INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

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VOLUME 46 NUMBER 9 NOVEMBER 2006

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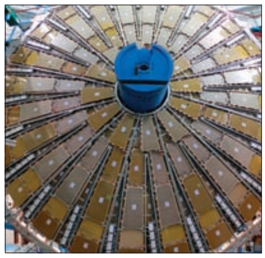
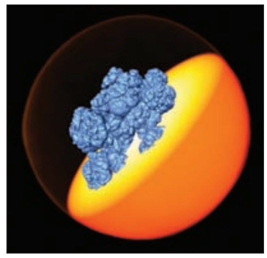


The first big wheel for ATLAS p8



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LBNL celebrates at 75 p31

Cover: The OPERA long-baseline neutrino-oscillation experiment (CNGS1) has seen its first neutrinos in Hall C at the Gran Sasso underground laboratory (p24).

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

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ADVERTISING FEATURE

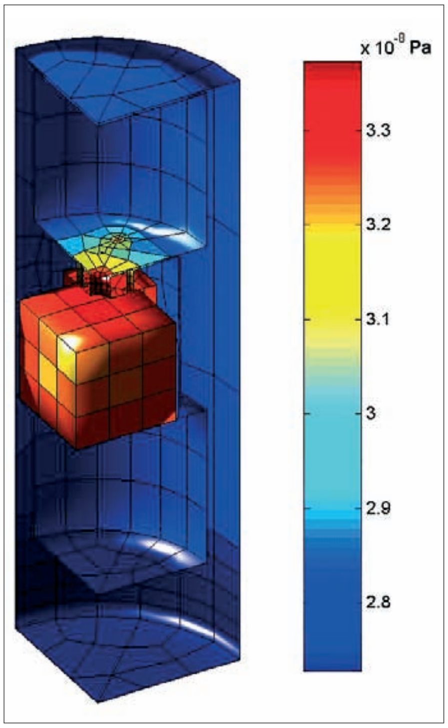
SAES® GETTERS TAKES PART INTO LISA, THE FIRST ASTRONOMICAL OBSERVATORY FOR LOW FREQUENCY GRAVITATIONAL WAVES

The modelling phase of the inertial sensor head of the interferometer has been completed by SAES for Carlo Gavazzi Space. Results define the pressure conditions in the vacuum enclosure for mission' success.

SAES Getters, world leader in getter technology for high vacuum applications and in mercury dispensing solutions for LCD backlighting, concluded the pressure modeling of the interferometer inertial sensor head, commissioned by Carlo Gavazzi Space within the frame of the LISA Pathfinder project.

LISA (Laser Interferometer Space Antenna) is the ESA-NASA mission involving three spacecrafts in orbit around the Sun and flying approximately 5 million kilometres apart in an equilateral triangle formation. This spacecraft constellation acts as a Michelson interferometer to measure the distortion of space caused by passing gravitational waves. On board lasers will be used to measure minimal changes in the separation distances of free-floating masses within each spacecraft. LISA space-based interferometer is planned for launch in 2015 and, after a 13-month transfer to its operational orbit, it will stay in orbital phase for 2 years. Ultimate target of the project is the detection of gravitational waves, whose existence was predicted in Einstein's general relativity theory, and that are thought to be generated by massive objects, such as black holes.

LISA Pathfinder is to demonstrate the key technologies to be used in the future LISA mission. Planned for launch in 2009, it will put two test masses in a near-perfect gravitational free-fall and control and measure their motion with unprecedented accuracy. This is achieved through state-of-the-art technology comprising the inertial sensors, the laser metrology system, the drag-free control system and an ultra-precise micro-propulsion system.



Modelling of the hydrogen pressure distribution inside the inertail sensor head. In yellow-brown colors the Au-Pt test mass.

SAES Getters has been in charge to model the inertial sensor head of the interferometer, in order to set the vacuum pressure requirements necessary to support the space mission. Pressure stability and its uniform distribution inside the vacuum enclosure of the inertial sensor head is in fact fundamental for the success of the project: an inadequate level in pressure might cause the shifting of the sensor inertial mass, which thing would alter the experiment results and impair the whole mission.

The model realized for Carlo Gavazzi Space at SAES Getters' laboratories in Lainate shows that pressure in the vacuum chamber of the inertial sensor head needs to be at least as low as 10^{-7} mbar for two years. This vacuum level will ensure the sensor correct operation also by avoiding that possible pressure gradients in the vacuum chamber interfere with the experiment.

Data obtained from this modeling also indicate that the mission vacuum requirements can be best addressed by the zirconium non-evaporable getter (NEG) technology. Particularly, SAES Getters' porous NEGs, having enhanced sorption capacity thanks to their high porosity and large surface area, are planned to be mounted on the interferometer sensor. Their porous structures in fact allow the gases to diffuse through the pores inside the getter mass, thus involving the inner parts of the getter body in the sorption process and delivering a dramatic increase in sorption for N_2, H_2, CO and other oxygenated gases.

The results of the modeling will be later on confirmed through extensive dedicated experimental tests, which will also allow to finally select the suitable number of NEGs and the most appropriate distribution inside the sensor head chamber.

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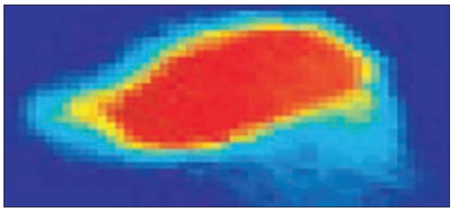
ACCELERATORS

Wakefield device exceeds 1 GeV

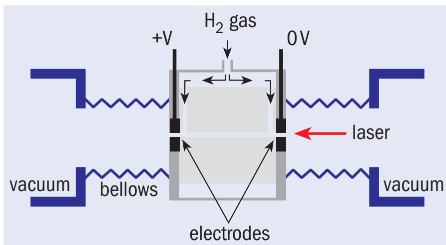
Researchers at the Lawrence Berkeley National Laboratory (LBNL), together with colleagues from the University of Oxford, have accelerated electrons to more than 1 GeV in only 3.3 cm. This is the highest energy achieved with laser-wakefield acceleration, which harnesses the electric field of a plasma wave driven by a laser beam. *Nature Physics* has published the results (W P Leemans *et al.* 2006).

In laser-wakefield acceleration, a laser pulse travelling through a plasma excites plasma waves in its wake, setting up electric fields that accelerate electrons from the plasma. This produces accelerating gradients of 10–100 GV m^{-1}, compared with 10–50 MV m^{-1} for standard radio-frequency-based systems, but it has proved difficult to sustain the laser-wakefield acceleration over the distances needed to reach energies greater than about 100 MeV and to control the energy spread. About two years ago, however, Leemans and colleagues in the Laser Optics and Accelerator Systems Integrated Studies (L'OASIS) group at LBNL, and two other teams in France and the UK, reported using intense laser pulses in millimetre-length gas jets to reach 70–200 MeV with much-reduced energy spreads (*CERN Courier* November 2004 p5).

The teams in Europe used laser pulses of 30 TW with relatively large spot sizes to produce sufficiently long laser–plasma interaction lengths in the gas jet. The L'OASIS group developed an alternative solution by creating a plasma density channel in the gas jet to guide the laser drive pulse. An igniter pulse forms a narrow channel of plasma, which is shaped by a heater pulse to create a guide channel for the final drive pulse. Using this method in hydrogen gas, the L'OASIS team reached around 80 MeV with a drive pulse of just 9 TW in a channel 2 mm long.



An electron bunch at 1 GeV with an energy spread (horizontal axis) of about 2.5% rms, and an extent (vertical axis) of about 5 mm.



In the 1 GeV laser wakefield accelerator a high-voltage discharge forms a plasma channel in a hydrogen-filled capillary in a sapphire block. The wakefield of a laser drive pulse sent through the channel then accelerates plasma electrons.

To achieve higher energies with these techniques implies using petawatt lasers or channelling over longer distances. However, the latter option at first seemed limited. One problem in wakefield acceleration is that the electrons tend to outrun the wake, limiting the length of the accelerator and hence the energy reached. This limiting distance, called the dephasing length, can be increased by lowering the plasma density, but the formation of the plasma guide channel by the igniter-heater method becomes less efficient at lower densities.

The solution emerged when Leemans met Simon Hooker from Oxford University and discovered that Hooker's group was using capillary guide channels in sapphire. Now the groups have joined forces and built a system that accelerates electrons for centimetres rather than millimetres.

The capillary is laser-machined in two halves in the faces of two blocks of sapphire, which are fixed together to form a thin tube 3.3 cm long. Hydrogen gas then flows in through other slots to fill the tube. A high-voltage discharge across the capillary both turns the hydrogen gas into plasma and heats it, creating a low-density region along the centre. When a laser drive pulse passes through this channel, the wakefield accelerates the plasma electrons.

The team has measured the energy of the bunches of electrons leaving the capillary accelerator using a 1.2 T spectrometer, which deflects the electrons onto a phosphor screen that is viewed by a CCD camera. With drive pulses of 12 TW, density of 3.5×10^{18} cm^{-3} and a capillary 225 μm in diameter, the researchers reliably produce a 0.48 GeV beam with an energy spread of less than 5% rms. Increasing the diameter to 310 μm and the power to 40 TW (density 4.3×10^{18} cm^{-3}), yields a 1 GeV beam with spread of 2.5% rms, although the performance is less stable.

Leemans and his colleagues are now looking at injecting particles into the capillary, which may help with stability, and increasing the energy by "staging" sequential capillary sections. They are also considering what will be needed to reach 10 GeV.

Further reading

W P Leemans *et al.* 2006 *Nature Physics* **2** 699.

Sommaire

NOBELS

Mather and Smoot share Nobel for precise observations of the CMB

The Nobel Prize in Physics 2006 recognizes research that studies the young universe, before the first stars were born and before galaxies began to form. John Mather of the NASA Goddard Space Flight Center (GSFC) and George Smoot of the Lawrence Berkeley National Laboratory share the prize "for their discovery of the blackbody form and anisotropy of the cosmic microwave background (CMB) radiation". Both physicists' work involved the Cosmic Background Explorer (COBE) satellite, which in the early 1990s provided an exciting new view of CMB radiation. This carries the imprint of the universe as it was some 300 000 years after the Big Bang, when radiation and matter decoupled and atoms began to form. COBE's findings strongly supported the Big Bang scenario and began to turn cosmology into a precise observational science.

John Mather during a press conference held at NASA headquarters in Washington, DC. (Courtesy NASA/Bill Ingalls.)

Joint Nobel prize-winner George Smoot enjoys the accolades at a press conference held at Lawrence Berkeley National Laboratory. (Courtesy Peg Skorpinski.)

Mather and Smoot share a long-standing interest in cosmology. For Smoot this followed a PhD in 1970 in particle physics, and he soon concentrated on producing experimental data about the early universe – in particular to study the CMB, the discovery of which by Arno Penzias and Robert Wilson in 1964 had, in Steven Weinberg's words, shown that there was such a thing as an early universe to study. (Penzias and Wilson went on to share the Nobel prize in 1978.) By 1974, Smoot had submitted a proposal to NASA to measure and map the CMB in search of imprints of what had happened at earlier epochs.

At the same time, Mather, with an interest in infrared astronomy, led efforts for the first proposal for COBE. After moving to the GSFC, he became study scientist (1976) and then project scientist (1988) for COBE, as well as principal investigator for the Far Infrared Absolute Spectrophotometer (FIRAS) on board COBE. Smoot, meanwhile, became principal investigator of COBE's Differential Microwave Radiometer (DMR).

The original plan was for a space shuttle to launch COBE, but shuttle operations came to a standstill in 1986 after *Challenger*'s horrific accident. However, Mather and his collaborators negotiated the use of a rocket and launched the satellite in November 1989. The FIRAS, designed to measure the CMB radiation spectrum with unprecedented precision, soon revealed a blackbody spectrum perfect to within 50 ppm, corresponding to 2.725±0.002 K, formidable evidence for the Big Bang.

More slowly, Smoot and his colleagues analysed the DMR measurements to create maps of the sky that revealed tiny temperature variations (about 10 ppm) in the generally uniform radiation. These indicated density variations in the primordial universe, which would eventually lead to regions of galaxies and clusters of galaxies separated by empty space. The data proved invaluable in constraining models of the early universe.

A thousand physicists, engineers and others involved in the project both before and after the satellite's launch contributed to COBE's success. The satellite took data until the end of 1993, and in 2003 its successor, the Wilkinson Microwave Anisotropy Probe, provided an even more detailed look, measuring temperature fluctuations to millionths of a degree.

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

***CERN Courier* welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send your proposal to the editor at cern.courier@cern.ch.**

BROOKHAVEN

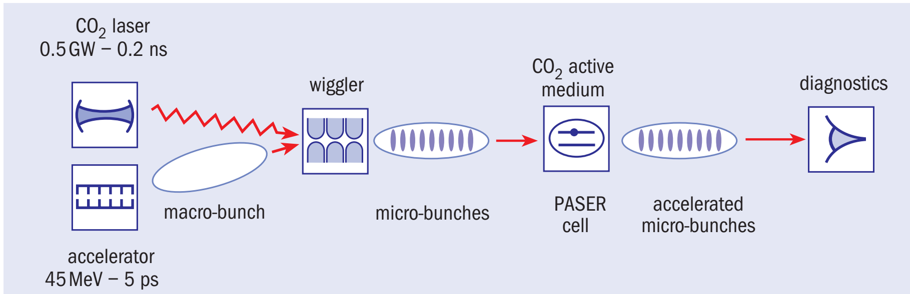
Researchers unveil the PASER: a novel acceleration scheme

Researchers from the Technion – Israel Institute of Technology have used the Accelerator Test Facility (ATF) at the US Department of Energy's Brookhaven National Laboratory to demonstrate the feasibility of particle acceleration by stimulated emission of radiation (PASER). This is in effect a particle analogue of the laser process.

Levi Schächter at Technion initially demonstrated theoretically the concept behind PASER. Its essence relies on the possibility of transferring energy stored in an active medium (with excited atoms) directly to electrons interacting with the medium, and thereby increasing their energy.

In lasers, photons traversing an active medium stimulate the atoms via collisions so that the atoms give up their excess energy as additional photons forming a coherent beam. In PASER, the atoms in the active medium transfer their energy directly to an electron beam in a coherent way.

To reach significant acceleration in a PASER, a macro-bunch of electrons injected into the PASER cavity should be modulated, forming a train of micro-bunches with a periodicity identical to the resonance frequency of the medium. In other words, coherent collisions of the second kind between the electrons in the train and the excited molecules should occur.



The PASER set-up. Electrons (macro-bunch) from a linear accelerator are modulated into a train of micro-bunches by interacting with a CO_2 laser in a wiggler. This train then gains energy through its interaction with the excited molecules of CO_2 in the PASER cell.

In the proof-of-principle experiment by Samer Banna, Valery Berezovsky and Schächter, electrons in a macro-bunch with an energy of 45 MeV were modulated by their interaction with a high-power CO_2 laser in a wiggler, to make a train consisting of about 150 micro-bunches, each several femtoseconds long. About 15% of the electrons in the train collected at the spectrometer at the end of the PASER cavity had absorbed energy stored in the cavity, increasing the total kinetic energy of the macro-bunch by about 0.15%.

Accelerating electrons in this way provides new opportunities as the effective quality factor of such a cavity may become comparable to that of macroscopic superconducting cavities. In particular it will be a challenge to try to use this technique to generate ultra-low-emittance beams.

Further reading

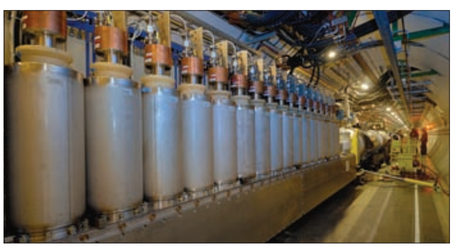
S Banna *et al.* 2006 *Phys. Rev. Lett.* **97** 134801.
S Banna *et al. Phys. Rev. E*, in press.

LHC NEWS

LHC prepares for cooling while magnets pass the 1000 mark

The first cryogenic feedbox designed to supply electricity to the superconducting magnets for one of eight arcs has been installed at Point 8 of the Large Hadron Collider (LHC). This milestone is the precursor to the cool-down of sector 7-8, scheduled for the coming months. Researchers will position a total of 16 such feedboxes at either end of the eight arcs, forming the ends of the continuous sections of cryostat. Each one weighs 12.7 t, is 10 m long and must withstand a pressure of 0.25 MPa.

Power leads, the lower extremities of which are immersed in liquid helium, bring the electrical power from room temperature to cryogenic temperature. Helium gas actively cools them and is injected at their base at 20 K and comes out at room temperature at the top. The power leads use ceramic high-temperature superconductor to limit the heat loads – the first time that these materials have been used on this scale.



Now that the first of the large feedboxes is in, sector 7-8 is preparing to cool down.

The 1000th cryomagnet during installation in the LHC tunnel on 5 September.

The power supply to the LHC's straight sections requires smaller electrical feedboxes. There will be 44 feedboxes around the LHC ring, equipped with 1200 current leads carrying 120–13 000 A.

Meanwhile, on 5 September the 1000th cryomagnet (superconducting magnet system) was installed between Point 3 and Point 4. During the same week, the final cryomagnet for sector 8-1 was also installed. There are 1746 cryomagnets, of which 1232 are the famous dipoles (*CERN Courier* October 2006 p28).

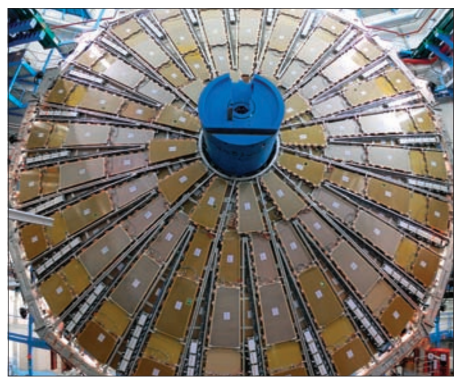
LHCf: a tiny new experiment joins the LHC

While most of the LHC experiments are on a grand scale, LHC forward (LHCf) is quite different. Unlike the massive detectors that are used by ATLAS or CMS, LHCf's largest detector is a mere 30 cm. Rather like the TOTEM detector (*CERN Courier* April 1999 p9), this experiment focuses on forward physics at the LHC. The aim of LHCf is to compare data from the LHC with various shower models that are widely used to estimate the primary energy of ultra-high-energy cosmic rays.

The LHCf detectors will be placed on either side of the LHC, 140 m from the ATLAS interaction point. This location will allow the observation of particles at nearly zero degrees to the proton beam direction. The detectors comprise two towers of sampling calorimeters designed by Katsuaki Kasahara from the Shibaura Institute of Technology. Each is made of tungsten plates and plastic scintillators of 3 mm thickness for sampling.

Yasushi Muraki from Nagoya University leads the LHCf collaboration, with 22 members from 10 institutions and four countries. For many of the collaborators this is a reunion, as they had worked on the former Super Proton Synchrotron experiment UA7.

ATLAS installs first of the big wheels



The first wheel of the muon spectrometer is completed and measures 25 m across.

September saw the completion in the underground cavern of the first of the big wheels for the ATLAS muon spectrometer. The muon spectrometer includes four large wheels at each end of the barrel part of the detector, each measuring 25 m across. Six of these wheels will be composed of thin-gap chambers for the muon trigger system – the first wheel is one of these – while the other two will be made of monitored drift tubes to measure the position of the muons.

SCIENCEWATCH

Compiled by Steve Reucroft and John Swain, Northeastern University

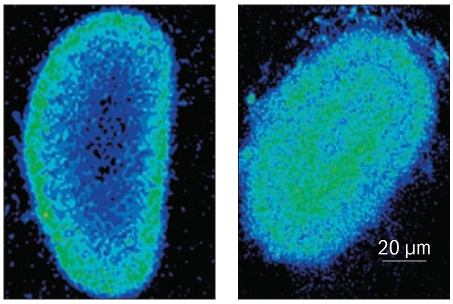
Ancient hair-dye recipe used nanotechnology

Nanotechnology is often regarded as one of the most modern and progressive fields of scientific research. Now, it appears to go back at least a couple of thousand years, as researchers have found that a lead-based hair darkener that has been used from Greco-Roman times up to the present day achieves its effect through the creation of nanocrystals.

Philippe Walter of the CNRS National Centre for Museum Research and Restoration in Paris and colleagues have called on an armoury of modern microscopy techniques to study the effects of an ancient hair-dyeing recipe that uses lead salts. Basically, the salts react with sulphur in the amino acids in hair to form dark crystals of lead sulphide (PbS), with obvious cosmetic value.

The researchers used a simple mixture of water, slaked lime (calcium hydroxide) and lead oxide (PbO) to dye blonde human hair over periods up to 72 hours. Optical microscope pictures showed the hair progressively darkening towards the centre, and electron microscopy and spectroscopy techniques revealed the corresponding increase in lead concentration (see figure).

Further electron microscopy revealed in detail the deposits of tiny PbS crystals around the macrofibrils that make up the cylindrical cortex of the hair. The crystals are on average about 5 nm across, and appear similar to PbS quantum dots synthesized by modern materials-science methods, even though they are created using low-cost ancient technology. The researchers are now using other metal ions to learn more about how hair works as a "nanoreactor", which they say "could open new perspectives in the development of nanocomposites".



Maps showing cross-sections through human hairs treated for 6 hours (left) and for 72 hours (right) show a progressive radial fixation of lead from the cuticle to the centre of the hair (concentration increasing from dark blue to green).

Further reading

Philippe Walter *et al.* 2006 *Nano Letters* **6** 2215.

The Klein paradox and pencil lead

The Klein paradox – in which relativistic particles can penetrate surprisingly high potential barriers – is well known to particle physicists and usually thought of as a high-energy phenomenon, related to the creation of particle–antiparticle pairs in strong fields. However, it has so far defied direct experimental tests.

Mikhail Knatelson of Radboud University Nijmegen in The Netherlands and colleagues have now pointed out that the paradox could be tested in the laboratory using Dirac-like quasiparticles in graphene – a mono-atomic layer of carbon that can be picked up from a line drawn with a graphite pencil.

This is just the latest in an ever increasing variety of phenomena that are exotic and hard to do in the normal, real world, but which have some interesting condensed-matter analogues.

