December 1974).

For messy programmers

The first reaction of someone who is presented with a "finished" or "working" program is normally complete amazement that such a frightful lash-up could ever succeed. So why not make all your source code look as if it really was designed that way by making it as legible as possible? A new facility, INDENT, is now available on all CDC machines. This automatically indents DO-loops by five columns so that in nested DOs the statements begin in columns 7, 12, 17... depending on the depth of nesting. (April 1978).

NAG program library now at CERN

The NAG (Numerical Algorithms Group) Program Library has now been installed on the CDC 7600 and on the IBM system at CERN. This library is a large and coherent collection of high-quality subroutines for numerical and statistical analysis. It is the fruit of many years' work by nearly all the British universities, and is widely distributed (commercially) around the world. (May 1979).

GRID CHALLENGE

Computing Grid succeeds in one gigabyte-per-second challenge

On 15 February the Worldwide LHC Computing Grid collaboration (WLCG) officially announced the successful completion of a service challenge at the Computing for High Energy and Nuclear Physics 2006 conference (CHEP'06) in Mumbai, India. The challenge involved sustaining a continuous flow of physics data on a worldwide Grid infrastructure at up to 1 GB/s. The maximum sustained data rates achieved correspond to transferring a DVD of scientific data from CERN every five seconds.

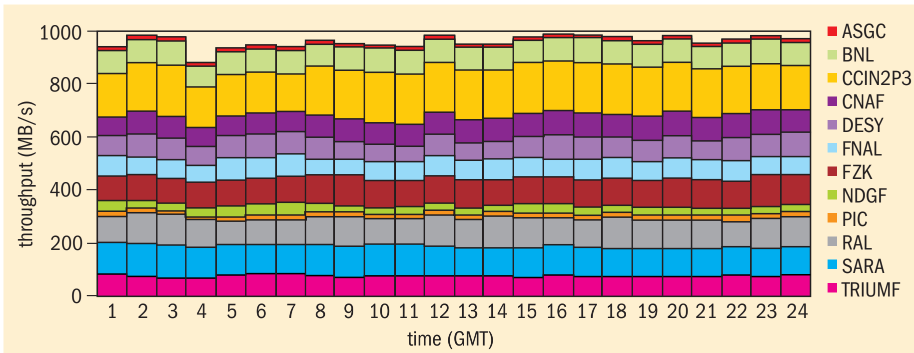
The data were transferred from CERN to 12 major computer centres worldwide. More than 20 other computing facilities were involved in successful tests of a global Grid service for real-time storage, distribution and analysis of the data. The completion of this service challenge is a key milestone on the way to establishing the necessary computing infrastructure for the Large Hadron Collider (LHC), which is scheduled to start up in 2007. The results represent a step forward from a previous service challenge in early 2005 that involved just seven centres in Europe and the US and achieved sustained rates of 600 MB/s.

LHC scientists designed a series of service challenges to ramp up to the level of computing capacity, reliability and ease of use that will be required by the worldwide community of more than 6000 scientists working on the LHC experiments. During LHC operation, the major computing centres involved in the Grid infrastructure, so-called Tier-1 centres, will collectively store the data from all four LHC experiments, in addition to a complete copy being stored at CERN.

Much of the data analysis will be carried out at more than 100 Tier-2 computing facilities in universities and research laboratories in more than 30 countries, where researchers will access the data via the Grid resources that the WLCG is bringing together. Already these computing facilities provide a combined computing power of more than 20 000 PCs, and this number is expected to reach 50 000 by the time the LHC is in operation. During the recent service challenge, the participating computing centres sustained more than 12 000 concurrent computing jobs.

Speaking on behalf of the organizers of CHEP'06, Sabyasachi Bhattacharya, director of the Tata Institute of Fundamental Research in Mumbai, remarked: "The fact that this announcement is being made in India reflects the truly global significance of these new results. This sort of collaboration, which we in India are delighted to be taking part in, provides an excellent example of what scientists from around the world can achieve when they have a clear, common goal."

● The computing facilities involved in this service challenge were: Academia Sinica Grid Center (ASGC); Brookhaven National Laboratory (BNL) in Brookhaven, NY; the Computing Center of the National Institute of Nuclear Physics and Particle Physics (CCIN2P3) in Lyon; the German Electron Synchrotron Laboratory (DESY) in Hamburg; Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois; Forschungszentrum Karlsruhe (FZK) in Karlsruhe; the National Center for Research and Development in Technology, Computer Science and Data Transmission (INFN-CNAF) in Bologna; the Nordic DataGrid Facility (NDGF), a distributed facility in Denmark, Finland, Norway and Sweden; Port d'Informació Científica (PIC) in Barcelona; the National Center for Computing and Networking Services and the National Institute for Nuclear Physics and High Energy Physics (SARA-NIKHEF) based in the Netherlands; the Rutherford Appleton Laboratory (RAL) in Oxfordshire; and the National Laboratory for Particle and Nuclear Physics (TRIUMF) in Vancouver.



Hourly averaged throughput on 22 January 2006 from CERN to 12 major computing centres during the service challenge, demonstrating data rates up to 1 GB/s.

GRID COMPUTING

EGEE goes global

The EU has recently co-funded several new projects that will expand the Grid infrastructure of the Enabling Grids for E-science (EGEE) project to the Baltic States, China, the Mediterranean area and Latin America.

The Baltic Grid Project started on 1 November 2005 and will last for 30 months. The project involves 10 leading institutions in Estonia, Latvia, Lithuania, Poland, Sweden and CERN. The project will ease the formation of effective research collaborations with scientists anywhere, with a focus on connections to other European Grids. The project will train providers, administrators and users of Grids in the Baltic States to a level of state-of-the-art expertise in Grids.

On 24 January 2006 the EUChinaGRID project officially began with a meeting in Athens. For the next two years this project will support the integration and interoperability of the Grid infrastructures in Europe (EGEE) and China (CNGrid) for the benefit of e-science applications and worldwide Grid initiatives, in line with the support of the intercontinental extension of the European Research Area. To improve the accessibility of the Grid infrastructure for new research groups and applications, EUChinaGRID will also be active in dissemination and training, promoting scientific and, possibly, industrial developments.

The EUMEDGRID Project started on 6 February 2006 with a meeting on Malta – located, symbolically and geographically, at the heart of the Mediterranean. Over two years, a group of experts will collaborate to develop a Grid infrastructure for e-science (such as hydrogeological and medical applications) across the Mediterranean. The initiative aims to bridge the digital divide and foster collaboration between Europe and its Mediterranean neighbours.

The EELA Project, which will create a human network dedicated to work on Grids, e-infrastructures and e-science in Europe and Latin America, started on 1 January 2006 and was officially launched with meetings at CIEMAT in Madrid and Trujillo (Spain) on 30 January – 2 February. EELA will build a digital bridge between existing e-infrastructure initiatives in Europe (in the framework of the EGEE project), and those that are emerging in Latin America. Over the next two years EELA will establish a collaboration network to identify and promote a sustainable infrastructure for e-science in Latin America, taking advantage of the first regional research and education network in Latin America, RedCLARA, developed by the America Latina Interconectada Con Europa project.

Further information

www.balticgrid.org.
www.euchinagrid.org.
www.eumedgrid.org.
www.eu-eela.org.

US GRID PROJECTS

Open Science Grid elects managerial team

The Open Science Grid (OSG), a US project that enables collaborative scientific research through distributed computing, has elected its first executive director and council chair and appointed its first executive board. The new management team will lead the operation and expansion of the OSG, a community Grid built by research groups from US universities and national laboratories.

Executive director Ruth Pordes became involved in scientific Grid computing in its infancy as one of the principal investigators of the US Department of Energy-funded Particle Physics Data Grid. "The OSG is an exciting opportunity and a great challenge," said Pordes, a Fermilab employee. "We will work hard over the next two years to provide a solid distributed-computing facility for LHC [Large Hadron Collider] physics, support all our scientific communities and expand our capabilities and user base."

Council chair William Kramer, general manager of the National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory, has extensive experience managing large projects and divisions at NASA and at NERSC. "It's been gratifying to see the OSG grow over the past year, adding new members, new partners and new technologies, and I look forward to building on our successes," said Kramer.

The OSG Consortium, which includes 28 organizations representing more than 50 institutions and hundreds of researchers, works closely with partner projects such as Enabling Grids for E-Science and TeraGrid. Over the past year the OSG has provided distributed computing, storage and network resources to collaborations from particle and nuclear physics, astronomy, bioinformatics and computer science. The members of the board are Paul Avery, Alan Blatecky, Rob Gardner, Mark L Green, Leigh Grundhoefer, John Huth, Albert Lazzarini, Miron Livny, Doug Olson, Don Petravick, Alain Roy, Torre Wenaus, Mike Wilde and Frank Würthwein.

Delegates at the recent OSG meeting at the University of Florida in Gainesville, US.

Calendar of events

April

2–6 High Performance Computing Symposium (HPC 2006) Huntsville, Alabama, www.caip.rutgers.edu/hpc2006

3–7 HEPiX meeting CASPUR in Rome, Italy, www.hepix.org

25–29 20th IEEE International Parallel & Distributed Processing Symposium Rhodes Island, Greece, www.ipdps.org

May

3–6 Grid and Pervasive Computing (GPC 2006) TungHai University, Taiwan, hpc.csie.thu.edu.tw/gpc2006

4–5 DEISA Symposium Bologna, Italy, www.deisa.org/symposium/index.php

9–12 GGF17 Tokyo, Japan, www.ggf.org

15–18 TERENA Networking Conference 2006 Catania, Italy, www.terena.nl/conferences/tnc2006/

16–19 Grid Asia 2006 Singapore Management University, Singapore, www.ngp.org.sg/gridasia/2006/

28–31 International Conference on Computational Science (ICCS 2006) University of Reading, UK, www.iccs-meeting.org/iccs2006/index.html

30 May – 1 June First International Conference on Scalable Information Systems (INFOSCALE 2006) Hong Kong, www.infoscale.org

September

22–24 6th WSEAS International Conference on Simulation, Modelling and Optimization (SMO '06) Lisbon, Portugal, www.worldses.org/conferences/2006/lisbon/smo, paper deadline 15 May

25–28 IEEE International Conference on Cluster Computing (Cluster 2006) Barcelona, Spain, cluster2006.org, paper deadline 28 April

28–29 Grid 2006, 7th IEEE/ACM Intl. Grid conference Barcelona, Spain, people.ac.upc.edu/rosab/grid2006, paper deadline 7 April

25–29 EGEE'06 conference Geneva, Switzerland, egee-intranet.web.cern.ch/egee%2Dintranet/conferences/EGEE06

October

21–23 GCC 2006 Changsha, China, www.vce.org.cn/gcc2006, paper deadline 20 April

November

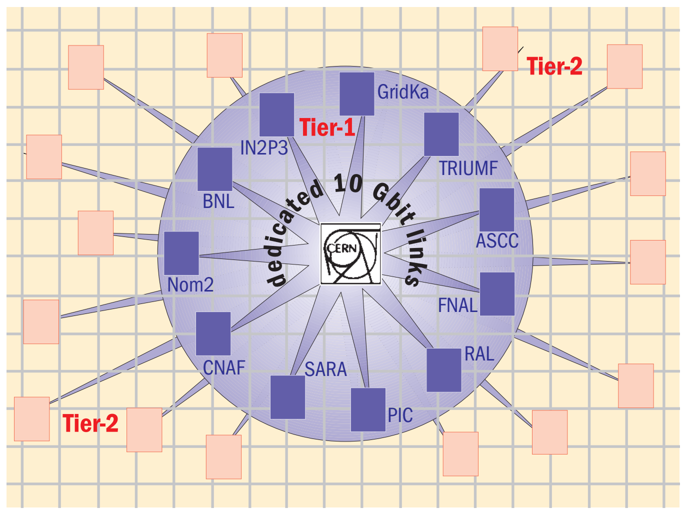
11–17 SC06 Tampa, USA, sc06.supercomputing.org, paper deadline 17 April

Networking tackles the LHC challenge

David Foster describes how the challenging requirements of the LHC Computing Grid have changed the way that networking is organized for high-energy physics.

It is well known that the Grid will provide storage and computing for the experiments at the Large Hadron Collider (LHC), which will generate vast amounts of data. However, this would not work without a networking infrastructure to move data from the experiments to the collaborating institutes and then to the physicists. The LHC Computing Grid (LCG) infrastructure is built on the concept of tiers, with different institutes providing certain services. Briefly, CERN is Tier-0, while Tier-1 institutes are responsible for long-term data storage services, and Tier-2 centres mainly provide CPU and temporary storage services. All institutes connected to the LCG infrastructure have to communicate with each other, so the networking has to deal with traffic crossing a number of networks and network-management domains.

The end-to-end path between a scientist somewhere in the world and the data coming from the detectors comprises the on-site campus network infrastructures as well as the connectivity between the experiments, the CERN Computer Centre and the Tier-1 and Tier-2 centres. This connectivity is provided on infrastructures of various types, and different international collaborative initiatives contribute to a dynamically evolving situation.



Conceptual view of the interconnectivity between computing centres for the LHC. The Tier-1 centres are connected by dedicated links up to 10 Gbit/s to the Tier-0 centre at CERN, while Tier-1 and Tier-2 centres are interconnected by many research networks. All of the centres are also interconnected by the general-purpose Internet (indicated by the mesh). In this way any Tier-2 centre may access data at any Tier-1 centre.

The CERN network

The CERN network itself consists of a number of interconnected infrastructures that provide all the connectivity to user desktops, experimental areas, computer-centre farms and the collaborating institutes around the world. The core of the CERN LCG network architecture is based on a set of highly redundant and high-throughput routers interconnected with multiple 10 Gbit/s connections, using a mesh of Force-10 routers, each equipped with 40 10-Gbit/s interfaces.

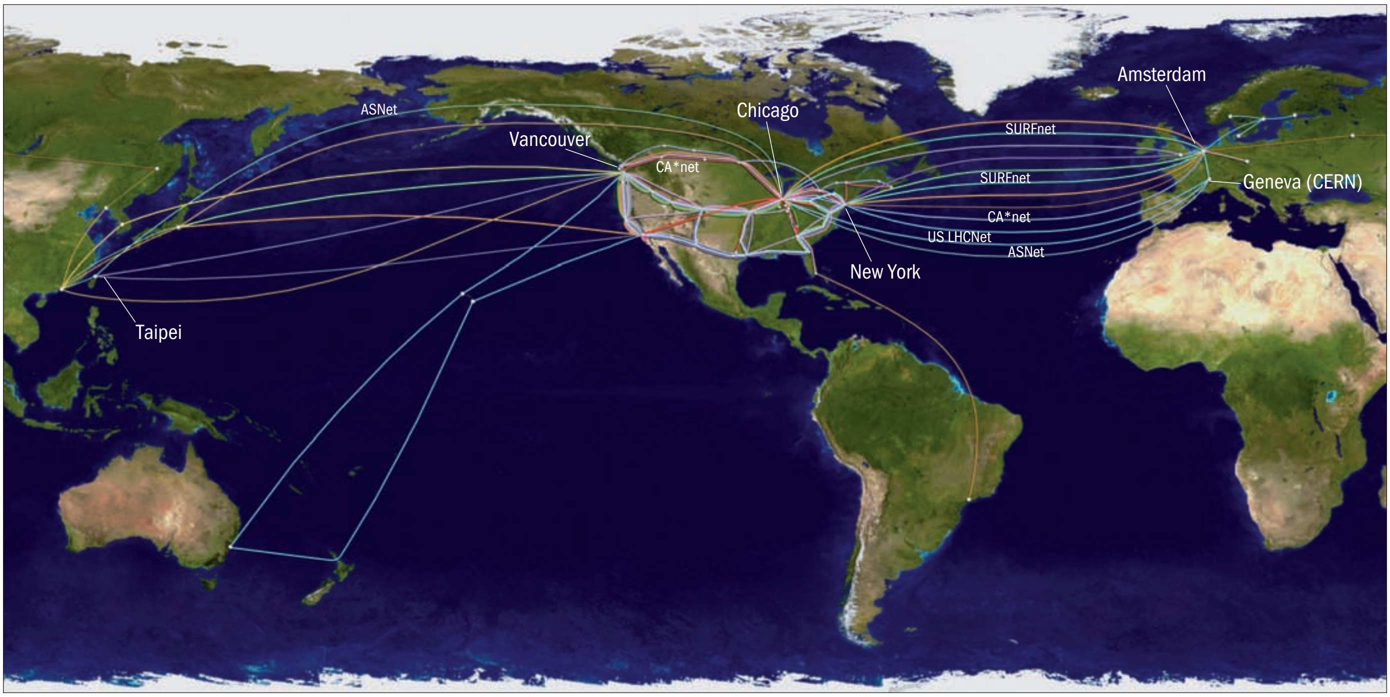
The local computing farm at CERN, which includes the CERN part of the LCG, is expected to grow to around 6000 processors and about 2000 tape and disk storage devices, and each of these systems is connected to the LCG farm core using 1 Gbit/s Ethernet. This farm core is in turn connected via a dedicated network infrastructure to the Tier-1 centres.

Desktop computers at CERN are connected to the campus core infrastructure using these highly available and redundant routers with 10 Gbit/s links. This campus core is connected both to the LCG farm core and the external network infrastructure to allow complete connectivity of CERN desktops to the LHC physics computing and the worldwide network infrastructures.

