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CERN COURIER

VOLUME 46 NUMBER 6 JULY/AUGUST 2006

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In search of the elusive axion p19

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

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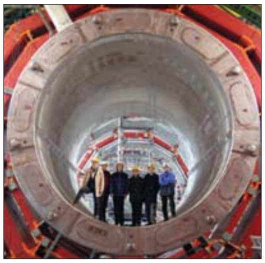
CERN COURIER

VOLUME 46 NUMBER 6 JULY/AUGUST 2006

The LHC is on track for 2007 p5

Golden 'buckyballs' discovered p9

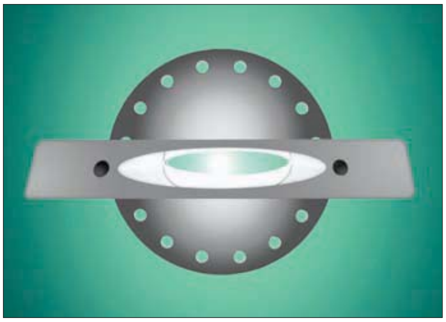


CMS prepares for testing p28

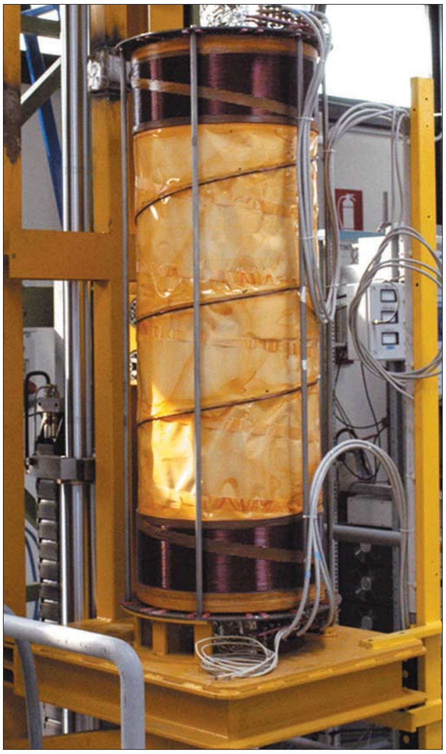
Cover: The COMPASS experiment at CERN uses ring imaging Cherenkov (RICH) counters to identify particles produced in high-energy muon collisions, in studies to understand better the spin structure of the nucleon (p15). This image shows the mirror wall of RICH 1.

Brookhaven National Laboratory chooses SAES® Getters' new NEG thin-film technology to coat the RHIC machine

IntegraTorr™ sputtered non-evaporable getter thin film has been chosen to coat 108 vacuum chambers of the Relativistic Heavy Ion Collider (RHIC) machine



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



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

Project outline

Brookhaven National Laboratory at Upton, Long Island, NY has chosen IntegraTorr™, SAES Getters' new non-evaporable getter (NEG) thin-film technology for ultra-high vacuum pumping, to coat 108 vacuum chambers of the Relativistic Heavy Ion Collider (RHIC) machine. The world-class scientific research facility attracts about 1,000 physicists each year from around the world who gather at RHIC to investigate what the universe may have looked like in the first few moments after its creation. RHIC drives two intersecting beams of gold ions traveling at 99.995% the speed of light head-on to create subatomic collisions, which cause the matter to heat to more than a billion times the temperature of the sun. Phenomena originating from these heavy ion collisions help scientists study the fundamental properties of the basic building blocks of matter, deepening understanding about the laws of the physical world, from the smallest subatomic particles to the largest stars.

Worldwide market leader in getter components for cathode ray tubes and vacuum tubes, SAES Getters is a technology forerunner of getter solutions for ultra-high vacuum (UHV) applications, including particle accelerators. Dozens of machines around the world, encompassing electron and positron storage rings, synchrotrons, ion colliders and nuclear radiation facilities, employ SAES' NEG technology for primary pumping of their vacuum chambers and systems.

RHIC has recently implemented a two-year vacuum upgrade plan which includes NEG-coating and activation of most of its warm straight sections, to provide extra linear pumping and reduce secondary electron yield (SEY) and electron stimulated desorption (ESD). Four-hundred-forty meters of NEG-coated chambers have already been installed and additional chambers for more than one hundred-sixty meters are scheduled to be installed by BNL in 2006. First results obtained at BNL have showed the ability of NEG coated pipes to reduce pressure instabilities and to increase remarkably the machine luminosity. Once installed, total NEG-coated pipes at RHIC will exceed 600 meters, covering 40% of the total warm sections.

Boosting high-energy machine performance

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

IntegraTorr is a highly innovative way to integrate non-evaporable getterpumping into a particle accelerator vacuum chamber. It is achieved by depositing a sputtered NEG film about 1 micron thick onto the vacuum chamber, thus providing a very effective barrier to the gas species which would otherwise desorb from the chamber surface. The NEG film also acts as a powerful, fully distributed "in situ" pump, efficiently absorbing molecules and keeping extremely low pressures, unmatched by other techniques. If the whole vacuum chamber is coated, a distributed pump with huge sorption speed is created: under these conditions, IntegraTorr has the potential to achieve pressures in the extreme high vacuum (XHV) range, below 1×10^{-12} mbar.

Thanks to its unique features, IntegraTorr significantly improves the ultimate dynamic vacuum in high energy mach-ines, allowing the achievement of stable beam conditions and improved current parameters.

The NEG coating can be supplied for chambers up to six meters long, which is an important additional advantage for the specific application field, since it reduces the risk of possible leaks due to vacuum chamber welds and ensures a more homogeneous film deposition.