Further reading

M I Knatelson, K S Novoselov and A K Geim 2006 *Nature Physics* **2** 620.

Double pulsar makes best test yet of general relativity

General relativity has scored yet another impressive success. Measurements on a double pulsar system 2000 light-years away have confirmed Albert Einstein's theory to within 0.05%, providing the most precise test made so far. The measurements, led by Michael Kramer of the University of Manchester's Jodrell Bank Observatory, are based on more than two years of observations made of the double pulsar system PSR J0737-3039A/B since its discovery by many of the same team in 2004 (*CERN Courier* March 2004 p12).

The work takes earlier single pulsar measurements a step further as the radio beacons of two pulsars provides much more detailed data. The data constrain alternatives to general relativity in a region where gravitational fields are strong, with pulsars only about 20 km across but with masses larger than the Sun.

Further reading

M Kramer *et al.* 2006 *Science* **314** 97.

Nanostrips extend negative refraction

Negative indices of refraction are a hot topic these days, with applications to exotic optics such as "superlenses" and forms of "invisibility". Practical work, however, has been limited to the microwave region because of the difficulty in fabricating the tiny elements required. Now Uday Chettiar and colleagues at Purdue University in Indiana may have made a breakthrough. They report simulations of designs for materials made from metallic nanostrips separated by a dielectric layer. These should be easy to fabricate down to 10 nm and could lead to practical negative refraction in infrared and even optical regions of the spectrum.

Further reading

Uday K Chettiar *et al.* 2006 *Optics Express* **14** 7872.

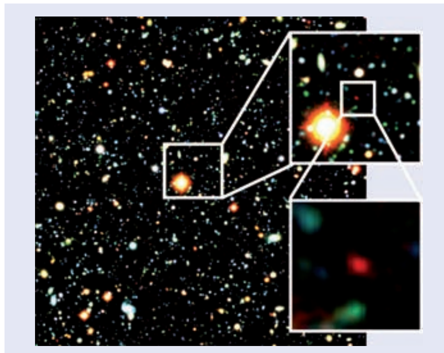
Compiled by Marc Türler, INTEGRAL Science Data Centre and Geneva Observatory

Subaru finds most distant galaxy

Japanese astronomers using the Subaru Telescope in Hawaii have detected the most distant known galaxy in the universe. Light from this source was emitted 780 million years after the Big Bang, at a time when the universe was eight times smaller. The surprise is that such distant galaxies are apparently much less numerous than expected. Are we seeing the very first massive galaxies emerging from the dark ages?

Twenty years ago, the remotest known galaxy was at a redshift z of less than 2. This was pushed back to a redshift of 4.55 ten years later and since 2002 the record redshift was 6.56. Then in 2004 the detection of galaxies amplified through gravitational lensing at $z = 7$ and even $z = 10$ was announced (*CERN Courier* May 2004 p13). While the first of these detections has not yet been confirmed spectroscopically, the nature of the second galaxy is still a puzzle, although it is now quite clear that it is not at a redshift of 10.

A new step forward has now been achieved with the definite detection of a galaxy at a redshift of 6.96 by a Japanese team led by Masanori Iye. They found the galaxy with a special filter and camera mounted on the 8.2 m aperture Subaru Telescope at the summit of Mauna Kea on Hawaii. The filter is designed to catch Lyman-alpha emission from star-forming galaxies at a redshift between 6.94 and 7.11. The near-infrared camera has 84 million pixels to cover a relatively wide field of view. Among 41 533 sources detected through this filter only two objects are not detected at shorter wavelengths. Spectroscopic follow-up observations of the brightest of these two sources clearly identified the Lyman-alpha emission line shifted by a factor of $z + 1 = 7.96$ from its rest wavelength of 121.6 nm to an observed wavelength of 968.2 nm. The second candidate source was too faint to be confirmed spectroscopically.



A series of images zooming in on Galaxy IOK-1, the reddish object in the centre of the last panel, which is currently the most distant known galaxy located about 12.88 billion light-years away. The wide-field image covers 254 × 284 arcsec of the region observed in the search for distant galaxies. The close-up image measures 8 × 8 arcsec. (Copyright Subaru Telescope.)

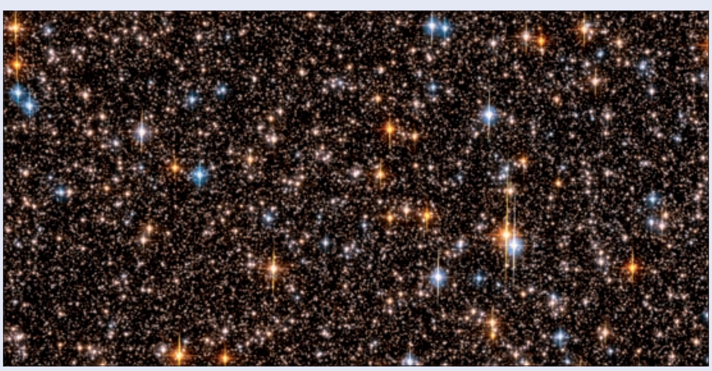
The detection of only one or possibly two galaxies in this survey is well below the expectation of six sources, based on the number of galaxies observed in the same field at a photometric redshift of 6.6. A similar deficit of high-redshift galaxies was also found by R J Bouwens and G D Illingworth at the University of California Santa Cruz. They found only one candidate galaxy between a redshift of 7 and 8 in the Hubble Ultra Deep Field instead of the 10 expected, based on the galaxies found at a redshift around 6. Both results suggest that very luminous galaxies are rare around 700 million years after the Big Bang.

This is an important result as it gives the timescale needed for the building up of luminous galaxies. According to the polarization measurements of the cosmic microwave background by the Wilkinson Microwave Anisotropy Probe (*CERN Courier* May 2006 p12) the first stars in the universe were formed at a redshift of up to 12 or 13 some 300 million years after the Big Bang. Another 400 million years would have been needed to allow small galaxies to merge and form the luminous galaxies we start detecting at a redshift of 7. To detect the fainter galaxies emerging from the dark ages we might have to wait for the launch of the James Webb Space Telescope (JWST) currently scheduled for 2013.

Further reading

R J Bouwens and G D Illingworth 2006 *Nature* **443** 189.
M Iye *et al.* 2006 *Nature* **443** 186.

Picture of the month



This image is one-half of the Hubble Space Telescope's field of view in the Sagittarius Window Eclipsing Extrasolar Planet Search (SWEEPS). It contains approximately 150 000 stars in the crowded central bulge of our galaxy. The SWEEPS observation lasted one week with the aim of detecting the slight dimming of a star when a Jupiter-sized planet passes in front of it. Altogether it looked at 180 000 stars and found 16 candidates for extrasolar planets, which agrees statistically with the planets in our solar neighbourhood. However, five of them orbit their star in less than a day. Such close planets only survive against evaporation if the star is smaller and cooler than the Sun. (Courtesy NASA, ESA and K Sahu [STScI].)

CERN COURIER ARCHIVE: 1963

A look back to CERN Courier vol. 3, November 1963

DUBNA

International conference focuses on high-energy accelerators

Last year CERN hosted the International Conference on High-energy Physics, under the auspices of the International Union of Pure and Applied Physics. This year it was the turn of Dubna, the Joint Institute for Nuclear Research, where the companion International Conference on High-energy Accelerators took place. Twenty-one physicists and engineers, including the director-general, went from CERN.

The conference brought together some 300 participants, about a quarter from the US and a quarter from Western Europe. No doubt because there are so few secrets among scientists and engineers working in this field, much of the material presented was already known. However, for the Americans and Western Europeans there was the added interest of being able to hear of the Soviet work at first hand and to visit the major laboratories (at Dubna itself and in Erevan, Kharkov, Leningrad, Moscow, Novosibirsk and Serpukhov).

Development of existing accelerators

Beam intensity, always important for experimenters, had in most cases been improved. For instance, the 6 GeV Bevatron at the Lawrence Radiation Laboratory, Berkeley, US, had reached 2.3×10^{12} protons per pulse. The Cambridge Electron Accelerator, US, had 5×10^{10} electrons per pulse: with a repetition rate of 60 per second this represented 10^{12} electrons per second. The achievement by the CERN Proton Synchrotron (PS) of 0.9×10^{12} protons per pulse was announced to the conference.

Accelerators recently completed

Information was presented on three new proton accelerators, all completed this year, two just in time for the conference: the Princeton–Pennsylvania Accelerator (3 GeV) at the Forrestal Research Center, Princeton, US; Nimrod (8 GeV) at the Rutherford High Energy Laboratory, Chilton, UK; and the Zero Gradient Synchrotron (12.5 GeV) at the Argonne National Laboratory, Chicago, US.

Accelerators under construction

The machine that attracted most attention was the 70 GeV proton synchrotron being built at Serpukhov. Essentially a conventional strong-focusing synchrotron, that is, a larger version of the CERN PS or the Brookhaven Alternating Gradient Synchrotron, it is expected to come into operation in about three years' time.

The other machines under construction are all for accelerating electrons. The largest is the Stanford Linear Accelerator (sometimes known as "the monster") in the US, which will initially reach 20 GeV. Another linear accelerator, for 2 GeV, is being built at Kharkov, USSR. At Hamburg, Federal Republic of Germany, DESY – an electron synchrotron designed for 6 GeV – is now nearing completion, and a very similar machine is well under way at Erevan in Armenia. Finally, there is the new British machine, Nina, for 4 GeV, to be built at Daresbury, Cheshire.

Accelerator projects

There are a number of new design studies for larger proton synchrotrons. In the US, a group at the Lawrence Radiation Laboratory, Berkeley, is working on a 200 GeV machine and a group at the Brookhaven National Laboratory is working on an even larger machine, in the range 600–1000 GeV. Western European work in this field is centred at CERN, where the outline of a 300 GeV synchrotron has been produced. A 500 GeV synchrotron is under consideration at the Institute of Theoretical and Experimental Physics in Moscow. A second Russian group, however, is working on plans for a machine operating on so-called "cybernetic principles", to give 1000 GeV. Another unconventional design, for a 10 GeV electron synchrotron, is being worked on at Cornell University, US. This would have the magnet inside the vacuum tank.

Storage rings and colliding beams

A number of papers on the CERN design for a pair of rings to be fed by the 28 GeV PS were read at the conference.

At Stanford, US, in conjunction with Princeton University, a pair of rings has been constructed for 500 MeV electrons. Early operation revealed that stored beams were limited to 15–20 mA by vertical oscillations. Trouble has also been experienced with a pair of electron–positron rings designed by the Frascati Laboratory, Italy, and being tested with the aid of the linear accelerator at Saclay, France.

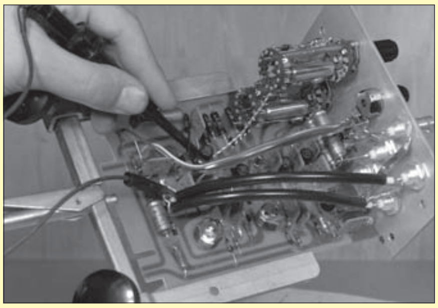
In the USSR, the Institute of Nuclear Physics at Novosibirsk has a pair of rings in which 50–100 mA of electrons can be stored for up to about an hour at 100 MeV and a pair of electron–positron rings for 700 MeV is in an advanced state of construction. A pair of rather more conventional rings for 100 MeV is being built at Kharkov.

New ideas

Apart from the innovations already mentioned, the most interesting new idea was the non-linear accelerator proposed by the Soviet physicist Orlov, said to be capable of accelerating protons to any energy between 1 GeV and 1000 GeV with enormous beam intensities.

● Compiled from a feature on the Dubna conference pp143–145.

CERN NP electronics



Various people from all over CERN had a hand in the sordid but useful subject of standardization, from whence came the versatile chassis-building system. Produced by the Nuclear Physics (NP) Division Electronics Group, this system enables electronic "boxes" of many shapes and sizes to be built from a small number of standardized components. This piece produces a standard output pulse when triggered by a suitable input signal.

● From a feature on the CERN NP Electronics Group pp141–142.

COMPUTING NEWS

Compiled by Hannelore Hämmerle and Nicole Crémel

GRID PROJECTS

EGEE gets down to business

Three companies have signed up as the first EGEE Business Associates (EBAs) to work with the Enabling Grids for E-sciencE (EGEE) project. The aim of this collaboration with business is to make the distributed computing infrastructure of the Grid more user friendly, effective and secure in an industrial context. The news was announced at the EGEE'06 conference, held in Geneva on 25–29 September.

NICE Italy will develop its GENIUS Grid Portal and EnginFrame FrameWork, to make it compatible with the EGEE middleware gLite. The company works with others in mechanics, energy, biotech, aerospace, electronics and telecoms, as well as with research and education organizations, to solve problems that are related to computing resource optimization and rationalization. The systems infrastructure software company Platform Computing will work with EGEE to improve the interoperability of the gLite middleware with load-sharing facilities (LSF), so that resources that are connected through the LSF local resources management system can be better exploited on the Grid. Founded in 1992, Platform has been a pioneer in high-performance, cluster and Grid computing technologies. The third company to become an EBA is the professional-services giant PriceWaterhouseCoopers, who will collaborate with EGEE on issues that relate to Grid security, contributing their extensive experience in risk management.

EGEE is working with business players in the Grid arena on many levels and in many areas to ensure effective two-way communication and pro-active discussions. The EBA programme is an important component in EGEE's strategy for the take-up of its work by business and industry, providing a framework in which companies can confidently adopt Grid technologies. With this collaboration EGEE is paving the way to making Grids the technology of the future for business in all sectors.

EGEE'06 presented the different channels that the EGEE project has set up for working with industry. For the first time the conference included a dedicated two-day business track with more than 20 industry and research experts who are geared to introducing their recent developments of corporate Grid adoption in the context of major IT trends, such as security, standardization and virtualization issues. Representatives from the financial, automotive, petroleum and public administration sectors, and more, have been selected to analyse how Grids, as part of the global evolution of corporate information technology, will benefit industry in the future. Special emphasis is now on industrial applications that could use the EGEE infrastructure and middleware, making sure that the industry-specific requirements are fed into the project on an equal footing with those from the scientific applications.

OSG receives $30 m for scientific computing collaboration

The US National Science Foundation (NSF) and the Office of Science of the US Department of Energy (DOE) have joined forces to award $30 million over five years to the Open Science Grid (OSG). The OSG will use the funding to operate and expand as a computing environment that is used by scientists to harness computing resources and scientific data from around the world.

The OSG Consortium, a unique partnership of universities, national laboratories, scientific collaborations and software developers, built and operates the OSG. Computing resources from more than 50 sites in the US, Asia and South America, ranging from small clusters of 10 computers to large facilities with thousands of processors and petabytes of data storage, are now shared through the OSG. Together with other Grid computing projects, from computing Grids on university campuses to large national and international Grid projects such as TeraGrid and Enabling Grids for E-sciencE, the consortium works to create a worldwide computing infrastructure for scientific research.

Scientists from many fields, including astrophysics, bioinformatics, computer science, nanotechnology, nuclear science and particle physics, use the OSG infrastructure. In particle physics, US participants in the ATLAS and CMS collaborations will rely on the OSG to connect them with data from the Large Hadron Collider when it starts up. In astrophysics, the scientific collaboration behind the Laser Interferometer Gravitational-Wave Observatory (LIGO) will use the OSG to integrate its computing facilities and enable its search for gravitational waves. Over the next five years, the consortium will reach out to more scientists and scientific collaborations, helping them to harness the power of Grid computing for their research.

Les gros titres de l'actualité informatique

MIDDLEWARE

KnowARC project gets going

The KnowARC project, which will improve and extend the state-of-the-art technology in the Advanced Resource Connector (ARC) Grid middleware, commenced on 1 June. The 6th EU Framework Programme will fund the project, which involves 10 partners from seven European countries, for three years. Its full name, Grid-enabled Know-how Sharing Technology Based on ARC Services and Open Standards, reflects the goals and means. The aim is to deliver innovative general-purpose software solutions to utilize existing Grid technologies and international standards.

A decade of Grid development has produced a variety of solutions, yet the Grid remains a largely academic phenomenon. The KnowARC project sets out to develop software foundations for a Grid solution that will suit everybody, businesses and individuals alike. Its goal is to fuse methods for know-how sharing with the Grid technology that is offered through the ARC software by NorduGrid and the Hungarian ClusterGrid infrastructure (*CERN Courier* September 2006 p22). Ultimately it will provide a Grid-enabled way to navigate through the flood of information and methodologies for individual and corporate users in Europe and beyond. The objectives of the project focus on moving the ARC software to a service-oriented architecture and achieving an industrial quality by meeting the requirements of standard conformance, interoperability, reliability, security and overall usability.

The most important architectural vision of the project is the creation of a middleware that is composed of elementary building blocks, i.e. computer and data-storage components or special services that can be accessed through Web or Web-communication encapsulated protocols. It is key that all of the software components should be easy to install and be available on a broad range of operating systems. Other important goals are to ensure that the different software components satisfy existing Grid standards and to identify standard improvement possibilities in both Web and Grid services. The KnowARC solutions should be interoperable with key European Grid infrastructure initiatives such as Enabling Grids for E-sciencE. The condition is that all of the developed core software will follow the Open Source licensing standards and will be available free of charge for all. Currently, more than 6000 CPUs in more than 60 installations worldwide are joined through using ARC.

AWARDS

GRIDtoday honours CERN and e-Science

CERN and the UK e-Science Programme were honoured for their leadership in Grid computing at GridWorld, a major conference for enterprise Grids that was held in Washington DC on 11–15 September. The publishers of *GRIDtoday*, a leading Web-based news source on Grid technology for the business world, presented the awards as part of the *GRIDtoday* Annual Readers' and Editors' Choice Awards.

CERN received two Readers' Choice Awards, which are based on a poll of several thousand readers representing IT companies and industrial sectors that use Grid technology intensively. One award is for the research organization that demonstrates the most innovative Grid implementation in government research, the other is for the research Grid initiative that has earned the reputation of overall "Top Research Grid".

The Editors' Choice Awards recognized the UK e-Science Programme, also in the category for the most innovative Grid implementation in government research. This programme started in 2001 and has invested £250 million in Grid research, development and deployment. It fosters the development of IT and Grid technologies to enable faster, better or different research, with the aim of establishing a sustainable, national e-infrastructure for research and innovation that meets the aims of the government's Investment Framework for Science and Innovation 2004–2014.

WEB DEVELOPMENT

W3C to support more languages in voice applications

The World Wide Web Consortium (W3C) has announced the results of the second Workshop on Speech Synthesis Markup Language (SSML), which was held on 30–31 May in Crete. At the workshop, speech experts from around the world presented ideas for expanding the range of languages that are supported by SSML 1.0.

The results include an initiative to revise SSML 1.0 to support more languages, including Mandarin, Hindi, Arabic, Russian, Hebrew and other languages that are spoken in India and Asia. These results reinforce important discoveries from the first SSML workshop in Beijing in 2005, which provided crucial information on many Asian languages. The announcement of the results also calls researchers around the world to join the effort to improve the specifications.

It is estimated that within three years the Web will contain significantly more content from currently under-represented languages, such as Chinese and Indian language families. In many of the regions where these languages are spoken, people can access the Web more easily through a mobile handset than through a desktop computer. There are more than 10 times more mobile phones today than there are Internet-connected PCs. An improved SSML will increase the ability of people worldwide to listen to synthesized speech through mobile phones, desktop computers or other devices, greatly extending the reach of computation and information delivery into nearly every corner of the globe.

Workshop participants expressed the need to add to the SSML standard the ability to represent features in spoken language, including tone, syllabic stress or accent, and duration in a machine-readable fashion. For some languages, these attributes are an important factor in determining meaning. Organizations, particularly those with native understanding of the languages of Japan, China, Korea, Russia and India, are encouraged to participate in the W3C Voice Browser Activity.

SIMULATION

Jefferson Lab attracts record numbers to Geant4 workshop

The Geant4 workshop that was held at Jefferson Lab in May was well attended by professionals and students from nuclear and high-energy physics, as well as from industry and healthcare.

An additional electricity supply was needed to power the laptops that were required for the Geant4 workshop's hands-on tutorials.

A five-day hands-on workshop that was based on the simulation toolkit Geant4 attracted an unexpectedly high number of participants when it took place at Jefferson Lab on 22–26 May. To the organizers' amazement, within hours of sending the first Geant4 tutorial e-mail announcement, all of the planned 65 slots were filled. "I have never seen such overwhelming interest in a physics conference before," said the organizing-committee chair, Paul Gueye, of Hampton University.

Geant4 is a toolkit for the simulation of the passage of particles through matter, and has applications in research that extends beyond particle and accelerator physics to space and medical science (*CERN Courier* January/February 2005 p27). Participants travelled from around the world to attend the workshop, coming from a wide range of fields, such as healthcare and industry, as well as nuclear and high-energy physics. As the requests for spots continued to pour in, the local organizers scrambled to find capacity for more participants, including electrical power for the laptops required for the hands-on sections of the tutorial. Ultimately, the organizers accepted more than 140 participants by using Jefferson Lab's auditorium with temporarily installed electrical power.

The tutorial workshop began with talks from Jefferson Lab scientists presenting physics experiments conducted at the Lab, along with examples of how Geant4 is employed. The remainder of the day was devoted to introductory talks on Geant4, while the organizers ensured that the conference participants successfully installed Geant4 on their laptops. Those with Linux, MacOS or Windows were all running Geant4 by the end of day.

For the next three days, participants were treated to an interesting mixture of lectures and hands-on tutorials that were led by Geant developers from SLAC: Joseph Perl, Makoto Asai, Bennis Wright and Jane Tinslay. The topics ranged from particle physics to medical applications and covered all aspects of the Geant4 toolkit from basic installation through to advanced topics. This co-operative learning experience was a success, as the participants could ask the experts or their neighbours if they became stuck on a problem.

The final day of the workshop was spent reviewing Geant4 documentation and encouraging workshop participants to ask specific questions about any problems that they had encountered with Geant4. The Jefferson Lab conference organizers and the SLAC team held meetings to discuss how to incorporate the medium-energy cross-section values that Jefferson Lab has measured into the Geant4 physics model. In particular, these data could serve as a validation benchmark for the electromagnetic and hadronic pieces of the toolkit in the giga-electron-volt energy range. The conference ended with tours of Jefferson Lab's electron accelerator and the three experimental halls.