The edge of this campus network is being upgraded with 1 Gbit/s switches from HP ProCurve. It is worth comparing this with the situation in 2000, at the end of the era of the Large Electron–Positron collider, where the equivalent core had 100 Mbit/s connectivity, and the edge 10 Mbit/s.

Tier-0 to Tier-1

A prominent networking goal that has been set is to achieve aggregate data flows from CERN to the collaborating institutes of several gigabytes a second on a continuous basis by the time the LHC is up and running. The planned starting date for production traffic on the LHC networking infrastructure is summer 2007, but the links will ▷



Map of the GLIF infrastructure, which provides connectivity for researchers worldwide, showing a selection of the network links for sharing and transferring data. A full version containing details of all of the links can be found at www.glif.is.

be tested at full bandwidth during 2006 as part of the service challenges that are now under way. Already, peaks of 1 GB/s have been achieved (p15).

The resources available at the Tier-1 centres are not all the same and therefore the average network load is expected to vary. However, the network should be able to sustain the peak loads at any given time, so as a starting point at least one dedicated 10 Gbit/s transmission path between CERN and each Tier-1 will be recommended. This network is based on permanent 10 Gbit/s light paths, which form a so-called optical private network for the LCG.

The infrastructure that transports the data from CERN to a particular Tier-1 depends on the location of the Tier-1. In general, a combination of national networks, international projects and commercial links are used (see table, p21). The responsibility for providing network equipment, physical connectivity and manpower is distributed among the co-operating parties. CERN provides the interfaces to each Tier-1 link termination point at CERN.

Tier-1 to Tier-2

The Tier-1 centres are connected with CERN through dedicated links to ensure high reliability and high-bandwidth data exchange, but they are also connected to many research networks and to the Internet, a worldwide network providing Internet Protocol communication between computers at research institutions. These infrastructures ensure good connectivity between Tier-2s and Tier-1s, as well as Tier-1 to Tier-1 communication.

As with the general-purpose Internet, the research networks are in fact a set of interconnected networks that link together the national and international networking initiatives through bi-lateral agreements. In Europe, for example, GEANT links together the national research networks of European countries and provides peering with other networks, for example Abeline in the US. The Energy Sciences Network (ESNet) provides a backbone in the US, linking metropolitan area networks.

To understand which of the many and varied initiatives taking place worldwide could be used to provide connectivity for research purposes – not just in high-energy physics, but in a wide range of scientific applications – the Global Lambda Integrated Facility (GLIF) was established in 2003 at a meeting in Iceland that brought together the major players funding and installing research networks.

GLIF may have important implications for the general-purpose connectivity between Tier-1 and Tier-2 centres as well as inter-Tier-2 connectivity, as it helps organize a complex set of research initiatives worldwide. In particular, GLIF promotes the sharing between participants of lambdas – single wavelengths on multiple-wavelength optical fibres – which provides additional connectivity between networks. Other developments, such as falling bandwidth costs, will also have an impact, leading to an increasing number of high-speed direct links (10 Gbit/s or more) between Tier-1 and Tier-2 centres in the near future, as research-network initiatives continue to acquire affordable dark fibre.

The way forward

The Tier-1 and Tier-2 centres already have plans to implement the required infrastructures for connecting at sufficient bandwidth to fulfil the needs of the LHC experiments. The service challenges will continue to exercise the total end-to-end infrastructure, increasing the load and the number of sites involved. The infrastructure and design being implemented at the moment will be adequate for LHC start-up according to the experiments' computing models. Impressive as this recent progress may seem, it is just the beginning. As an increasing volume of data is created by the experiments, the requirements to transfer these data as quickly as possible between sites will expand.

Part of the solution will be so-called open optical exchanges, which will use pure wavelength switching to allow opportunities for networks to interconnect and provide global connectivity for research and education. Such facilities will be commonplace once the underlying optical technologies achieve sufficient maturity. Equally important, as physicists worldwide start to work on the LHC data, is the challenge to ensure that the tremendous resources made available through the many Grid initiatives around the world can be used effectively, even at the edge of the networks where bandwidth is limited. The issue here is also about bridging the digital divide between well-connected and poorly-connected regions of the world.

This evolution will only be possible through a constant, incremental improvement of networking worldwide in terms of capacity, cost and availability. By providing a clear and visible goal both for scientists and for key decision-makers to target, LHC computing is helping to accelerate that process. This benefits scientists in all fields, and ultimately ordinary citizens around the globe.

National, international and commercial links

Tier-1	Location	End-to-end path
ASGC	Taipei	ASnet
BNL	Upton, NY	USLHCnet/ESnet
CCIN2P3	Lyon	RENATER
CERN	Geneva	
CNAF	Bologna	GEANT/GARR
FNAL	Batavia, IL	USLHCnet/ESnet
GridKa	Karlsruhe	GEANT/DFN
NDGF	Nordic countries	GEANT/NORDUnet
PIC	Barcelona	GEANT/RedIRIS
RAL	Didcot	GEANT/UKERNA
SARA	Amsterdam	GEANT/SURFnet
TRIUMF	Vancouver	CANARIE

Résumé

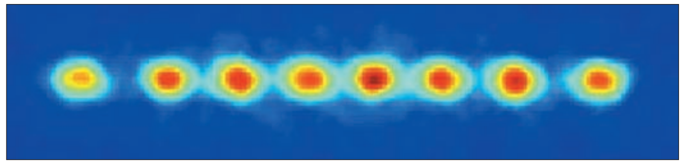
Les réseaux face aux défis du LHC

On a beaucoup parlé des capacités de stockage et de calcul de la Grille pour les expériences au LHC. Cependant, elles resteraient inopérantes sans l'infrastructure des réseaux qui permettent de transporter les données des expériences aux instituts des collaborations, puis aux physiciens. Tous les instituts reliés à l'infrastructure de la Grille de calcul du LHC doivent communiquer et la réseautique doit assurer le trafic à travers les différents réseaux et domaines. Cet article présente brièvement certaines des infrastructures de réseau et leurs relations avec le projet LHC. Toutes les activités sont nécessairement menées à une échelle mondiale.

David Foster, *CERN*

Counting on uncertainty

Quantum computing lies at the boundary between physics and computer science, and is regularly yielding headline news.



CCD image of the first qubyte, comprising eight calcium ions in an electromagnetic trap, observed at the University of Innsbruck. The separation between the ions is 5 μm. The ions are in a vacuum, to minimize sources of decoherence, and long-range electrostatic forces between them ensure quantum entanglement. They are detected by fluorescence caused by laser pulses. (All images courtesy H Häffner, University of Innsbruck.)

Quantum computing is based on quantum bits or "qubits". While classical bits can be in either a 0 or 1 state, qubits are a superposition of two quantum states of a system, representing 0 and 1. Qubits thus encapsulate the ambiguous, uncertain world of quantum mechanics. They can be realized by the superposed polarization states of photons, or superposed spin states of electrons, ions or even molecular nuclei.

The importance of qubits for computer science arises because of the phenomenon of quantum entanglement. When several qubits interact, their quantum states become correlated. This allows an assembly of qubits to represent a lot of information. For example, whereas two bits of information can represent only one of four binary numbers, 00, 10, 01 or 11, two entangled qubits can represent all four at the same time. N qubits can thus represent 2^N binary numbers. By operating on an assembly of entangled qubits in a suitable manner – for example putting spin-based qubits in a magnetic field – parallel computations can effectively be carried out on all the binary numbers at once.

This exponential growth in information content and processing power with the number of qubits means that quantum computers are uniquely efficient at certain tasks that their classical counterparts find excessively time consuming. This is the case for the factorization of large numbers. An algorithm developed for quantum computation by Peter Shor of Bell Labs in 1994 allows factorization of a number with N digits in a time that scales as the $\log(N)^3$, whereas the best classical algorithms take times that grow exponentially with N.

Shor's algorithm means that factorizing a number of several hundred digits could be done on a fairly simple quantum computer in less than a year, whereas it might take billions of years on one of today's best supercomputers. This has major implications for "public key" cryptography, which relies on the difficulty of factorizing large numbers to encode digital data securely. Another potentially practical development is a quantum database-search method known as Grover's algorithm, invented by Lov Grover of Bell Labs in 1996, which also produces significant speed-ups over classical methods.

To exploit these theoretical breakthroughs, the challenge is to make quantum computation work in practice. The announcement of the first qubyte, or eight qubits, in December 2005, by a group at the University of Innsbruck characterized the state-of-the-art in assembling qubits (Häffner *et al.* 2005). The group used eight calcium ions in a magnetic ion trap to achieve this feat. However, in practice, the nuclear spins of molecules in a liquid, which can be addressed using NMR technology, have proved the most fertile ground for testing the principles of quantum computation. The reason for this is that by having huge numbers of identical molecules carry out the same quantum calculation, the system is much more robust against the phenomenon of decoherence, where any interaction of a qubit with the environment – even with a single photon – causes a quantum computation to crash.

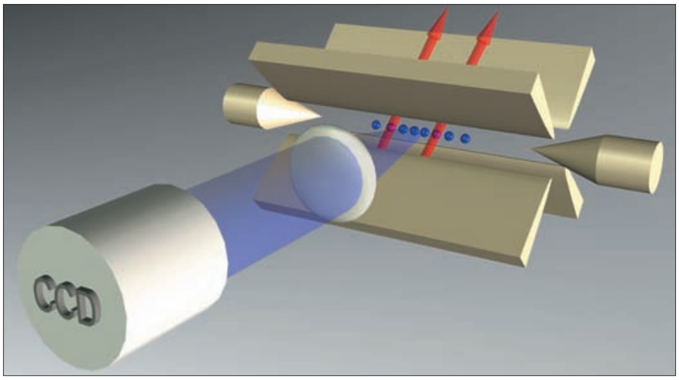
The massive redundancy offered by a macroscopic ensemble of molecules means that although many individual molecules may be affected by decoherence, a quantum calculation can still be carried out in a few seconds. In 2001, IBM's Almaden Research Center and Stanford University used NMR to demonstrate Shor's algorithm experimentally for the first time: they factorized the number 15 into 5 and 3.

Great expectations

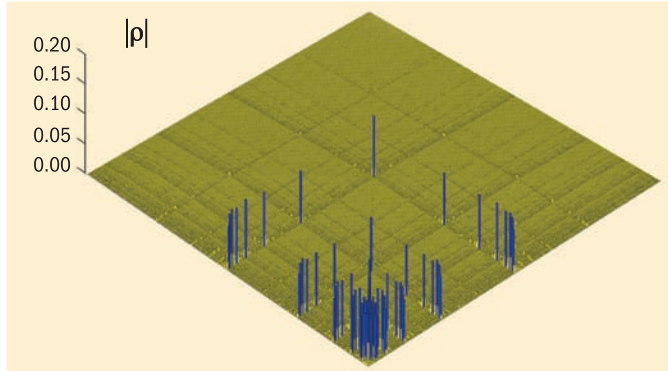
This was admittedly a modest start. But Nicolas Gisin from the University of Geneva, one of the pioneers of quantum computing, remarks, "Over the last few years the field developed very rapidly and a lot of progress was achieved both in quantum computing and quantum communication. There are a tremendous number of ideas, and we are optimistic that we will see huge progress." Indeed, in 2001, a spin-off from Gisin's research group called id Quantique was the first company to put commercial quantum cryptography on the market.

Quantum cryptography involves encoding information in the form of polarized photons, in such a way that any attempt to eavesdrop on a communication between two parties will result in a measurement of the photon polarization. This inevitably changes the state of some of the photons, and can thus be detected. The approach is much more robust than traditional public-key cryptography. Ironically, the reason some companies and government organizations are showing interest in quantum cryptography is the fear that, some years from now, practical quantum computers may be able to crack public-key systems by factorizing large numbers rapidly. Last year, id Quantique began offering turn-key secure communications service to Swiss firms, by partnering with Fibrelac, a provider of the optical-fibre links that are needed for quantum-cryptography-based communications.

On the research front, Gisin's group is already investigating combining quantum computing and quantum communication. In September they described how qubits could be transferred from one place to another, using photons as the natural "flying" qubit states (Tanzilli *et al.* 2005). This involves translating the information in stationary atomic qubits – in this case alkaline atoms that absorb and emit at 800 nm



The set-up for observing the qubyte. Eight qubits can code 256 binary numbers, and to measure the quantum mechanical density matrix of such a system requires 65 536 independent measurements. This means keeping the qubyte stable for more than 10 h, measuring 20–50 data points a second.



Density matrix of the qubyte in a "W state", comprising one ion in the S state and the others in the D state. The figure indicates that the qubyte contains far more information than the 256 possible binary numbers in a byte. The reconstruction of the density matrix from the data took a university computing cluster two days.

wavelength – into photon wavelengths that can travel down typical optical fibres at 1310 nm or 1550 nm. This proof-of-principle is another step down the long road to useful quantum computers.

"Experiments are limited to small numbers of qubits at the moment and not only the number is important, but also the quality," says Gisin. "We need to develop a laboratory model of quantum processors, including error correction, to bring the different fields together with further advances in theory: new computational models and architectures, further understanding of entanglement and decoherence."

On the positive side, great strides are being made in assembling long-lived registers of qubits. For example, researchers at the Max Planck Institute for Quantum Optics have cooled single rubidium atoms in every direction of motion and kept them for an average of 17 s in an optical resonator (Nußmann *et al.* 2005). This enables experiments to study the interaction of individual atoms with individual photons. The trapped atoms can in principle be used to store qubits, and the photons they emit effectively carry out the quantum computing operations.

In another breakthrough, a group at the National Institute of Standards and Technology (NIST) has demonstrated a quantum physics version of computer memory lasting more than 10 s (Langer *et al.* 2005). The researchers used superposition of two internal energy levels of a beryllium ion to create their qubits, and by choosing the energy levels carefully, maintained superposition 100 000 times longer than in previous experiments on such ions. On the other hand, theoreticians at Leiden University have discovered that the coherence of qubits will spontaneously disappear over time (van Wezel *et al.* 2005), challenging even the most sophisticated efforts to avoid decoherence.

Hope remains, however, that a full-scale quantum computer may still produce reliable results, even if its components perform no better than today's experimental qubits. The idea is to correct errors faster than they occur, and theoretical considerations show this will work even if the correction mechanism itself is not error-free. One proposed route to achieving this uses the phenomenon of quantum teleportation. This *Star Trek*-like process transmits the quantum properties of one photon instantaneously to another far-removed photon, while at the same time destroying the state of the original photon. It is an extreme case of quantum entanglement operating over large distances.

The idea proposed by Emanuel Knill at NIST last year is to use quantum teleportation of information at regular intervals from an assembly of qubits, to double-check continuously the accuracy of qubit values (Knill 2005). This both tracks how errors are affecting the qubit assembly and transfers stored information to other qubits not yet affected by decoherence. The proposed procedure is to create a hierarchy of qubits at various levels of validation, and only the top-tier – the most accurate qubits – are actually used for computations.

While researchers pursue different avenues to solving the many challenges facing quantum computing, a comprehensive roadmap has already been published tracing the anticipated progress of the field towards practical applications (see http://qist.lanl.gov/qcomp_map.shtml). It is unlikely that "QC inside" will adorn your laptop anytime soon. But the field promises to remain rich in both scientific and technological opportunities for many years to come.

Further reading

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C Langer *et al.* 2005 *Phys. Rev. Lett.* **95** 060502.
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Résumé

Les chats de Schrödinger savent compter

Le calculateur quantique se trouve à la frontière de la physique et de l'informatique et représente un domaine de recherche très dynamique. Régulièrement, le calcul, la cryptographie et la téléportation quantiques font les gros titres de la presse. En 2005, des annonces successives ont porté sur le premier "quoctet" (comportant huit bits quantiques ou "qubits"), sur les progrès dans la transmission pratique de l'information stockée sur des qubits et sur les avancées dans la version quantique d'une mémoire d'ordinateur. Quels que soient les obstacles qu'il reste à surmonter, il s'agit là d'étapes capitales vers la réalisation d'un authentique calculateur quantique.

François Grey *and* **Hannelore Hämmerle**, *CERN.*

Prague meeting focuses on colliders and cosmic rays

The C2CR meeting in Prague targeted the interface between cosmic-ray physics and the current and future results from accelerators and colliders.

Well known landmarks of Prague – Charles Bridge and the Prague Castle – from a less well known angle on a boat trip on the Vltava River. (Photos courtesy Radomir Smida.)

Research on elementary particles – a frontier area of physics – emerged as a distinct field during the mid-20th century, following the discovery of the pion and strange particles, and the construction of particle accelerators reaching energies of more than 100 MeV. The first high-energy physicists had grown up as nuclear or cosmic-ray scientists, but in subsequent years the liaison between cosmic-ray physics and accelerator-based elementary particle physics seemed to fade, with little communication between these two lively and interesting areas of physics. Recently this situation has begun to change, with closer interaction between the two fields. Cosmic-ray physicists need better data on particle interactions and production, and particle physicists at accelerators are interested in exploring phenomena reported from cosmic-ray studies. Also, some theorists are looking at effects that should be detectable at the future Large Hadron Collider (LHC) and may be even more notable at cosmic-ray energies.

It was in this spirit that physicists at the Institute of Physics of the Czech Academy of Sciences, the Czech Technical University and Charles University in Prague organized the conference From Colliders to Cosmic Rays (C2CR) in September 2005. Their aim was to bring together cosmic-ray and particle-accelerator physicists to discuss their latest results and problems common to both communities. An International Advisory Committee was established, representing a broad spectrum of universities and laboratories in Europe and America, with Jan Ridky of the Institute of Physics as head of the Local Organizing Committee.