In addition to Brookhaven National Laboratory, the IntegraTorr technology is also currently adopted in several synchrotron facilities including SOLEIL (F) and ELETTRA (I). Traditional NEG vacuum pumping solutions based on getter pumps have been recently adopted for Petra III at Desy (D) and for the upgrade of the Beijing Electron Positron Collider (PRC).

For further information:
www.saesgetters.com
neg_technology@saes-group.com

CERN

LHC start-up confirmed for 2007

As far as the eye can see – magnets are now filling the LHC tunnel.

Installation of the cryogenic distribution line on sector 1-2 of the LHC.

First collisions in the Large Hadron Collider (LHC) will occur in November 2007, LHC project leader Lyn Evans told the 137th meeting of the CERN Council on 23 June. A two month run in 2007, with beams colliding at an energy of 0.9 TeV, will give the accelerator and detector teams the opportunity to run-in their equipment, ready for a run at the full collision energy of 14 TeV to start in Spring 2008.

The schedule announced to the Council ensures the fastest route to a high-energy physics run with substantial quantities of data in 2008, while optimizing the commissioning schedules for the accelerator and the detectors that will study the particle collisions. It foresees closing the 7 km ring of the LHC in August 2007 for equipment commissioning. Two months of running will start the following November, allowing the accelerator and detector teams to test their equipment with low-energy beams. After a winter shutdown, during which commissioning will continue without beam, the full-energy run will begin. Data collection will then continue until a predetermined amount of data has been accumulated, allowing the experimental collaborations to announce their first results.

Progress with the LHC project is being closely followed by a machine advisory committee composed of experts from around the world. This committee believes that "experience indicates that [the proposed schedule] is the most efficient way to get to high-energy, high-luminosity operation at the earliest date".

Meanwhile, installation of the LHC accelerator has reached full speed, and all of the industrial procurement projects are coming to a conclusion. The last magnet for the LHC will be delivered to CERN in October 2006 and magnet testing will conclude by December. The last magnet will be installed in the LHC ring in March 2007, after which the machine will be closed ready for commissioning in August, with first collisions scheduled for November.

At the meeting the Council also unanimously approved a preliminary draft budget for 2007 and took note of projections for 2008–2012, with no new initiatives in the scientific programme. However, this exercise is continuing in parallel with the definition of a European strategy for particle physics (*CERN Courier* July/August 2005 p5). If approved by the Council at its meeting in Lisbon on 14 July, this strategy will have financial implications and will require new resources, which will have to be taken into account when the medium-term plan for CERN is discussed later this year.

Sommaire

COSMIC RAYS

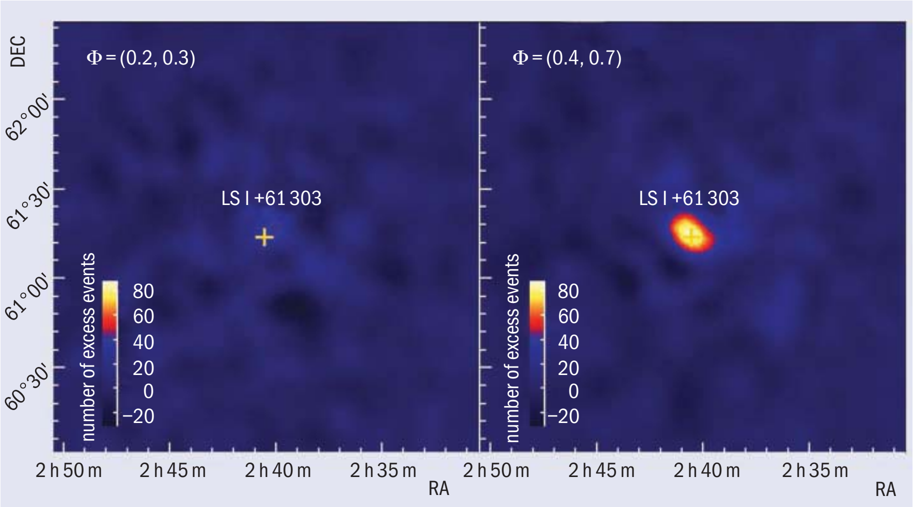
MAGIC discovers variable very-high-energy gamma-ray emission from a microquasar

The Major Atmospheric Gamma-ray Imaging Cherenkov (MAGIC) Telescope has discovered variable very-high-energy gamma-ray emission from a microquasar. The telescope, on the island of La Palma, observed the microquasar called LS I +61 303 between October 2005 and March 2006. The observations show a clear variation with time and suggest that gamma-ray production may be a common property of microquasars.

Microquasars are gravitationally bound binary-star systems consisting of a massive ordinary star and a compact object of a few solar masses that is either a neutron star or a black hole. The two stars orbit a common centre and when close enough the mutual tides can cause a sudden transfer of mass from the normal star onto the compact companion. Some of the gravitational energy released in this exchange gives rise to jets of particles ejected at close to the speed of light, together with spectacular emission of radiation. Microquasars appear to be scaled-down versions of quasars, but in this case the small mass of the compact object means that events occur on a much smaller timescale – days rather than years – making them interesting objects to study. They are also a possible source of high-energy cosmic rays.

MAGIC detected LS I +61 303, one of about 20 known microquasars, at a rate of one gamma ray per square metre per month (Albert 2006). The telescope registers gamma rays through the Cherenkov radiation produced by the showers of particles created by the gamma rays as they enter the atmosphere (*CERN Courier* December 2003 p7).

LS I +61 303 was observed over six orbital cycles and a clear variability was found that is consistent with the orbital changes in aspect of the compact object (see figure). There is also evidence of periodicity. This shows that the very-high-energy gamma-ray emission is directly related to the interaction between the two stars.



Map of gamma rays measured by MAGIC around the location of LS I +61 303 at two different points along the orbital cycle. Left: when the two stars are closest to one another (periastron passage). Right: a third of an orbit away from the periastron passage.