● Those interested in attending an upcoming Geant4 tutorial should check the events section of the Geant4 home page at http://cern.ch/geant4/. Copies of the Jefferson Lab Geant4 tutorial presentations are at http://geant4.slac.stanford.edu/tutorial/jlab06/agenda.html.

CNL ARCHIVE

CNL celebrates 40 years of news

A general view of the CERN Computer Centre in March 1998.

Renovation of the Computer Centre at CERN in July 2003. Half of the equipment of the large ground-floor room has been removed. A large-scale spring-cleaning operation took place before the renovation. Workers removed 15 km of cables that were no longer needed from the cavity floor for recycling, to prepare for PC farms.

After CERN's 50th anniversary in 2004, this year there is another anniversary: the first *CERN Computer Newsletter* (*CNL*) was circulated in 1966. This is the last part of the review to celebrate *CNL*'s 40th birthday, concentrating on the period from 1990 until the early years of the 21st century when the Grid is first mentioned. Here you will find a brief look at previous issues of *CNL*; for an extended retrospection read *CNL*, which is also available at www.cerncourier.com.

Crack: a CERN password checking service

Passwords are the primary security loophole on a system. If users have guessable passwords then "bad guys" can use their accounts without being detected. These intruders can cause damage to the individual user and also to other users. The use of security tools like Kerberos or shadow passwords are not sufficient since the "crackers" can still try to guess passwords. The only really safe solution is to make users aware of the dangers and understand the following:

- why it's dangerous to have guessable passwords (for them and for CERN);
- how to choose a good password.

[...] However, some guessable passwords will always be used and conscientious system administrators should try to reduce the number of users with a guessable password. This is the purpose of the "Crack service" (*CNL* 221 July–December 1995).

The "Year 2000" problem
The Millennium Bug – the Bug is born

The Millennium Bug is not some exotic insect, but an error that is lurking in computer programs, waiting for the chimes of midnight on 31 December 1999, before emerging to bite us – hard. Even as the champagne corks are popping to herald in the last year of the second millennium, planes will start to fall from the sky, lifts will stop working, banks will stop paying correct interest and society in general will grind to a halt – or so the story goes. To illustrate what the fuss is about, consider an early sign of the Bug's presence. In 1993, a lorry carrying a consignment of corned beef attempted to deliver its load to a British supermarket. Corned beef has a shelf-life of seven years, but when the supermarket's computer tried to check this, instead of subtracting 1993 from 2000 to get seven, it performed truncated arithmetic, subtracting 93 from 00, to give –93. The load was refused (but accepted manually) (*CNL* 228 June–September 1997).

Remote/mobile computing at CERN

With the growing number of portable computers, palm-tops and mobile phones, as well as the need to keep in touch with CERN not only from home, but also while on business travel, a coordination activity has been started in IT division for remote/mobile computing (*CNL* 232 July–September 1998).

A new mail address for spam complaints

Following a *de facto* standard in the Internet world a new contact address at CERN has been defined for matters related to unsolicited bulk mail (spam). Please direct your questions or complaints concerning spam to abuse@cern.ch. This will allow us to share the workload more efficiently (*CNL* 234 January–March 1999).

European DataGrid project demonstrated successfully

On Friday 1 March, the EU-funded DataGrid project successfully passed the first-year review performed by external experts appointed by the European Union [...] Once "connected" to the Grid, the end-user will see it essentially as one large computer system. For these reasons, many believe the Grid to be the most practical solution to the so-called data-intensive science problem that must be overcome if the computing needs of scientific communities, such as processing of physics data from LHC experiments, are to be satisfied (*CNL* 2002-001 January–March 2002).

VOLUNTEER COMPUTING

LHC@home moves its base to the UK

Particle physicists in the UK are preparing for an influx of help, with the announcement that a successful volunteer computing project is to move to Queen Mary, University of London, with support from Imperial College. The LHC@home program has already run on 30 000 home or office computers. Now CERN has agreed to move the hub of the project to the UK.

LHC@home distributes Sixtrack, an accelerator simulation program that is used at CERN. Volunteers download parameters to simulate particles circulating in the accelerator under different conditions, uploading the results after each simulation (*CERN Courier* April 2005 p18). The physicists submit a large batch of simulations and then analyse the results before submitting the next batch, so there is sometimes no work for LHC@home volunteers. However, like SETI@home and many other distributed computing projects, LHC@home uses the BOINC platform (*CERN Courier* September 2004 p62). Users can opt to run other projects, such as modelling climate change or controlling malaria, during quiet periods.

So far, users in more than 100 countries have contributed the equivalent of about 3000 years on a single computer. According to Lyn Evans, head of the Large Hadron Collider (LHC) project, "the results from this initiative are really making a difference, providing us with new insights into how the LHC will perform."

Physicists from the GridPP project in the UK will manage LHC@home from later this year. GridPP is the UK's contribution to the huge worldwide Grid that will deal with data from the LHC once it starts up next year.
● See http://cern.ch/athome.

Calendar of events

November
11–17 **SC06** Tampa, US, http://sc06.supercomputing.org/

21–24 **CIC 2006** Mexico City, Mexico, http://magno-congreso.cic.ipn.mx/CIC-2006/

22–24 **IST 2006** Helsinki, Finland, http://europa.eu.int/information_society/activities/istevent/index_en.htm

December
4–6 **e-Science 2006** Amsterdam, Netherlands, www.escience-meeting.org/eScience2006/

February 2007
13–15 **PDCN 2007** Innsbruck, Austria, www.iasted.org/conferences/home-551.html

Symposium focuses on scientific supercomputing

The second DEISA symposium focused on Perspectives in High Performance Computing, looking at developments in high-end supercomputer architectures and the grand challenges in computational science and scientific supercomputing. **Hermann Lederer** reports.

Supercomputing was the theme of the second annual Distributed European Infrastructure for Supercomputing Applications (DEISA) symposium, in the Palazzo Re Enzo, Bologna, on 4–5 May. In 2005, DEISA, the European counterpart of the US National Science Foundation's TeraGrid project, launched a call for challenging projects within the DEISA Extreme Computing Initiative (DECI). During the symposium, principal investigators of active DECI projects explained their specific scientific challenges and their approaches in answering open questions using supercomputers. Subjects included supernova research, climate modelling, quantum chromodynamics (QCD), space missions and cosmology, computational fluid dynamics, materials science and computational biology.

In astrophysics, Wolfgang Hillebrandt, director at the Max Planck Institute for Astrophysics in Garching, illustrated the challenge of modelling thermonuclear supernovae in 3D. His DEISA project, Supernova, calibrating type Ia supernova models, used 512 tightly coupled processors for the simulation in collaboration with the University Würzburg, Torino Observatory, The Institute of Theoretical and Experimental Physics in Moscow, and Stockholm Observatory. Hillebrandt explained the challenges and open questions of supernova physics and its prime importance for modern cosmology, and presented first results from the DEISA simulation (figure 1).

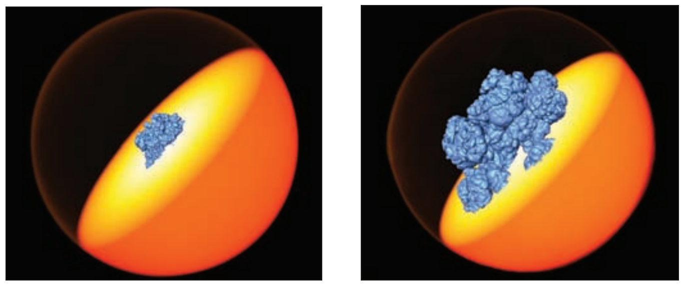


Fig. 1. The DECI project, Supernova. Simulation of the time evolution of a thermonuclear supernova explosion (type Ia), showing the stellar gas density with the flame front expansion after 0.4 s (left) and 0.8 s (right). (Courtesy W Hillebrandt.)

Karl Jansen from the John von Neumann Institute for Computing, Jülich, and DESY, Zeuthen, reported on the quest for solving quantum chromodynamics (QCD), and introducing the basics, he explained why the simulation of fermions is so computer intensive. He then discussed the concept of twisted-mass QCD (TMQCD). The DECI project TMQCD, on QCD simulations with light quark flavours, deals with twisted-mass fermions. It is fully instrumented with the Uniform Interface to Computing Resources (UNICORE) middleware. For the simulation runs the scientists use resources from four DEISA sites, which are all connected to a shared global file system. The TMQCD DECI project resulted from the European Twisted Mass Collaboration (ETMC) with partners from France, Germany, Italy, Spain and the UK.

The first DECI project to be completed is Channel-2000, which involves computing turbulence at experimental Reynolds numbers. Sergio Hoyas, of the Universidad Politécnica de Madrid, described the project and talked about the energy flux in homogeneous flows, and the nature of a turbulent channel and cascades in wall turbulence. He explained why he needed almost a million CPU hours and 25 TB of storage: the simulations must resolve the energy cascade down to a physical cut-off scale, which is determined by the viscosity of the medium. The Channel-2000 simulation had gone far beyond previous simulations, as figure 2 indicates. A potential future Channel-4000 project could have a resource requirement of about 20 million CPU hours.

Henk A Dijkstra from Utrecht University discussed ensemble simulations of extreme weather events, the subject of his DECI project, ESSENCE. Such simulations are important to assess the probability of rare, extreme events and to study their characteristics. They require many realizations or ensemble members. Probabilities are time-dependent as the external climate forcing is time-dependent, and external climate variations must be separated from internal ones: the ensemble average corresponds to external variations, while the historical climate evolution represents just one realization.

In space science, Fabio Pasian from the Osservatorio Astronomico di Trieste presented end-to-end simulations for the Low Frequency Instrument (LFI) for the ESA Planck space mission. On behalf of the LFI Consortium, he described the scientific goals of the Planck mission, its set-up and operations, the instruments and the data processing. The main scientific goal is to obtain sky maps of all the major sources of microwave to far-infrared emission as well as of the temperature, polarization and anisotropies of the cosmic microwave background, and to evaluate the main cosmological parameters. For the LFI-sim DECI project, Passian gave details of

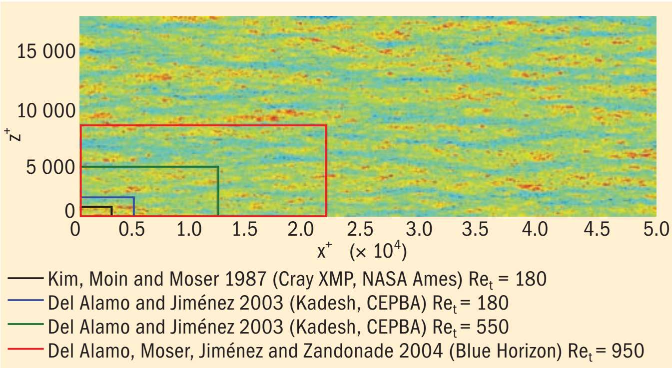


Fig. 2. Channel-2000, which reaches an experimental Reynolds number (Re_t) of 2000, calculating wall turbulence up to large scales from the wall, compared with previous simulations, to lower values of Re_t. (Courtesy J Jiménez.)

the simulations with respect to the processing pipeline, the computational challenges and the expected results.

Finally, Peter Coveney from University College London (UCL) discussed large-scale computation for materials and life sciences using DEISA. He explained the strategies and methods of the UCL Centre for Computational Science in scientific parallel and Grid computing, and presented the Application Hosting Environment of the RealityGrid project in the UK. The studies in his DEISA project, Large-scale Intensive Applications of Molecular Dynamics, deal with clay-polymer nanocomposites and HIV protease-inhibitor mutation pathways, as well as highly scalable applications when the Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS from Sandia) or NAMD (from the University of Chicago) are applied. The study of the molecular basis of drug resistance in HIV-1 proteases is related to the European Union FP6 e-Health project, ViroLab.

● DEISA's main objectives are to deploy and operate a consistent, production-quality, distributed supercomputing environment with continental scope and to enable scientific discovery across a broad spectrum of science and technology. The DEISA supercomputing Grid is a European research infrastructure that is structured as a layer on top of the national supercomputing services, significantly contributing to progress in high-end supercomputing.

Résumé

Colloque sur le supercalcul scientifique

Le supercalcul était le thème du 2ème Colloque annuel de DEISA (Infrastructure européenne répartie pour les applications de supercalcul) qui s'est tenu à Bologne les 4 et 5 mai. En 2005, DEISA, dans le cadre de l'initiative DECI, a invité les équipes scientifiques à soumettre des projets de calcul extrême. Au cours de l'édition de cette année, des participants à des projets DECI en cours ont exposé leurs projets scientifiques particuliers. Les domaines visés étaient très divers: recherche sur les supernovas, modélisation climatique, chromodynamique quantique, missions spatiales et cosmologie, dynamique des fluides computationnelle, science des matériaux et bio-informatique.

Hermann Lederer, *Rechenzentrum Garching der Max-Planck-Gesellschaft.*

Right on target: CNGS gets off to an excellent start

Six years after its construction began, the CNGS facility at CERN has sent its first batch of neutrinos 732 km to Gran Sasso in Italy in a highly successful commissioning run.

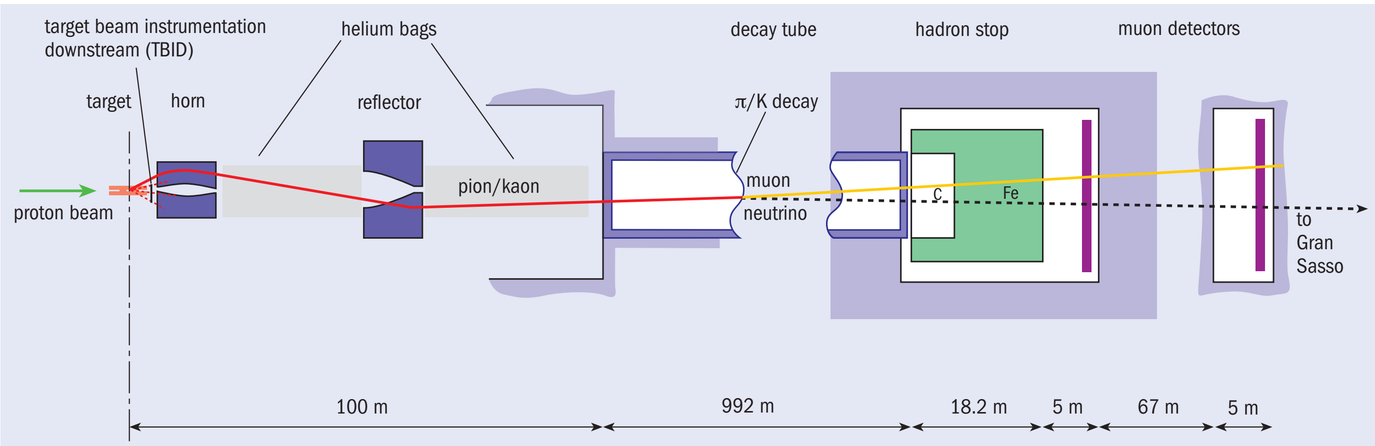


Fig. 1. The various components of the CERN Neutrinos to Gran Sasso facility, which produces an intense beam of muon-neutrinos.

The CERN Neutrinos to Gran Sasso (CNGS) facility was built to create a neutrino beam to search for oscillations between muon-neutrinos and tau-neutrinos. An intense, almost 100% pure beam of muon-neutrinos is produced at CERN in the direction of the Gran Sasso National Laboratory (LNGS), almost 732 km away in Italy. There, the OPERA experiment (p24) is being constructed to find interactions of tau-neutrinos among those of other neutrinos.

The production of the CNGS beam of muon-neutrinos follows the "classic" scheme that was first used in the 1960s at Brookhaven and CERN, and has been refined ever since. An intense proton beam from CERN's Super Proton Synchrotron (SPS) is sent to strike a target, in this case graphite. Protons that interact with nuclei in the target produce many particles, mostly unwanted, but including positively charged pions and kaons – mesons that decay naturally into pairs of muons and muon-neutrinos. Two magnetic lenses – the horn and the reflector – collect these mesons within a selected momentum range and focus them into a parallel beam towards LNGS (figure 1). After a decay tube nearly 1 km long, all the hadrons – i.e. protons that have not interacted in the target, pions and kaons that have not yet decayed, and so on – are absorbed in a hadron stopper; only neutrinos and muons can traverse this solid block of graphite and iron. The muons, which are ultimately absorbed downstream in around 500 m of rock, are measured first in two detector stations. Only the neutrinos are left to travel onwards through the top layer of the Earth's crust towards LNGS.

For the experimenters at LNGS, the beam's key feature is the energy spectrum, as this determines the number of events that they can expect to measure. Two important energy-dependent ingredients have to be taken into account to maximize the number of tau-neutrino events that are anticipated: the probability for muon-neutrino to tau-neutrino oscillation over the 732 km, and the probability for the tau-neutrino to leave a signal in a detector, i.e. the interaction cross-section for tau-neutrinos in matter, which is zero below a threshold of around 4 GeV. The product (convolution) of these two energy-dependent probabilities defines in effect an envelope in which the actual energy spectrum of the beam should fit. Figure 2 compares this convolution with the energy spectrum that was expected for the CNGS beam, as derived through Monte Carlo simulation, and shows how closely the match has been achieved. Note that the event rate at the OPERA detector at LNGS is very low. It will take many months of continuous CNGS running before the experiment can be expected to produce a neutrino energy spectrum like that in figure 2.

Six years in the making

CERN council approved the CNGS project in December 1999. Civil construction work began in September 2000 and was completed in June 2004. The underground work included the tunnel around 50–80 m below the surface for the 800 m proton beam line, as well as several caverns and access galleries. The facility uses protons from an extraction region at point 4 on the SPS, in common with the proton transfer line TI 8 for the Large Hadron Collider

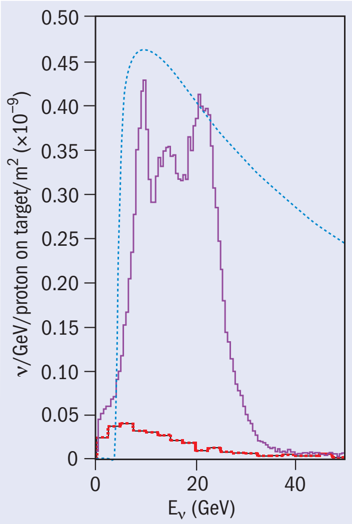


Fig. 2. Monte Carlo simulations of the muon-neutrino energy spectrum at Gran Sasso with (purple) and without (red) the focusing of pions/kaons by the horn and the reflector. The blue curve is the convolution of the probability for muon-neutrino to tau-neutrino oscillation over the 732 km, and the interaction cross-section for tau-neutrinos in matter (zero below a threshold of around 4 GeV).

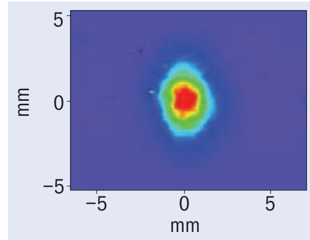


Fig. 3. Proton beam spot (above) from one of the eight screens. The screens are thin foils (left) in which protons produce optical transition radiation, a flash of light that a CDD camera can record to give an exact image of the proton beam spot.

(LHC) (*CERN Courier* October 2005 p6). A switch magnet at 100 m decides where the proton batches are sent: if the magnet is off, beam goes to the LHC, and if it is on, beam goes to the CNGS target. The beam line for CNGS then slopes down from the level of the SPS to a final slope of 5.6%, so that it points towards the LNGS.

While civil construction work continued, between July 2003 and April 2004 the beam dump (hadron stopper) and the 1 km decay tunnel were installed (*CERN Courier* October 2004 p27). Then in July 2004, with the construction work complete, an intense period of work began to install the electrical services, water-cooling and air-handling facilities. The overhead crane in the target chamber is an unusual feature that uses a rack-and-pinion system to cope with the slope of the tunnel. As well as being used in installation work, it will be needed for remote-handling in the harsh environment that is expected in the target chamber once the beam is operating at high intensity.

During the summer of 2005, installation of the services gradually gave way to the equipment installation in the proton beam tunnel as well as in the target chamber. By the end of November 2005, the proton beam was fully installed and the vacuum system closed, while work in the target chamber continued until spring 2006.

Testing, testing

During February to April of 2006, large parts of the CNGS facility closed as detailed tests of all components in the facility began. In particular, all of the 119 dipole and quadrupole magnets in the proton beam line were tested at nominal power and their polarities checked, and the water-cooling and ventilation systems were operated under nominal conditions. The control-system experts artificially introduced magnet faults in all of the elements to test in detail how the beam interlock system responded to such errors.

At the same time technicians performed exercises in which they completely changed the target and horn under realistic conditions, performing a large fraction of the work remotely, using the crane in the target chamber. The exercises allowed detailed log-sheets of every step to be established, recording the crane co-ordinates for the approach, picking-up, lifting, translating and depositing for every shielding block as well as for the target and horn systems.

Once the equipment experts had tested all of the CNGS components, it was time for the commissioning team to move to the CERN Control Centre (CCC) (*CERN Courier* May 2006 p15). Using a wealth of computers and display screens, the team tested every aspect of the CNGS facility under the most realistic conditions – as if there was beam, but without beam. This was a stressful period for the controls group and colleagues in the SPS operations team who were writing software. However, they responded to the challenge and, as commissioning with beam later demonstrated, these dry runs meant that the systems were working, saving much valuable beam time.

Large parts of the CNGS facility were closed on 19 May, in time for start-up with beam on 29 May. However, a last-minute schedule change, caused by a powering problem at the Proton Synchrotron, which feeds the SPS, implied that the first proton beam to CNGS could not be delivered until 10 July. This change of schedule allowed for another useful set of dry runs.

Beam commissioning begins

During the week of 10 July, the first of three CNGS beam commissioning weeks, the atmosphere in the SPS corner of the CCC was cheerful, but tension was nevertheless palpable. Initial tests of the extraction system with a CNGS-type beam had been done in autumn 2004, closely linked to the initial tests of the TI 8 beam (*CERN Courier* March 2005 p26). So it was no surprise to find that after only a few iterations, the kickers and septum magnets of the extraction channel from the SPS towards CNGS were well tuned, establishing a "golden trajectory". On 11 July the first proton batch headed off to the CNGS target, and it was reassuring to see the proton beam well centred in all of the eight screens along the proton beam line (figure 3).