A significant antecedent to the C2CR meeting was the Needs from Accelerator Experiments for the Understanding of High-Energy Extensive Air-Showers (NEEDs) workshop held in Karlsruhe in April 2002 (*CERN Courier* July/August 2002 p26). Also relevant was the 12th (biennial) International Symposium on Very High Energy Cosmic Ray Interactions, which was held at CERN in July 2002.

A common thread in these discussions is the fact that the flux of primary cosmic rays of energies above a few hundred tera-electronvolts is so low that direct observation is not practical from balloon- or satellite-borne detectors. Our understanding of the composition and energy spectra of these cosmic rays is totally dependent on ground-level observations, and on the simulation of primary interactions and atmospheric cascades based on accelerator data. In this context, there are constant efforts to improve the interaction Monte Carlo simulation programs, which are essential components for the interpretation of the cosmic-ray data. At C2CR, Sergey Ostapchenko from the Forschungszentrum Karlsruhe presented the theoretical input into his latest version of the QGSJET program, where gluon saturation is taken into account, while his colleague Tanguy Pierog described numerical methods used in the simulation of showers that involve tens of billions of secondary particles. CERN's Hans-Peter Wellisch also raised interest by his claim that extensive cosmic-ray air showers can be simulated within the framework of GEANT4, the latest version of the well-known toolkit for simulating the passage of particles through matter.

The experimental information available and efforts or proposals to carry out new measurements of hadronic interactions at accelerator and collider energies formed a major topic. Representatives from the experimental collaborations presented recent results from the CDF and D0 experiments at Fermilab's Tevatron collider, from the HERA collider at DESY, and from the Hadron Production Experiment at the Proton Synchrotron accelerator at CERN. Heavy-ion physics results were also reported from experiments at CERN's Super Proton Synchrotron and from the BRAHMS and PHOBOS experiments at Brookhaven's Relativistic Heavy Ion Collider. Martin Block of Northwestern University presented a projection of the proton–proton total cross-section to LHC energies, and both he and Leonid Frankfurt of Tel Aviv discussed other cross-sections, such as proton–air and nucleus–nucleus, at higher energies.

The observables from cosmic-ray interactions are dominated by the most energetic final-state particles and these are mostly produced at small forward angles. Among the talks on this topic, Mark Strikman of Penn State University discussed small-x physics and forward dynamics in proton–proton and proton–nucleus ultra-high-


A student choir singing at the welcome party in the baroque Michna Palace in the historical part of Prague.

energy collisions. Others described the discovery potential of the LHC, as well as the potential in diffraction and forward physics of the CMS/TOTEM/CASTOR experiment complex at the LHC, and LHCf, a proposed zero-degree calorimeter at the LHC.

Currently, the Karlsruhe Shower Core and Array Detector (KASCADE) with its associated muon and hadron detectors is the most sophisticated and productive cosmic-ray air-shower experiment in operation, and the Karlsruhe group was well represented in Prague. Marcus Risse, Andreas Haungs and Holger Ulrich discussed different aspects of the KASCADE data, results and interpretation, including the sensitivity of the interpretation of their data to models of the primary hadron interaction.

The intercommunication between accelerator-based and cosmic-ray physicists is perhaps nowhere more apparent than in the area of neutrino physics, with the studies of neutrino masses and mixing. The meeting heard about various aspects of neutrino physics, including results from existing detectors, theoretical ideas and plans for new detectors. For example, the Antarctic Impulsive Transient Antenna and the Salt Shower Array are planned to detect radio pulses from coherent Cherenkov radiation produced by the reaction products of ultra-high-energy cosmic-ray neutrinos interacting in ice and rock salt, respectively.

No cosmic-ray conference nowadays would be complete without some discussion of the highest-energy cosmic rays and indeed C2CR had several excellent reports. These covered the current status of the problem with ultra-high-energy cosmic rays, the latest from the High Resolution Fly's Eye experiment, and the status and first results from the Pierre Auger Observatory. Jim Cronin of Chicago, one of the founders of the observatory and spokesman emeritus for the collaboration, was a lively and valuable participant.

An interesting cross-link between the cosmic-ray and accelerator physics communities is the use of the large detectors at colliders for studies of cosmic-ray muons. The meeting heard reports on physics results obtained with cosmic-ray muons in the detectors for the Large Electron–Positron collider at CERN. These included muon multiplicity studies and absolute differential muon spectra, both of which have been obtained with greater precision than was previously possible with detectors built for cosmic-ray studies.

Participants also heard about the latest generation of cosmic-ray detectors, with talks on Super-Kamiokande, the BAIKAL experiment, the Search for Light Magnetic Monopoles on Mount Chacaltaya in Bolivia, the AMANDA and IceCube detectors at the South Pole, the satellite-borne Cosmic Ray Energetics and Mass detector, and the planned 1 km^3 Neutrino Mediterranean Observatory.

Around 60 people attended the conference, which proved a successful opportunity for the participants to learn new physics, to interact with colleagues in other areas of elementary-particle physics and particle astrophysics – and also to enjoy Prague, with a trip to the nearby Konopiste Castle over the weekend and the conference banquet aboard a river cruise boat.

During the discussions at the meeting's final session, it was suggested that the topic of colliders and cosmic rays might appropriately become the theme of a biennial conference series. A probable site and time for the next conference is the Granlibakken Conference Center on Lake Tahoe, California, 25 February – 1 March 2007.

Further reading

The presentations of the speakers are available on the conference web pages at www.particle.cz/conferences/c2cr2005/prog.html. Proceedings will be published as a supplement issue of the *Czechoslovak Journal of Physics*.

Résumé

Des collisionneurs aux rayons cosmiques

Les premiers physiciens des hautes énergies avaient fait leurs armes dans le nucléaire et les rayons cosmiques, mais par la suite les liens se sont distendus entre leurs successeurs, utilisant aujourd'hui des accélérateurs, et les cosmiciens. Cependant, tout change à nouveau: les cosmiciens attendent de leurs collègues les meilleures données dont ils ont besoin sur la production et les interactions des particules, tandis qu'inversement ces derniers s'intéressent à l'exploration des phénomènes découverts dans l'étude des rayons cosmiques aux plus hautes énergies. La réunion C2CR de Prague a réuni les chercheurs des deux domaines pour discuter des derniers résultats et des problèmes communs aux uns et aux autres.

Lawrence Jones, *University of Michigan, and* **Jan Ridky**, *Institute of Physics of the Czech Academy of Sciences.*

HERMES looks for final pie

Having successfully fulfilled its mission to track down the quark contribution to the nucle

At the end of the 1980s, a major part of the nucleon's spin suddenly went missing. The European Muon Collaboration at CERN uncovered what has since been called the "spin puzzle" – the fact that the spins of the valence quarks that make up the nucleon account for only about 25–30% of the nucleon's spin. The finding was soon confirmed by second-generation experiments at CERN and SLAC. Designed to determine the total spin contribution of the quarks, however, they left several questions unanswered. If the quark spin contribution is so small, what then are the main contributions? What is the contribution of the different quark flavours? Is there a polarization in the quark sea that could account for the missing spin? In 1995, the HERMES experiment at DESY's HERA electron–proton collider in Hamburg took over the search, with the goal of finding an answer to just these questions.

In contrast to its predecessors, most of which could detect only the scattered electron and thus measure inclusive deep inelastic scattering (DIS) reactions, the HERMES collaboration took a new experimental approach. Its combination of a longitudinally polarized high-energy electron beam from the HERA storage ring incident on undiluted polarized atomic gas targets (see p30) is unique in the field, and its spectrometer is designed to identify all types of hadrons produced in coincidence with the scattered electron. Using such semi-inclusive DIS reactions on longitudinally polarized targets, the HERMES team achieved the world's first assumption-free flavour separation of the quark contributions to the nucleon spin, thereby slotting a major new piece into the nucleon-spin puzzle.

The results obtained from data taken during HERMES' first run (1995–2000) are the most precise information available so far on quark helicity distributions – the spin alignment of the quarks with respect to the nucleon spin – and they provide for the first time separate determinations of the polarizations of the up, down and strange sea quarks (figure 3, p28). They reveal that the largest contribution to the nucleon spin comes from the valence region, where the up quarks give a positive contribution as their spin is preferably aligned with the spin of the nucleon, while the down quarks give a contribution with opposite sign. The polarizations of the sea quarks are all consistent with zero – an especially important result.

The interpretation of the inclusive data from previous experiments was based on the assumption of SU(3) flavour symmetry – the postulation that all flavours of quark, including up, down and the virtual strange quarks, behave in the same way dynamically inside the nucleon despite the substantially greater mass of the strange quark. The older analyses therefore led to the conclusion that the strange quarks play a significant, cancelling, role in the nucleon spin, even though their existence there is fleeting. The HERMES results now show that the polarizations of the sea quarks are all small: there is thus little evidence for such a "cancellation" between the contributions of valence and sea quarks. In particular, there is no evidence in the measured range in x, the momentum fraction carried by the

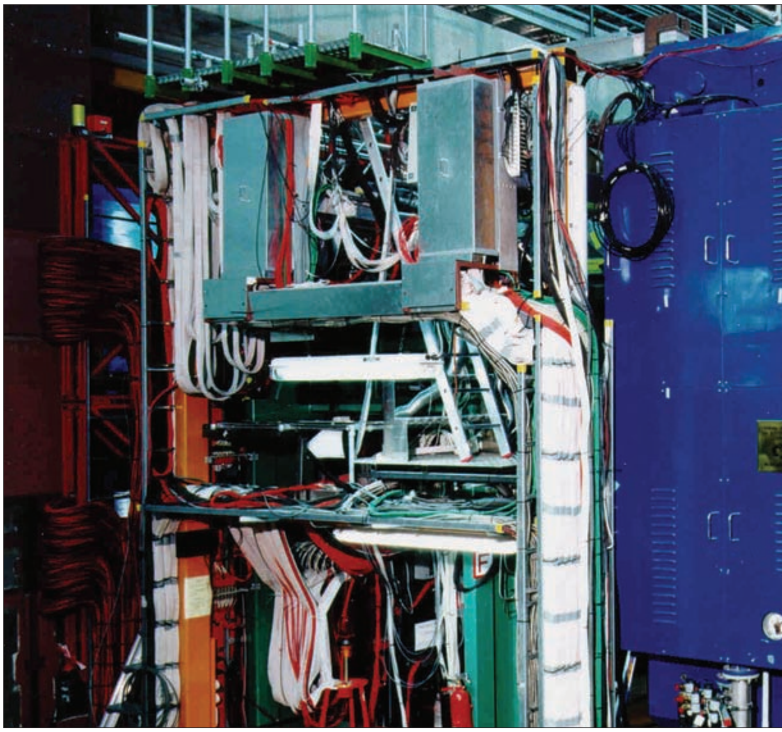


Fig. 1. The HERMES spectrometer at DESY's HERA collider uses the storag investigate how the different building blocks of the nucleon contribute to its

quarks, that the contribution of the strange quarks is negative, as was indicated by the model-dependent analysis.

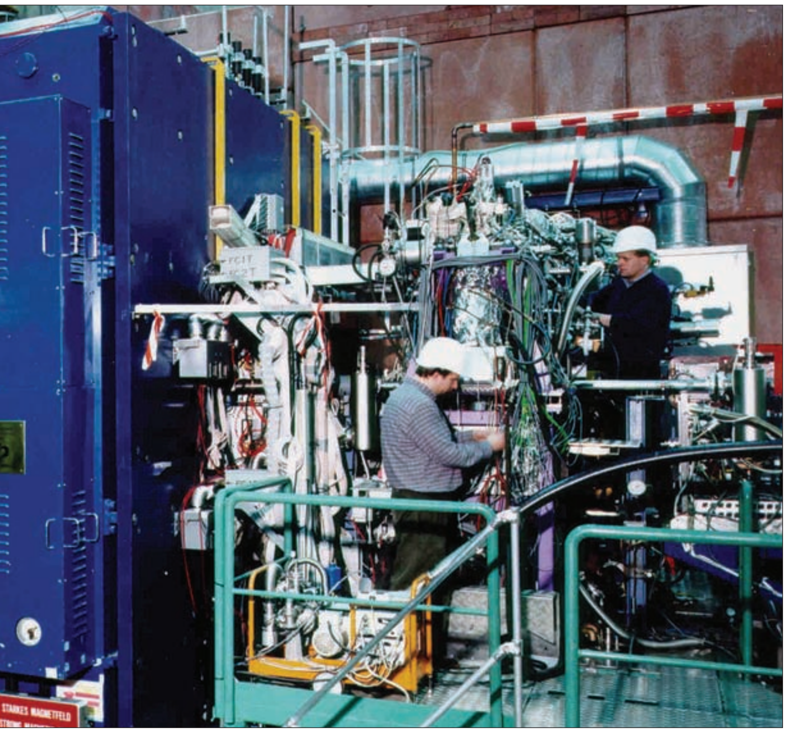
Taken together, all these measurements definitely show that the spin of the quarks generates less than half of the spin of the nucleon, and that the quark spins that do contribute come almost exclusively from the valence quarks. The proton-spin puzzle thus continues to evolve and the contributions of the orbital angular momenta of the quarks, as well as the spins and orbital angular momenta of the gluons, are now expected to be important.

The HERMES team has already reported the first evidence that the gluon polarization could make a positive contribution to the nucleon spin and new results will follow soon. The gluon polarization is also currently being investigated in the COMPASS experiment at CERN and at the Relativistic Heavy Ion Collider at the Brookhaven National Laboratory. As recent theoretical insights have shown, the orbital angular momentum can in principle be probed by hard exclusive processes leaving the target nucleon intact – a field that HERMES is now exploring in detail during its ongoing second run, which will last until summer 2007.

During HERMES' first run, the emphasis was on the determination of the helicity structure of the nucleon using longitudinally polarized targets and beam. For HERA Run II, the collaboration has

ces in nucleon-spin puzzle

n's spin, HERMES now aims at providing an even more complete picture of nucleon spin.



ring's polarized electron beam incident on a polarized gas target to overall spin. (Courtesy DESY, Hamburg.)

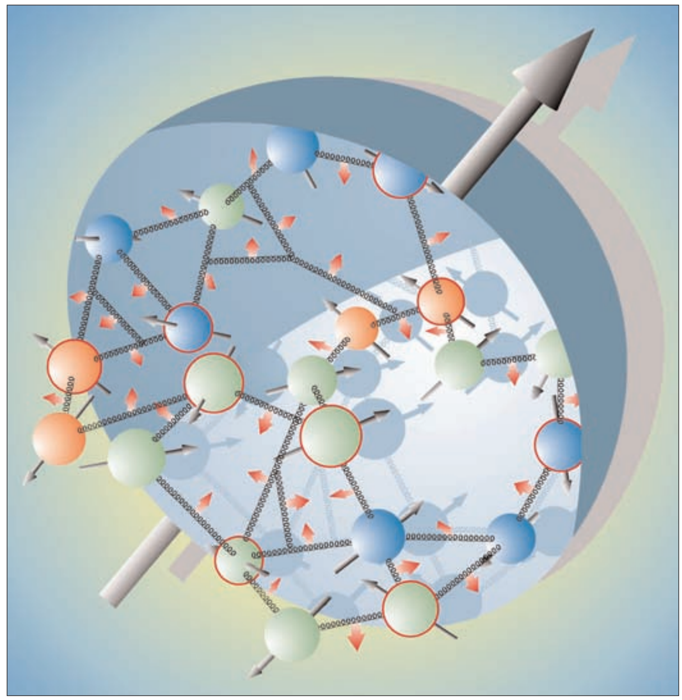


Fig. 2. In addition to the three valence quarks, the nucleon contains a sea of quarks and antiquarks and gluons, all of which contribute to the nucleon's spin.

turned its attention to transversely polarized targets (i.e. with polarizations perpendicular to the electron beam direction) to extract the so-called transversity distribution – the last unknown leading-twist quark distribution function of the nucleon.

Probing transversity

Phenomenologically, the nucleon can be characterized in terms of parton distribution functions that describe how often the constituents of the nucleon will be found in a certain state. Within this framework, there are three fundamental quark distributions: the quark number density, which has been measured with very high precision, for example with the HERA collider experiments H1 and ZEUS; the helicity distribution, which was the main result of the HERMES run on longitudinally polarized targets; and the transversity distribution, which describes the difference in the probabilities to find quarks in a transversely polarized nucleon with their spin aligned to the spin of the nucleon and quarks with their spin anti-aligned.

In absence of relativistic effects, the transversity and helicity distributions should be the same. A difference between the two distributions would therefore be a measure of the extent to which relativistic effects have to be considered in the description of the nucleon.

Transversity has remained unmeasured so far because it is odd under chirality transformations, whereas hard interactions conserve chirality (they are chiral even). However, it may be probed by a process involving some additional chiral-odd structure (*CERN Courier* October 2004 p51). In semi-inclusive DIS, as done at HERMES, this could be a chiral–odd fragmentation function. The so-called Collins fragmentation function is the most prominent candidate, as this gives rise to an asymmetry in the angular distribution of the hadrons produced during the scattering process if they are generated from a transversely polarized quark. Results from the BELLE collaboration at KEK suggest that the Collins function has a substantial magnitude, and thus measurements of single-spin asymmetries in semi-inclusive DIS employing transverse target polarization are expected to constrain transversity itself.