Further reading

J Albert *et al.* 2006 *Science* **312** 1771.

FELS

EIFast workshop presents XFEL project to international industry

A total of 57 companies and 14 institutions from 13 countries demonstrated their interest in the European X-ray free-electron laser (XFEL) project at an industry workshop held at DESY on 9–10 May. Organized by the European Industry Forum for Accelerators with Superconducting RF Technology (EIFast), the event was intended to inform potential suppliers from European industry about the current design status of this new large European machine, for which construction should start at the beginning of 2007.

Companies attending were asked to comment and give their opinion on the technical layout of the XFEL facility, the purchasing strategy and other relevant issues.

The decision to hold the workshop before an agreement has been reached at the political level to create and finance the European XFEL Facility GmbH was considered to be a wise move, as it demonstrated to companies that the preparation of the project has come to maturity. More than 170 participants attended, representing the whole spectrum of services required for the construction of the XFEL, from the building of the surface halls and underground facilities to the development and supply of components and measurement devices. Attendees unanimously agreed that the workshop had been highly beneficial, and praised the detailed presentation of the XFEL project and the timely involvement of industry, which allows potential suppliers to plan the required capacities and make the necessary technical preparations on time.

● For more information on the European industry forum EIFast, see the website at https://trac.lal.in2p3.fr/SCRF/.

DETECTORS

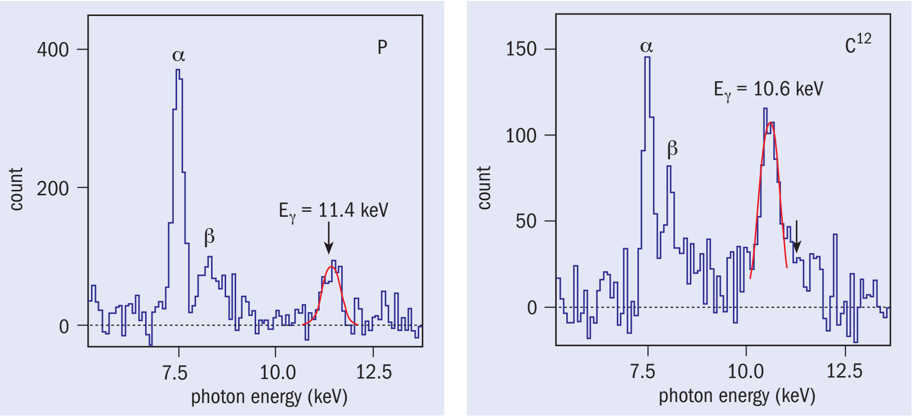
Parametric X-ray radiation yields new tool to detect relativistic nuclei

Researchers at the Nuclotron at the Laboratory for High Energies at the Joint Institute for Nuclear Research (JINR), Dubna, have observed parametric X-ray radiation (PXR) from moderately relativistic nuclei interacting with crystals. Predicted theoretically in 1971, PXR has already been detected and investigated in electron beams at various energies, but this is the first time that it has been observed for heavy charged particles. It could lead to a new diagnostic method for use in nuclear beams at high-energy accelerators.

PXR emission by fast charged particles in crystals occurs when the virtual-photon field of the particles is diffracted by the crystallographic planes. The radiation arises from the uniform straight-line motion of the charged particle in the crystal and the yield depends only weakly on the value of the particle's relativistic factor γ. It was natural to assume that the observation of PXR from heavy charged particles – relativistic nuclei – was a real possibility. Moreover, PXR from nuclei with a charge $Z>1$ should be more intense than PXR from electrons, because the parametric-radiation yield is proportional to the square of Z.

The variation of the yield with γ contrasts with the case for radiation produced by the change of a particle's velocity, such as bremsstrahlung and synchrotron radiation, where there is a strong dependence on γ. Both bremsstrahlung and synchrotron radiation are practically absent for protons and nuclei with the energies typical of the Nuclotron in contrast with electrons with the same energies.

The measurements at the Nuclotron were performed by a collaboration from JINR, the Institute of Physical-Technical Problems in Dubna, the Nuclear Physics Institute in Tomsk Polytechnical University and the Moscow State Institute of Electronic Technology. The team used silicon and graphite crystals in extracted beams of 5 GeV protons and 2.2 GeV/u carbon nuclei. The beam fell onto a thin (001) silicon-crystal target, inclined to the beam axis at an angle, θ_B, near 20°. The detector was placed close to an angle $2\theta_B$, which is the diffraction angle of virtual photons in a particle field from the (001) planes.



Radiation spectra registered with a semiconductor detector when a thin (001) silicon crystal is irradiated by a 5 GeV proton beam (left) and a 2.2 GeV/u carbon-nuclei beam.

The figures show the X-ray spectra measured for a 5 GeV proton beam and a 2.2 GeV/u carbon-nuclei beam incident on the silicon crystal. The peaks α and β correspond to the characteristic radiation of nickel atoms that were excited in the detector casing by secondary particles. The peaks E_γ are due to parametric radiation.

The angular density of the parametric radiation was found to be 2.25×10^{-6} and 9.76×10^{-5} photon/(particle·sr) from protons and carbon nuclei, respectively, for a crystal inclination angle $\theta_B=22.5°$. The considerably higher radiation density from carbon nuclei confirms qualitatively the dependence of the parametric-radiation yield on particle charge Z.

This observation of parametric X-ray radiation from relativistic nuclei in the experiments at the Nuclotron opens possibilities for applications of the effect as a nuclear-beam diagnostic at other high-energy accelerators. The significant advantage is the large angle of PXR photons to the beam direction. The crystal target for the diagnostics can be made very thin – less than 100 μm – to decrease its influence on the beam. The application of bent crystals for collimation of the LHC beams is also under investigation. Detection of PXR generated by the beam halo particles in the crystal collimator could provide information about the stability of its angular position and also, as a by-product, about the structure of the crystal.