The next step was to bring the beam position monitors (BPM) into operation. These important monitors were recuperated from the Large Electron–Positron collider, and equipped with sophisticated log-amp electronics, allowing them to measure the beam position rapidly and accurately. They revealed that the proton line was well tuned over its 800 m, with the maximum beam excursion far less than the permitted ±4 mm.

The CNGS commissioning also allowed a valuable test for the Beam Interlock System that was developed for the LHC. The ▷

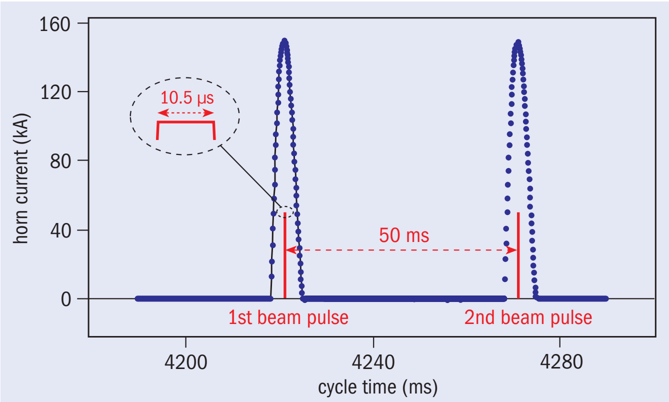
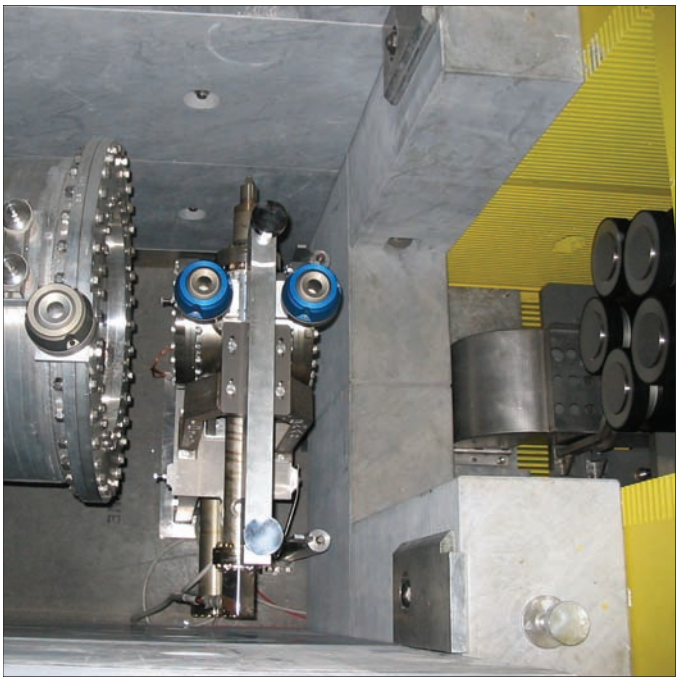


Fig. 4. The current pulses in the CNGS horn, as seen on the monitors in the CERN Control Centre. The 150 kA peaks of the two 7 ms pulses of the current are tuned to be in time with the arrival of the two 10.5 µs beam pulses, which are 50 ms apart.



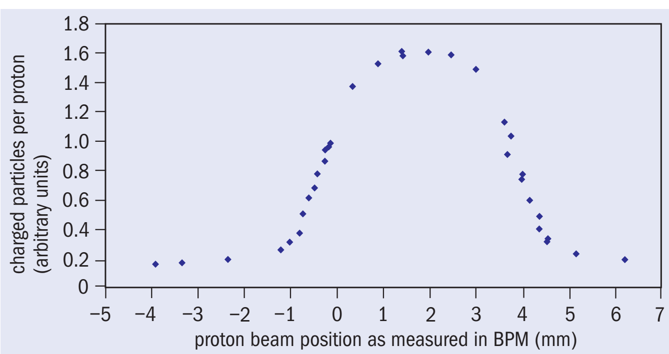


Fig. 5. Top: the TBID monitor, downstream of the target (on the right) and upstream of the horn, measures the integral of charged particles produced in the target. Bottom: the number of charged particles produced for different beam positions incident on the target; the result is a convolution of the target rod size (mainly 4 mm in diameter) and the proton beam spot.

BPMs provide one of the crucial inputs to this system: any beam position that is more than 0.5 mm from the nominal trajectory creates an interlock to inhibit the next proton extraction and, in turn, provides an alarm to the SPS operations team. In addition, a series of beam loss monitors (BLMs) along the path of the protons measure tiny losses of protons, which would indicate that the beam is off course. Together, the BPMs and BLMs form a powerful means to protect the equipment in the CNGS proton beam line against damage from any losses larger than permitted by the very low thresholds in the system.

The beam size along the proton beam line was very close to the expectations from simulations. For a high-intensity beam – some 10^{13} protons for each extraction – the beam spot at the target was the expected 0.5 mm rms. The measured beam position stability is about 50 µm rms averaged over several days, and is much better than initially specified. Both the size and the stability of the beam are extremely important for protecting the target rods against rupture from the thermo-mechanical shock that is caused by the intense beam pulse: the beam size must not be too small (and hence concentrated) and the beam must hit the target close to the centre.

Much of the CNGS beam commissioning was done using a very low intensity proton beam – around a hundred times lower than the nominal value of 2.4×10^{13} protons for each extraction. This was necessary to protect the equipment from potential faults and other surprises. It was only during the last two days of commissioning that intensities reached the 10^{13} range. As a result of this economic use of the beam, less than 7×10^{15} protons were sent to CNGS during the entire commissioning phase, corresponding to about an hour of standard CNGS operation. In addition, while standard CNGS operation is foreseen with two 10.5 µs 400 GeV/c proton beam extractions for every SPS–CNGS magnet cycle, most of the commissioning work was done with one extraction only.

Lining up

The CNGS proton beam is directed at a graphite target (CERN *Courier* October 2005 p6). The target consist of 13 graphite rods 10 cm long and 9 cm apart; the first two rods are 5 mm in diameter, while the others rods are 4 mm in diameter. The rods need to be thin and interspaced with air to let high-energy pions and kaons that are produced at smaller angles fly out of the target without interacting again. This is important for the relatively high-energy neutrino beam at CNGS, as pions of higher energies decay in flight into neutrinos of higher energies. Beyond the target lie the magnetic focusing system comprising the horn and reflector (*CERN Courier* March 2006 p6). The two focusing systems are operated with a pulsed current of 150 kA for the horn and 180 kA for the reflector. Both horn and reflector are pulsed twice for each SPS cycle; the two pulses are separated by 50 ms, in-time with the two beam pulses (figure 4).

An important step during the beam commissioning was to cross-check the centring of the proton beam on the target. This is done by the Target Beam Instrumentation Downstream (TBID) monitor in which secondary electrons are produced by charged particles traversing a 145 mm diameter, 12 µm thick titanium sheet in a vacuum box. A beam scan across the target provides information on the maximum production of charged particles, in other words, on the best alignment of the proton beam with respect to the target (figure 5).

The last check that can be made along the neutrino beam line is on the production of muons that are created in association with the muon-neutrinos in the decay of the pions and kaons produced in the target. Unlike the neutrinos, the muons are charged and can be rather easily detected, so during beam commissioning muon detector stations provided online feedback for the quality control of the neutrino beam. In CNGS these detectors must register up to 10^8 muons for each cm^2 in a very short pulse of 10.5 μs. This implies that the muons cannot be counted individually. So to monitor the muons CNGS uses nitrogen-filled, sealed ionization chambers. Such detectors have been used for many years, for example as BLMs around the SPS. CNGS could however take advantage of the most recent development of ionization chambers, which will be used as BLMs at the LHC. The first 76 of more than 3000 of these BLMs are now in use at CNGS. There are 37 fixed muon detectors in each of the two muon detector chambers. The monitors are arranged in a cross-shaped array to record permanently the horizontal and vertical profile (figure 6). An identical motorized monitor is installed downstream of the fixed ones to allow cross-calibration of the fixed monitors and to probe the muon profile where there is no fixed monitor.

Muons passing through the monitors produce electron–ion pairs, which are collected on sets of electrodes that are 5 mm apart at 800 V. Each muon monitor has 64 electrodes over an active length of 345 mm. The signal recorded is the integral number of charges for each beam pulse. The CNGS beam-commissioning team used the muon detector stations as an online feedback for the quality control of the neutrino beam (figure 7). The measurement is in reasonably good agreement with the preliminary expectations based on the FLUKA simulation package.

● CERN funded the CNGS project with special contributions from Belgium, France (in kind, via LAL/IN2P3), Germany, Italy (INFN and Compania di San Paolo), Spain and Switzerland. The CNGS proton-beam magnets were built in Novosibirsk, within a collaboration agreement between the Budker Institute of Nuclear Physics, DESY and CERN. The CNGS facility has been constructed and the beam commissioned on schedule and within budget. We would like to thank the many colleagues involved in CNGS, who have worked hard to help make this project a success.

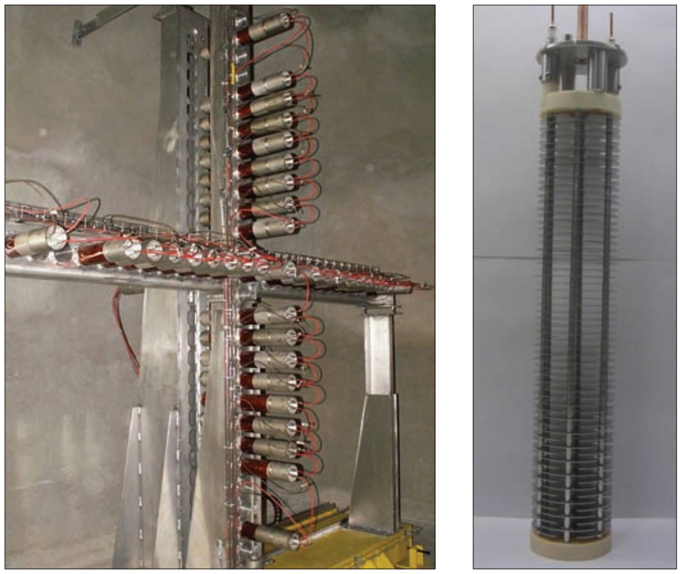


Fig. 6. Left: the muon-detector array. Right: a single detector.

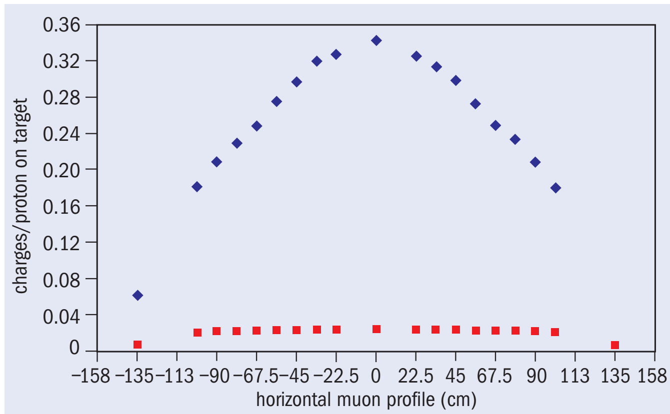


Fig. 7. Measured horizontal profile in the first muon detector chamber with the horn and reflector "on" (dark blue) and "off" (red), giving a muon yield that is roughly 10 times lower.

Résumé

En plein dans le mille: le CNGS est bien parti

L'expérience CNGS (Neutrinos du CERN vers le Gran Sasso) a été conçue pour créer un faisceau de neutrinos, dans le but d'étudier les oscillations entre neutrinos du muon et neutrinos du tau. Tout d'abord, un intense faisceau de protons issu du SPS du CERN vient frapper une cible en graphite spécialement construite à cet effet, produisant ainsi des pions et des kaons. Un système magnétique, constituée d'une corne et d'un réflecteur, concentre les pions et les kaons de sorte que ceux-ci, en se désintégrant, forment un faisceau intense de neutrinos du muon dirigé vers le laboratoire souterrain du Gran Sasso, en Italie, à une distance de 732 km. Six ans après le début de la construction de la structure, et après une série d'essais menés cet année, CNGS a envoyé sa première salve de neutrinos à destination du Gran Sasso, à l'occasion d'une mise en service tout à fait réussie.

Konrad Elsener, **Edda Gschwendtner** *and* **Malika Meddahi**, *CERN.*

OPERA makes its debut under the Gran Sasso

After three years of construction, the OPERA experiment has detected the first neutrinos from CNGS, and an automated production and assembly line is in full swing to complete the detector so that its full search for the appearance of tau neutrinos can begin.

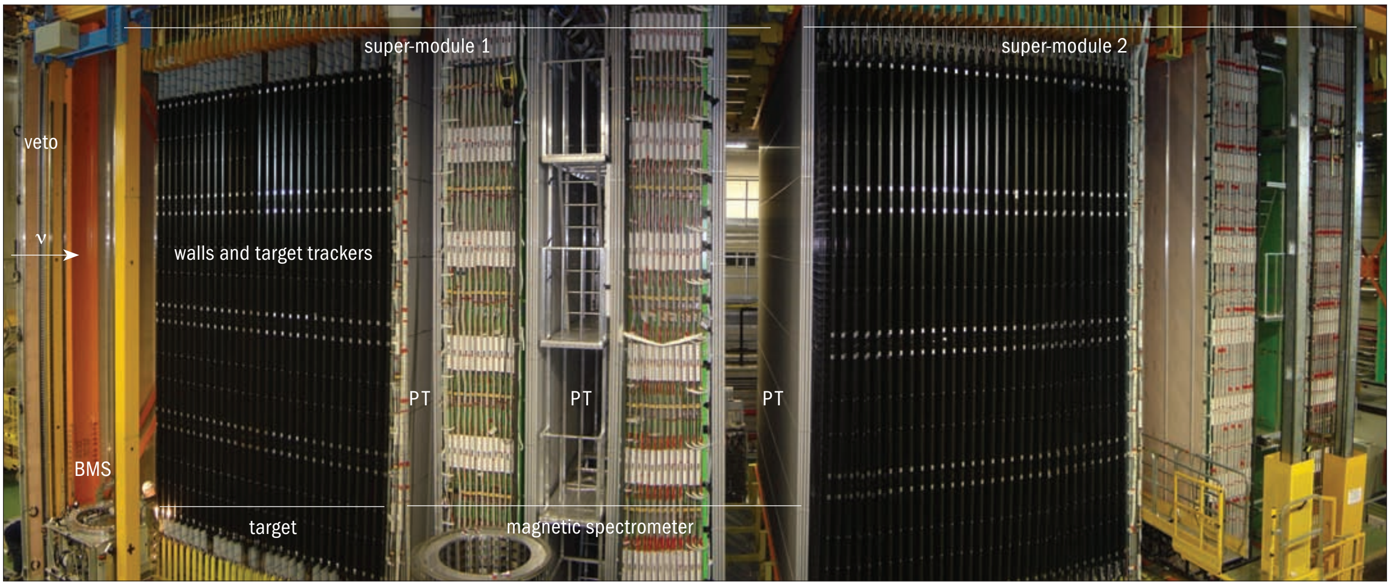


Fig. 1. Fish-eye view of the OPERA detector, indicating the layout of the two super-modules for directly observing tau neutrinos.

Neutrino physics is a special field in which large-mass targets, which are needed to detect these elusive particles, are often combined with the ambitious goal of precision measurements, which are needed for firm conclusions. The Oscillation Project with Emulsion-tRacking Apparatus (OPERA) is a good example. It aims to observe directly the appearance of tau neutrinos (ν_τ) in oscillations from muon neutrinos ($\nu_\mu \rightarrow \nu_\tau$) in the long-baseline beam of the CERN Neutrinos to Gran Sasso (CNGS) project. This would confirm the oscillation hypothesis for atmospheric neutrinos and unambiguously clarify its nature.

In 1998, the Super-Kamiokande collaboration announced that muon neutrinos change flavour (oscillate). The evidence came from detecting fewer muon neutrinos than expected in showers created by cosmic-ray interactions in the atmosphere. More recently, the KEK-to-Kamioka (K2K) experiment, using a man-made neutrino beam from KEK to the Super-Kamiokande detector, and the MINOS experiment, which uses a neutrino beam from Fermilab, have confirmed the oscillations that were observed in atmospheric neutrinos (*CERN Courier* July/August 2004 p7 and May 2006 p5). These experiments showed that muon neutrinos disappear, but there is no evidence of what they become. Only detecting the appearance of tau neutrinos from muon neutrinos will confirm the current theories underlying neutrino oscillation.

OPERA is searching for ν_τ by directly detecting the decay of the tau lepton that is produced in charged-current interactions of the ν_τ with nucleons in matter. To be sensitive to the oscillation parameters that are indicated by the deficit of muon neutrinos in the Super-Kamiokande data ($\Delta m^2 = 1.9–3.1 \times 10^{-3}$ eV^2, 90% CL, full mixing) and confirmed by the K2K and MINOS experiments, the experiment uses a 732 km baseline from the neutrino source to the detector – the distance from CERN to the Gran Sasso National Laboratory (LNGS) under the Gran Sasso massif in Italy. The ν_μ beam of CNGS has been optimized to obtain the maximum number of ν_τ charged-current interactions at OPERA and has an average ν_μ energy of about 17 GeV (see p20).

Detecting the ν_τ through the charged-current interaction is a challenging task. It demands not only a massive neutrino target (about 1.8 kilotonnes), but also particle tracking at micrometre resolution to reconstruct the topology of the tau decay: either the kink – a sharp change (> 20 mrad) in direction occurring after

Fig. 2. The piling station with the anthropomorphic robots, which interleave the emulsion sheets and the lead plates.

about 1 mm – as the original tau lepton decays into a charged particle and one or more neutrinos, or the vertex for the decay mode into three charged particles plus a neutrino. For this purpose, the emulsion cloud chamber (ECC) – exploited by the DONUT collaboration at Fermilab for ν_τ detection in a beam-dump experiment in 2000 – combines in a sandwich-like cell the high-precision tracking capabilities of nuclear emulsions (two 40 μm layers on both sides of a 200 μm plastic base) and the large target mass provided by lead plates (1 mm thick).

Anatomy of the detector

The design of OPERA is completely modular and allows real-time analysis of neutrino interactions. The target will eventually consist of 206 336 bricks, each comprising 56 consecutive ECC cells with transverse dimensions of 10.2 cm × 12.7 cm and weighing 8.3 kg. The bricks are being built underground at LNGS in the automated brick-assembly machine (BAM). They are then inserted into the experiment by two robots – the brick manipulator system (BMS) – into planar structures, or walls, which are interleaved with planes of scintillator tracker (5900 m^2), built from vertical and horizontal strips of plastic scintillator 2.6 cm wide. The scintillators provide an electronic trigger for neutrino interactions, localize the particular brick in which the neutrino has interacted, and perform a first tracking of muons within the target. Localizing the brick is the first step in locating events in OPERA's emulsions; the electronic trackers then provide predictions for the search for the particle tracks in the vertex brick with a position resolution of the order of 1 cm and an angular accuracy (on the muon tracks) of about 20 mrad.

The target sections are arranged in two independent super-modules (figure 1), each with 31 walls and 64 layers of 52 bricks for each wall. Each super-module includes a muon spectrometer after the target section. The study of the muonic tau-decay channel needs muon identification and charge measurement. More generally, they are fundamental handles for suppressing the background from the decay of charmed particles, which are produced in ordinary ν_μ charged-current interactions and decay similarly to the tau. The identification, with more than 95% efficiency, of the primary muon from the neutrino interaction that produces the charmed particle, allows this background to be effectively killed.

Each muon spectrometer comprises a dipolar magnet made of two iron arms (1 kilotonne of iron magnetized at 1.55 T), interleaved by pairs of 7 m long vertical drift-tube stations, 8064 tubes in total. These are the precision trackers (PTs) for precisely measuring the bending in the spectrometer. Twenty-two planes of resistive plate counters, 1525 m^2 for each magnet, are inserted between the iron plates to provide coarser tracking in the magnet and a range measurement of stopping particles. An Ethernet-based data-acquisition system time-stamps and records asynchronously all detector hits in the target trackers and the spectrometers.

Selected bricks can be extracted daily from the target by the BMS for emulsion development and analysis. Each brick is equipped externally with a pair of emulsion sheets – the changeable sheets (CSs) – attached to its downstream face. Once a brick with an event has been localized, the CSs provide a first confirmation of the neutrino interaction and the initialization for the scanning analysis of the brick. Automatic fast microscopes scan large areas of emulsion and perform track reconstruction, searching for the tau-decay topologies and measuring the event kinematics. Track momenta are measured from their multiple scattering in the brick, while energies of electrons and photons are reconstructed from the development of electromagnetic showers.

Industrial production

When OPERA is fully operational, about 30 bricks a day will be extracted from the target with 1800 emulsion foils. The total emulsion surface to be measured corresponds to a few thousand square metres in five years. To cope with the real-time analysis of the neutrino interactions, high-speed automatic scanning microscopes were developed in Europe and Japan. These scan around 20 cm^2 an hour – 20 times faster than in previous experiments.

As well as the special development of the microscopes, a large automation effort had to be put in to the brick production and handling, emulsion processing and chemical development, which together represent a small industry. Brick production has to be done underground to minimize the number of background tracks from cosmic rays and environmental radiation – LNGS has an average overburden of 1400 m of rock. Owing to space constraints the bricks must then be inserted immediately into the detector.