There is even more to explore, however. Using a transversely polarized target one can also study a new class of more complex distribution functions that depend not only on the longitudinal momentum fraction carried by the quarks, but also on their transverse momentum inside the nucleon. One such function is the so-called Sivers distribution function, which describes an asymmetry in the distribution of unpolarized quarks in a transversely polarized nucleon.

The Sivers function generates transverse single-spin asymmetries. As such it is a so-called T–odd distribution function. The time- ▷

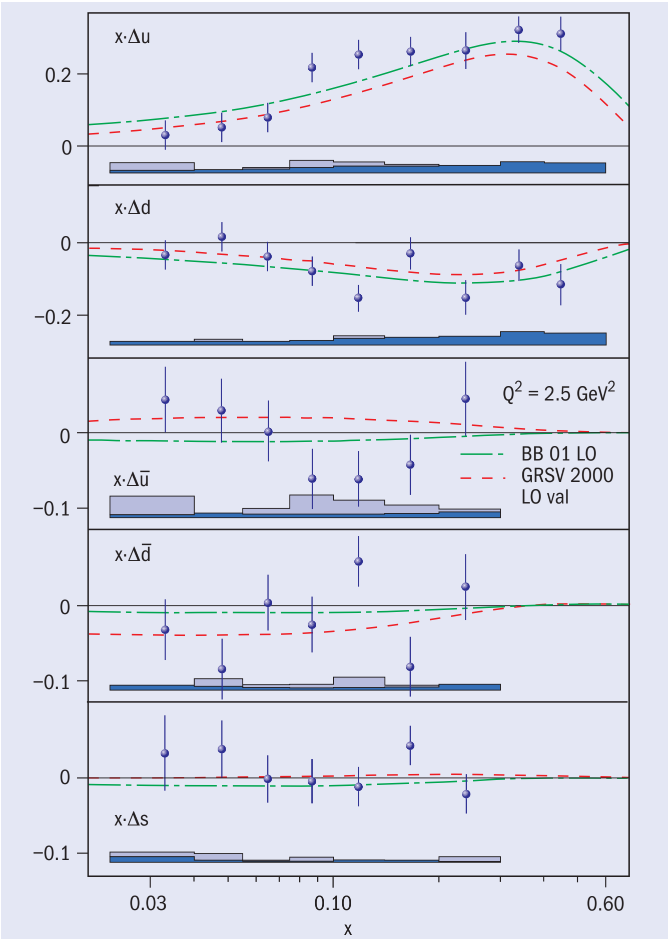


Fig.3. During its first run, HERMES gathered the most precise information on quark helicity distributions available so far, and provided the first separate determinations of the polarizations of the up, down and strange sea quarks. The quark helicity distributions shown here are evaluated at a common value of Q^2=2.5 GeV^2 as a function of x and compared with different parametrizations. The data reveal that while the spins of the up valence quarks point in the same direction as the overall nucleon spin, the down valence quarks carry a spin pointing in the opposite direction. The polarizations of the sea quarks are all consistent with zero (Airapetian et al. *2005a).*

reversal symmetry properties of quantum chromodynamics should therefore forbid its existence, or so it was believed for a long time. Only recently has it become clear that there are loopholes in the theory, for example, missing gauge links in the description of nucleon structure, which permit such T–odd distribution functions. The study of the Sivers function is thus doubly interesting. On one hand, it may be used to test the validity of these theoretical considerations, and may lead to a better understanding of results from hadron–hadron collision experiments where large but unexplained transverse single-spin asymmetries have been observed. On the other hand, the Sivers function must vanish in the absence of quark orbital angular momentum. A measurement of the Sivers function may thus provide important constraints on this missing piece in the nucleon-spin puzzle.

The measurement both of transversity and of the Sivers function can be carried out using semi-inclusive DIS events. By reversing the spin direction of the nucleon, one can study the dependence of the preferred direction of the outgoing hadron on the nucleon's spin direction. After its first year of data-taking with a transversely polarized target, HERMES has observed enough scattering events of this kind to venture a worldwide first look at these angular dependencies (figure 4).

One striking result is the comparably large signal for the π^- Collins effect. This came as quite a surprise, since a behaviour similar to that seen with a longitudinally polarized target had been expected, namely a signal that is larger in size for the π^+ than for the π^-. This result will have important consequences for understanding how the hadron is formed from the struck quark. Currently the statistical significance is insufficient to make definite statements about the exact behaviour of the involved functions. However, since the Collins asymmetries are clearly non-vanishing, the HERMES team has good reason to hope that the data collected in 2005, which are more than doubling the statistics taken in the years before, will indeed allow them to achieve a first measurement of transversity using the information on the Collins fragmentation function collected by BELLE.

An equally interesting result is the observation that for the π^+ the signal for the Sivers function is significantly positive. This is the first confirmation that the Sivers function is indeed non-zero and thus some first evidence for a non-vanishing T–odd parton distribution function. More data on the Sivers asymmetries from HERMES up to November 2005 should allow an extraction of the Sivers function for up and down quarks.

Exclusive reactions

The contributions of the orbital angular momenta of quarks and gluons are the last unknown pieces in the puzzle of the spin content of the nucleon; how to determine them has been hotly debated for several years. In the middle of the 1990s, it was realized that the framework of generalized parton distributions (GPDs) might give access to these orbital angular momentum contributions. Quite apart from that, the study of these off-forward extensions of the standard parton distribution functions can provide a wealth of new information on the structure of the nucleons.

The GPDs can be determined in exclusive reactions – scattering processes in which the target nucleon does not fragment but instead remains in its ground state, or close to it. The various scattering reactions provide access to different GPDs: exclusive vector-meson production allows the determination of unpolarized GPDs, whereas the exclusive production of pseudoscalar mesons can be used to measure the polarized GPDs. Because of the multidimensional structure of the GPDs, it is essential to study as many different processes as possible to be able to disentangle the functions from the measured observables. In particular, measurements with the transversely polarized target at HERMES are sensitive to the two main GPDs (H and E) necessary to determine J_q, the total orbital angular momentum of quarks in the nucleon.

The cleanest example of a reaction that provides direct access to GPDs is deeply virtual Compton scattering (DVCS), an exclusive reaction in which a real photon is created. This type of reaction was identified for the first time in 2001 by the H1, ZEUS and HERMES experiments at DESY, and the CEBAF Large Angle Spectrometer in Hall B at Jefferson Lab. Since then, a large body of data has been collected on DVCS. Here, HERMES is in a rather fortunate position. Despite the DVCS cross-section being usually much lower than that

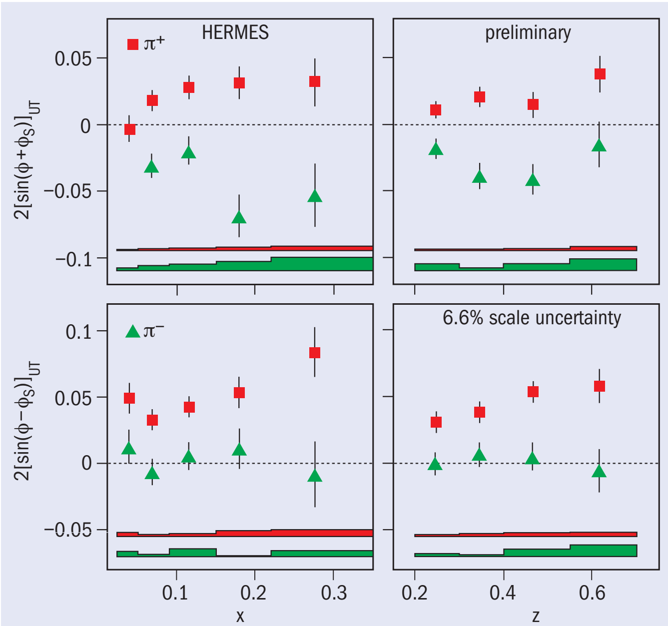


Fig. 4. Collins (top) and Sivers (bottom) asymmetry amplitudes for positive and negative pions as functions of the Bjorken scaling variable x and the energy fraction z of the pion. These asymmetries show for the first time that the Collins function is indeed non-zero. The π^- Collins effect is unexpectedly large, which will have important consequences for understanding how the hadron is formed from the struck quark. The positive π^+ Sivers signal is the first evidence for a non-vanishing T–odd parton distribution function (Airapetian et al. *2005b).*

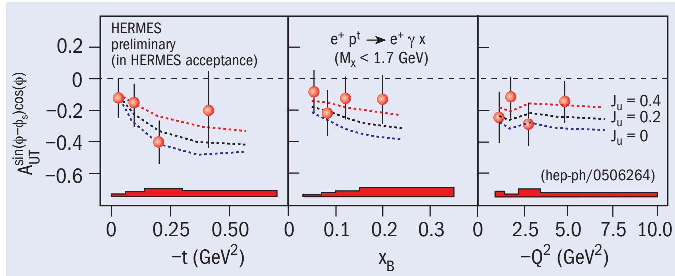


Fig.5. HERMES recently provided the first model-dependent determination of the total angular momentum J_u of the up quark by interpreting the measured amplitudes of the transverse target-spin asymmetry associated with deeply virtual Compton scattering. These are shown here compared with predictions from a model for generalized parton distributions using various total angular momenta J_u for the up quark, while fixing the total angular momentum for the down quark $J_d = 0$ (Ye 2005).

of an indistinguishable process – the Bethe–Heitler process – with identical final state, the interference term between the processes allows the study of DVCS because it leads to observable asymmetries in the azimuthal angular dependence of the real photons produced from the nucleon. As HERMES can measure all azimuthal asymmetries involving polarized beams and/or polarized targets and different charges, the collaboration was able to determine the DVCS target-spin asymmetry by using an unpolarized beam incident on a transversely polarized target. This asymmetry is sensitive to the GPD E and thus allowed HERMES to realise the first model-dependent extraction of J_u, the total angular momentum of the up quark (figure 5).

To study these asymmetries in even more detail, the HERMES collaboration decided to run during its final phase from 2006 to 2007 with a new recoil detector in combination with an unpolarized target. The device will employ silicon detectors and scintillating fibre trackers as well as a detector to measure photons. It will sit closely around the target and detect the slow-moving recoil proton in coincidence with the electron and the photon, thus ensuring full exclusivity of the data sample.

The enhanced selectivity of these measurements will provide a unique opportunity to assess the promise of GPDs as the next step in understanding the spin structure of the nucleon. In particular, data taken with this new detector will put serious constraints on the GPD H. In combination with the already existing DVCS data and measurements of the only other known reaction to access the GPD E on a proton target – the elastic electroproduction of ρ^0 vector mesons with the proton being transversely polarized, already measured at HERMES (2002–2005) – these forthcoming results will eventually allow an extraction of the total angular momentum of the up quark in the nucleon through the remaining GPD models.

In addition to these studies on polarized targets, the physics programme at HERMES also includes a great variety of other points of interest, such as measurements of unpolarized DIS events. These allow the collaboration to search for pentaquark exotic baryon states, give insight into quark propagation in nuclear matter and quark fragmentation, and provide a rigorous test of factorization. DESY's HERA accelerator will continue operations through to summer 2007. Every effort is being made at HERMES to maximize the impact of the remaining beam time, with the goal of fitting in as many pieces of the nucleon-spin puzzle as possible.

Further reading

The HERMES website is at www-hermes.desy.de.
A Airapetian *et al.* 2005a *Phys. Rev D* **71** 012003.
A Airapetian *et al.* 2005b *Phys. Rev. Lett.* **94** 012002.
Z Ye 2005 http://arXiv.org/abs/hep-ex/0512010; to appear in the proceedings of the International Europhysics Conference on High Energy Physics, 21–27 July 2005, Lisboa, Portugal.

Résumé

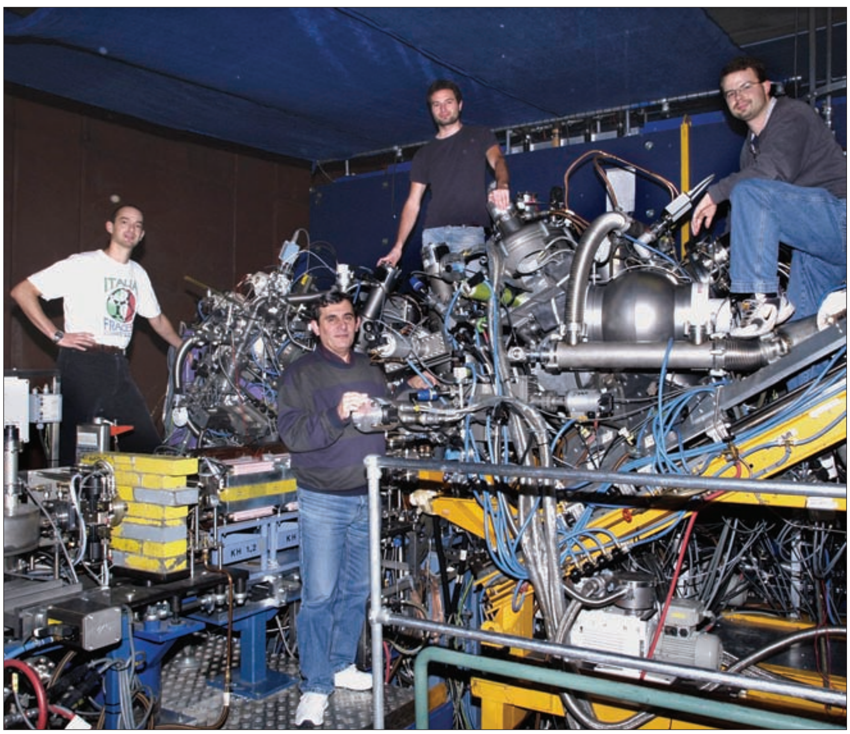
HERMES vise à compléter le puzzle du spin du nucléon

Les quarks de valence ne contribuent qu'à hauteur de 25 à 30% au spin du nucléon, ce qui constitue l'une des grandes énigmes de la physique des particules. L'expérience HERMES a été conçue pour étudier ce problème à l'aide d'un faisceau d'électrons de haute énergie, longitudinalement polarisé et stocké dans un anneau d'HERA, qui vient frapper des cibles denses de gaz atomique polarisé. Dans ces conditions inédites, HERMES a montré que la contribution des spins des quarks de la mer est minime. Par contre, de premières preuves apparaissent sur l'importance des spins des gluons, tandis que les études en cours dans HERMES portent sur la contribution du moment cinétique orbital.

Elke Aschenauer *and* **Ilka Flegel***, DESY.*

The HERMES gas target: 10 years on

Erhard Steffens describes the various phases in a successful decade of operation of the HERMES gas target, which may live on with future use for antiproton polarization.



Preparations for lifting the target out of the HERMES detector. The target was removed in November 2005 after a decade of operation.

Over the past decade, the HERMES experiment at HERA, DESY, has successfully explored the spin structure of the nucleon. Unlike the H1 and ZEUS experiments, which detect collisions between electron and protons travelling in opposite directions in beams stored in HERA, HERMES has scattered HERA's 27.5 GeV polarized electron beam off polarized nucleons at rest in a sophisticated target cell of polarized hydrogen or deuterium gas. This target, which has run throughout the decade, has been a key to the experiment's success.

To achieve its goals, the design of the target had to overcome three major challenges. These were to develop a gas target of high polarization with unequalled areal density; to measure its electron and nuclear polarization online to a precision of 3%; and to operate a target over long periods in the environment of a high-energy storage ring, without affecting the operation of the collider experiments too much.

Meeting the challenges

The first challenge dates back to the design achieved while preparing a proposal for the FILTEX experiment, which was submitted to CERN in 1985. The idea was that antiprotons circulating in the Low Energy Antiproton Ring at CERN were to be polarized by spin-dependent attenuation of the beam, a process known as spin-filtering. To achieve a reasonable build-up time of around 10 hours, this required a hydrogen filter target with high polarization, $P \sim 1$, and an areal density, $t = 10^{14}$ atoms/cm^2. These figures represent a benchmark that still holds today. For a deep inelastic scattering (DIS) experiment in a high-energy electron ring, luminosity in the order of 10^{31}/cm^2 is needed; for a 30 mA electron current, this requires target figures comparable to those in the FILTEX proposal. However, the densities of gas-jet targets available in the 1980s were a few 10^{11}/cm^2, and the most dense thermal atomic-beam target recently developed has been for the Relativistic Heavy Ion Collider at Brookhaven with a density of $(1.3\pm0.2)\times10^{12}$/cm^2 (*CERN Courier* October 2005 p15).

The areal density of a polarized jet can be boosted by a factor of around 100 by using a storage cell or vessel, as Willy Haeberli of the University of Wisconsin proposed in 1965. Figure 1 illustrates this principle. Polarized atoms enter the T-shaped storage cell ballistically, without hitting the walls, via a narrow feed tube. On their way out, they perform many collisions with the walls (~300) resulting in an increase of the gas density.