A D Kovalenko and A M Taratin, JINR.

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.

LHC DETECTORS

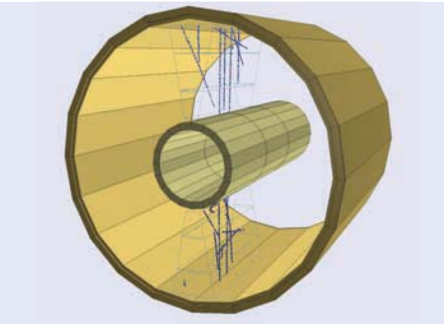
ALICE experiment sees first cosmic-ray events

On 16 June the time projection chamber (TPC) for the ALICE experiment at the Large Hadron Collider (LHC) started to record its first real events, reconstructing the tracks of cosmic rays. ALICE will search for evidence for quark-gluon plasma in head-on collisions of lead ions at the LHC. This requires precise tracking to record the paths of thousands of particles produced in the collisions. ALICE is therefore built around the largest TPC in the world. Based on a cylindrical field cage 5 m long and 5 m in diameter, the TPC is now nearing completion, with all the read-out chambers installed and the custom electronics complete for the approximately 560 000 read-out channels.

The TPC consists of a field cage made of carbon-fibre composites, which contains the central high-voltage electrode and four potential-divider chains to create a uniform electric drift field in the active volume of 95 m^3, filled with a mixture of Ne, CO_2 and N_2. The high-voltage electrode is run at 100 kV and shielded to the outside by containment vessels filled with CO_2 gas. The detector is now running stably at 100 kV with the final gas mixture.

The TPC read-out system on the aluminium endplates is partitioned into 18 sectors on each side. Each sector comprises an inner (small) and outer (large) trapezoidal read-out chamber based on multiwire proportional chambers with pad read-out. The signals from the pads are passed via flexible Kapton cables to 4356 front-end cards located some 10 cm away from the pad plane. In the front-end cards, the signals are amplified, converted to digital format, and then pre-processed by a specially designed combination of read-out chips. With the ultra-low power consumption of its electronics (< 45 mW/channel), the whole TPC requires about 25 kW of electrical power for full operation. However, only a fraction of the power and of the corresponding water-cooling plant is available in the clean room, so commissioning is proceeding with two sectors at a time.


The ALICE TPC in its clean room, where it is undergoing commissioning of all its sectors.


One of the first cosmic-ray events recorded and reconstructed in two sectors of the TPC.

The tests use the ALICE cosmic muon trigger detector ACORDE, as well as a specially designed UV laser system, to produce tracks in the detector. Preliminary analysis of the cosmic-ray events and the laser-induced tracks indicate that the drift velocity and diffusion of electrons liberated by traversing charged particles, as well as the spatial resolution, are very close to the design values. Commissioning, during which every one of the 36 sectors will be turned on and its performance studied, will last until October. The TPC will then be transferred into the ALICE underground area prior to installation and final connection of all services ready for first collisions in November 2007.

PRECISION

ASACUSA measures antiproton mass with record precision

The Japanese–European ASACUSA team at CERN has measured the antiproton-to-electron-mass ratio to record-breaking accuracy. The answer is 1836.153674, with an error margin of 5 in the last decimal place, which is equivalent to measuring the distance between Paris and London to within 1 mm. The corresponding ratio for the proton is 1836.15367261, so the new result shows that the mass of the antiproton is the same as that of the proton to nine significant figures (Hori 2006). This precision has been achieved using the "frequency comb" technique, development of which earned John Hall and Theodor Hänsch the Nobel prize in 2005 (*CERN Courier* June 2006 p30),

In the ASACUSA experiment, samples of antiprotonic helium – an atom with an antiproton and an electron orbiting a normal helium nucleus – were produced using CERN's Antiproton Decelerator facility, and irradiated with a tunable laser beam, the frequency of which could be measured very precisely with the Hall–Hänsch frequency-comb technique. The laser beam could be tuned to one of several characteristic frequencies of the antiprotonic atoms, each frequency corresponding to an atomic transition of the antiproton. Since these frequencies were determined by the properties of the antiproton, the ratio of the antiproton mass to the electron mass could then be calculated from the measured values.

The results can also be combined with an earlier high-precision measurement of the antiproton's cyclotron frequency (which determines the curvature of its path in a magnetic field). This shows that there is no difference in the proton and antiproton charges either, apart from the sign. Still more precise experiments are planned with the optical comb, and may soon give an even smaller margin of error for the antiproton than the best one obtained for the proton itself (currently about five times smaller). Surprisingly, the antiproton may soon be known better than the proton.

Further reading

M Hori *et al.* 2006. *Phys. Rev. Lett.* **96** 243401.

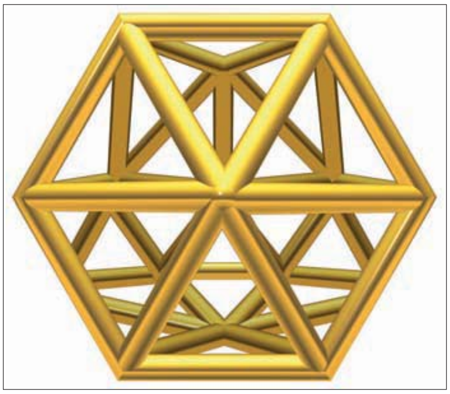
SCIENCEWATCH

Compiled by Steve Reucroft and John Swain, Northeastern University

Researchers find golden 'buckyballs'...