BAM specifications imply the production of about 1000 bricks a day, with 0.1 mm accuracy in each dimension. The BAM consists of an automated production line with several stations arranged in three different sections: input/output, BAM-in-light and BAM-in-dark. The input/output section manages the input of the lead containers (8 tonnes a day) and the output of bricks (1000 a day). In the BAM-in-light section (a class 10 000 clean room) the lead containers are automatically opened and pallets of lead are dispatched towards the dark room. In the BAM-in-dark room (class 10 000 and red light) the bricks, each comprising 57 emulsion sheets interleaved with 56 lead plates, are piled up under a pressure of 3 bar. This operation is performed in parallel by five piling/pressing stations, each using two anthropomorphic robots and a custom-built press machine (figure 2). The brick pile has to be aligned within 50 μm precision, while its components must be handled in such a way as to guarantee 10 μm flatness. The bricks are then wrapped with aluminium adhesive tape by a large anthropomorphic robot. Once the bricks are light-tight they are sent back to the BAM-in-light ▷

Fig. 3. The brick manipulator system approaching a wall for brick loading.

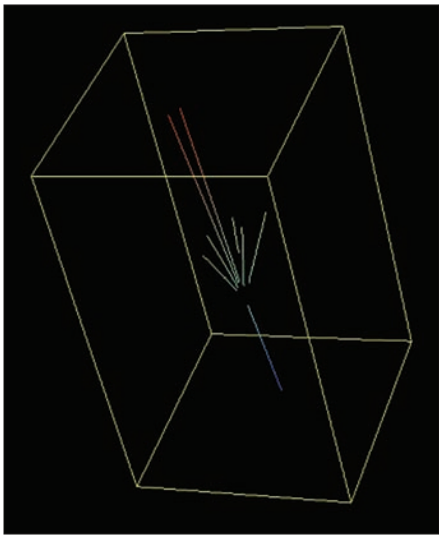


Fig. 4. Reconstructed vertex of a pion interaction in one of OPERA's bricks.

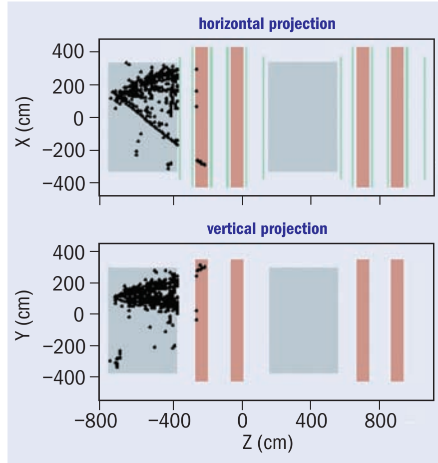


Fig. 5. Charged-current neutrino interaction that was recorded in the scintillator planes of the first super-module during the August 2006 run.

section where their external dimensions are checked again, they are equipped with Teflon skates (to reduce friction during insertion into the detector) and a CS box, and labelled.

The bricks are stored in a transport cage – the drum – which brings them in groups of 234 to OPERA, where the BMS positions them in the walls. This must be done simultaneously on both sides of the detector to maintain a balance, and so requires two independent BMS units. Each BMS comprises a 10 m high portico that can slide along the side of the two super-modules. A platform on the portico moves vertically to reach the different parts of the walls, which it accesses with a lift bridge with micrometre accuracy (figure 3). The platform has a rotating buffer disk (or carousel) hosting 32 bricks and devices for inserting the bricks (the pusher) and extracting them. The latter is a small vehicle with a vacuum (VV) sucker on the front.

To place bricks into a wall, the drum is placed on a loading station, and bricks are loaded into the BMS. They are then pushed one at a time on the lift bridge with the pusher, until a row of 26 bricks has been inserted and aligned to its nominal position in the semi-wall. This operation is repeated for each wall layer until the 64 layers are complete. Each BMS can handle about 500 bricks a day, following the BAM speed. It will take a year to fill the detector.

During extraction, the VV approaches the bricks on the appropriate wall layer through the lift bridge. The bricks are extracted by suction one by one onto the carousel until the selected one is found. The remaining bricks are then pushed back into the wall together with a replacement brick from the periphery of the target, which becomes slowly smaller with time.

The analysis chain

The bricks with neutrino interactions are placed in the drums and transported to a brick-handling area where the CSs are removed and processed while the bricks wait for the analysis to confirm an event. If an interaction is not confirmed, the brick is equipped with a new CS box and placed back in OPERA. However, if the analysis confirms an event, the brick is brought to the external LNGS laboratory, exposed for a day to cosmic rays for alignment and then disassembled. The films are stamped with an identifier and reference marks, developed with an automatic system with several parallel processing chains as in a big photographic laboratory, and dispatched to the scanning laboratories. (The scanning of the CSs is performed locally to provide fast feedback.)

A charged particle crossing an emulsion layer ionizes the medium along its path, leaving a sequence of aligned silver grains, with a linear size of about 0.6 μm. Typically, a minimum ionizing particle leaves about 30 grains in 100 μm. Observing with a high-magnification optical microscope, silver grains appear as black spots on a bright field. To reconstruct particles' trajectories, the computer-driven microscope adjusts the focal plane of the objective lens through the whole thickness of the emulsion, obtaining an optical tomography at different depths of each field of view with typically one image every 3 μm. Each image is filtered and digitized in real time to recognize track grains as clusters of dark pixels. A tracking algorithm reconstructs 3D sequences of aligned grains and extracts a set of relevant parameters for each sequence. The position accuracy obtained for the reconstructed tracks is about 0.3 μm, with a resulting angular resolution of about 2 mrad – adequate for reconstructing the tau-decay topology.

Matching tracks in the two CSs are extrapolated in the most downstream foil of the brick and followed plate by plate until the interaction vertex is located. A plate-by-plate alignment procedure is applied so that tracks can be followed back with a precision of few micrometres and the search for each track can be performed in one field of view (about 300 μm × 300 μm). Once the vertex has been located, a volume scan (about 5 mm × 5 mm in several consecutive plates) around the interaction point is done. All track segments that are found in this volume are recorded (figure 4). Vertex reconstruction algorithms are applied to classify the event and search for particle decay topologies. Taking advantage of cosmic-ray tracks, recorded during the deliberate exposure of the bricks after their extraction, sub-micrometre precision can be reached on the reconstructed vertex, as required for detecting kink topologies with angles of a few milliradians and for the kinematical analysis of the event.

Commissioning and running

OPERA was proposed in 2000, with installation starting in May 2003; it detected the first neutrinos from CNGS on 18 August 2006. This first run was of 11 days, with 5 days of equivalent beam time. It was devoted to the final commissioning of the electronic detectors (target trackers and spectrometers) with data-taking in global mode, to check the synchronization of the OPERA and CNGS clocks and to test the reconstruction algorithms. The detector collected more than 300 neutrino interactions, with a live-time greater than 95%. These interactions mainly occurred in the rock and in the iron of the two magnets (figure 5).

The August run was conceived to tune the electronic detector performance using CNGS neutrino interactions without bricks. OPERA has now started the next phase, which aims to observe neutrino interactions in the bricks. Brick production and insertion started in the second half of September, ramping up to 1000 a day. A first test run of three weeks with some thousand bricks exposed to CNGS was scheduled to begin in mid-October. Then the full tau search will proceed with the run in 2007.

The experiment should run for five years, with an integrated fluence of 2.25×10^{20} protons on the CNGS target. OPERA is sensitive to practically all of the tau-decay modes, with very low background levels: overall a total background of 1 event is expected. If $\nu_\mu \rightarrow \nu_\tau$ oscillations occur, the average number of detected signal events will be 8.0–21.2 in the Super-Kamiokande 90% CL region, corresponding to 13.9 events for the best-fit value ($\Delta m^2 = 2.5 \times 10^{-3}$ eV^2, full mixing, Walter and Inoue 2006). OPERA can also search for $\nu_\mu \rightarrow \nu_e$ oscillations with improved sensitivity on the still-unknown mixing angle θ_{13}, compared with the best world limit obtained by the reactor experiment CHOOZ in 1998.

Further reading

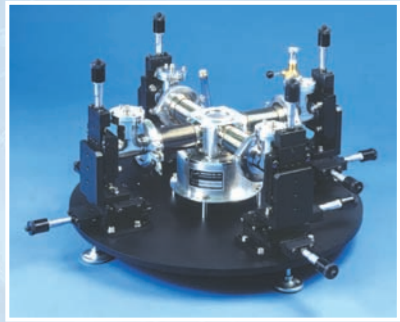
C Walter and K Inoue 2006 *XXXIII International Conference on High Energy Physics (ICHEP'06)* http://ichep06.jinr.ru/.

Résumé

OPERA: une première sous le Gran Sasso

Le projet OPERA (Oscillation Project with Emulsion tRacking Apparatus) a pour but d'observer directement l'apparition de neutrinos du tau dans les oscillations issues de neutrinos du muon dans le faisceau produit par l'installation CNGS (Neutrinos du CERN vers le Gran Sasso). Le détecteur est constitué de deux supermodules identiques, dont chacun contient un section cible et un spectromètre de grande ouverture. La partie cible est constituée de parois de briques émulsion-plomb alternées avec des modules de bandes de scintillateur. Après trois ans de construction, l'expérience vient de détecter les premiers neutrinos en provenance de CNGS. Une ligne de production et d'assemblage automatisée fonctionne à présent sans relâche pour achever le détecteur, afin que puisse commencer la recherche des neutrinos du tau.

Dario Autiero, *IPN Lyon*, **Salvatore Buontempo**, *INFN Naples, and* **Saverio Simone**, *University of Bari and INFN, for the OPERA collaboration.*



Hawking brings the origin

During a week-long visit to CERN's Theory Unit to discuss his current research, Stephen Ha

Stephen Hawking is the best known physicist alive. His book *A Brief History of Time* was a bestseller around the world, but sometimes his star status obscures his continued activity at the frontiers of theoretical physics. For some 40 years his research has centred on theoretical cosmology and black holes. When he started work as a theoretical physicist in the 1960s, particle physics and cosmology seemed to be separate worlds, but now these topics are increasingly intertwined. So it was not surprising that Hawking should want to visit the Theory Unit at CERN, to meet fellow theorists and give a seminar on his current work.

In the 1960s, Hawking and Roger Penrose developed the famous singularity theorems in general relativity, which provided a precise set of general conditions under which the existence of gravitational collapse is inevitable, leading to black holes. In particular Hawking provided a fairly complete theory of black holes and their classical properties, which led to intriguing analogies with the laws of thermodynamics. An important application of this work led to the theory that our universe began with a Big Bang, with an initial singularity.

Perhaps more famously, however, in the early 1970s Hawking shocked the world by showing that if one considered quantum mechanics (quantum field theory) in the presence of black holes, these are not black after all, but rather they emit radiation with a thermal spectrum and a temperature that depends only on the basic characteristics of the black-hole state: namely, its mass, angular momentum and charge. In the simplest case, the temperature is inversely proportional to the mass. This phenomenon is known as black-hole evaporation.

Hawking went even further, however, and made the provocative proposal that the laws of quantum mechanics must be changed in the presence of black holes. Specifically, quantum information and quantum coherence are irreversibly lost in the formation and evaporation of black holes. This proposal has generated much work in the past 30 years, and we are only now beginning to understand that quantum mechanics does not after all need to be modified. However, many aspects of the theory of quantum gravity need to be understood in detail before we can claim that the paradox has been resolved.

The Hawking evaporation phenomenon also has basic observational consequences. If a black hole has a small mass, then it will radiate more copiously, so we can put an observational limit on the size of remnant black holes from the origin of the universe. Furthermore, if CERN's Large Hadron Collider (LHC) produces mini black holes we know that they will evaporate with a nearly thermal spectrum, an important characteristic in identifying them.

Currently Hawking is working on quantum cosmology. He is studying a top-down approach to cosmology that combines the string landscape with the scenario of no-boundary initial conditions. The theory seminar that he presented at CERN was based on this work in collaboration with Thomas Hertog, who is currently a fellow with the Theory Unit.

Dwarfed by CMS, Hawking talks to CMS spokesperson-elect Jim Virdee, le theorist Thomas Hertog, right, who works with Hawking on quantum cosm

In his general colloquium, which attracted an audience of 850, Hawking discussed one of his favourite topics – the origin of the universe. He argued that thanks to what we have learned over the past 100 years we may finally have a scientific way to address this subject. General relativity predicts that the universe, and time itself, would have begun in a Big Bang. It also predicts that time ends in black holes. The discoveries of the cosmic microwave background radiation and of black holes support these conclusions; adding in quantum mechanics begins to yield the rudiments of a theory of structure in the observed universe. However, much still remains to be understood on this subject, although as Hawking argued in his seminar, a scientific cosmogony is both possible and within reach of theoretical and experimental work.

ns of the universe to CERN

Hawking visited the LHC, gave a well attended general lecture and talked to *CERN Courier*.

eft, and
nology.

Hawking during his tour of the ATLAS cavern, with, from left to right, theorist Thomas Hertog, ATLAS spokesperson Peter Jenni and ATLAS deputy spokesperson Fabiola Gianotti.

In the general colloquium that he delivered at CERN, Hawking talked on one of his favourite topics: the origin of the universe.

During his stay at CERN, Hawking also visited the ATLAS and CMS experiments, as well as the tunnel of the LHC, where installation work proceeds rapidly (see p7). He was interested in the details of the experiments, and in the possible discovery of mini black holes. He also met with the director-general, Robert Aymar, and their discussion covered topics ranging from open-access publishing to the start-up of the LHC. Congratulating Aymar and the CERN community on their scientific work, he commented "You have an exciting two years ahead of you."

Further reading

Hawking's talks at CERN are on the web. For the theory seminar see The Semi-Classical Birth of the Universe at http://agenda.cern.ch/fullAgenda.php?ida=a063459. For the general colloquium see The Origin of the Universe at http://agenda.cern.ch/fullAgenda.php?ida=a063382.

Hawking on CERN, black holes and the LHC

You last came to CERN in 1986, as preparations were underway for the Large Electron–Positron collider. What is your impression of CERN today?
It is nice to be back. The place feels just the same.

Much of your own work has concerned the physics of black holes. Do you consider it will be possible to test the laws of black-hole dynamics experimentally in the near future?
We will be able to test the classical laws of black-hole dynamics with future gravitational-wave detectors such as LIGO and LISA. If black holes are produced in future collision experiments one will be able to study the quantum black-hole dynamics and see if they evaporate. However, you will have to measure all the particles, including the graviton, to verify if information was lost.

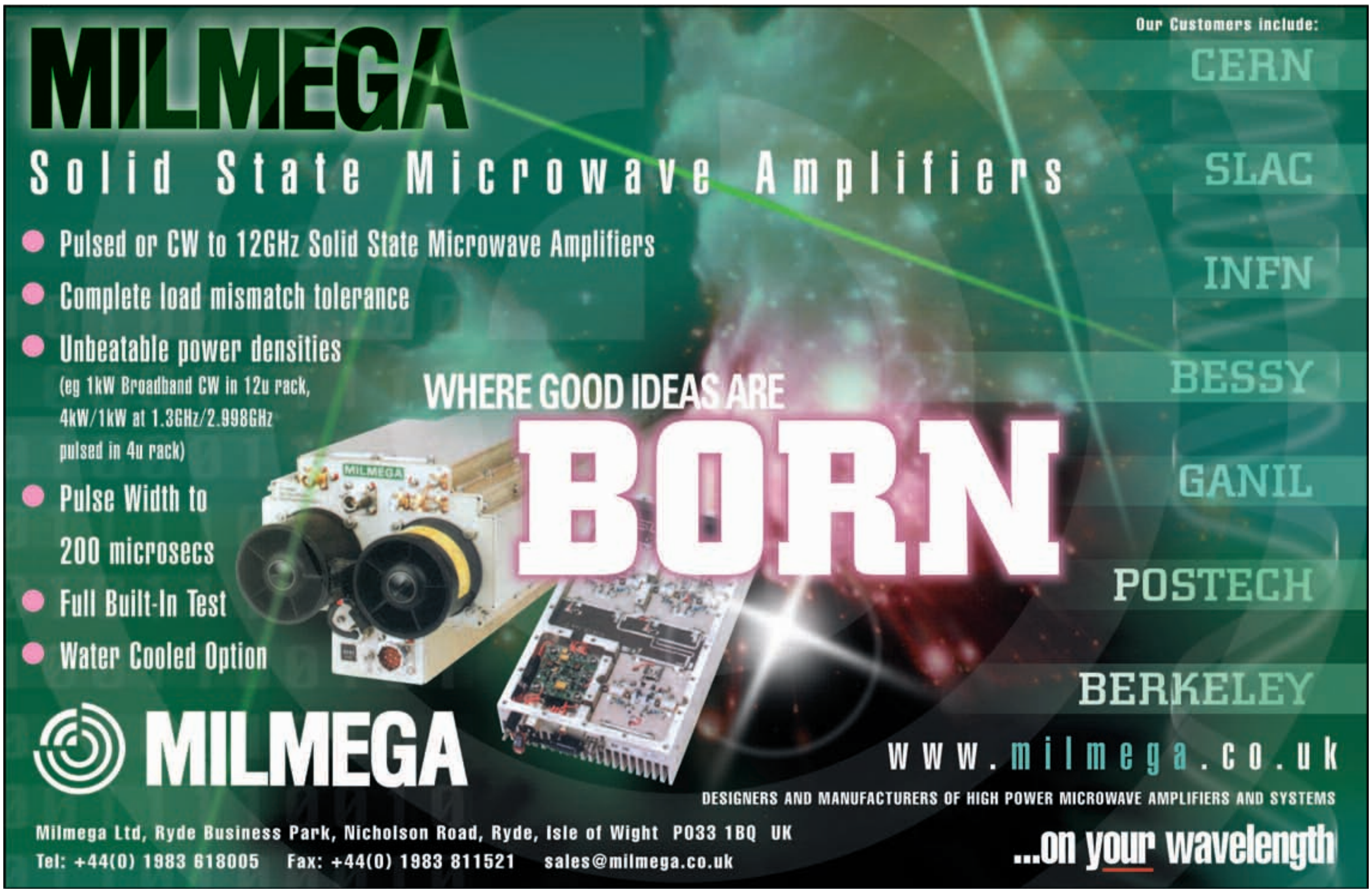
Do you think it is possible that black holes will be created in collisions at the LHC, which is due to start up next year?
I think the chance that you will find mini black holes is less than 5%. I haven't booked my ticket to Stockholm yet.

What would you regard as the most important discovery that experiments at the LHC could make?
You have to weight the importance with the probability. There are three candidates: superpartners, black holes and the Higgs. Superpartners would be very important and I estimate a 50% probability. Black holes would also be very important. The Higgs would not be so important, and rather probable.

Résumé
Stephen Hawking amène les origines de l'Univers au CERN

Stephen Hawking est le plus célèbre des physiciens vivants. Depuis 40 ans, ses recherches se sont centrées sur la théorie de la cosmologie et des trous noirs. Aujourd'hui la cosmologie et la physique des particules sont plus liées que jamais. Ce n'est donc pas une surprise si Hawking a rendu visite à l'Unité de théorie du CERN pour discuter de ses recherches sur la cosmologie quantique. Durant son séjour au CERN, il a donné une conférence générale qui a connu un grand succès et visité le LHC et les expériences ATLAS et CMS. Les théories de Hawking impliquent que des mini-trous noirs pourraient être créés avec le LHC, mais il en estime la probabilité à seulement 5%.

Luis Alvarez-Gaume *and* **Christine Sutton**, *CERN.*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LABORATORIES

NSF funds NSCL with $100 million

The US National Science Foundation has awarded the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University more than $100 million to fund operations through 2011. Established in 1963, the NSCL is the largest nuclear-science facility on a university campus in the US and educates about 10% of US nuclear-science doctoral students.

Much of the new funding will support the ongoing operation of the NSCL as a user facility and the work of NSCL nuclear scientists, which includes developing specialized methods of production and in-flight separation of nuclei with unusual proton-to-neutron ratios.

The NSCL's Coupled Cyclotron Facility is one of the leading user facilities for rare-isotope research, serving more than 700 users from 100 institutions in 35 countries. Fast beam techniques developed there have already advanced efforts to determine the basic properties of rare isotopes. In addition, researchers at the NSCL have implemented ion-trap techniques for precision experiments after slowing isotopes from more than 100 MeV per nucleon to thermal energies. Associate director Thomas Glasmacher received the 2006 Sackler Prize in the Physical Sciences for developing new, sensitive techniques to study the structure of exotic nuclei.

The National Superconducting Cyclotron Laboratory at Michigan State University.

Currently, the NSCL is implementing the capability to re-accelerate stopped rare isotopes for studies at energies near the Coulomb barrier. In collaboration with its user community, it is developing plans for a significant upgrade to its MSU-based laboratory, with the Isotope Science Facility as its working name.

Further reading

For more information about the NSCL see www.nscl.msu.edu.

COLLABORATION

East meets West at Rencontres in Hanoi

Two Rencontres du Vietnam held in Hanoi in August allowed physicists from Vietnam and neighbouring countries to meet with those from more distant place s, including Europe and the US. Organized by Jean Tran Thanh Van, the parallel meetings on Challenges in Particle Astrophysics, and Nanophysics: from Fundamentals to Applications attracted more than 400 participants, including two Nobel laureates, James Cronin and Klaus von Klitzing. Highlights included a tour of the experimental facilities of VATLY, the cosmic-ray research group at the Institute of Nuclear Science and Technology, Hanoi, which is working with the Auger Collaboration under the leadership of Vo Van Thuan, former director of the Institute, and Pierre Darriulat, former research director of CERN.

The meetings also allowed Vietnamese physicists to express their interest in collaborating with CERN, particularly on the Large Hadron Collider (LHC) and on theoretical physics. A group led by Nguyen Mong Giao from Ho Chi Minh City is already participating in the D0 experiment at Fermilab, and is now exploring contacts with the ATLAS collaboration at the LHC, while a group led by Nguyen Mau Chung from Hanoi is working with the LHCb collaboration. The Institut national de physique nucléaire et de physique des particules and the Ecole Polytechnique Fédérale de Lausanne are already supporting these initiatives, as is the president of the Vietnam Academy of Science and Technology, Dang Vu Minh.

Participants in the 2006 Rencontres du Vietnam saw the rapid economic strides now being made by Vietnam. The omens are good for a growing Vietnamese presence at CERN, where several Vietnamese physicists are already active.