In the 1980s and early 1990s, high-intensity atomic-beam sources and radiation-resistant coatings for the cell walls were developed, and the first test of a high-density storage-cell target in

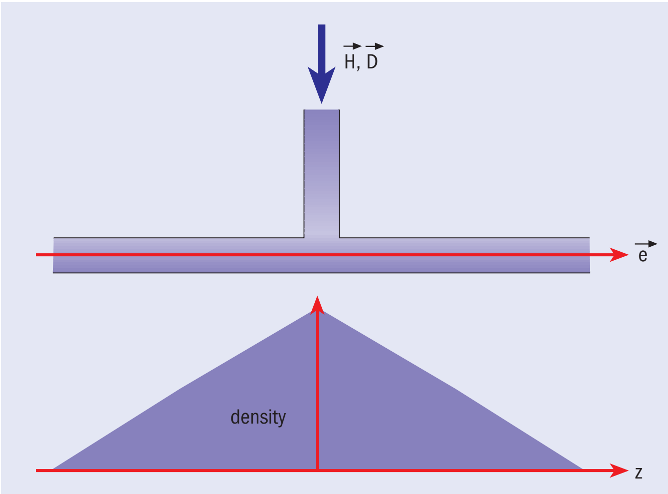


Fig. 1. The principle of the HERMES storage-cell target. Polarized atoms enter the T-shaped storage cell via a narrow feed tube. On their way out, they undergo many collisions with the wall, leading to the compression of the gas (Steffens and Haeberli 2003).

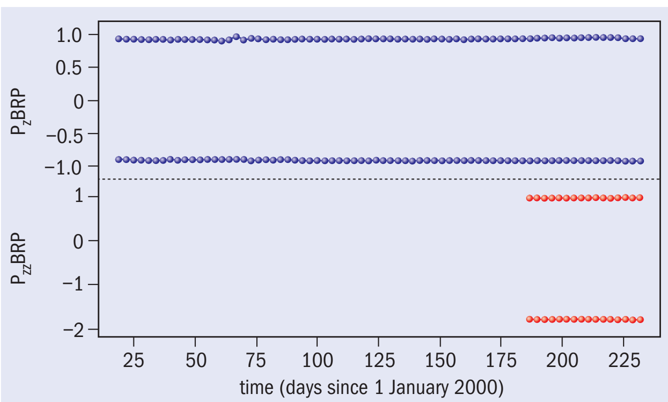


Fig. 2. The high-quality data from the Breit–Rabi–Polarimeter (BRP) for deuterium polarization during the run in 2000 demonstrates the stable performance of the HERMES target.

a storage ring was performed in 1992 in the Heidelberg Heavy-Ion Test Storage Ring. This had a target density $t = (0.96\pm0.04) \times 10^{14}$ atoms/cm^2 and a measured polarization $P = 0.46\pm0.01$ in a low magnetic field, which was expected to double in a strong guide field (Zapfe *et al.* 1996).

During the same period, the use of a polarized storage cell target for DIS experiments was being discussed. A first letter of intent to DESY dates back to 1988 and in 1990 the HERMES collaboration submitted a proposal for the study of the nucleon's spin structure. After the successful target tests and encouraging results on the electron polarization, HERMES was approved in 1992 and constructed during the following two years. For the commissioning run in 1995, an optically pumped ^{3}He target was operated to study the neutron-spin structure (de Schepper *et al*. 1998). Then in 1996, the hydrogen target set-up was installed. The elliptical, 40 cm long storage cell operating at 100 K was protected by a narrow tungsten collimator – the "bottleneck" of the HERA electron ring.

The challenge of a precise polarization measurement independent of the stored beam was met by using a polarimeter that measured the complete substate population of a sample beam extracted from the centre of the cell. This made possible the precise online determination of the target parameters, i.e. the polarization of protons and electrons, P_z and P_e, respectively, and the fraction of molecules, which for a high-quality surface was at most a few percent. One of the potentially harmful effects is RF depolarization caused by harmonics of the HERA bunch frequency of 10.4 MHz, so a strong guide field was carefully chosen to avoid resonances. With all these precautions, stable operation with longitudinally polarized hydrogen was obtained, leading to high-quality data on the proton-spin structure.

In 1998, the target was converted to one of longitudinally polarized deuterium with nuclear spin one. This allowed not only vector polarization P_z but also second-rank tensor polarization P_{zz} to be produced. The latter is related to the structure function b_1 of the deuteron, which HERMES measured for the first time. Owing to the low magnetic moment of the deuteron, decoupling of nuclear and electron spin at the guide field of 0.33 T was nearly complete, resulting in close to ideal performance, i.e. no detectable depolarization by the cell walls. In addition, recombination to molecules was also negligible. The experiment collected a large data sample of high-quality deuterium data, in particular during the successful run in 2000. The extremely stable target performance during this run is shown in figure 2.

For the next phase, from 2001 to 2005, a transversely polarized hydrogen target was required to study transversity, the last missing leading-twist structure function of the nucleon (see p26). For this purpose, a dipole magnet with a large gap and high uniformity was developed with a field limited to 300 mT. This resulted in acceptable synchrotron radiation power levels and high target polarization.

All the running with the polarized target at HERMES was performed in parallel with the operation of the collider detectors H1 and ZEUS. The areal density achieved with the storage-cell target was only about an eighth of the density allowed before it would adversely affect the stored electron beam. There were also special studies using unpolarized gas such as H_2, D_2, He, N_2, Ne, Ar, Kr and Xe in the target cell. In this case the density was chosen according to the maximum allowed reduction of the electron-beam lifetime, yielding higher statistics relative to running with the polarized target. In additional special end-of-fill runs, when the collider experiments were switched off, the remaining beam of 12–15 mA was consumed within about an hour at extra-high densities, yielding high statistics data samples with little extra time.

End of an era

In the course of running the HERMES experiment, the physics interest has moved from semi-inclusive to exclusive measurements, such as deeply virtual Compton scattering). Clean exclusive measurements require the detection of recoil particles, e.g. the proton. However, a recoil detector turned out to be incompatible with the polarized storage cell. Therefore, the HERMES collaboration decided to run during the final phase from 2006 to 2007 with a recoil detector in addition to the standard forward spectrometer and an unpolarized high-density, very compact storage-cell target. On 13 November 2005 polarized running ended and the target was removed. Commissioning of the recoil detector to replace the target set-up began in February 2006. ▷

The removal of the target marks the end of a very fruitful era extending over 20 years. Groups from Beijing, Erlangen, Ferrara, Heidelberg, Liverpool, Marburg, Munich, Wisconsin, Yerevan and elsewhere have contributed to the target's outstanding performance and stability. In this way, the original idea for FILTEX, which led to the HERMES target, has enabled 20 years later a wealth of new results on nucleon-spin structure. Fortunately, after ten years of operation in HERA, there is a good chance that the present target may serve future experiments. The project for the Facility for Antiproton and Ion Research (FAIR) at GSI, Darmstadt, with its planned antiproton source, has again stimulated interest in using spin filtering to produce polarized stored beams of antiprotons, this time for measurements by the Polarized Antiproton Experiments (PAX) at the facility's High Energy Storage Ring. Tests with protons and antiprotons in preparation for PAX are foreseen at Forschungszentrum Jülich and CERN. The HERMES target may thus play a key role in paving the way for a new experiment at FAIR, aimed at studying hadron structure in the interaction of polarized protons with polarized antiprotons.

● The contribution of numerous students, postdocs, senior scientists and technicians to the unprecedented performance of the HERMES target is gratefully acknowledged. Special thanks are owed to my colleagues G Court, P Dalpiaz-Ferretti, D Fick, G Graw, W Haeberli, B Povh, and K Rith; to P Lenisa, the target coordinator from 2000 to 2005; to the funding agencies, in particular the Bundesministerium für Bildung und Forschung in Germany and INFN in Italy; and to the HERMES and DESY management.

Further reading

The operation and performance of the hydrogen and deuterium target over the full running period are summarized in a paper (Airapetian *et al.* 2005) in which many additional references can be found. For more about the PAX experiment see www.fz-juelich.de/ikp/pax.

A Airapetian *et al.* 2005 *Nucl. Instr. Meth. A* **540** 68.
D De Schepper *et al.* 1998 *Nucl. Instr. Meth. A* **419** 16.
E Steffens and W Haeberli 2003 *Rep. Progr. Phys.* **66** 1887.
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Résumé

La cible gazeuse d'HERMES: une décennie de protons polarisés

Depuis 10 ans, l'expérience HERMES au collisionneur HERA explore avec succès la structure en spin du nucléon. Mais, contrairement aux expériences H1 et ZEUS qui détectent les collisions frontales des électrons avec des protons dans HERA, il s'agit dans le cas d'HERMES de diffuser le faisceau d'électrons polarisés d'HERA par le gaz d'hydrogène ou de deutérium polarisé d'une cellule-cible perfectionnée. Cette cible, utilisée durant toute la décennie, a été la clé du succès de l'expérience. Actuellement, les études dans HERMES continuent avec une cible non polarisée, mais la cible polarisée pourrait connaître une seconde carrière dans des expériences avec des antiprotons polarisés.

Erhard Steffens, *University of Erlangen-Nürnberg.*

Nucleon form factors stride into the future

At a three-day meeting at Frascati, physicists from around the world met to discuss the implications of striking new results on the nucleon space-like and time-like form factors.

Form factors are the most fundamental dynamical quantities for describing the inner properties of a composite particle. The nucleon form factors provide detailed information about the spatial distribution of charges and currents in the nucleon.

They are directly accessible from experiment by differential cross-section and polarization observables and from theory by all nucleon models as they enter explicitly in the expression of the hadronic current. On 12–14 October 2005 the first workshop specifically dedicated to a global view on electromagnetic hadron form factors in both space-like and time-like regions was held at the INFN-Laboratori Nazionali di Frascati (LNF). The N'05 Workshop on Nucleon Form factors attracted 85 participants from 18 countries. Forty-five talks, followed by animated discussions during breaks and dinners covered the most recent findings, ideas and suggestions for future developments in experiments and theory.

Umberto Boccioni's striding figure, Unique Form of Continuity in Space *(1913), which represents the interaction of a moving object with the surrounding space, was chosen to represent the spirit of N'05, the first global workshop on nucleon form factors. The bronze statue measures 126.4 × 89 × 40.6 cm and can be seen in the Museum of Modern Art, New York. (Courtesy Claudio Federici, INFN Frascati.)*

After the opening welcome from Mario Calvetti, director of the LNF, Antonino Zichichi of Bologna and CERN presented a vivid historical introduction to the topic of electromagnetic form factors. He recalled his first measurements at CERN in 1963, and underlined the role played by Frascati in the field, in particular for time-like neutron form factors, where the only existing data were collected by the FENICE collaboration at the end of 1980s. He also discussed the role that Frascati could and should play in the future.

The experimental evidence, that form factors are twice as large in the time-like region as in the space-like region and that time-like neutron form factors are much larger than time-like proton form factors, could be owing to a possible $N\bar{N}$ resonance below threshold. Discovering and studying the properties of this resonance through dedicated and precise measurements in the threshold region would be an important step in understanding nucleon structure and nucleon spectroscopy. In Zichichi's opinion, this is one of the 10 most compelling problems in high-energy physics, which he listed in his impressive review. Dan Olof Riska of Helsinki underlined the importance of precise data on all hadron form factors – transition, axial, and strange. He drew particular attention to the role of two-photon exchange in solving the discrepancy among electric proton form-factor data, and the importance of the pion cloud in the nucleon structure.

The first session following the overview was dedicated to the current status of the research programmes at Jefferson Lab, the Bates Linear Accelerator at the Massachusetts Institute of Technology and at the Mainz Microtron. Presentations paid special attention to the discrepancies among the recent precise measurements of the electric proton form factor at large values of momentum-transfer squared, Q^2, whether measured ▷

through the recoil proton-polarization method or via the unpolarized differential cross-section in elastic electron–proton scattering. Polarization measurements have been implemented only recently, after the advent of high-luminosity polarized-electron beams and the development of hadron polarimeters and polarized targets. The surprising feature revealed by the polarization experiments, which are far more sensitive to the small electric contribution, is that the electric and magnetic distributions inside the proton are different, contrary to what was previously assumed and suggested by results from experiments based on the unpolarized method.

A discussion between Antonino Zichichi (left), Enzo De Sanctis (centre) and Evgeni Solodov at the N'05 meeting at LNF (Courtesy Roberto Baldini, INFN Frascati.)

The search for a solution to this problem focuses on radiative corrections, particularly on the possibility of a mechanism where momentum is not transferred by only one photon, as generally assumed, but equally shared by two photons. This would change the angular dependence of the cross-section, and, at least qualitatively, provide a better agreement between the two sets of data. The presence of such a mechanism would make life much more complicated in all electron-induced reactions, and would call for a revision of many other sets of data. Two-photon exchange induces complex amplitudes, which should be mostly imaginary. A non-zero, but small imaginary part has been found in very precise measurements on parity violating terms, as Frank Maas of Mainz described, but no experimental evidence confirms the presence of the two-photon mechanism (real part) in the present data. Therefore, theoretical and experimental efforts continue and the question remains open. Such a mechanism should be more evident in the time-like region, where form factors are complex, and could be an interesting topic for the future at Frascati, with the DAFNE storage ring upgraded in energy.

Into the time-like region

The experimental situation in the time-like region was clearly described by Diego Bettoni of Ferrara, who pointed out that until now no separation of the electric and magnetic form factors has been possible, owing to the lack of statistics. He also drew attention to the importance of a precise measurement of the neutron form factors as well as of the relative phase of form factors and the role of the possible narrow resonance below threshold. Note that the Rosenbluth separation technique in the space-like region implies measurements at fixed Q^2, which requires changing both the energy of the electron beam and the scattering angle of the emitted electron, whereas, in the time-like region, it requires a precise angular distribution of the emitted nucleon (or antinucleon) while keeping the beam conditions unchanged.

Form factors have been recently accessed from initial state radiation at the BaBar experiment at SLAC. The results, presented by Vladimir Druzhinin and Evgeni Solodov of Novosibirsk, are impressive and raise new questions about the ratio of the electric and magnetic form factors, G_E/G_M, near threshold. Contrary to measurements at CERN's Low Energy Antiproton Ring, the new results show that G_E/G_M increases quickly and also reveal unexpected evidence for a step-like behaviour of the proton time-like form factor, at threshold, around 2.2 GeV and around 2.9 GeV.

Stanislav Dubnicka of Bratislava presented model-independent properties of polarization observables in the time-like region. The extension of this formalism has recently been derived for scattering and annihilation channels in the presence of two-photon exchange and was presented for proton–antiproton annihilation into two leptons by Gennady Gakh of Kharkov.

The strange and axial nucleon form factors are strongly related to the electromagnetic form factors, and their extraction from experimental observables is largely influenced by our knowledge of these quantities, thanks to the impressive precision that experiments have achieved. The first data from the G0 experiment at Jefferson Lab were presented during a review of current experiments on parity violation by Serge Kox of Grenoble. The precision of the measurement of the asymmetry in electron–proton unpolarized scattering – around 10^{-6} (parts per million) – is impressive, and the combined result is surprising, as it suggests a large and positive strange-proton form factor (*CERN Courier* October 2005 p19).

Theory and outlook

The session devoted to theory covered various nucleon models. Mauro Giannini of Genova and Gottfried Holzwarth of Siegen, for example, underlined the role of relativistic corrections in the constituent quark model, and in the soliton model, respectively. A global description of the four nucleon form factors in the space-like and time-like regions can be obtained by vector-dominance models and also through dispersion relations, which can be analytically continued to the time-like region. Simone Pacetti of Frascati presented an original approach based on an extrapolation from the time-like region of dispersion-relation requirements. This showed that BaBar data would constrain a zero of G_E/G_M in the space-like region.

Form factors are intimately related to other quantities describing the nucleon. For example, they provide a boundary for generalized parton distributions (GPDs), which are supposed to give a global, 3D picture of the nucleon. The connections with this important subject were discussed in a dedicated session. Recent results on real, virtual and deeply virtual Compton scattering (DVCS) show in particular that single-spin observables are very promising for selecting DVCS and describing the nucleon from GPDs. Nucleon polarizabilities, interpreted in the context of dispersion relations, also show evidence for a pion cloud. Peter Kroll of Wuppertal presented a first attempt to extract the GPDs from form-factor data from Jefferson Lab. A correlation with time-odd GPDs and a test of time-reversal invariance in electromagnetic interactions would be possible with a future energy upgrade of the DAFNE linac.

Looking to the future, plans for the Facility for Antiproton and Ion Research at GSI will allow precision form-factor measurements and access their phase, in particular in the region of large momentum-transfer. The PANDA experiment will allow proton time-like form factors to be measured individually and PAX will focus on polarized measurements. At the Budker Institute for Nuclear Physics in Novosibirsk, a measurement is planned at the existing linac of the two-photon contributions in electron/positron–proton scattering. An exploration of the proton form factor very near threshold is also foreseen at the new electron–positron collider, VEPP-2000. The meeting also heard about the future programme for BESIII, together with first results in the threshold region from the Bejing Electron–Positron Collider.

The project for a complete measurement of the nucleon form factors in the time-like region at Frascati with the upgraded DAFNE storage-ring, which has already triggered a great deal of interest within the community, was presented by Marco Mirazita of Frascati. An upgrade in luminosity and energy of the machine would provide a unique tool for measuring individual nucleon form factors, in particular for the neutron. The additional possibility of measuring the polarization of the outgoing nucleon would provide the first determination of the relative phase of the form factors, in addition to their moduli.

Stan Brodsky of SLAC concluded the meeting with a talk in which he stressed the importance of the high-momentum behaviour of form factors as a fundamental test of scaling in perturbative quantum chromodynamics (QCD), helicity structure and asymptotic freedom. He also showed the potentiality of a formalism based on duality between string theory in anti-de Sitter space and conformal field theory, which should provide a direct connection between QCD and nucleon amplitudes.

● N'05 was financially supported by Istituto Nazionale di Fisica Nucleare, the Hadron Physics Integrated Infrastructure Initiative and the US Department of Energy's Jefferson Lab. For the full programme and the complete list of speakers see www.lnf.infn.it/conference/nucleon05.