The first "free-standing" elemental hollow cages – structures that would rival "buckyballs" but be made of an element other than carbon – have been reported. Researchers at the University of Nebraska, Washington State University and the Pacific Northwest National Laboratory (PNNL) in Washington State have presented experimental and theoretical evidence for cage-like structures made only of gold atoms, dubbed "bucky gold".

Carbon buckyballs – or fullerenes – with a hollow structure of 60 carbon atoms were discovered in the 1980s. Now the researchers in the US seem to have made the first metallic version. These structures have only 16 to 18 atoms and form a structure made from triangles – more like a gem than a football. They have average diameters of more than 5.5 Å and could hold a guest atom inside, although the researchers have yet to attempt this. Applications could exploit the fact that at the scale of atoms, gold becomes highly reactive and is a very good catalyst.



Gold atom cluster, the first known metallic hollow equivalent of the hollow carbon fullerenes ("buckyballs"). (Courtesy PNNL.)

Further reading

Satya Bulusu, Xi Li, Lai-Sheng Wang and Xiao Cheng Zeng 2006 *Proc. Natl. Acad. Sci.* **103** *22* 8326.

...while World Cup balls get rounder

The shape of buckyballs is perhaps best known as the shape of the traditional football. In mathematical terms, the football is a "truncated icosahedron" – a shape with 60 vertices and 32 faces, 12 of which are pentagons (five-sided) and 20 of which are hexagons (six-sided). Before the World Cup in 1970, professional football casings were made of rectangular strips. After that, the balls were made of a combination of 12 pentagonal and 20 hexagonal panels, a design that was successively simplified for subsequent World Cups.

However, this year saw a radical change – the official ball for the World Cup in Germany was made of 14 wing- or butterfly-shaped panels (similar to those of a tennis ball). The designers claimed that this structure reduces the area of contact, making the ball lighter and more spherical.

Further reading

www.icm2006.org/press/bulletins/bulletin09/#1.

The question of particles and free will

Here's another disturbing thing about the universe to ponder when you can't get to sleep in the middle of the night. From the abstract of a paper entitled "Particles and free will" by John Conway and Simon Kochen of Princeton University: "we prove that if the choice of a particular type of spin 1 experiment is not a function of the information accessible to the experimenters, then its outcome is equally not a function of the information accessible to the particles."

That is, if you believe that your will is not determined by external causes but is ultimately something that you come up with yourself, then you have to ascribe that same notion of free will to a single particle.

Further reading

John Conway and Simon Kochen 2006 http://xxx.lanl.gov/abs=quant-ph/0604079.

A way of detecting 'Casimir friction'

The Casimir effect is usually thought of as a force arising from the presence of boundaries that distort the zero-point energy of the vacuum, but when those boundaries move around, that same force can produce real photons – "the dynamical Casimir effect". Woo-Joong Kim of Dartmouth College in New Hampshire and colleagues have proposed that photons from the dynamical Casimir effect may be directly observable in a suitable high-*Q* cavity with a mechanical resonator that pushes photons out of the quantum mechanical vacuum.

The proposed experiment is at the limits of present-day technology, but could lead to an elegant illustration of one of the great subtleties of quantum-field theory.

Further reading

Woo-Joong Kim, James Hayden Brownell and Roberto Onofrio 2006 *Phys. Rev. Lett.* **96** 200402.

Measurements cast doubt on 'constant'

Comparisons of the spectra of hydrogen gas in the lab and from distant hydrogen clouds could indicate that the ratio of proton mass to electron mass has changed over time.

Wim Ubachs of the Vrije Universiteit Amsterdam and his colleagues have made ultra-high-resolution spectroscopic measurements of hydrogen in the extreme-ultraviolet range – a region of the spectrum which is notoriously difficult to work in. They then compared their results with the absorption spectra of distant hydrogen (absorbing light from quasars that are even farther off) taken by the European Southern Observatory in Chile.

They researchers see evidence at the 3.5 σ level for a fractional change of 0.000024 in the ratio of proton mass to electron mass compared with 12 billion years ago.

Further reading

E Reinhold *et al.* 2006 *Phys. Rev. Lett.* **96** 151101.

ASTROWATCH

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

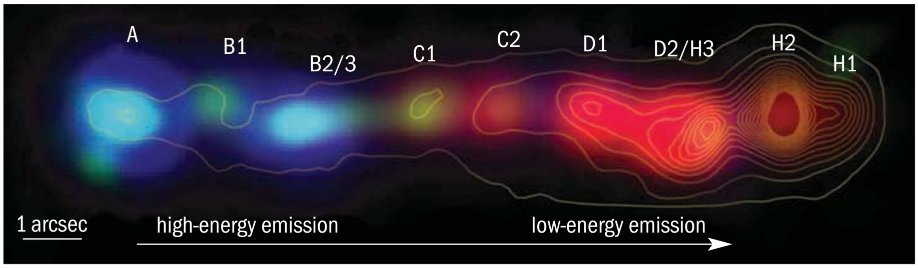
Quasar jets could be powerful accelerators

Infrared observations of the quasar 3C 273 by the Spitzer Space Telescope are giving new insight into the physics at play in its large-scale jet. The new images, combined with complementary radio, optical and X-ray observations, reveal two distinct spectral components. There is evidence that the component emitting X-rays is also producing synchrotron radiation, implying that ultra-energetic particles are continually accelerated all along the jet.

Back in 1963, 3C 273, an apparently faint star with associated radio emission, was found to be at a cosmological distance (redshift of 0.158). This implied that this "quasi-star" – the first identified quasar – was about 100 000 billion times more luminous than the Sun. It is also the brightest of this class of extreme active galactic nuclei, which completely outshine their host galaxies. At the time of discovery, deep optical images of 3C 273 revealed a faint jet with an extension of about 100 000 light-years ending at the exact position of a second radio source.