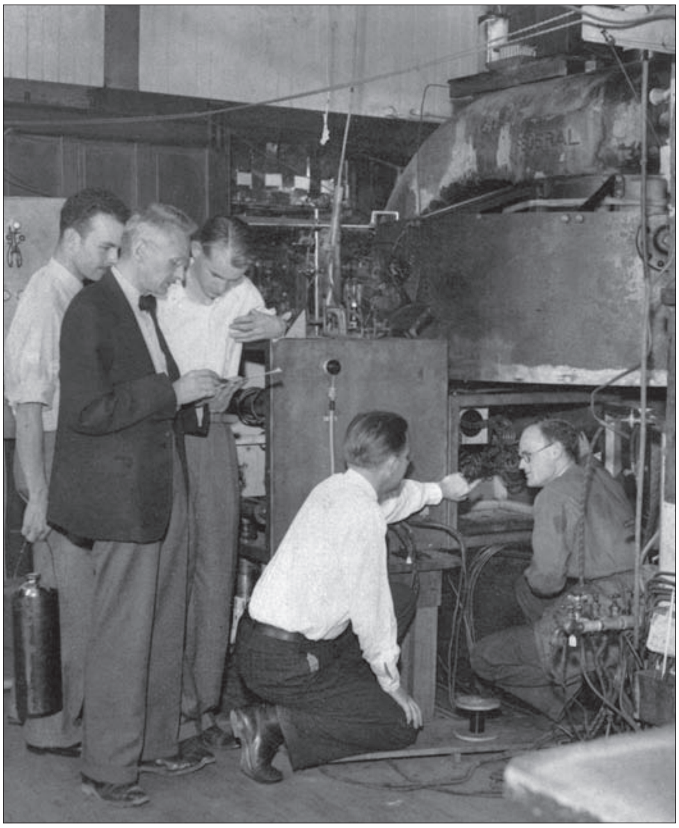
Vietnamese President Nguyen Minh Triet, sixth from right, receives a delegation from the Rencontres at his palace.

ANSWERS FROM P15

Top: This is not used for physics; it is a "Remy" rake known as the "Sun". Attached to a tractor, its task is to rake up the cuttings from those areas of the site given over to grassland. Robust and easy to handle, it enables the work to be carried out in difficult, even acrobatic, positions (such as on "Mount Citron" and the mounds of the Proton Synchrotron ring).

Bottom: No connection with the [other] photo, this many-legged octopus, tended by Mario Grossi, is actually a pile of three "pancakes" destined for a DC electromagnet under construction in NPA Division. The magnet will produce a field of 100 000 gauss and will be used for testing the properties of superconducting samples. Each pancake is made of a rectangular-section hollow conductor, 8.5 mm × 5.5 mm, spirally wound and cast in epoxy resin; it is so arranged that there are 11 parallel water circuits for cooling, but one continuous electrical circuit as in a simple coil. The complete magnet contains eleven pancakes mounted in an iron yoke.

● Taken from *CERN Courier* December 1963 pp156–157, with captions on p158.



Ernest Lawrence and colleagues with the 27 inch cyclotron.

Steve Chu, LBNL director and Nobel laureate, closing a time-capsule during Founders Day. The capsule will remain sealed until it is opened on the lab's 100th anniversary in 2031.

as many pre-war leaders left to work on atomic weapons, radar and other military technology.

The lab's next machine was a big step up in energy and complexity: a 6.5 GeV synchrotron, the Bevatron. Its energy could reach the threshold for antiproton production; by 1955 the accelerator was complete and antiprotons were indeed observed (*CERN Courier* November 2005 p27). Later, it supported a long series of experiments that used progressively larger bubble chambers. Throughout the late 1950s and early 1960s, researchers used these chambers to discover a large number of meson and baryon resonances. Still later, the Bevatron was converted to accelerate heavy ions, ushering in the new field of relativistic heavy-ion collisions.

In 1959, with the death of Ernest Lawrence, Ed McMillan became the lab's second director. The 1960s saw a period of expansion, with many new buildings and facilities, including the 88 inch cyclotron, still used for nuclear structure studies. The Heavy Ion Linear Accelerator (HILAC), and later Super-HILAC, continued the laboratory's studies of heavy elements, producing atoms of elements 102 and 103. The lab took its first steps beyond the world of particle and nuclear physics, with initiatives in materials science (initially to study the effects of radiation on different materials), and later, chemical lasers.

Of course, the laboratory was part of the Berkeley community. By the late 1960s, the US was involved in the Vietnam War, and Berkeley was the scene of massive antiwar protests. Lab scientists were themselves divided, but most had great sympathy for the antiwar movement, and many actively demonstrated against the war. The 1960s also led to new concerns for human rights, and LBNL scientists were active in supporting oppressed scientists in the former Soviet Union.

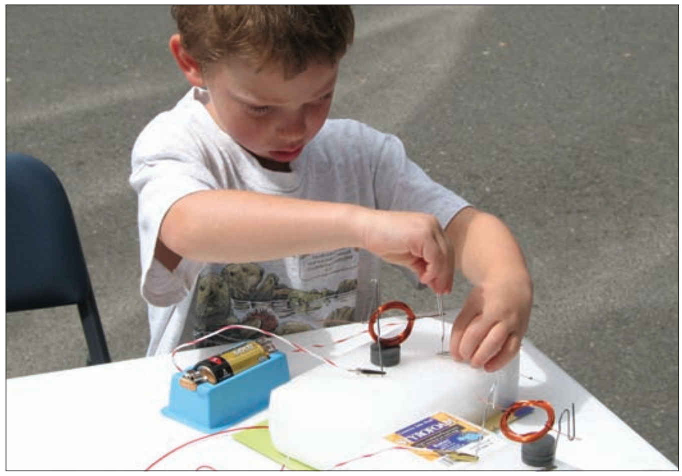
Besides the antiwar movement, the 1960s and 1970s brought tremendous political and intellectual ferment. Energy became scarce and environmentalism appeared. In 1971, US president Richard Nixon declared war on cancer. Basic research lost some of its lustre. Under the leadership of its third director, Andrew Sessler, the lab responded to these pressures by diversifying into a variety of fields: biology, earth science and materials science.

Today, this diversity is a hallmark of LBNL. The lab has major programmes in many fields, including synchrotron radiation (the 1.5 GeV advanced light-source accelerator and a strong accelerator development programme), computing (the National Energy Research Supercomputing Center), genome sequencing and cancer biology, as well as continuing programmes in electron microscopy, energy efficiency in buildings, and nanotechnology. The lab has also developed strong electrical and mechanical engineering and computer-science groups; their contributions are apparent in the complicated instrumentation built at LBNL. Recent examples include the vertex detectors for the BaBar experiment at SLAC and CDF at Fermilab, and contributions to ATLAS at CERN; the time projection chamber for the STAR detector at Brookhaven's Relativistic Heavy Ion Collider (RHIC); the support structure for the Sudbury Neutrino Observatory; and the Gammasphere germanium detector.

Although birthdays are good opportunities to reminisce, the lab also used Founders Day to look forward to the next 75 years. The foreseeable future looks bright. In particle physics, a strong programme in the ATLAS experiment is accompanied by a cosmology programme, which is exploring the nature of dark energy, most notably by studying distant supernovae. SNAP, an orbiting telescope with a billion-pixel camera, should launch early in the next decade. In nuclear physics, the STAR time-projection chamber continues to study heavy-ion collisions at RHIC, and LBNL is contributing to the effort to build an electromagnetic calorimeter for ALICE at CERN. Future nuclear structure studies will be built around GRETINA, a precision germanium tracking calorimeter currently under construction. Efforts in neutrino oscillation, θ_{13}, double beta decay and neutrino astronomy with IceCube complement these large programmes. Accelerator design has always been a hallmark of the lab; future designs include a low-energy, high-current light-ion accelerator for astrophysical studies and work on linear colliders. Other accelerator efforts are focused on producing ultra-short pulses of X-rays, and studies using lasers to accelerate particles (see p5). Over the next few decades, these efforts are likely to lead to radically new types of accelerators.

A key focus of current lab director Steve Chu is helping to solve the world energy crisis, through studies including hydrogen storage, carbon sequestration, solar energy (perhaps involving photosynthesis), biomass-to-fuel conversion and improved nuclear power systems. This effort will involve many of the lab's divisions.

Founders Day included activities and exhibits looking back at many of these periods. Memorabilia from Lawrence's research, including an early cyclotron were on display, as well as clothing worn by some of the lab's 10 Nobel prize winners. An exhibition of vintage cars included a 1935 Dodge Brothers Coupé, said to have been driven by Lawrence and Robert Oppenheimer on clandestine late-night beer runs. A cinema showed classic science-fiction greats, from *Flash Gordon* to *Frankenstein*, and modern documentaries. Dance performances included traditional Scottish dance and modern fire-spinning. For children, there were hands-on scientific activities ranging from bubble-blowing to build-your-own electric motors and extracting genes from strawberries, as well as two bouncy inflatables where they could expend their energy. Who knows where the next Lawrence will come from?



Children learning about science on Founders Day at LBNL. The build-it-yourself electric motors proved to be very popular, while bubbles taught about the science of surface tension.

Further reading

For more details see www.lbl.gov/.

Résumé

75 bougies pour le LBNL

La science avait une ambiance de fête au Laboratoire national Lawrence de Berkeley (LBNL) qui fêtait le 26 août son 75ème anniversaire en organisant une journée des fondateurs. Connu à l'origine sous le nom de "Rad Lab", le Laboratoire a été fondé en 1931 pour abriter la dernière en date des machines construites par Ernest Lawrence, inventeur du cyclotron. Depuis lors, ce laboratoire, qui était au départ destiné à abriter un cyclotron de 68 cm, est devenu un centre de recherche multidisciplinaire avec un avenir prometteur. Il a à son actif de nombreuses découvertes importantes, notamment le carbone 14, plusieurs éléments nouveaux et l'antiproton. Il continue à mettre en œuvre un programme de recherche important en physique des particules expérimentale et en conception des accélérateurs.

A pristine 1935 Dodge Brothers Coupé (87 horsepower Police Special), which is said to have been driven by Ernest Lawrence and Robert Oppenheimer on their late-night beer runs.

Spencer Klein, *LBNL.*

PHYSTAT tackles the significance problem

Physicists and statisticians met in Banff for the latest PHYSTAT workshop, where they discussed how to tackle upper limits, significance and separating signal from background.

A significant peak? The view from the Banff Center, where the latest PHYSTAT workshop was held. (Courtesy Kyle Cranmer.)

When analysing data from particle-physics experiments, the best statistical techniques can produce a better quality result. Given that statistical computations are not expensive, while accelerators and detectors are, it is clearly worthwhile investing some effort in the former. The PHYSTAT series of conferences and workshops, which started at CERN in January 2000, has been devoted to just this topic (*CERN Courier* May 2000 p17). The latest workshop was at Banff in the Canadian Rockies in July and was also a culminating part of the spring 2006 programme of astrostatistics which had taken place earlier in the year at the Statistical and Applied Mathematical Sciences Institute (SAMSI) in the Research Triangle Park, North Carolina.

The initiative for the Banff workshop came from Nancy Reid, a statistician from Toronto who has delivered invited talks at the PHYSTAT conferences at SLAC and Oxford (*CERN Courier* March 2004 p22 and January/February 2006 p35). The Banff International Research Station sponsors workshops on a variety of mathematical topics, including statistics. The setting for these meetings is the Banff Center, an island of tranquillity and vigorous intellectual activity in the town of Banff. Most of the activities at the centre are in the arts, but science and mathematics are found there too.

Thirty-three people attended the workshop, of whom 13 were statisticians, the remainder being mostly experimental particle physicists, with astrophysicists making up the total. It concentrated on three specific topics: upper limits, in situations where there are systematic effects (nuisance parameters); assessing the significance of possible new effects, in the presence of nuisance parameters; and the separation of events that are signal from those that are caused by background, a classification process that is required in almost every statistical analysis in high-energy physics. For each of these topics there were two coordinators, a physicist and a statistician.

The three topics, of course, interact with each other. Searches for new physics will result in an upper limit when little or no effect is seen, but will need a significance calculation when a discovery is claimed. The multivariate techniques are generally used to provide the enriched subsample of data on which these searches are performed. Just as for limits or significance, nuisance parameters can be important in multivariate separation methods.

As this was a workshop, the organizers encouraged participants to be active in the weeks before the meeting. Reading material was circulated as well as some simulated data, on which participants could run computer programmes that incorporated their favourite algorithms. This enabled all participants to become familiar with the basic issues before the start of the meeting. The workshop began with introductory talks on particle physics and typical statistical analyses, and Monte Carlo simulations in high-energy physics. These primarily described for statisticians the terminology, the sort of physics issues that we try to investigate in experimental particle physics, what the statistical problems are and how we currently cope with them, and so on.

Jim Linnemann of Michigan State University publicized a new website, www.phystat.org, which provides a repository for software that is useful in statistical calculations for physics. Everyone is encouraged to contribute suitable software, which can range from packages that are suitable for general use, to the code that is specifically used in preparing a physics publication.

The convenors of the various subgroups led the remaining sessions on the first day. Very few talks were scheduled for subsequent days, specifically to leave plenty of time for discussions and for summary talks and to provide an opportunity for exploring fundamental issues.

Limits and significance

The discussion about limits ranged from Bayesian techniques, via profile likelihood to pure frequentist methods. Statisticians made the interesting suggestion that hierarchical Bayes might be a good approach for a search for new physics in several related physics channels. There was a lively discussion about the relative merits of the possible approaches, and about the relevant criteria for the comparison. After a late evening session, it was decided that data would be made available by the limits convenor, Joel Heinrich of the University of Pennsylvania, so that participants could try out their favourite methods, and Heinrich would compare the results. This work is expected to continue until November.

Discussions considered the significance issue within particle physics, with several other examples in astrophysics. Indeed it arises in a range of subjects in which anomalous effects are sought. Luc Demortier of Rockefeller University in New York, the physics convenor on significance, detailed eight ways in which nuisance parameters can be incorporated into these calculations, and discussed their performance. This will be a crucial issue for new particle searches at the Large Hadron Collider at CERN, where the exciting discoveries that may be made include the Higgs boson, supersymmetric particles, leptoquarks, pentaquarks, free quarks or magnetic monopoles, extra spatial dimensions, technicolour, the substructure of quarks and/or leptons, mini black holes, and so on. In all cases some of the backgrounds will be known only approximately and it will be necessary to distinguish among peaks that are merely statistical fluctuations, errors and genuine signals of new physics.

Demortier also addressed the issues of whether it is possible to assess the significance of an interesting effect, which is obtained by physicists adjusting selection procedures while looking at the data; and why particle physics usually demands the equivalent of a 5 σ fluctuation of the background before claiming a new discovery. (The probability of obtaining such a large fluctuation by chance is less than one part in a million.)

Signal or background?

The sessions on multivariate signal–background separation resulted in positive discussions between physicists and statisticians. Byron Roe of the University of Michigan explained the various techniques that are used for separating signal from background. He described how for the MiniBooNE experiment at Fermilab, Monte Carlo studies showed that boosted decision trees yielded good separation, and coped with more than 100 input variables. An important issue concerned assessing the effect on the physical result, in this case neutrino oscillation parameters, of possible systematic effects. One of the conventional methods for doing this is to vary each possible systematic effect by one standard deviation, and to see how much this affects the result; the different sources are then combined. Roe pointed out that there is much to recommend an alternative procedure, which investigated the effect on the result of simultaneously varying all possible systematic sources at random.

Radford Neal, a statistician from Toronto University, took up this theme in more detail, and also emphasized the need for any statistical procedure to be robust against possible uncertainties on its input assumptions. One of Neal's favourite methods uses Bayesian neural nets. He also described graphical methods for showing which of the input variables were most useful in providing the separation of signal and background.

Ilya Narsky of Caltech gave a survey of the various packages that exist for performing signal–background separation, including R, WEKA, MATLAB, SAS, S+ and his own StatPatternRecognition. Narsky suggested that the criteria for judging the usefulness of such packages should include versatility, ease of implementation, documentation, speed, size and graphics capabilities. Berkeley statistician Nicolai Meinshausen gave a useful demonstration of the statistical possibilities within R.

The general discussion in this sub-group covered topics such as the identification of variables that were less useful, and whether to remove them by hand or in the programme; the optimal approach when there are several different sources of background; the treatment of categorical variables; and how to compare the different techniques. This last issue was addressed by a small group of participants working one evening using several different classifiers on a common simulated data set. Clearly there was not the time to optimize the adjustable parameters for each classification method, but it was illuminating to see how quickly a new approach could be used and comparative performance figures produced. Reinhard Schweinhorst of Michigan State University then presented the results. ▷

As far as the workshop as a whole was concerned, it was widely agreed that it was extremely useful having statisticians present to discuss new techniques, to explain old ones and to point out where improvements could be made in analyses. It was noted, however, that while astrophysics has been successful in involving statisticians in their analyses to the extent that their names appear on experimental papers, this is usually not the case in particle physics.

Several reasons for this have been suggested. One is that statisticians enjoy analysing real data, with its interesting problems. Experimental collaborations in particle physics tend to be very jealous about their data, however, and are unwilling to share it with anyone outside the collaboration until it is too old to be interesting. This results in particle physicists asking statisticians only very general questions, which the statisticians regard as unchallenging. If we really do want better help from statisticians, we have to be prepared to be far more generous in what we are ready to share with them. A second issue might be that in other fields scientists are prepared to provide financial support to a statistics post-doc to devote his/her time and skills to helping analyse the data. In particle physics this is, at present, very unusual.

There was unanimous agreement among attendees that the Banff meeting had been stimulating and useful. The inspiring location and environment undoubtedly contributed to the dynamic interaction of participants. The sessions were the scene of vigorous and enlightening discussion, and the work continued late into the evenings, with many participants learning new techniques to take back with them to their analyses. There was real progress in understanding practical issues that are involved in the three topics discussed, and everyone agreed that it would be useful and enjoyable to return to Banff for another workshop.

Further reading

The most recent PHYSTAT conference was in Oxford (see www.physics.ox.ac.uk/phystat05/, which has links to the earlier meetings). Details about the Banff meeting are at www.pims.math.ca/birs/birspages.php?task=displayevent&event_id=06w5054.

Résumé

Un atelier PHYSTAT se penche sur les problèmes de la signification

Dans l'analyse des données recueillies par les expériences de physique des particules, l'utilisation des meilleures techniques statistiques peut aboutir à des résultats de meilleure qualité. Comme les calculs statistiques, contrairement aux accélérateurs et aux détecteurs, ne coûtent pas trop cher, il est rentable d'investir dans ce type d'outil. La série de conférences et ateliers PHYSTAT, lancée au CERN en janvier 2000, est précisément consacrée à cette question. Le dernier atelier en date a eu lieu à Banff, dans les Rocheuses canadiennes, en juillet. À cette occasion, des physiciens des particules, des astrophysiciens et des statisticiens se sont rassemblés pour discuter de questions telles que les limites supérieures, la signification et les moyens de distinguer le signal du bruit.

Jim Linnemann, *Michigan State University, and* **Louis Lyons**, *Oxford University.*

POSIPOL 2006 lines up options for ILC and CLIC

Experts from around the world came to CERN to discuss the production of polarized positrons for future linear colliders, using the Compton back-scattering technique.

POSIPOL 2006, an international workshop that was held earlier this year at CERN, was dedicated to the production of polarized positrons using the Compton back-scattering of a high-power laser beam by electrons of a few giga-electron-volts. The particular focus was on applications to the two future linear-collider studies, the International Linear Collider (ILC) and the Compact Linear Collider (CLIC). The workshop, which attracted around 50 experts from Europe, Asia and the Americas, was jointly organized by the CLIC team at CERN, the European CARE-ELAN network, the Japanese high-energy accelerator research organization, KEK, and the Laboratoire de l'Accélérateur Linéaire (LAL) at Orsay. It led to a roadmap and a series of recommendations for future R&D on positron sources for linear colliders.

Polarized positrons (POSItons POLarisés in French, hence POSIPOL) are produced by bombarding a tungsten target with polarized photons. The latter are generated either from a helical undulator or from the scattering of a polarized high-power laser beam with an unpolarized high-energy electron beam. For this second scheme, requirements on the intensity of both the electron beam and the laser beam are significantly relaxed by stacking the laser beam in an optical cavity with an enhancement factor of up to 1000, and by re-using the electrons, which are stored in a so-called Compton ring. This scheme also implies the stacking of the produced positrons in a storage ring. Control of the laser system and of the high-quality optical cavity is crucial, as is the electron-beam dynamics in the presence of electron-laser collisions. The various aspects of this scheme, as well as comparisons with the undulator method, formed the main topics for the sessions at the workshop.

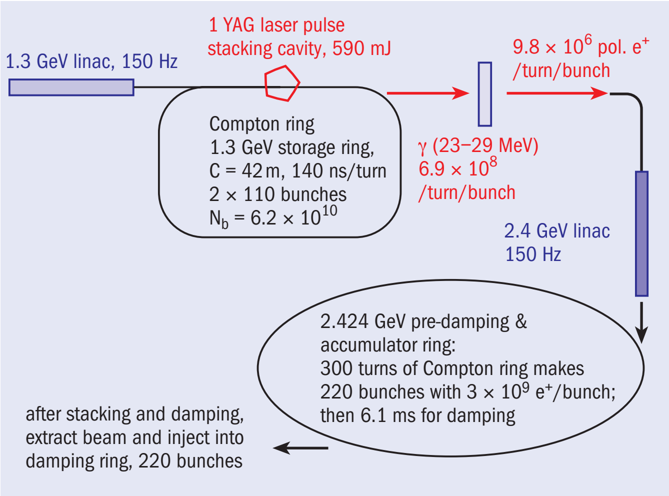
Robert Aymar, CERN's director-general, opened the workshop, and was followed by Louis Rinolfi, POSIPOL chair, who set the scene with a look at the state-of-the-art for producing polarized positrons and a reminder of the scope of the workshop. In the first overview session, Gudrid Moortgat-Pick from CERN stressed the importance of positron polarization for future linear colliders. Both a Compton source and an undulator scheme are being considered for the ILC, as described by KEK's Junji Urakawa and John Sheppard of SLAC respectively. Frank Zimmermann of CERN presented a proposal for a Compton source for CLIC, demonstrating that the pertinent requirements are much less demanding than they are for the ILC. He also emphasized the large synergy with ongoing developments for a Compton ring for medical applications.

POSIPOL participants in front of the Globe of Innovation.