Résumé

Les facteurs de forme vers un brillant avenir

Les facteurs de forme sont les quantités dynamiques les plus importantes pour décrire les propriétés internes des particules composées. Dans le cas d'un nucléon, ils apportent des informations détaillées sur la distribution spatiale de ses charges et courants internes. En octobre 2005, s'est tenu à Frascati le premier atelier spécifiquement consacré à une vue d'ensemble des facteurs de forme électromagnétiques du hadron dans les régions de genre temps et de genre espace. 45 exposés, suivis de discussions animées, ont traité des résultats les plus récents et des idées ou suggestions pour le développement futur des expériences et de la théorie.

Alessandra Fantoni, *INFN Frascati, and* **Egle Tomasi-Gustafsson**, *CEA Saclay.*

APPOINTMENTS

KEK welcomes new director-general

Atsuto Suzuki, vice-president of Tohoku University, has been selected to be the next director-general of KEK, the Japanese high-energy accelerator-research organization. He he takes over from Yoji Totsuka and will serve for three years, beginning on 1 April.

Suzuki has been involved in underground neutrino experiments at the Kamioka Observatory in Gifu province for almost 25 years. Now he is moving into the world of particle-accelerator science, with an exciting future ahead at KEK. In the coming years, the organization will play leading roles in particle, nuclear and material science.

The construction of the Japan Proton Accelerator Research Complex at Tokai, with its high intensity 50 GeV proton synchrotron, will be completed in 2008 and experiments will begin. As the central institute in Asia, KEK will also make vital contributions to the design and technical efforts for the proposed International Linear Collider. At the same time, KEKB, the B-meson factory at Tsukuba, will be expected to provide more new physics with the highest luminosity in the world. The design of a new photon factory based on an energy-recovery linac will also be undertaken soon.

Atsuto Suzuki begins his three-year term as director-general of KEK on 1 April.

"To guide this unique laboratory during the critical years ahead is extremely challenging," says Suzuki, "and I will do my best to overcome any difficulties we encounter. In realizing the programmes mentioned above it is essential to make international collaborations from both experimental and financial points of view. I would like to open these discussions to the world's high-energy physics laboratories."

DUBNA

JINR council gets ready for jubilee

The 99th session of the Scientific Council of the Joint Institute for Nuclear Research (JINR), Dubna, was held on 19–20 January, presided over by the new director, Alexei Sissakian. The issues discussed included the draft of the JINR strategic development plan, scientific results from the institute and new research programmes. The organizing committee for the preparations for JINR's 50th anniversary also met during the session. The jubilee celebration will take place in Dubna on 25–26 March 2006.

Left to right: Sergey Mazurenko, Alexander Fursenko, Alexei Sissakian, Mikhail Itkis, JINR vice-director, and Yuri Oganessian, FLNR scientific leader.

Minister of Education and Science for the Russian Federation and the Russian Federation's Plenipotentiary at JINR, Alexander Fursenko, and the head of the Federal Agency on Science and Innovation, Sergey Mazurenko, took part in the session. They visited the Flerov Laboratory of Nuclear Reactions, where they learned about research on the synthesis and studies of the superheavy elements, and innovative projects using the application of nuclear-physics methods.

CERN

Italian high technology shows its wares at CERN

A representative explains a point to Guido Possa (centre) and Jos Engelen, CERN's chief scientific officer (right), during the Italian exhibition at CERN in November.

Italian industry held an exhibition at CERN on 14–17 November with 26 firms displaying innovative technological developments. In particular it featured categories such as mechanics, high-vacuum technologies, electronics for detectors, and electric and civil engineering. The exhibition was inaugurated in the presence of Guido Possa, vice-minister for education, universities and research.

The event was organized by Sandro Centro, INFN researcher and Industrial Liaison Officer at CERN, along with Federico Ferrini, scientific officer for International Organizations of Geneva and the Italian Chamber of Commerce in Switzerland. Italy is among the most important supplier countries for CERN's particle-physics experiments.

AWARDS

EPS-AG committee announces prize winners for 2006

On 22 February 2006 the European Physical Society Accelerator Group (EPS-AG) Prize Selection Committee decided on the winners of two of the three prizes for 2006.

Vladimir Teplyakov of the Institute for High Energy Physics, Protvino, won the Achievement Prize for outstanding work in the accelerator field, for "the invention of radio frequency quadrupole (RFQ) accelerator structure, in collaboration with I M Kapchinsky". This work revolutionized the technique for accelerating low-energy ion beams.

The prize for an individual in the early part of his or her career, having made a recent significant, original contribution to the accelerator field, goes to Lutz Lilje, of DESY. Lilje receives the prize "in recognition of his major role in the development and testing of high-gradient superconducting RF structures, including his original contributions to the development of fast tuning systems".

The prizes will be awarded on 29 June at the 10th European Particle Accelerator Conference (EPAC'06) at the Edinburgh International Conference Centre, and the winners will present their work. A third prize, for a student registered for a PhD or diploma in accelerator physics or engineering, or to a trainee accelerator physicist or engineer in the educational phase of their professional career, for the quality of work and promise for the future, will be decided at the beginning of the conference.

● For more information about EPAC'06 see www.epac06.org/.

On 31 January, CERN welcomed for the first time Janez Potocnik of Slovenia, who is European commissioner for science and research (left). His visit to the facilities included a tour of the Large Hadron Collider magnet testing hall, and he was accompanied by CERN's director-general, Robert Aymar (centre) and Philippe Lebrun, head of the Accelerator Technology Department, who is seen here explaining the testing procedure.

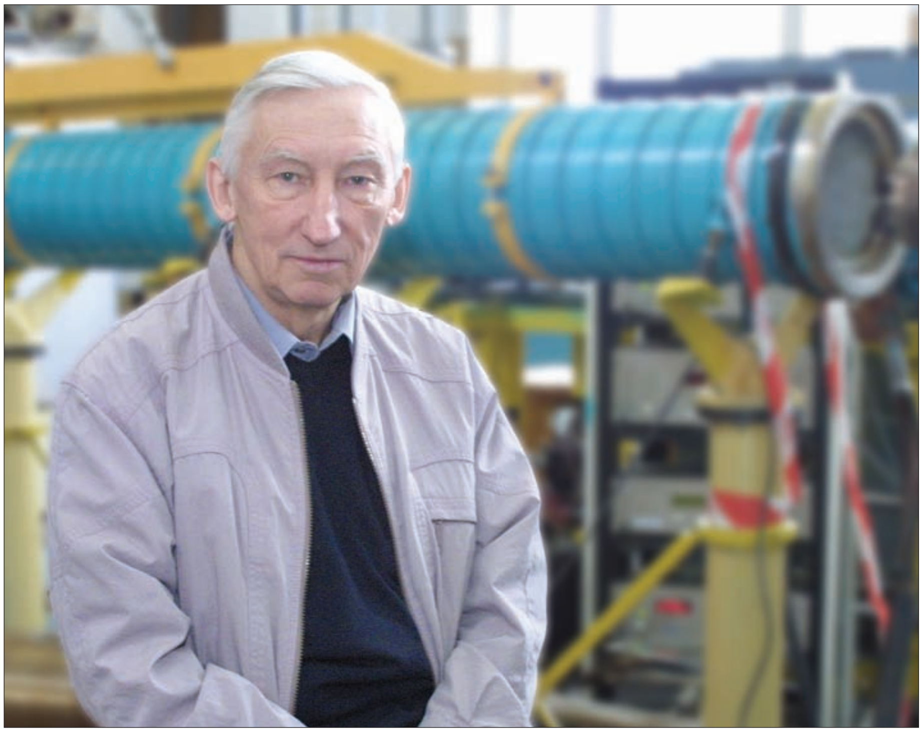
CELEBRATION

JINR's Meshkov celebrates 70th birthday…

Igor Meshkov of the Joint Institute for Nuclear Research (JINR) was 70 in January. Currently an adviser to the JINR Directorate on problems associated with charged-particle accelerators, Meshkov is well known in beam and accelerator physics and techniques.

Working with colleagues in the Budker Institute of Nuclear Physics (BINP), Novosibirsk, Meshkov developed and demonstrated for the first time electron cooling of charged particles. Under his leadership, the Physics Technological Centre at the BINP was created, where, in particular, an electron gun and a collector for the Low Energy Antiproton Ring at CERN were designed.

Meshkov continues to play an active role in accelerator projects at JINR. He is a spokesperson for the Low Energy Positron Toroidal Accumulator project, which is based on an idea proposed together with Alexander Skrinsky, the current director of BINP. This new type of accelerator, commissioned in 2004, uses a focusing system with a longitudinal magnetic field and full magnetization of circulating particles. The goal is to produce positronium through the recombination of the stored positrons with cooling electrons in the ring. This could be used in conjunction with an antiproton accelerator to generate the antihydrogen atoms in flight.



Igor Meshkov, who was 70 in January, is still actively involved with JINR's accelerator projects.

Meshkov has been head of the Scientific Council of the Russian Academy of Sciences on the problems of particle accelerators for many years. In addition, a large number of young scientists have been educated under his leadership. He is an experienced mountaineer and rock-climber, and a good skier, and he still keeps up his sporting activities.

… while Oxford marks Perkins' 80 years

Donald Perkins of Oxford University celebrated his 80th birthday in September 2005. Perkins, former head of particle physics in Oxford, has been chairman of CERN's Scientific Policy Committee and was for many years an experimenter at CERN. He was a leading figure in the neutrino-physics programme at the laboratory from the 1960s to 1980s, notably with the CERN Heavy Liquid Bubble Chamber, Gargamelle and the Big European Bubble Chamber. He is also author of one of the most popular textbooks on particle physics.

Former CERN research director Roger Cashmore, who is now principal of Brasenose College, Oxford, hosted a lunch to mark the occasion of Perkins' birthday.

*Donald Perkins (left) with Brian Foster (centre), head of particle physics at Oxford, and Richard Dalitz, who sadly died in January (*CERN Courier *March 2006 p38).*

ICSC-WL

L'aide au développement à travers la science

Le CERN a récemment accueilli les réunions annuelles de l'*International Centre for Scientific Culture* (ICSC) – *World Laboratory* (WL), notamment la réunion du Comité Exécutif et la réunion conjointe des Directeurs de projets et des membres du Comité Exécutif. L'ICSC-WL, qui a vu le jour au CERN, à Genève, en juillet 1986, émane d'une idée faisant écho à la "Déclaration d'Erice" écrite en 1982 par Paul Dirac, Piotr Kapitza et Antonino Zichichi. Il a été fondé par des institutions scientifiques de premier rang et par d'éminents scientifiques dont cinq lauréats du prix Nobel.

L'ICSC-WL dès sa fondation s'est assigné comme objectifs de promouvoir la collaboration scientifique et technique Est-Ouest et Nord-Sud pour une recherche sans secrets et sans frontières; de favoriser la libre circulation de l'information scientifique, des scientifiques et des chercheurs, en particulier au moyen de bourses et de financements de programmes de visiteurs scientifiques; de réaliser des projets dans les domaines scientifiques, techniques et médicaux, en particulier au bénéfice des pays en voie de développement, en collaboration avec des chercheurs d'autres institutions sans discrimination que ce soit de nature géographique, politique, idéologique, religieuse ou raciale.

Depuis sa création, l'ICSC-WL a centré ses activités, qui sont de plus en plus nombreuses, autour de combats contre les dangers qui menacent la planète qu'ils soient de source purement humaine, comme par exemple le terrorisme, ou d'origine naturelle, comme le réchauffement de la planète, éventuellement renforcés par les comportements humains.

De gauche à droite: Antonino Zichichi, Vanna Wick, Richard Dalitz et Tsung-Dao Lee durant la cérémonie d'attribution de la Médaille d'Or Gian Carlo Wick 2005 de l'ICSC-WL à Lausanne.

Pour atteindre ses objectifs, l'ICSC-WL, grâce à la participation totalement bénévole de ses collaborateurs scientifiques et de ses chefs de projets, sous la direction ferme et éclairée de son Président, Antonino Zichichi, a mené à bien toute une série d'actions. Quarante-deux laboratoires spécialisés ont été créés, en particulier dans les pays en voie de développement en Afrique, en Amérique Latine et en Asie. Quatre branches ont été mises en place en Estonie, Géorgie, Lituanie et Ukraine. Des projets visant à résoudre des problèmes spécifiques ont été mis en place dans des pays en voie de développement, en collaboration avec l'élite scientifique de ces pays. A ce jour, cent programmes concernant les différents champs de la science ont été conduits à terme.

Enfin, un programme international de bourses a été mis en place. Il permet à des étudiants des pays en voie de développement d'acquérir une formation scientifique de haut niveau dans des laboratoires de renommée internationale en participant à leurs recherches. Le CERN en particulier a accueilli bon nombre de ces étudiants. Depuis plusieurs années ce dernier programme a progressivement fait place à un vaste programme de bourses nationales permettant à de nombreux étudiants des pays en voie de développement de poursuivre des travaux de formation et de recherche dans leurs pays d'origine, sous la direction de professeurs qualifiés des institutions scientifiques de ces pays. Sept mille bourses ont déjà été attribuées.

A signaler enfin la prestigieuse "Médaille d'Or Gian Carlo Wick" que l'ICSC-WL attribue tous les ans depuis 1993 à un illustre physicien suivant les indications d'un comité de sélection présidé par Tsung-Dao Lee. En 2005 celle-ci a été attribuée à Richard Dalitz, brillant physicien des particules britannique de l'Université d'Oxford, qui est malheureusement décédé le 13 janvier 2006.

MEETINGS

The CERN–Fermilab **2006 Hadron Collider Physics Summer School** will be held at Fermilab on 9–18 August. The main goal of this new school is to offer students and young researchers a broad picture of theoretical and experimental aspects of hadron-collider physics. The emphasis of the first school will be on the physics potential of the first years of data-taking at the Large Hadron Collider (LHC), and on the experimental and theoretical tools needed to exploit that potential. Lectures and informal discussions will include an introduction to the theoretical and phenomenological framework of hadron collisions, and current theoretical models of frontier physics, as well as an overview of the main detector components, the initial calibration procedures and physics samples, and early LHC results. The application deadline is 8 April. For further information see http://hcpss.fnal.gov/.

The **2nd Symposium on Neutrino, Dark Matter and Dark Energy** (NDM06) will take place in Paris at the Ecole Normale Supérieure on 3–8 September. The purpose is to discuss research frontiers and perspectives on currently developing subjects together with younger researchers, and to help promote collaborations. The number of participants will be limited to 120, so it is advisable to register early. The registration fee will be reduced for PhD students and young researchers. For further information see http://events.lal.in2p3.fr/conferences/NDM06/.

A **European XFEL workshop** will be held by the European Industry Forum for Accelerators with SCRF Technology at DESY in Hamburg on 9–10 May. The workshop is aimed at companies that are potentially interested in providing goods and services to the European XFEL and at research institutes interested in an involvement in the XFEL project. The meeting will consist of plenary presentations and working-group sessions. Further information can be found at https://trac.lal.in2p3.fr/SCRF.

OBITUARY

Douglas Grant Michael 1960–2005

Douglas Michael, a well known experimental particle physicist at Caltech and co-spokesperson of the MINOS collaboration, died on Christmas Day after a year-long struggle with lymphoma.

Doug was born in Grant, Nebraska, US, on 9 May 1960 and moved with his family to Arizona when he was three years old. He attended Stanford from 1978 to 1982, where he strengthened his long-standing interest in mathematics and science. His initiation into high-energy physics was through a senior-year research project, in which he and another student built and operated a two-man experiment to test quantum electrodynamics in the waning days of the old SPEAR ring at SLAC.

Experimental particle physicist Douglas Michael, who died last December, aged 45. (Courtesy John Hanson, Caltech.)

Doug did his graduate work in physics at Harvard, receiving his Masters degree in 1984 and his PhD in 1990. His thesis experiment, performed under the guidance of Frank Pipkin and Dick Wilson, was E-665, a study of deep-inelastic muon scattering at Fermilab's Tevatron. Upon graduation, he moved to Caltech, where he became an essential member of an energetic group building the MACRO experiment to search for magnetic monopoles at Gran Sasso. Doug's work on MACRO fuelled his strong interest in neutrino physics and led to his proposal in 1994 for GENIUS, a long-baseline neutrino-oscillation experiment at Fermilab. He became a founding member of the MINOS collaboration that same year and was instrumental in designing and constructing the MINOS long-baseline neutrino-oscillation experiment.

During the past few years Doug devoted much of his energy to leading a drive to organize the improvements to the Fermilab accelerators that are essential for producing the intense neutrino beam for MINOS. His strong encouragement of young particle physicists to work on accelerator upgrades for MINOS has been a critical component of a "back to our roots" culture-shift at Fermilab in recent years.

Doug enjoyed playing the piano, painting and cooking. At Stanford he was on the track team and became proficient at throwing the hammer and discus. His taste for fine wine and good food, his extravagant use of the English language, and his fearless honesty in expressing strongly held opinions have become legendary among his colleagues. He will long be remembered for his high-spirited energy and boundless optimism, his deep insights into particle physics and detectors, and his ability to inspire and motivate those who had the privilege of working with him. His short, intense and productive life was celebrated at a memorial service at Caltech on 28 January.

Dave Ayres, Charlie Peck and Stan Wojcicki.