More than 40 years later, the detailed structure of this jet has been studied by NASA's three great observatories: in visible and ultraviolet light by the Hubble Space Telescope, in X-rays by the Chandra Observatory and now also in the infrared by the Spitzer Space Telescope. This, together with radio observations by the Very Large Array (VLA), enables this powerful jet to be studied across the whole electromagnetic spectrum.

A team led by Y Uchiyama at Yale University has now shown that the overall spectrum of individual bright features in the jet contains two distinct spectral components. The first component extends from the radio to the infrared and the second becomes dominant in the visible up to the X-rays. While the low-energy component is undoubtedly of synchrotron origin (electron radiation in a magnetic field), the nature of the second component is uncertain.



Composite image of the jet of 3C 273 made from images in infrared (shown as red) and visible (green) obtained by the Spitzer and Hubble space telescopes, and in X-rays (blue) by the Chandra satellite. The superimposed radio-map contours are from the VLA. Letters label the main structures along the jet; knot A is closest to the quasar (Y Uchiyama et al.*).*

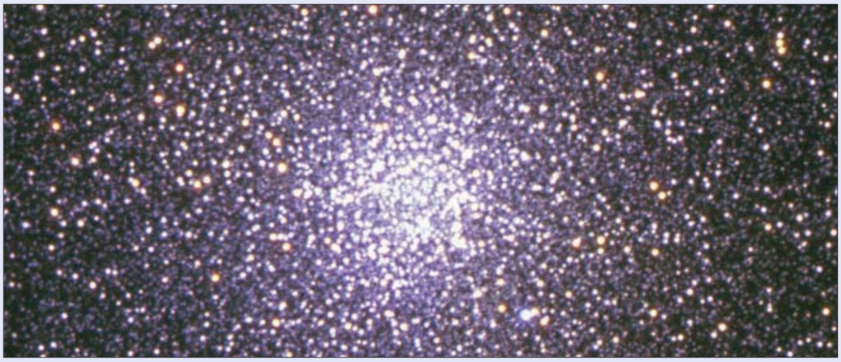
The strong X-ray emission of quasar jets detected by Chandra was thought to be due to inverse-Compton radiation produced by electrons scattering off the cosmic microwave background (CMB) photons. This model requires a strong bulk velocity of the jet flow to enhance relativistically the CMB photon field as seen from the electrons. The new finding that the visible ultraviolet emission is apparently related to the X-ray spectral component adds additional constraints to this model, which conflicts with the observed radio and optical polarization.

It now seems more likely that the high-energy component is also of a synchrotron nature. This would require a distinct electron acceleration process all along the jet, which could occur in a region of velocity shear between a central spine of the jet flow and an outer sheath, as suggested by S Jester at Fermilab and collaborators. In such conditions, according to Uchiyama *et al.*, ultra-high-energy protons could also be accelerated to energies up to 10^{19} eV enabling proton–synchrotron X-ray emission. This would mean that quasar jets are powerful particle accelerators producing extragalactic cosmic-ray protons with energies of 10^{16}–10^{19} eV.

Further reading

S Jester *et al.* (in press) *Astrophysical Journal* http://arxiv.org/abs/astro-ph/0605529.
Y Uchiyama *et al.* (in press) *Astrophysical Journal* http://arxiv.org/abs/astro-ph/0605530.

Picture of the month



Several tens of globular clusters are orbiting our galaxy. The second in size and brightness is 47 Tucanae, visible to the naked eye in the southern sky near the Small Magellanic Cloud. This beautiful image from the Very Large Telescope (VLT) shows the central parts of this spherical cluster of several tens of thousands of stars held together by mutual gravity. The stars are all thought to be born at the same time from the same cloud of gas. 47 Tucanae is so dense that stars are less than 0.1 light-years apart, which is about the size of the solar system. (Courtesy ESO.)

A look back to CERN Courier vol. 3, July/August 1963

PROFILE OF A PROGRAMME

CERN's fellows and visitors get involved

Not all the visitors at CERN are scientists. Seen in this picture is Noria Christophoridou, librarian of the Greek Atomic Energy Commission, who has been sent by her government to CERN for a year to widen her experience of library and documentation services. In the photograph she is providing information to Kurt Gottfried, a CERN visiting scientist from Harvard University, who is spending a year with CERN's Theory Division.

Recent discussion of ways in which the smaller member states of the organization might obtain more benefit from their membership has included suggestions for increasing the opportunities available for fellows and other visitors who stay at Meyrin for relatively short periods. Out of some 260 physicists at present working directly on research in CERN, about 190 are fellows or visitors. Applied physicists, engineers and technicians add about another 80 to this last total.

The visits to CERN of young scientists from some countries – Poland and Japan are good examples – have already produced remarkable results in the development of interest in high-energy physics in their countries. The presence of visitors from Argentina, Australia, Brazil, Canada, Czechoslovakia, India, Israel, Japan, Lebanon, Pakistan, Poland, Romania, Syria, Turkey, the US, USSR and Yugoslavia – the list is not exhaustive – shows that at least in one activity the countries of the world can work together in harmony and to good purpose.

A grant from the Ford Foundation enables CERN to invite some 20 visitors each year from non-member states. There is also a growing number of visitors now coming to CERN with independent support, either on sabbatical leave, through the US National Science and Guggenheim Foundations or the International Atomic Energy Agency Fellowship programmes on various exchange programmes with, at present, Brookhaven (US), Dubna (USSR) and the Weizmann Institute (Israel), or simply paid for by their institutes.

● Extracted from an article by R W Penney, August 1963 pp101–102.