Several talks by Susanna Guidicci of Frascati, Alessandro Variola of LAL, and Eugene Bulyak and Peter Gladkikh of the Kharkov Institute for Physics and Technology (KIPT) discussed the beam dynamics and optics designs for Compton rings. One suggestion was to use a pulsed mode of operation for the Compton ring with a specific technique for radio frequency (RF) phase modulation. Vitaly Yakimenko of Brookhaven National Laboratory described the merits of an alternative single-pass Compton scattering approach involving a high-duty-cycle electron linac and a battery of CO_2 lasers.

Several talks addressed advances in laser systems, including those by Igor Pogorelsky of Brookhaven, Brent Stuart of Lawrence Livermore National Laboratory and Sudhir Dixit of Oxford. Yoann Zaouter of Amplitude Systems highlighted the dramatic evolution of fibre lasers over the past decade. Products from Time-Bandwidth, presented by Thomas Ruchti, achieve parameters close to what is needed.

Tsunehiko Omori of KEK presented the first experimental results on polarized positron production using Compton back-scattering at KEK's Accelerator Test Facility (ATF), which have recently been published in *Physical Review Letters*. The E-166 undulator experiment at SLAC also has results, as described by Andreas Schaelicke of DESY/Zeuthen. ▷



Schematic of the proposed CLIC Compton positron source.

Ian Bailey of the UK's Cockcroft Institute discussed aspects of positron production, in particular targets, and described the development of a conversion target. Vladimir Strakhovenko of the Budker Institute of Nuclear Physics (BINP) presented theoretical calculations of the radiation spectrum and photo-production in a target. Robert Chehab of IN2P3/Lyon and Wei Gai of Argonne National Laboratory addressed the positron production process, in particular matching and capturing positrons downstream of the target. Masao Kuriki of KEK talked about systems considerations for the positron source at the ILC, in particular construction, commissioning and availability of undulator and Compton schemes.

In the session on equipment and diagnostics, Fabian Zomer of LAL discussed ongoing studies of non-planar optical resonators, and Peter Schueler of DESY looked at beam polarimetry issues. A final R&D session focused on optical cavities. Viktor Soskov of the Institute for High Energy Physics, Moscow, reviewed R&D on a high-finesse cavity at LAL, and Hiroki Sato of Hiroshima described R&D on an optical cavity for the ILC. Kazuyuki Sakaue of Waseda University, Tokyo, described the experimental plan for X-ray generation using a pulse-stacking optical cavity.

At the end of the workshop, POSIPOL participants identified a number of critical issues that still need to be demonstrated, both for positron sources that are based on an undulator scheme and for the alternative Compton scattering scheme. The two approaches are in principle equivalent, but there are differences in the photon spectrum, photon energies, angular photon spectrum, power on the conversion target, collimation efficiency, operational efficiency and implementation cost. For the Compton scheme, the photon and positron yields must be simulated with a realistic lattice and energy spread. Many items require further study, including laser systems, 6D positron distribution, stacking in a pre-damping ring, required RF power, Touschek lifetime, beam instabilities and the heat-load limit of optical cavities.

The workshop also agreed on a roadmap for future R&D to address the common issues in Compton and undulator sources. Noteworthy common recommendations for the two schemes concern the analysis of the systematic errors in the polarization measurements, the comparison of yields and polarization, the optimization of pre- and post-selection of positrons and the evaluation of the cost.

For the undulator scheme, the main recommendations were the publication of E-166 results, the evaluation of emittance degradation in the undulator and the technical demonstration with an undulator several metres long. For the Compton scheme, the main recommendations were the publication of the design of a Compton ring with a chicane and with optimization of the energy of the Compton photons, the development of a reliable power laser taking into account the polarization, the simulation of stacking into a damping ring, the comparison of a single-pass scheme with the ring scheme and the comparison of CO_2, YAG and fibre lasers.

The workshop also addressed validating design choices and demonstrating feasibility in experiments at KEK's ATF, Brookhaven's ATF and the DAΦNE storage ring at Frascati. In May, the KEK–ATF Technical Board approved an experimental programme of installing and operating laser pulse-stacking cavities in the ATF damping ring during 2006 and 2007. The goal is the simultaneous demonstration of the high enhancement factor that is required by POSIPOL, the small laser spot and a small beam–laser collision angle in multi-bunch operation. Optimized optical cavities from LAL may be installed later at the KEK-ATF, enabling the study of high-intensity multi-bunch gamma-ray generation by Compton scattering.

Another new project at KEK would allow accumulation experiments with electron beams. An experimental optimization for the Compton source inside a laser cavity is also foreseen at the Brookhaven ATF, and single-pass Compton collisions could be tested with the drive beam of the CLIC Test Facility 3 at CERN.

Since the POSIPOL workshop, LAL has written a letter of intent concerning R&D activities on polarized positron sources. The idea is to submit a proposal as a Joint Research Activity (JRA–POSIPOL) in the context of the European Framework Programme 7. Several institutes have already expressed their interest: LAL, INFN/Frascati, CERN, DESY Zeuthen, the Institut de Physique Nucléaire de Lyon, BINP, the National Science Center KIPT, Université-Paris-XI, KEK, Waseda University and Kyoto University.

● Further information including all presentations of the POSIPOL workshop can be found at www.cern.ch/posipol2006. All detailed recommendations are in the summary session.

Résumé

L'atelier POSIPOL étudie les options pour l'ILC et le CLIC

POSIPOL 2006, atelier international tenu cet année au CERN, était consacré à la production de positons polarisés par la rétrodiffusion Compton d'un faisceau laser de grande puissances par des électrons de quelques gigaélectronvolts. Il a été question en particulier des applications de cette technique aux deux projets de collisionneurs linéaires, le Collisionneur linéaire international (ILC) et le Collisionneur linéaire compact (CLIC). Cette technique a aussi été comparée avec celle basée sur un ondulateur hélicoïdal. L'atelier a réuni une cinquante d'experts venus d'Europe, d'Asie et d'Amérique; il s'est conclu par l'adoption d'une feuille de route et d'une série de recommandations pour la R&D future sur les sources de positons polarisés pour les collisionneurs linéaires.

Louis Rinolfi, *CERN, POSIPOL chair.*

Exotic atoms cast light on fundamental questions

A workshop in Trento explored how experiments on exotic atoms, deeply bound kaonic states and antihydrogen provide a low-energy route to addressing fundamental physics.

As particle physics heads towards tera-electron-volt energies with the Large Hadron Collider, it may be surprising to find that not all valuable research requires hadron beams of the highest energy available. Indeed, the opposite can be true. Experiments on processes that involve hadrons at kilo-electron-volt or even electron-volt energies can address some unresolved questions in quantum chromodynamics (QCD), its associated symmetries such as chiral symmetry, and CPT-invariance. This quickly developing field, which connects atomic, nuclear and particle physics, as well as astrophysics, was the subject of an international workshop, Exotic Hadronic Atoms, Deeply Bound Kaonic Nuclear States and Antihydrogen: Present Results, Future Challenges, which was held at the European Centre for Theoretical Nuclear Physics and Related Areas (ECT*) in Trento on 19–24 June. The workshop brought together some 50 experts in exotic atoms and nuclei to assess the current experimental and theoretical status of the field, and identify the most relevant topics to be addressed in the future. The rich programme extended from the pionic, kaonic and antiprotonic varieties of exotic atoms to antihydrogen, and exotic nuclear clusters, better known today as deeply bound kaonic nuclei. The workshop discussed the latest results from many experiments on these exotic atoms, and outlined future plans that are based on improved experimental techniques in detectors and/or hadronic beams.

Studies of exotic atoms in which a hadron such as a π^-, K^- or $\bar{p}$ replaces an electron can reveal important information about spontaneous chiral-symmetry breaking in QCD, which governs the low-energy interactions of the lightest pseudoscalar mesons (pions and kaons) with nucleons. Such experiments can access hadronic scattering lengths at zero energy by direct measurements of bound-state parameters, which is not possible through other experimental approaches. The Paul Scherrer Institut in Villigen has investigated pionic hydrogen (π^-–p) and deuterium (π^-–d), and DAΦNE in Frascati has investigated their kaonic counterparts. Other no-less-important species include kaonic and antiprotonic helium, which have been studied at the Japanese High Energy Accelerator Research Organization (KEK) and CERN, and yet another exotic variety is formed by the non-baryonic π^+–π^-(pionium) and πK atoms. Finally, the antihydrogen atom, $\bar{p}$–e^+, which CERN has copiously produced, is in a class of its own owing to its importance for testing the CPT theorem to extremely high precision.

The latest kaonic hydrogen results from the DAΦNE Exotic Atoms

Workshop participants at the Villa Tambosi of the ECT, Trento.*

Research (DEAR) experiment, as presented by Johann Marton of SMI Vienna, gave rise to a lively discussion on the possibility of accommodating them with kaon–nucleon scattering data. More precise data and further theoretical calculations will evidently be needed in this domain. The SIDDHARTA experiment that is planned for DAΦNE, which aims at 10 times higher precision on the kaonic hydrogen atom and the first measurement on kaonic deuterium, should contribute to a better understanding of the physics of the kaon–nucleon interaction at very low energies.

In the pion–pion scattering sector, the DIRAC experiment at CERN has measured pionium and yielded new values for the scattering lengths. However, the study of the kaon decaying to three pions provides a valid alternative for determining these quantities to an unprecedented accuracy. Gianmaria Collazuol, of INFN and Pisa, presented results from the NA48/2 experiment at CERN on the (a_0–a_2) difference of pion–pion scattering lengths with a precision of about 6%, equally shared between systematic and statistical uncertainties. This value is in agreement with various theoretical predictions that were discussed at the workshop. Further refinements in the precision of the results will need an interplay between experiment and theory, since most of the systematic error is caused by theoretical uncertainties.

Researchers at the Antiproton Decelerator (AD) at CERN are ▷

Wolfram Weise leads the round-table discussion on antikaon-mediated bound nuclear systems at the workshop in June.

pursuing precision spectroscopy of antiprotonic helium, as Ryugo Hayano of Tokyo described. The study of the metastable three-body system $\bar{p}$–e^-–He^{2+} has led to the most stringent tests of the equality of the charge and mass of the proton and antiproton at a relative precision of 2 ppb and, for the first time, produced a value of the antiproton-to-electron mass ratio (*CERN Courier* July/August 2006 p8).

Antihydrogen, the simplest atom of antimatter, offers even higher sensitivity to violations of CPT symmetry, because the properties of its conjugate system, hydrogen, are known to very high precision (10^{-12} for the ground-state hyperfine structure, and a few parts in 10^{14} for the 1S–2S two-photon transition). The ATRAP, ALPHA and ASACUSA collaborations at the AD are pursuing the formation of cold antihydrogen atoms for precision spectroscopy. Nikolaos Mavromatos of King's College London and Ralf Lehnert of Massachusetts Institute of Technology discussed theoretical aspects of these interesting tests of CPT and Lorentz invariance, as well as the possibility of using antihydrogen to investigate the gravitational properties of antimatter.

Finally, an important part of the workshop programme discussed a new type of exotic nucleus – the antikaon ($\bar{K}$)-mediated bound nuclear system, with $\bar{K}$ as constituents. Soon after the theoretical prediction of such states, both KEK and the Laboratori Nazionali di Frascati reported preliminary experimental evidence for their existence, and several experiments in Europe and Japan are currently searching for them. Attendees heard a critical review of the present experimental results, followed by an extended discussion on the foundations of the predictions. A lively discussion took place between those defending the existence of these deeply bound kaonic nuclear states and others who express doubts on their existence. There was also a critical analysis of the conditions under which such states might exist. New experiments, studying both the formation and the decay processes of the exotic nuclei, will play a key role in clarifying this interesting physics. These include a recently accepted proposal at the Japanese Proton Accelerator Research Complex (J-PARC), the AMADEUS experiment at DAΦNE and the future possibility of investigating double $\bar{K}$ systems at the Facility for Low-energy Antiproton and Ion Research (FLAIR) within the international Facility for Antiproton and Ion Research (FAIR) to be built at Darmstadt.

A round table on the deeply bound $\bar{K}$–nuclear systems, led by Wolfram Weise of Munich, concluded the workshop. He stressed the importance of new experimental studies and further theoretical efforts, showing that progress is expected on one side from next-generation experiments, and on the other by understanding of the $\bar{K}$–nucleon interaction (in the SIDDHARTA experiment) by realistic modelling of the nucleon–nucleon interaction and of the $\bar{K}$–nucleon–nucleon → hyperon–nucleon absorption. Weise also discussed the interesting connection with dense matter, namely kaon condensation in high-density media.

The workshop confirmed that many fundamental and still-open questions in low-energy QCD and related symmetries can be assessed and answered with experiments in the low-energy domain, by creating and measuring new forms of matter – exotic atoms, exotic nuclei and antihydrogen. An active and growing scientific community supports the great expectations of the field.

● For the full programme and the compete list of speakers see www.itkp.uni-bonn.de/~rusetsky/TRENTO06/trento06.html.

Résumé

OPERA: une première sous le Gran Sasso

Le projet OPERA (Oscillation Project with Emulsion tRacking Apparatus) a pour but d'observer directement l'apparition de neutrinos du tau dans les oscillations issues de neutrinos du muon dans le faisceau produit par l'installation CNGS (Neutrinos du CERN vers le Gran Sasso). Le détecteur est constitué de deux supermodules identiques, dont chacun contient un section cible et un spectromètre de grande ouverture. La partie cible est constituée de parois de briques émulsion-plomb alternées avec des modules de bandes de scintillateur. Après trois ans de construction, l'expérience vient de détecter les premiers neutrinos en provenance de CNGS. Une ligne de production et d'assemblage automatisée fonctionne à présent sans relâche pour achever le détecteur, afin que puisse commencer la recherche des neutrinos du tau.

Catalina Curceanu, *Laboratori Nazionali di Frascati dell'INFN,* **Akaki Rusetsky**, *University of Bonn and Helmholtz-Institut für Strahlen- und Kernphysik, Bonn, and* **Eberhard Widmann**, *Stefan Meyer Institut für subatomare Physik, Austrian Academy of Sciences, Vienna.*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ERICE

School celebrates young physicists

Lecturers and young physicists from all over the world met in Erice from 29 August to 7 September. The event was the 2006 International School of Subnuclear Physics held at the Ettore Majorana Foundation and Centre for Scientific Culture, a particular feature of which is to promote "new talents" among the young generation of physicists.

The 44th in the series, the 2006 school covered some of the most advanced topics in physics under the theme "The logic of nature, complexity and new physics: from quark–gluon plasma to superstrings, quantum gravity and beyond". The novel topic of complexity could shed new light on the Standard Model and the extension that predicts grand unification and the resolution of the quantum-gravity problem via relativistic quantum string theory (RQST). The most popular model of RQST, developed by Raphael Bousso and Joe Polchinski at Stanford, has been shown to be "NP complete". The consequences could be remarkable.

Organized and directed by Nobel laureate Gerardus 't Hooft together with Antonino Zichichi, the school followed the traditional model of morning lectures on the most up-to-date topics in subnuclear physics, followed by afternoon sessions dedicated to the new talents and recipients of Enrico Fermi junior grants. During these sessions selected students at the school could make open presentations about their research. Each session was followed by a discussion of the lectures held during the morning.

The school was dedicated to the late Richard Dalitz. A former collaborator, Gary Goldstein at Tufts University, talked about Dalitz's contributions to particle physics in a lecture in his honour.

"Complexity exists at the fundamental level" was the theme of the opening lecture by Zichichi, followed by a series of lectures by Leonard Susskind of Stanford, who addressed the most advanced theories on "Landscape and its physics foundations" and "How string theory generates the landscape". These lectures summarized the latest news on physics beyond the Standard Model. Complementary lectures on complexity and landscape in string theory and on the status of lattice quantum chromodynamics (QCD) triggered lively discussions during the afternoon sessions.

Lecturers and students at the 2006 International School of Subnuclear Physics.

Other theory lectures included topics such as complexity and non-extensive statistical mechanics; complexity in stochastically quantized field theories and the Standard Model; QCD at low energy; how to detect extra dimensions; and black holes, attractors and quantum information.

Closer to experimental physics, Haim Harari of the Weizmann Institute presented an excellent overview – "Neutrino masses, leptogenesis and beyond: the incredible foresight of Ettore Majorana". This was very timely, as during the school the director of the Gran Sasso National Laboratories, Eugenio Coccia, outlined details of neutrino-oscillation experiments at the start-up of the CERN neutrino beam to Gran Sasso (see p20).

Reports from running experiments covered the latest results on B-physics, the physics at Fermilab's Tevatron and results from HERA at DESY. Yale's John Harris presented the American Institute of Physics' "top physics story of 2005" in his animated lectures on evidence for a quark–gluon plasma at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven. He outlined the present understanding of the "quark–gluon liquid" and highlighted the need for experiments at the Large Hadron Collider (LHC).

A preview of the future was contained in talks on the latest plans for a "super-beauty" project; the preparations for the International Linear Collider and Compact Linear Collider; start-up and upgrade scenarios for the LHC; and the future of supercomputers by Roberto Petronzio of the University of Rome II and INFN.

Closing lectures by 't Hooft and Zichichi looked forward to the LHC. Experiments there should confirm current theories beyond the Standard Model, but may also yield some totally unexpected discoveries. Referring to the interpretation of data from RHIC and the ALICE experiment at LHC, Zichichi presented an example of how to look for the unexpected. Together with his collaborators he is studying an experimental set-up to allow the quark–gluon coloured world (QGCW) to be investigated with a hard-scattering probe. The idea is that a beam of particles bombards the QGCW during its brief existence in heavy-ion collisions at the LHC, and special detectors measure the scattered particles.

The school ended in a festive atmosphere, celebrating the 60th birthday of its director, 't Hooft, and the distribution of diplomas to the young talents. The 2006 prize for the best student went to Yasuko Hisamatsu of the University of Tokyo for her presentation on the MEG experiment under preparation at the Paul Scherrer Institute, which will probe physics at the grand-unification scale.

Report from Horst Wenninger, CERN.

● For further information see www.ccsem.infn.it/issp2006/index.html.

LABORATORIES

UK opens two major centres for particle-accelerator research

Two major research centres for accelerator science and technology opened in the UK on 19 September. The Cockcroft Institute and the John Adams Institute will be national focal points for UK scientists and companies to develop leading accelerator technologies for major projects such as the International Linear Collider and a neutrino factory.

The Cockcroft Institute and the John Adams Institute were set up by the Particle Physics and Astronomy Research Council in partnership with the Council for the Central Laboratory of the Research Councils. The aim is to provide the facilities and infrastructure for research and training in accelerator science and engineering. The two institutes are already heavily involved in the research and development needed for future high-energy, high-intensity linear colliders as well as for the construction of new high-intensity neutrino sources.

The Cockcroft Institute is located on the new Daresbury Science and Innovation Campus and is a joint venture between the two research councils, the universities of Liverpool, Lancaster and Manchester, and the Northwest Regional Development Agency. The John Adams Institute is located at both the University of Oxford and Royal Holloway, University of London, and is a partnership between those two universities and the two research councils.

The Cockcroft Institute was officially opened by Lord Sainsbury, minister for science and innovation, in the presence of the children of Sir John Cockcroft, the Nobel prize-winner and one of the founders of modern accelerator research. After the opening ceremony, Sainsbury spent time with the staff in the laboratories discussing demonstrations of current R&D on RF systems, vacuum science and engineering, design simulation, and theoretical accelerator physics.

The John Adams Institute was opened by Christopher Adams, son of the accelerator designer and engineer Sir John Adams who was twice director-general of CERN and a leading figure in the construction of CERN's major accelerators. Sir John's daughter, Josi Shinzel, also spoke at the ceremony, as well as former CERN director-general Sir Chris Llewellyn Smith and Lyn Evans, head of the Large Hadron Collider project at CERN.

Lord Sainsbury (central with a blue shirt) with members of the Cockcroft Institute from Lancaster University at a demonstration of a prototype RF cavity.

The unveiling of the plaque celebrating the opening of the John Adams Institute, with Ken Peach (left) and Christopher Adams (right). (Courtesy Oxford Physics.)

WORKSHOPS

Physicists return to Tbilisi for hadron update

The possibility of polarizing antiprotons at the upcoming Facility for Antiproton and Ion Research at GSI has stimulated widespread interest within the hadron community. Measuring the Drell–Yan process in high-energy proton–antiproton collisions offers the best way to study the transverse spin structure of protons (transversity). This was the focus at the second Caucasian-German School and Workshop on Hadron Physics (CGSWHP) in Tbilisi, Georgia, on 4–8 September. Around 70 participants attended, from nine countries.

Spin filtering, in which a beam of antiprotons acquires polarization by repeated passage through a polarized hydrogen target, is believed to be the most effective means of producing a useful beam for transversity experiments. CGSWHP'06 discussed preparatory spin-filtering tests using proton beams. These could be at Cooler Synchrotron (COSY) at the Forschungszentrum Jülich, where there is an extensive physics programme involving polarized beams and targets. Results from COSY were also presented at the meeting.

Participants take a break from spin matters during an outing at CGSWHP'06 in Georgia.

Georgian media covered several sessions, as well as the meeting of the organizers with the rector of Tbilisi State University, and some of the social programme. TV interviews publicized the workshop, with local graduate students discussing their research.

The EC Integrated Infrastructure Initiative project, Hadron Physics, supported the workshop, which had the theme Spin in Hadron Physics and which was also sponsored by Forschungszentrum Jülich, the International Science & Technology Center, the Joint Institute for Nuclear Research and the Institute for High Energy Physics and Informatization, Tbilisi State University.

● See www.fz-juelich.de/ikp/cgswhp/.

CERN hosts sixth international workshop on neutrino beams

On 4–9 September, CERN hosted the sixth International Workshop on Neutrino Beams and Instrumentation (NBI2006). Some 60 accelerator physicists, particle physicists and engineers attended from Brookhaven National Laboratory, CERN, Fermilab, KEK, the Japan Proton Accelerator Research Complex and the Rutherford Appleton Laboratory, as well as from collaborating university groups. They included many of the world's top experts on building magnetic horns for neutrino beams.