NEW PRODUCTS

Berkeley Nucleonics Corporation (BNC) has released a new multi-channel Digital Delay/Pulse Generator, Model 565, which allows time-reference selection for each channel. Up to eight channels of delay and width control are available, with 500 ps timing resolution and widths and delays out to 1000 s. It provides USB, RS232 and GPIB programming standard with optional Ethernet connection. For more information see www.berkeleynucleonics.com/resources/BNC565_505.pdf, or contact John Yee (e-mail: john.yee@berkeleynucleonics.com).

Cedip Infrared Systems has announced new high-performance Ethernet connectivity for its complete product range. Each Cedip IR camera can now be equipped with its own IP address, allowing remote control of all functions and access to thermal images. High-quality images can be streamed without time delay for viewing on a PC or monitor. For further information tel: +33 1 6037 0100, e-mail: cedip_marketing@cedip-infrared.com or see www.cedip-infrared.com.

Dickson has introduced a new line of lower cost temperature and humidity chart recorders. There are three models of TH8 8 inch temperature/humidity chart recorders and five models of KT8 K-thermocouple remote-sensing chart recorders, each optimized for different temperature and/or humidity ranges. Features include remote probes for tight locations etc, dew-point recoding, 8 inch charts, and audio and visual alarms. For further information tel: +1 630 543 3747, fax: +1 630 543 0498 or see http://new8.dicksonweb.com.

Physik Instrumente (PI) offers its most advanced six-axis nanopositioning and scanning system, the P-587.6CD. Its unique features include six degrees of freedom, active trajectory-error compensation, nanometre resolution and long travel ranges. The six-axis digital controller provides 20 bit resolution and advanced multiaxis trajectory control. For further details see PI's redesigned website, with product and tutorial pages, at www.pi-usa.us/ or www.physikinstrumente.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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University of Cambridge

Faculty positions in the Department of Physics, Cavendish Laboratory

Two Readerships and Three University Lectureships

Applications are invited from Experimental and Phenomenological Particle Physicists

As part of a strategy to invest in new research areas and to support areas of excellence, the Cavendish Laboratory is engaging in a search for staff with outstanding research records at the level of Lecturer, Reader, and Professor, in all areas of physics.

Applications are now invited for two Readerships and three University Lectureships in the Department of Physics.

We expect that some of these positions will be used to support a major thrust in the physics of quantum systems, viewed broadly to include optical physics, atomic physics, and condensed matter physics. We are also searching for strong candidates in experimental and phenomenological particle physics, and in experimental astrophysics. These posts are additional to three recently advertised positions in experimental quantum condensed matter, bio-medical, and soft matter physics.

Appointments to the Readerships will be to the retiring age and to the University Lectureships will be for a probationary period of five years, with appointment to the retiring age thereafter. The pensionable stipend for a Reader is £47,262 per annum, and for a University Lecturer is on the scale £25,565 to £39,452 per annum.

Appointments will be from 1 October 2006 or as soon as possible thereafter.

Further details of the opportunities in particle physics may be obtained from Professor Janet Carter (e-mail: jrc1@hep.phy.cam.ac.uk).

Applications, including a curriculum vitae, a statement (up to six pages) of research experience to date and of research plans for the future, the names and contact details of three referees, and a completed form PD18 (available at http://www.admin.cam.ac.uk/offices/personnel/forms/pd18/) should be sent to the Head of Department, Professor P.B. Littlewood, Cavendish Laboratory, JJ Thomson Ave, Cambridge CB3 0HE, UK (e-mail: hod@phy.cam.ac.uk) by 30 April 2006.

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If you believe your motivation and experience would be an asset in our challenging environment, please send us a letter with a resume to:

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Email: human.resources@acqiris.com

Visit us at www.acqiris.com and find out more about our company.

Postdoctoral Position at Syracuse University

The Syracuse University High Energy Physics group seeks to fill a Postdoctoral position involving activities within the VELO group in LHCb and the RD50 collaboration, both related to the installation and commissioning of the VELO detector and R&D towards novel Si precision tracking devices for future LHC upgrades. The work will be done mostly at Syracuse with possible stays at CERN. The Syracuse group is also involved in the CLEO-c experiment, thus physics analysis opportunities are available. The Syracuse group includes four faculty, two research faculty, two PostDocs and six graduate students.

Interested candidates should send their CV and arrange for three letters of recommendation to
Prof. Sheldon Stone (stone@physics.syr.edu), Syracuse University, Physics Dept., 201 Physics Bldg., Syracuse, NY 13244-1130.

Deadline for applications is April 30th

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Rheinische Friedrich-Wilhelms-Universität Bonn

universitätbonn

The Institute of Physics in the Faculty of Mathematics and Natural Sciences at the University of Bonn, Department of Physics and Astronomy, seeks to fill the position of a

Professor (W2) for Experimental Physics (Particle Physics)

starting **1 October 2006.**

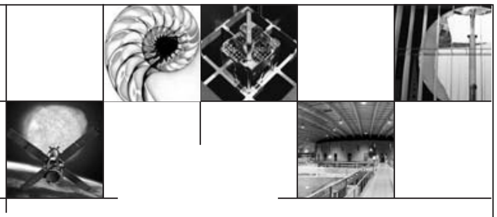
With this professorship the Department of Physics and Astronomy intends to strengthen the experimental particle physics research field. University research groups are involved in experiments at the LHC (CERN), at HERA (DESY) and at the TEVATRON (Fermilab). Candidates should have an international standing and have experience in the design, development and construction, as well as the analysis of data from accelerator experiments in high energy physics. Active participation in an LHC experiment would be very welcome. Applicants should be able to teach all aspects of particle physics. Teaching duties also include courses for science students from other disciplines.

Appointments follow the rules and regulations of the Universities of Northrhine-Westfalia. The University of Bonn aims at increasing the fraction of female staff and encourages women to apply. Equally qualified but disabled candidates will be appointed preferentially.

Applications including the usual professional documentation should be sent to the **Head of Department of Physics and Astronomy, Endenicher Allee 11-13, D - 53115 Bonn, Germany.** The deadline is **15 April 2006**.

PAUL SCHERRER INSTITUT

PSI



The Paul Scherrer Institut is a centre for multidisciplinary research and one of the world's leading user laboratories. With its 1200 employees it belongs as an autonomous institution to the Swiss ETH domain and concentrates its activities on solid-state research and material sciences, elementary particle and astrophysics, energy and environmental research as well as on biology and medicine.

High-intensity meson and neutron beams are produced at miscellaneous experimental facilities at PSI, using the world's most powerful proton accelerator. For the continuing upgrade and the extension of the facilities and for the work on scientific aspects of the disposal of radioactive components, the department Accelerator Facilities and Systems is looking for a

Nuclear or Elementary-Particle Physicist

Your task

You will calculate particle transport and nuclide production for the design of new facility components and shielding, for the study of radiation-protection related problems and for the disposal of radioactive waste components. To characterize the proton and neutron fields up to 600 MeV, you use well-known Monte-Carlo codes which you will complement with your own problem-specific routines. You keep abreast of the field by attending international symposia and develop new concepts for the advancement of the calculational methods and their validation within a small team.

Your profile

You are a nuclear or elementary-particle physicist with a good command of Fortran and several years of experience in the use of worldwide accepted particle transport codes (e.g. MCNPX, FLUKA). With your expert knowledge you understand the underlying physical processes. In addition, you have experience in the field of neutron and photon detection. You have the capability to introduce new ideas and define objectives. As a team-oriented and communicative person you enjoy working in an interdisciplinary group. You act independently, show initiative and have a cooperative and practice-oriented personality. Your profile is completed by a good knowledge of English and German and your willingness to work in radiation-controlled zones.

We are looking forward to your application.

Dr Gerd Heidenreich,
Ph. +41 (0)56 310 35 84,
E-Mail: gerd.heidenreich@psi.ch or
Dr Sabine Teichmann,
Ph. +41 (0)56 310 43 75,
E-Mail: sabine.teichmann@psi.ch
will be happy to answer your questions.

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Postdoctoral Position in Experimental Low-Energy Particle Physics at Indiana University

The Nuclear Physics group at Indiana University is seeking a strongly motivated experimentalist for a postdoctoral position, available immediately. The successful applicant will be expected to be actively involved in low-energy, "table top" particle physics experiments: a new search for the electric dipole moment of the electron using a paramagnetic solid sample; and development of a solid-oxygen based source of ultracold (neV) neutrons for fundamental physics measurements. Responsibilities will involve several aspects of each project, ranging from design and construction tasks to data acquisition and analysis, making use of techniques from cryogenics, condensed matter and neutron physics, and high-voltage and low-noise electronics. Experience in one or more of these techniques is preferred but not essential.

Initial appointment will be for one year, with possible renewal for up to two additional years. A Ph.D. in experimental physics is required. Applications will be accepted on a continuing basis until the position is filled. Applicants should submit a CV and a statement of research interests, and arrange to have three letters of recommendation sent to:

Prof. C-Y Liu
Indiana University Cyclotron Facility
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tel: 812-855-2896, fax: 812-855-6645 or electronically (preferred) to CL21@indiana.edu.

Indiana University is an Equal Opportunity/Affirmative Action Employer, with a strong commitment to excellence through diversity.

UNIVERSITY OF OXFORD

Wykeham Professorship of Physics

Applications are invited for the above post, tenable from 1st October 2006, or such later date as may be arranged. A non-stipendiary fellowship at New College is attached to the professorship. The Wykeham Professorship of Physics is held in the Department of Physics in the Sub-Department of Theoretical Physics.

The University seeks to appoint a person with a record of internationally esteemed research in Theoretical Physics, in an area that overlaps and enhances the current research in the Sub-Department, and who, through leadership and the distinction of his or her contribution to the field, will ensure the continuing pursuit of excellence in teaching and research in Theoretical Physics at Oxford, and its wide recognition outside.

Further particulars, including details of how to apply, are available from http://www.admin.ox.ac.uk/fp/ or from the Registrar, University Offices, Wellington Square, Oxford OX1 2JD (tel. (01865) 270200). The closing date for applications is 8th May 2006.

The University is an Equal Opportunities Employer.

DIRECTOR OF TRIUMF

TRIUMF is Canada's national research facility for particle and nuclear physics. We are located on the campus of the University of British Columbia, and are operated by a national consortium of universities, and funded by a contribution from the National Research Council of Canada. TRIUMF is a leader in particle and nuclear physics and accelerator development in Canada and abroad, through international partnerships. At TRIUMF, a 520 MeV H- cyclotron provides beam to a large number of experimental facilities including an advanced new radioactive beam facility, ISAC. Our facility provides key infrastructure support for the Canadian Particle Physics program as well as for leading research programs in molecular and materials science and life sciences. TRIUMF employs 375 scientists, engineers, technicians, and general staff and some 400 scientists visit from institutions worldwide to conduct experiments.

THE DIRECTOR will have the overall responsibility for the operation and development of TRIUMF and its program of science at the national and international level, as well as the authority for critical decisions involving the securement and management of the total operating budget, the safety of all workers, and changing or implementing policies, internal systems and programs.

The successful candidate will have a proven track record for attracting operational and capital funding for research projects; demonstrated leadership abilities, insight and vision; and an outstanding international research record. In addition, he/she will have achieved international stature in the fields of particle and nuclear physics and in the organization of activities related thereto. Qualifications include experience with the administrative and financial matters associated with a multi-million dollar project; strong communication, interpersonal, negotiating and relationship building skills; and an advanced degree in a physics related discipline with at least 15 years experience in a senior role.

The Director position is subject to a five-year initial appointment that is renewable. This position is available May 1, 2007. Additional information about TRIUMF can be found at http://www.triumf.info/public/ and a more detailed description of the position can be found under "Employment Opportunities" **Competition No. 995**. Salary will be commensurate with responsibilities. Please note the position is open to all qualified applicants, and in the case of equal qualifications, preference may be given to a Canadian Citizen or Permanent Resident.

Applications should be addressed to: **Dr. Pekka Sinervo, Chairman of the Search Committee, c/o Office of the Dean, Faculty of Arts and Science, University of Toronto, 100 St. George Street, Toronto, ON, M5S 3G3.**

ESO

European Organisation for Astronomical Research in the Southern Hemisphere

Eso operates the La Silla Paranal Observatory in Chile, and is the focal point for Europe's participation in the ALMA consortium, which is constructing a large submillimetre array in the Chilean Andes. ESO is opening the following management positions of

Associate Director

The primary purpose of this position is to support and assist the Director General in the discharge of his/her duties. The Associate Director reports directly to the Director General and is required to work closely with Division Heads and other senior staff in the Organisation. She/he shall carry out such tasks as requested or delegated by the Director General which shall include, but not be limited to, responsibility for:

- providing the Director General with briefing material and appropriate analysis on any matter which could have implications for the operation of ESO
- the management of the Council secretariat
- the management of the ALMA Board and European ALMA Board business, and specifically acting as ALMA Board Secretary when the Chair is nominated by ESO.

An appropriate professional qualification as well as substantial management and leadership experience within a scientific organisation, preferably international, are required. Excellent communication skills and a very good knowledge of English are essential.

Senior Astronomer - Director of the La Silla/Paranal Observatories

The Director responsible for the Observatories on La Silla, Paranal and APEX will lead a multi-disciplinary team and act as a link between User Community, the Director General and the Observatories. She/he will in particular be responsible for:

- the continuation, creation and implementation of scientific and technical policies for the operation of the Observatories in accordance with ESO's overall policy
- the management of the Observatories and their staff members through the definition and implementation of goals and objectives
- the Observatories' budget
- the representation of all Observatories in the science community, public and public relations (e.g. media support, exhibitions, presentations etc.) in close interaction with ESO's Representative in Chile and the Public Affairs Department.

The Director of the Observatories reports directly to the Director General. The Staff of the Observatories presently consist of about 70 International and 150 Local Staff Members who work in groups or teams. As a Senior Astronomer the Director of the Observatories is a member of the ESO Science Faculty and is expected and encouraged to actively conduct astronomical research. She/he should foster the participation and integration of the scientists of the Observatories in the ESO Faculty and in the Office for Science in Santiago.

Basic requirements for the position include a PhD in astronomy, astrophysics or physics, or related fields, substantial and long or equivalent experience in management and leadership preferably gained within multinational scientific organisations. A proven record in astronomical systems such as instruments, large optical telescopes or systems of equivalent complexity as well as an outstanding record of astronomical research and international scientific collaborations are required. Initiative, ability to judge, to decide and to work with people of different nationalities as well as excellent communication skills are essential. The position requires a very good knowledge of English and a working knowledge of Spanish or willingness to learn it.

As members of the ESO Management both job holders contribute directly to the development of the overall policy, the strategic planning, and maintain professional contacts at highest level outside the Organisation.

For details and to download an application form, please consult our homepage: **http://www.eso.org.** If you are interested in working in areas of frontline technology and in a stimulating international environment please send your application in English to:
ESO Personnel Department, Karl-Schwarzschild-Straße 2, D - 85748 Garching near Munich, or e-mail: vacancy@eso.org.

ESO is an equal opportunity employer.
Qualified female candidates are invited to apply.

ESO. Astronomy made in Europe

SUMMER SCHOOL & EVENTS

The Fourth International Summer School on Grid Computing 2006

Jolly Hotel delle Terme, Ischia, Bay of Naples, 9-21 July 2006

Grids underpin the rapidly emerging e-Infrastructure and Cyberinfrastructure. This will transform information-intensive and model-based thinking. It will enable global collaborations to make rapid advances addressing challenges in science, economics, design, engineering and medicine, in fact in all walks of life.

The School will bring together world experts and enthusiastic students. It will examine the conceptual and practical underpinnings of today's grids. Experts will discuss the challenges of building and sustaining e-Infrastructure, report its rapid influence on the way we research, design and make decisions. They will share their vision of the developments and challenges ahead.

The School will include lectures on the principles, technologies, experience and exploitation of Grids. Lectures will also review the research horizon and report recent significant successes. Lectures will be given in the mornings. In the afternoons the practical exercises will take place on the equipment installed at the School site in Ischia, Italy (near Naples). The work will be challenging but rewarding. A social programme will help the students to form lasting friendships.

To support the hands-on laboratory sessions, a testbed will be established that will host widely used middleware produced by projects in the USA, Europe and Asia. The testbed will be connected to major international Grids and provide a rich environment for hands-on learning and experimentation. Exercises and team work will encourage students to learn by using this testbed. Students will be fired with enthusiasm, equipped with practical skills and will leave with many shared experiences, new friends and a new capacity for research into and using advanced distributed computing systems.

The target audience will include enthusiastic young researchers who expect to use or develop grids in their research. We look forward to greeting participants from virtually every continent. Applications are invited from enthusiastic and ambitious researchers who have recently started (or are about to start) working on Grid projects. Students may come from any country. They may be planning to pioneer or enable new forms of e-Infrastructure, to engage in fundamental distributed systems research or to develop new methods in any discipline that depends on the emerging capabilities of e-Infrastructure. In all previous years the School has been oversubscribed. Selection for the School is therefore competitive based on the information supplied on the application form and by an applicant's referee. We expect to accept between 60 and 70 students.

We will be looking for students with commitment and enthusiasm for Grid Research and development. We will expect competence and experience in some aspects of software development, distributed systems, computational systems, data systems and Grid applications. Most students will establish their credentials from academic qualifications, but some will base this on experience. We also welcome as participants educators who are planning to teach Grid computing. The Summer School will be conducted in English, so participants are expected to be comfortable using spoken English. We expect participants from computer science, computational science and any application discipline. The School will assume that students have diverse backgrounds and build on that diversity.