LAST MONTH AT CERN

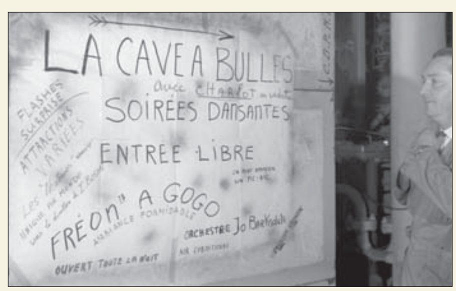
Neutrino pre-run is a great success

The most exciting news during June was that after years of preparation and the last few months of intense activity to install the equipment for the most complex experiment ever to be attempted at CERN, the neutrino pre-run was a complete success. The proton synchrotron, the fast ejected beam system, the CERN heavy-liquid bubble chamber and the massive spark chamber array all worked smoothly, and everything pointed to the fact that CERN now possesses a new and outstanding tool for scientific research.

Nothing much can be said about the results yet, since this was only a preliminary experiment. However, the kind of particle tracks so far obtained, both in the bubble chamber and in the spark chamber, agree with last year's Brookhaven result that muon neutrinos and electron neutrinos are two different kinds of particle.

At this stage the programme is exploratory and [...] the CERN experiments are designed to investigate in more detail the nature of the interactions both of neutrinos and antineutrinos (the latter coming from the decay of negative pions), and to search for the existence of a boson particle, thought by many to be involved in weak interactions in the same way as pions and kaons are involved in strong interactions.

● Extracted from July 1963 p86.



The photograph shows one of the lighter aspects of the neutrino experiment. This notice, in many colours (which we unfortunately cannot show), marks the entrance to the zig-zag passage, through concrete shielding in the South Hall of the Proton Synchrotron, leading to the enclosure that contains the CERN heavy-liquid bubble chamber.

The future's bright for the Pierre Auger Observatory

Researchers at the Pierre Auger Observatory have taken investigations of air showers created by very-high-energy cosmic rays to new heights. **Alan Watson** reports on progress.

In 1938, Pierre Auger and colleagues in Paris discovered that showers of cosmic rays can extend over wide areas when they recorded simultaneous events in detectors placed about 30 m apart. Nearly 70 years later, on the pampas of western Argentina, a cosmic-ray observatory bearing Auger's name is studying extensive air showers over a much wider area, many times the size of Paris itself. These showers are generated by particles with far higher energies than any man-made accelerator can reach, and they continue to challenge our understanding.

The nature and origin of the highest-energy cosmic rays remain obscure. Above 10^{19} eV (10 EeV) the rate of particles falling on the Earth's atmosphere is about 1/km^2 a year while at 100 EeV, where a small number of particles may have been identified, it falls to less than 1/km^2 a century. Thus detectors must be deployed over vast areas to accumulate useful numbers of events. Remarkably, this approach is practical because the cosmic rays generate giant cascades, or air showers, with more than 10^{10} particles at shower maximum for a 10 EeV primary cosmic ray. Some of the shower particles reach ground-level where they are spread over about 20 km^2. The particles also produce fluorescence light by the excitation of atmospheric nitrogen, which provides an alternative and powerful means of detecting the showers and useful complementary information.

The strategy behind the design of the Pierre Auger Observatory is to study showers through detecting not only the particles, with an array of 1600 water Cherenkov detectors, but also the fluorescence light, using four stations, each with six telescopes overlooking the particle detectors. The water tanks are used to measure the energy flow of electrons, photons and muons in the air showers, while the faint light emitted isotropically as the shower moves through the atmosphere can be detected with the fluorescence telescopes. The observatory is now around 70% complete and has been taking data for more than two years.

Unlike previous observatories for ultra-high-energy cosmic rays, the Pierre Auger Observatory combines the potential of high statistics from the water tanks, which are on nearly all of the time, with the power of a calorimetric energy determination from the fluorescence devices; it has become known as a hybrid detector. Figure 1 shows an event in which signals are seen in water tanks and in a fluorescence detector.

Alone, the signals from the tanks can be related to the energy of the primary cosmic ray by making assumptions about hadronic interactions. Our limited knowledge about such interactions at the relevant energies will be enhanced by the LHC at CERN, particularly from the forward-physics projects that are being prepared. For now, the

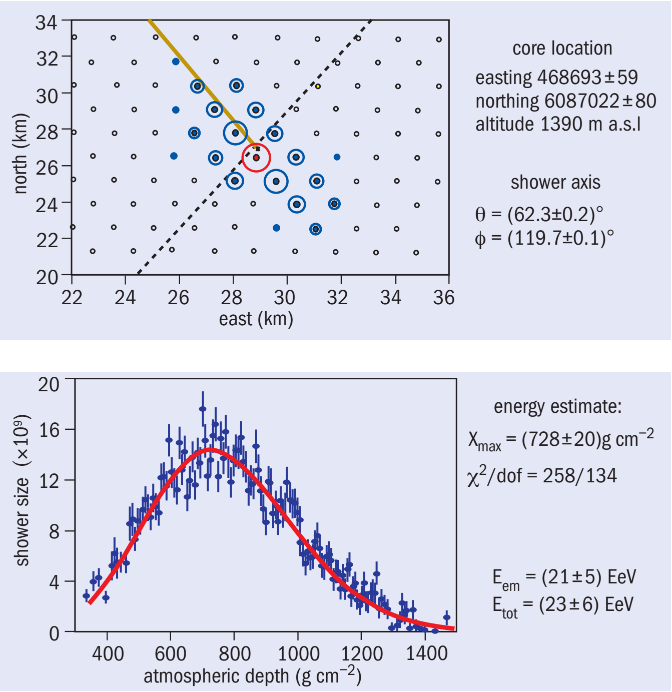


Fig. 1. An event detected both in water tanks (top) and in a fluorescence detector (bottom) at the Pierre Auger Observatory.

energy transferred into the leading particle, the multiplicity and the cross-section for the interaction must all be estimated, while the sparse information on pion–nucleus collisions can be boosted by fixed-target experiments. Additionally, assumptions about the mass of the primary particle must be made, as an iron nucleus, for example, will yield a smaller number of particles at ground level than a proton. With the fluorescence technique, however, these problems can be finessed, and the primary energy can be deduced rather directly.