Inaugurated in 1999 by Kazuhiro Tanaka of the KEK laboratory, the NBI workshop series has permitted the exchange of knowledge in the design of what are known as conventional neutrino beams, which were pioneered in the 1960s at Brookhaven and CERN. In these systems, an intense beam from a proton accelerator strikes a target, and secondary particles from the target are collected by horn-shaped magnets into a drift tunnel where they decay in flight to produce neutrinos. These include the neutrino beams for KEK to Kamioka (K2K, which operated until 2004), MiniBoone and Neutrinos at the Main Injector at Fermilab, and the CERN Neutrinos to Gran Sasso (CNGS) project at CERN (see p20). The challenge for current and future neutrino beams is to cope with the ever larger power of proton accelerators, which it is hoped will eventually reach 4 MW (*CERN Courier* September 2004 p29).

In the Jura mountains, the top experts on magnetic horns received a performance by a group of experts on alpine horns.

The presentations and discussions at NBI2006 centred on high-intensity proton-beam transport lines, target design, neutrino horns, instrumentation able to withstand the intense particle beams, and personnel protection and shielding. As more operational experience is gathered, the session on handling radioactive components is becoming increasingly important.

The participants could also visit sections of the underground CNGS facility and spare beam-line components that are on display in the target and horn laboratories. Discussions continued throughout the week, particularly during a dinner in the Jura mountains and on an excursion to the mountains around Chamonix.

The next NBI workshop will be in early 2008 in Japan, where the next-generation neutrino-beam facility, from Tokai to Kamioka (T2K), is being built.

● For more information about NBI2006 see http://proj-cngs.web.cern.ch/proj-cngs/NBI2006/NBI2006.html.

OBITUARIES

Ziemowid Sujkowski 1933–2006

Ziemowid Sujkowski, a distinguished Polish physicist, died on 9 July, aged 73. He began his career in 1955 at the Institute of Nuclear Research (IBJ) in Świerk, near Warsaw. He soon went to the Nobel Institute in Stockholm, completing his PhD and *venia legendi* at Stockholm University. In 1961 he became head of physics at IBJ and obtained his professorship in 1971. For the past 10 years he was director of the Institute for Nuclear Studies in Świerk, Warsaw.

Sujkowski concentrated on nuclear structure and atomic physics, studying multiple inner-shell ionization accompanying nuclear collisions and the properties of atoms ionized by energetic ion beams. He initiated a technique of radiative transitions and coincidence experiments in the search for Majorana neutrinos, and rediscovered, developed and popularized the long-forgotten idea of neutrinoless double-electron capture, a method offering low background. Another idea of his was to look for Majorana neutrinos in helicity-flip measurements in boosted neutrino sources, or beta beams.

Sujkowski was significant in Polish scientific life and was a major player in establishing international collaborations for Poland. His collaboration with the Kernfysisch Versneller Instituut Groningen lasted more than 20 years and he initiated co-operation with Fribourg University. He supervised studies at GSI Darmstadt, the Paul Scherrer Institute, Villigen, and the Research Center for Nuclear Physics, Osaka. He was also on advisory committees at many international conferences and was chair of the Mazurian Lakes Conferences in Poland.

Sujkowski contributed to nuclear-research collaborations to develop new frontiers of science. He will be remembered for his work on nuclear, particle, astroparticle and atomic physics. He supervised 21 PhD students in Poland and abroad. He will also be remembered for his personal contributions to several generations of physicists, his honesty, his cheerfulness in adversity, his sense of humour and his commitment to bringing out the best in others.

Friends and colleagues.

John Strong 1941–2006

Our friend and colleague John Strong died from a brain tumour on 31 July, a few days before his 65th birthday. John started his career and obtained his PhD at Westfield College under Ted Bellamy, initially working at Rutherford Appleton Laboratory (RAL). From the early 1970s, however, he focused on experiments at CERN with notable contributions. The Omega spectrometer used a system that John had developed for RAL using vidicon cameras to record tracks in the spark chambers. This highly automated system allowed Omega to be used in a similar way to bubble chambers.

John contributed to NA1 and NA7, developing the electronic trigger systems. The Westfield group worked with Italian colleagues to measure the pion and kaon form factors, and the lifetime of some of the newly discovered charm particles. The paper on the pion form-factor had been cited 323 times before John's death. NA7 also allowed the first measurement of π^0 production in pion–electron scattering and provided one of the few model-independent tests of the existence of three colours when this postulate still required experimental confirmation. After moving to Royal Holloway, University of London, he developed the second-level trigger system for the ALEPH detector and led a team for five years to design and build the system, which ran for 12 years.

In 1990 John presented a paper on second-level triggering at the Large Hadron Collider and he continued to develop these ideas in the RD-11 project and then within ATLAS. The data-handling requirements for this system were unprecedented. John was an early champion of the idea that large farms of PCs interconnected by commodity networks could meet the demanding ATLAS requirements, and he helped to realize this idea. He led the development of the ATLAS second-level trigger for a number of years and for a period was UK spokesperson for ATLAS. When he took early retirement in December 2002, the design of the final system was almost complete, but John continued to be involved with the Read Out Buffer (ROBin) cards as they moved into production. Even during his illness he retained a lively interest in the work and he was delighted to know that these cards, one of only two components in the final ATLAS Data Acquisition/High Level Trigger system to use custom electronics, were completed before he died.

John was active in university life. He became professor of experimental physics in 1995 and served as head of physics from 2000 until his retirement. He was a dedicated teacher, whose positive approach inspired his students. He was also on many committees, where his clarity of thought and diplomacy were invaluable. He was a man of integrity and a friend to many. He will be missed.

Friends and colleagues from Royal Holloway, University of London, and ATLAS.

George Randolf Kalbfleisch 1931–2006

George Randolph Kalbfleisch, who discovered the η' meson and was founder of the high-energy group at the University of Oklahoma (OU), died aged 75 on 12 September in Norman, Oklahoma, of complications resulting from Lewy–Body disease.

George Kalbfleisch was born on 14 March 1931 in Long Beach, California. He graduated from high school on time, despite losing a year to rheumatic fever. He received his Bachelor of Science degree in chemistry from Loyola University, Los Angeles, in 1952, and his PhD in experimental high-energy physics in 1961 from the University of California, Berkeley, under the direction of M Lynn Stevenson, studying K-meson production in $\bar{p}p$ collisions. By then he had seven publications, mostly on hyperon production and decay.

George worked with Luis Alvarez at Berkeley as a postdoctoral associate until 1964. His work there culminated in discovering the ninth member of the pseudoscalar nonet of mesons, the η'.

He then moved to Brookhaven National Laboratory, where he continued to unravel hyperonic and mesonic properties. Less conventionally, he also published a search for tachyons, and compared muon and neutrino velocities in a test of special relativity. He received tenure in 1968 and stayed at Brookhaven until 1976. He then spent three years at Fermilab developing superconducting quadrupole magnets for the Tevatron.

George was recruited to OU in 1979 and established a high-energy physics group. He developed the silicon microstrip detectors that are used by the D0 collaboration at the Tevatron, and his research included the charm and beauty quantum states at Fermilab, as part of the D0 collaboration, and neutrino properties at OU. From 1995 to 2004 he cut up pieces of the old CDF and D0 detectors at Fermilab and ran them through an induction detector to search for any magnetic monopoles that might have been produced at the Tevatron. In this he was inspired by his mentor Alvarez, who had used a similar detector to look for monopoles in moon rocks. In the last few years, he worked on detecting the electric dipole moment of the electron.

George published more than 190 articles in elementary-particle physics and became a fellow in the American Physical Society in 1982. He inspired all those around him. He was a wonderful family man and is survived by his wife of 52 years, Ruth Ann, and his four children. He will be sorely missed.

Kimball A Milton, H L Dodge Department of Physics and Astronomy, University of Oklahoma.

PRIZES

Flerov prize board invites submissions for 2007 award

The Joint Institute for Nuclear Research will award the G N Flerov prize for outstanding research in nuclear physics in March 2007, the year of the 50th anniversary of the Flerov Laboratory of Nuclear Reactions (FLNR). The prize, established in 1992 in memory of the eminent physicist Georgy Nikolaevich Flerov (1913–1991), rewards contributions to nuclear physics related to Flerov's interests.

Entries for the 2007 prize (which should include a CV, an abstract of research and copies of major contributions) should be sent before 1 February 2007 to the directorate of the FLNR: Andrey G Popeko, Scientific Secretary of Flerov Laboratory of Nuclear Reactions, Joliot Curie str. 6, 141980, Dubna, Moscow Region, Russia, or e-mail popeko@jinr.ru.

LETTERS

Val Telegdi – an appreciation from Caltech

A recent obituary in *CERN Courier* (September 2006 p49) provided essential details of Val's life, particularly from the CERN and ETH perspectives. Since Val was also a faithful and welcome guest at the Caltech High Energy Theory Group during his later years, a few words from here on this remarkable scientist may be appropriate.

Every winter Val and Lia would appear in Pasadena and stay for about three months, thereby endorsing one of Pasadena's original attractions. But of course Val remained a physicist, with growing interests in the (recent) history of our subject, of which he became a master. He would engage many of us in learned theoretical discussions and arguments, from which one always emerged with some new wisdom and perspective. This persisted almost until the end. His last colloquium – also at the end – was on significant and elegant experiments in physics, which he had mastered. As usual, he held a large and diverse audience enthralled by his wit, taste and breadth of knowledge. Val will be missed on both sides of the Atlantic.

Stanley Deser and John Schwarz, Caltech.

Gribov and Ter-Martirosyan

It seems to me that the obituary of Karen Ter-Martirosyan (*CERN Courier* July/August 2006 p40) did not emphasize enough the ties between Ter-Martirosyan and Vladimir "Volodia" Gribov, even if a common paper was quoted. At the 1962 conference in Geneva, Gribov presented a paper of Ter-Martirosyan because the latter could not attend the conference. Indeed, Ter-Martirosyan was very proud to say that Gribov was his student. Gribov was discovered by western physicists in 1960, because of a short but revolutionary paper in which he proved that the then-common belief that the total cross-section and slope of the diffraction peak were approaching finite, non-zero limits at infinite energy was wrong. Gribov continued to produce impressive results until his premature death.

André Martin, CERN.

NEW PRODUCTS

Acqiris has announced a range of free class-compliant Interchangeable Virtual Instrument (IVI) drivers that support the company's digitizers. Developed mainly for the automated test-equipment market, they comply with IviScope Class (IVI-4.1) specifications, which support oscilloscopes and common extended functionalities in more complex data-acquisition instruments. The drivers support all major test platforms that are supported by Acqiris, including PCI, PXI, Compact PCI and VXI, facilitating hardware independence without rewriting software. For further details tel: +41 228 843 390 or see www.acqiris.com.

Resolve Optics Ltd has introduced a new radiation-hard large-image-format camera lens. It gives uncompromised performance with large-image-format remote-head cameras in applications including nuclear vision and star-tracking. The 20 mm fixed-focus non-browning lens can withstand radiation up to 53 kGy and temperatures up to 55 °C without discoloring. The 30 mm compact f2 lens gives high resolution and minimum geometric distortion from 400 to 750 nm. For further information tel: +44 149 477 100 or e-mail sales@resolveoptics.com.

Volotek has launched the VGC1000 Vacuum Gauge Controller, the highest-precision controller offering scalability, reliability and high stability in the extreme high-vacuum range of 10^{-16} bar. The VGC1000 is a modular 1/3 rack 3U high, economical, single-channel controller for flexibility and is user-friendly. It has a low-noise integrated electrometer module with sensitivity of 1 fA or 10^{-15} A. The internal modularity allows the replacement of the Profibux interface with other option control and communication interfaces. For more information tel: +41 227 850 720 or see www.volotek.com.

CORRECTIONS

Some unfortunate errors occurred in the editorial process for the article "Precision pins down the electron's magnetism" in the October 2006 issue of *CERN Courier*. On page 36, it should say "The third use of the measured *g* is in probing the internal structure of the electron – limiting the electron to constituents with a mass $m^* > m/\sqrt{(\delta g/2)} = 130$ GeV/c^2." Unfortunately, the "/" was missing before the expression "$\sqrt{(\delta g/2)}$" in the original. On page 37, the magnitudes of q/m for the proton and antiproton were shown to be the same to better than nine parts in 10^{11} in the experiment referred to with one antiproton cooled to 4.2 K, not the same to better than nine parts in 10^{13} as printed. Also, LEP was of course the world's highest-energy electron–positron collider, not the world's highest-energy electron–proton collider (p37). *CERN Courier* apologises for these mistakes.

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IFMIF – EVEDA (International Fusion Materials Irradiation Facility – Engineering Validation Engineering Design Activities)

The European Union and the government of Japan have decided to sign an agreement for the joint implementation of a number of activities under the label “Broader Approach” activities”, contributing to jointly develop fusion power. Amongst them, there are the IFMIF-EVEDA activities, in view of constructing IFMIF, an intense 14 MeV neutron source, to test fusion relevant materials.

The European Union is in charge of the accelerator part of the EVEDA system and also of the design of the IFMIF accelerator. A management team for the accelerator will be set up and situated at Saclay, France, on one of the CEA site.

Project Office for the IFMIF-EVEDA Accelerator Project

The Accelerator management team is looking for a project control engineer, to define and implement the best project management practices to meet a challenging schedule. The activities will include:

- Defining the project management tools that will be used internally to manage the project and report to the project directorate and the EVEDA Steering Committee
- Maintaining the project management plan on behalf of the Project Leader
- Maintaining a reliable planning for the project
- Defining and implementing a reliable and effective documentation management system
- Supporting the project leader and the international partners in establishing common procurement rules for the project.

Safety Engineers for the IFMIF-EVEDA Accelerator Project

The accelerator management team is looking for a specialist in nuclear safety to work closely with the project team on the preparation of the safety case for the prototype accelerator to be constructed in Japan and for the final IFMIF accelerator.
The activities will include:

- Working closely with the accelerator technical team to prepare the safety case of the EVEDA accelerator and its interfaces
- Interfacing with the EVEDA Project team in Japan to write the nuclear safety documents for the Japanese nuclear authorities;
- Preparing the nuclear safety case, along with the design team, for the IFMIF accelerator.

System Engineers for the IFMIF-EVEDA Accelerator Project

The accelerator management team is looking for several professionals for a local team on system engineering for the accelerator.
The activities will include:

- Reviewing and up-dating the design of the EVEDA accelerator;
- Reviewing and validating the technical specifications for the industrial contracts;
- Managing the configuration control of the system;
- Preparing the integration phase on the experimental platform at Saclay;
- Preparing the installation and commissioning at Rokkasho;
- Defining and implementing a reliable Quality System for the project
- Managing the project risks
- Preparing the IFMIF accelerator full design report;

dapnia
cea
saclay

For further information and to apply for the above positions please contact acgouze@cea.fr or micolon@cea.fr

HadronPhysics I3
Study of Strongly Interacting Matter

HadronPhysics I3
Study of Strongly Interacting Matter

European Commission

Transnational Access to Research Infrastructures

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

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

A1. INFN-LNF, http://www.lnf.infn.it/cee/tarifp6/
A2. DESY-HERMES, http://www-hermes.desy.de/I3HP-TA-HERMES/
A3. FZJ-COSY, http://www.fz-juelich.de/ikp/tmr-life.html
A4. FZJ-NIC/ZAM, http://www.fz-juelich.de/nic/i3hp-nic-ta/
A5. GSI-SIS, http://www.gsi.de/informationen/users/EC-funding/I3/SIM_e.html
A6. U Mainz-MAMI, http://www.kph.uni-mainz.de/en/eu/
A7. ZIB, http://www.zib.de/i3hp
A8. LU-MAXLAB, http://www.maxlab.lu.se/kfoto/eu/MAXlabproposalsI3HP.html
A9. UU-TSL, http://www.tsl.uu.se/infrastr.htm

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

LEDERMAN FELLOWSHIP in EXPERIMENTAL PARTICLE PHYSICS or ACCELERATOR PHYSICS

The Fermi National Accelerator Laboratory (Fermilab) has an opening for a postdoctoral Lederman Fellow in experimental particle physics or accelerator physics. We are looking for candidates who have demonstrated outstanding ability in research. In recognition of Leon Lederman's commitment to the teaching of physics at all levels, the successful candidate will be also expected to participate, for a fraction of his/her time, in physics outreach. The Lederman Fellow will have a choice of opportunity within the broad program of experimental research at Fermilab which includes experiments at the energy frontier, neutrino physics, particle astrophysics and accelerators. See http://www.fnal.gov/ for more information.

Candidates should have obtained a Ph.D. in experimental particle or accelerator physics after November 15, 2005. The appointment is normally for three years with an extension possible. To apply, write to: Dr. Vaia Papadimitriou (Chair of Lederman Fellowship Committee), Fermi National Accelerator Laboratory, MS 306, P.O.Box 500, Batavia, IL 60510-0500 or vaia@fnal.gov. Applicants should send a letter including their research experience and noting any experience or interest in teaching and outreach, curriculum vitae, publication list and the names of at least four references. Applications will be accepted through January 5, 2007.

Fermilab

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BOOKSHELF

Books received

Linear Collider Physics in the New Millennium by Keisuke Fujii, David J Miller and Amarjit Soni (eds), World Scientific. Hardback ISBN 9812389083, £60 ($98).

The high-energy electron–positron linear collider is expected to provide crucial clues to many of the fundamental questions of our time. What is the nature of electroweak symmetry breaking? Does a Standard Model Higgs boson exist or does nature take the route of supersymmetry, technicolour, extra dimensions or none of the these? This book contains articles by experts on many of the most important topics on which the linear collider will focus. It is aimed primarily at graduate students but will be useful to any researcher interested in the physics of the next-generation linear collider.

Handbook on Secondary Particle Production and Transport by High-energy Heavy Ions by Takashi Nakamura and Lawrence Heilbronn, World Scientific. Hardback ISBN 9812565582, £33 ($58).

This handbook is a timely resource for the rapidly growing field of heavy-ion transport-model theory and its applications in accelerator development, heavy-ion radiotherapy and shielding of accelerators, as well as in space. Data from more than 20 years of experiments in the production of secondary neutrons and spallation products are contained in the handbook and on the accompanying CD. Transport modellers and experimentalists will find the detailed descriptions of the experiments and subsequent analyses valuable in utilizing the data for their applications.

Adventures in Theoretical Physics: Selected Papers with Commentaries by Stephen L Adler, World Scientific. Hardback ISBN 9812563709 £62, ($108). Paperback ISBN 9812565221 £33, ($58).

From 1964–1972, Stephen L Adler wrote seminal papers on high-energy neutrino processes, current algebra, soft pion theorems, sum rules and perturbation-theory anomalies, which helped lay the foundations for the current Standard Model of elementary-particle physics. These papers are reprinted here with detailed historical commentaries describing how they evolved, their relation to other work in the field and their connection to recent literature. The commentaries and reprints also cover later important work by Adler on a range of topics in fundamental theory, phenomenology and numerical methods. This book is a valuable resource for graduate students and researchers, and for historians of physics in the final third of the 20th century.

Time and Matter: Proceedings of the International Colloquium on the Science of Time by Ikaros I Bigi and Martin Faessler (eds), World Scientific. Hardback ISBN 9812566341, £56 ($98).

Time and matter are the most fundamental concepts in physics and in any science-based description of the world around us. Quantum theory has, however, revealed many novel insights into these concepts in non-relativistic, relativistic and cosmological contexts. The implications of these novel perspectives have been realized and, in particular, probed experimentally only recently. The papers in this publication discuss these issues in an interdisciplinary fashion from philosophical and historical perspectives. The leading contributors, including Nobel laureates T W Hänsch and G 't Hooft, address both experimental and theoretical issues. Physicists, philosophers, historians of science, and graduate physics students will find this an interesting read.

Analytical Mechanics by Antonio Fasano and Stefano Marmi, Oxford University Press. Hardback ISBN 9780198508021, £49.50 ($89.50).

Analytical mechanics is the investigation of motion with the rigorous tools of mathematics – a classical subject with fascinating developments, which is still rich with open problems. This book is intended to fill a gap between elementary expositions and more advanced material, explaining ideas and showing applications using plain language and "simple" mathematics. Basic calculus is enough for the reader to understand this volume; any further mathematical concepts are fully introduced in simple language.

Physics of Intensity Dependent Beam Instabilities by K Y Ng, World Scientific. Hardback ISBN 9812563423, £52 ($86).

This book comprehensively covers intensity-dependent particle-beam instabilities in accelerating rings. It briefly reviews the concept of wake potentials and coupling impedances in the vacuum chamber, and then discusses static and dynamic solutions to their effects on particle beams. It separately emphasizes proton and electron machines. Other topics include Landau damping, Balakin–Novokhatsky–Smirnov damping, Sacherer's integral equations, saw-tooth instability, Robinson stability criteria, beam loading, transition crossing and collective instability issues of isochronous rings. It provides a thorough description of experimental observations and discusses cures for the instabilities.

An Invitation to Astrophysics by Thanu Padmanabhan, World Scientific. Hardback ISBN 9812566384, £38 ($66). Paperback ISBN 9812566872, £21 ($36).

This book describes several aspects of astrophysics and cosmology in a way that a physicist or beginner in astrophysics can understand. It emphasizes current research and exciting new frontiers, and introduces complex results with simple, novel derivations, which strengthen the conceptual understanding of the subject. The book has more than 100 exercises, which will benefit students. Undergraduate and graduate physics and astrophysics students, as well as physicists who are interested in quickly grasping astrophysical concepts, will find this book useful.

Laser-driven Particle Accelerators: New Sources of Energetic Particles and Radiation by Keith Burnett, Dino Jaroszynski and Simon Hooker (eds), The Royal Society. Paperback ISSN 1364503X, £100 ($170).

The strong electromagnetic fields that are generated when intense laser pulses interact with plasma could produce a new generation of extremely compact particle accelerators. Laser-driven plasma accelerators are potentially versatile sources of energetic particle beams and coherent radiation that ranges from terahertz frequencies to X-rays. This issue of *Philosophical Transactions of the Royal Society A* contains papers by leading experts, beginning with basic concepts in plasma accelerators and the status and evolution of plasma-wakefield particle accelerators. It includes inverse free-electron lasers, high-intensity laser-driven proton acceleration and femtosecond electron diffraction.

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