ISSGC 06 Website: http://www.dma.unina.it/~murli/ISSGC06. For more information or enquiries email: issgc06@nesc.ac.uk

Deadline for applications is 1 May 2006

EGEE Training Programme

The International Summer School on Grid Computing is one of many Training Events that the EGEE Training Team help deliver. The EGEE Training Team currently offer a highly developed and wide ranging Training Programme. Over the last 2 years, as part of the wider EGEE Project, the Training Team have run more than 250 events with 2500 attendees in locations all over the world and in the next phase of the Project (EGEE II) the Team will deliver a continuing programme of training and services for the next 2 years.

For information on other courses and training material or to register for any events go to: **http://www.egee.nesc.ac.uk/index.html** where there is also the option to enter information about related events you may be running.

Important Forthcoming events include: 22 February 2006: Introduction to e-Infrastructure: Enabling the Research of the Future, London, UK, 27 - 28 February 2006: EGEE User Forum Training event: Geneva, Switzerland.

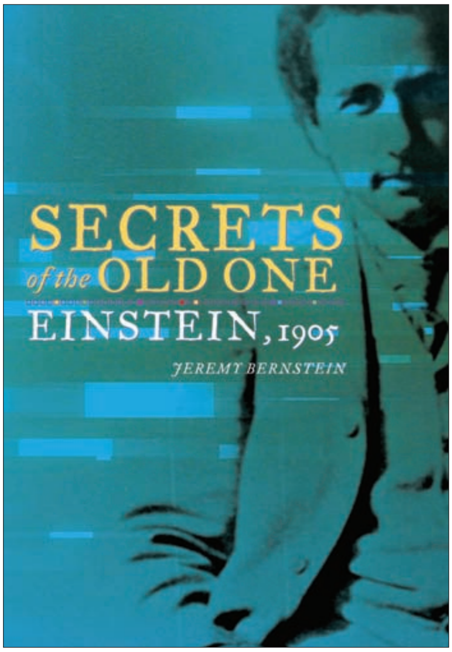
More information about EGEE: http://public.eu-egee.org/

ISSGC 06 Website: http://www.dma.unina.it/~murli/ISSGC06

For more information or enquiries email: issgc06@nesc.ac.uk

BOOKSHELF

Secrets of the Old One: Einstein, 1905 by Jeremy Bernstein, Springer Science. Hardback ISBN 0387260056, €19.95 ($25).
Henri Poincaré and Relativity Theory by A A Logunov, Nauka. Hardback ISBN 5020339644.



Bernstein's book is wonderful and, as far as I can judge as a professional physicist, very pedagogical for non-specialists. My only complaint is the title, which I came to understand only on page 163. For me, the "Old One" was Albert Einstein himself and the "secrets" were about his love affairs, including the one with the Russian girl who tried to extract atomic secrets from him (Einstein knew nothing). However, Bernstein gives only a relatively brief account of Einstein's life; on this subject there are many other more complete books available. What the author does instead is to delve into the past, as far as antiquity if necessary, and give the background to the three fundamental papers Einstein published in 1905 – special relativity, Brownian motion and the photoelectric effect – and, in fact, beyond, since general relativity is also mentioned.

In the course of the book Bernstein gives a wonderful lecture on the history of physics and chemistry, with colourful details about the main contributors: Epicurus, Lucretius, Galileo, Kepler, Newton, Bernoulli (one of them), Dalton, Avogadro, Maxwell, Smoluchowski, Perrin, Michelson, Lorentz, Poincaré and so on.

This brings me to Logunov's book about Henri Poincaré and relativity. The author claims that the role of Poincaré in the advent of relativity was much more important than is generally believed. This does not contradict Bernstein; he is also full of admiration for Poincaré in general and for his contribution to the genesis of relativity theory in particular. Max Born once said, "The theory of relativity resulted from the joint efforts of a group of great researchers: Lorentz, Poincaré, Einstein, and Minkowski."

Einstein never mentioned the contribution of Poincaré, which was slightly anterior and when, says Bernstein, Abraham Pais lent the text of Poincaré to Einstein, the latter returned it later without a word. Somehow it looks as though Einstein had decided to ignore Poincaré, which is difficult to understand when you see them both less than a metre apart at the 1911 Solvay Congress. However it is unclear whether Poincaré made the "big jump", while Einstein certainly did. In a text quoted by Logunov, Poincaré says "If we are to accept the relativity principle...", that is, there is an "if". It should be said, however, that according to Bernstein, Poincaré also ignored the work of Einstein, although he did write a letter of recommendation for Einstein to obtain a position at the Federal Institute of Technology in Zurich in 1909. In this letter Poincaré does not mention the word "relativity" once.

The question will remain forever open. Can we blame Einstein for ignoring Poincaré? No more than we can blame Bach for copying Vivaldi's concerto for four violins to transform it into the concerto for four pianos.

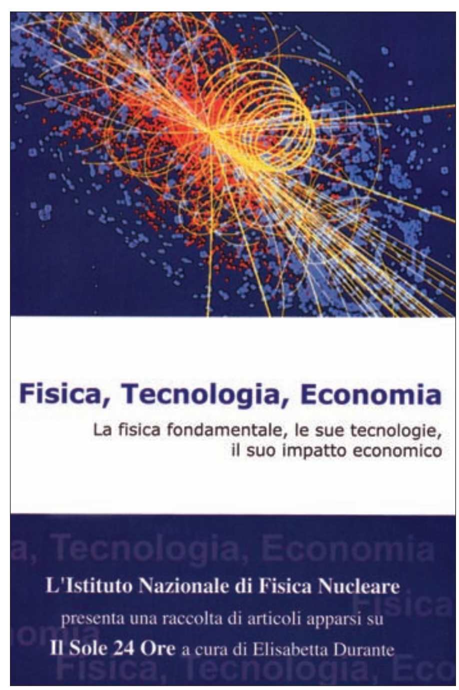
Where I cannot follow Logunov is the part in which he claims that Einstein's theory of general relativity is useless and wrong. Logunov presents explanations of the twin paradox and the Sagnac effect using only Poincaré's relativistic mechanics, but he does not seem to realize that we now have extremely refined tests of general relativity, and that the global positioning system could not work without relativistic corrections.

To conclude, I would say that, since the paternity of the Brownian motion theory is also controversial (what was the role of Marian Smoluchowski?), and since the importance of the 1917 paper on induced radiation was only realized later with the invention of the laser, I believe that the Swedish Academy, contrary to what I thought when I was young, was very wise in awarding Einstein's Nobel prize "for services in theoretical physics, and especially for his discovery of the law of photoelectric effect". For this Einstein had no competitor. Ironically this work led to quantum mechanics, with which Einstein was so unhappy: "the Old One [God] does not play dice".
André Martin, CERN.

Fisica, Tecnologia, Economia (Physics, Technology, Economy) by Elisabetta Durante (ed.), the Istituto Nazionale di Fisica Nucleare (INFN). Available from Presidenza INFN, Piazza dei Caprettari, 70 - 00186 Roma.

This booklet is a collection of articles published in one of Italy's most important newspapers, *Il Sole 24 Ore @lfa*, to celebrate the World Year of Physics in 2005. The authors are researchers and professors from INFN, the body that funds a major part of particle-physics research in Italy. Throughout the book, it is interesting to see the effort made to show how many important applications of particle physics there are in everyday life, and the strong links that exist between the complicated machines that serve this kind of research and the technological objects that we use every day.

The language is simple, the articles are short and, in my opinion, accessible to the lay public. For example, natural radioactivity is mentioned alongside archaeological lead in order to explain the basic functioning of the Cuoricino experiment in the Gran Sasso Laboratory. Each article about current theory and experiments is



followed by a spotlight on the application that has resulted from the research.

Two sentences in the book are particularly striking: the first sentence of all, which states "Physics has already understood all the easy things," and the last one, which reads "Young researchers who have experienced laboratories such as CERN are the best example of an effective technology transfer." I am not sure about what can be defined as "easy to understand" in physics but I do agree with the importance of sharing knowledge and how much this is done in international laboratories such as CERN.
Antonella Del Rosso, CERN.

Books received
Drawing Theories Apart: the Dispersion of Feynman Diagrams in Postwar Physics by David Kaiser, University of Chicago Press. Hardback ISBN 0226422666, ($80). Paperback ISBN 0226422674, ($30).

With the use of rich archival materials, interviews, and more than 500 scientific articles from the period, the author uses Feynman diagrams as a means to explore the development of American postwar physics. By focusing on the ways that young physicists learned new calculational skills, the story is framed around the crafting and stabilizing of the basic tools in the physicist's kit, thus offering the first book to follow the diagrams once they left Feynman's hands and entered the physics vernacular.

What is the Electron? by Volodimir Simulik (ed.), Apeiron. Paperback ISBN 0973291125, $25.

This collection brings together works by a number of authors, with the main purpose of presenting original papers containing new ideas about the electron. It thus provides different points of view on the electron, both within the framework of quantum theory and from competing approaches. Original modern models and hypotheses, based on new principles, are well represented. More than 10 different models of the electron are presented, and more than 20 models discussed briefly.

Accelerator Physics 2nd edition by S Y Lee, World Scientific. Hardback ISBN 981256182X, £51 ($84). Paperback ISBN 9812562001, £27 ($44).

Intended for use as a graduate or senior undergraduate text in accelerator physics and science, this book can also be used as preparatory material for graduate accelerator-physics students. The text covers historical accelerator development, transverse betatron motion, synchrotron motion, an introduction to linear accelerators, and synchrotron radiation phenomena in low emittance electron-storage rings, and introductions to special topics such as the free-electron laser and the beam–beam interaction. Each section is followed by exercises to reinforce the concept discussed and to solve a realistic accelerator design problem.

2006: l'impulsion relancée

Martial Ducloy et **Martin C E Huber** encouragent la communauté scientifique à tirer parti de l'élan donné par l'Année mondiale de la physique en 2005.

Maintenir et développer la communication entre la communauté scientifique et la société est un enjeu capital pour la physique. Dans le monde du début du 21e siècle, où l'on ignore souvent les découvertes les plus fondamentales des sciences physiques, il était nécessaire de rappeler que la physique et les sciences naturelles sont à la base non seulement de notre civilisation technologique, mais aussi de notre culture. Le centenaire de l'année miraculeuse d'Albert Einstein de 1905 était donc une excellente occasion d'attirer l'attention de la société, partout dans le monde, sur l'importance de la physique.

Cette initiative de faire de 2005 l'Année mondiale de la physique a été prise en l'an 2000 par la Société Européenne de Physique. L'année était lancée en janvier avec des conférenciers prestigieux, dont une dizaine de Prix Nobel, à l'UNESCO à Paris. L'Année mondiale de la physique a entraîné une mobilisation sans précédent des instituts et départements de physique, ainsi que des sociétés de physique sur les cinq continents.

L'objectif des physiciens était de faire partager leur vision de la science d'aujourd'hui, de faire connaître à un public le plus large possible les progrès et l'importance des sciences physiques dans notre civilisation contemporaine, et de rappeler leur caractère central dans la vie de tous les jours. Plus de 85 pays se sont mobilisés à cette occasion. Leur liste, avec celle des coordinateurs nationaux des activités de l'Année mondiale de la physique, est donnée sur le site www.wyp2005.org. Ils incluent également des pays en voie de développement d'Afrique, Asie et Amérique Latine. Tous ces pays ont été le théâtre de manifestations et d'événements de tous ordres, aussi bien dans le cadre restreint de la communauté scientifique qu'en direction d'une audience plus large incluant jeunes, étudiants, grand public et politiques.

Parmi la multitude d'événements organisés, on a noté une remarquable exposition à la Fondation Gulbenkian au Portugal sur l'Histoire de la physique d'Aristote à nos jours, et une autre exposition splendide sur la vie et l'œuvre d'Albert Einstein à Berne, cité où Einstein avait vécu son *annus mirabilis*.

Quelques-uns des jeunes ambassadeurs de la physique sélectionnés pour le "Physics Talent Search", durant la réunion finale en décembre dernier.

Des camions des sciences itinérants, comme le "Scientibus" de Limoges, ont sillonné plusieurs pays européens. Signalons notamment l'odyssée du camion des sciences du Royaume-Uni, "Lab in a Lorry", financé par la Fondation Schlumberger, qui a traversé l'Afrique pour se rendre à Durban en Afrique du Sud, à l'occasion de la Conférence de l'UNESCO sur Physique et Développement Durable. En Pologne, une symphonie, *Sinfonia de Motu*, a été spécialement composée par l'illustre compositeur polonais Wojciech Kilar. Dans plusieurs pays européens (Pologne, Italie, France, Serbie) des campagnes de mesures de polluants atmosphériques ou de la radioactivité naturelle du radon ont été menées par de jeunes écoliers et étudiants, reliés entre eux par *Internet*, pour établir une cartographie de la pollution ou de la radioactivité. Le programme La main à la pâte, lancé par Georges Charpak en France, est en cours d'extension en Europe (Serbie, Hongrie, etc.). Au Pays-Bas, des expériences interactives organisées dans la rue ou sur les plages néerlandaises durant l'été, ont connu un succès retentissant. Aux Etats-Unis, un certain nombre d'activités ont été organisées: "Physics on the Road", "Einstein@Home" etc. A l'échelle de l'Amérique du Nord, 800 classes ont reproduit l'expérience d'Eratosthène de mesure de la circonférence de la terre, reprenant une expérience modèle de La main à la pâte.

En outre, des manifestations et compétitions internationales ont été organisées avec un grand succès: "Physics enlightens the world", un relais de lumière autour de la Terre le 18 avril, coordonné par l'Autriche avec la participation d'un nombre impressionnant de pays à travers le monde; "Physics Talent Search" regroupant 21 pays, avec une compétition finale organisée à Taiwan fin décembre 2005; le 1er décembre 2005, le CERN lançait "Beyond Einstein", une émission diffusée sur le Web de 12 heures, avec des liaisons directes avec des laboratoires de physique et des musées des sciences dans le monde entier, de l'Europe à l'Amérique, de l'Asie à la Tasmanie, jusqu'en Antarctique.

Quelles leçons peut-on tirer de cette Année Mondiale? La forte mobilisation des scientifiques partout dans le monde a donné une formidable impulsion à la communication en direction du grand public sur les objectifs et les enjeux de la recherche en sciences physiques. Elle a montré aussi la forte implication des scientifiques dans les grands problèmes de la societé tels que l'énergie, l'environnement, la santé.

Une telle mobilisation ne doit pas s'arrêter. Il faut conserver l'impulsion acquise et établir un bilan détaillé des actions menées en 2005 pour faire ressortir les plus réussies. Le Forum Physique et société qui aura lieu du 19 au 22 avril à Graz en Autriche s'occupera de définir la forme la plus apte à les prolonger dans le futur et à les coordonner au niveau européen et international. Toute la communauté internationale de physique est invitée à y participer. Pour tout complément d'information, vous pouvez vous rendre à l'adresse www.wyp2005.at.

Martial Ducloy et Martin C E Huber, anciens Présidents de la Société Européenne de Physique, Président et Membre du Comité de Pilotage International de l'Année mondiale de la physique.

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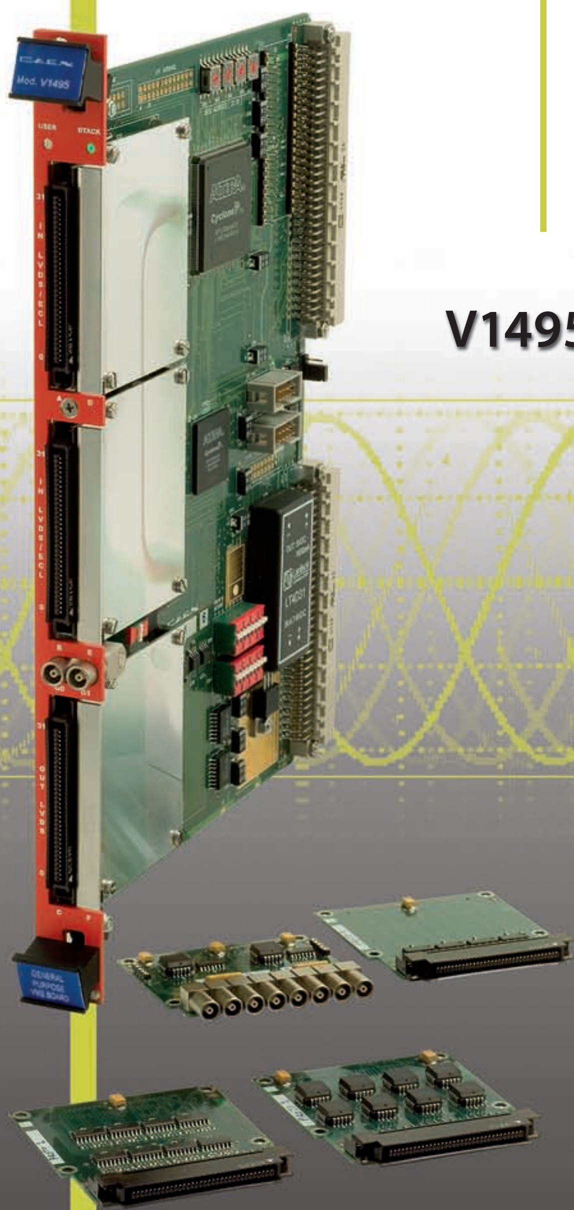
- A395B: 32 LVDS output channels
- A395C: 32 ECL output channels
- A395D: 8 NIM/TTL input/output channels

V1495 General Purpose VME board



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