Figure 2 shows the layout of the Pierre Auger Observatory on 31 March, by which time 1113 tanks had been deployed with all but five of them filled with 12 tonnes of pure water; 953 are fitted with electronics and are fully operational. Three of the four fluorescence stations are taking data; the building for the fourth is under construction and telescopes will be installed there in late 2006. When completed, the area covered will be about 30 times bigger than Paris.

All the water tanks operate in an autonomous mode: three 9 inch photomultipliers view each volume of water (10 m^2 × 1.2 m) with a

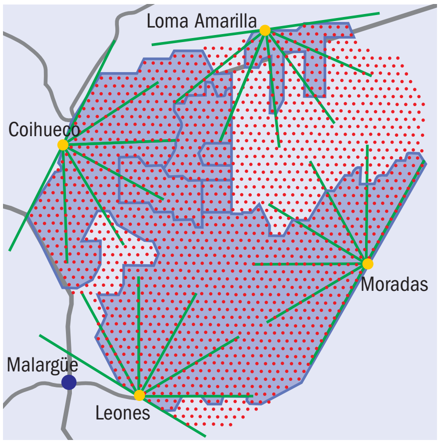


Fig. 2. The Pierre Auger Observatory, showing the locations of 1113 water tanks and four fluorescence detectors.

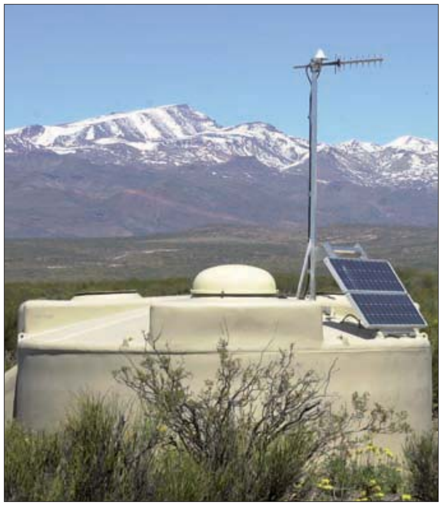


Fig. 3. One of the water tanks in position.

Fig. 4. The 440-photomultiplier camera at one of the fluorescence stations.

trigger rate set at about 20 Hz. The tank signals are calibrated in units of vertical equivalent muons, each of which gives a summed signal of around 300 photoelectrons. The time of each trigger, determined using a GPS receiver, is sent to a central computer using a purpose-built radio system coupled to a microwave link. The computer is used to find detectors clustered in space and time in the manner expected for an air shower, and when a grouping is identified a signal is sent to each detector requesting that other data be transmitted. Currently about 50 events are recorded every hour above a threshold below 1 EeV, with about two events a day from primaries with energies above 10 EeV. Solar cells provide 10 W for the electronics of each tank. Once in position and operational, as in the example in figure 3, these detectors need little attention except replacing the batteries every four years.

A single fluorescence station contains six telescopes, each fitted with a camera that collects light falling on an 11 m^2 mirror (see figure 4). The camera has 440 hexagonal photomultipliers (40 mm across), each viewing a different part of the sky. Nitrogen fluorescence at wavelengths of 300–400 nm is observed through a filter, which also keeps out dust. Schmidt optics eliminate coma aberration, achieving a spot size of 0.5°. The trigger for these detectors requires that one of a predefined set of patterns is recognized within a group of five photomultiplier pixels. Trigger details are then transmitted to the computer that records the water-tank information. Data from the fluorescence signal about the plane in space that contains the shower direction are combined with the time at which water tanks are struck to define the core position and direction with high precision. The core can be located to about 60 m while the direction is obtained to within around 0.5°. This accuracy is much higher than is possible with either detector type alone. Large showers are sometimes seen in stereo by two fluorescence detectors and a few tri-ocular triggers have been obtained: such events allow the accuracy of event reconstruction to be cross-checked.

A major goal of the Pierre Auger Observatory is to make a reliable measurement of the cosmic-ray energy spectrum above 10 EeV. In particular, the researchers aim to answer the question as to whether or not the spectrum steepens above around 50 EeV, as predicted by Kenneth Greisen, Georgi Zatsepin and Vadim Kuzmin shortly after the discovery of the 2.7 K microwave background. The point is that for protons above this energy the microwave radiation is seen Doppler-shifted to the extent that the Δ^+ resonance is excited. This reaction drains a proton of energy so rapidly that for a proton to be detected at 100 EeV, the cosmic-ray source is expected to lie within 50 Mpc. If there are heavy nuclei in the primary beam, they will be fragmented through photo-disintegration, with the diffuse infrared photon field as important as the 2.7 K radiation. The spectrum at the sources will also, of course, be reflected in the details of the spectrum shape.

To determine the spectrum, the Auger Collaboration aim to collect as many events as possible with the surface detectors and to measure the energy of a sub-sample using the fluorescence detectors. The hybrid event shown in figure 1 serves as an example, though in this case reconstruction of the fluorescence light curve, and hence the shape of the cascade, was somewhat simplified because the shower axis was nearly at right-angles to the direction of view. At other orientations the received light is a mixture of fluorescence and Cherenkov radiation arising from high-energy electrons traversing the air. The latter is a particularly serious problem when the trajectory of the shower is towards a telescope.

The data reported so far are from an exposure of 1750 km^2 steradian years a year, slightly larger than that achieved by the Akeno Giant Air Shower Array (AGASA) group in Japan. The energy spectrum has been derived from around 3500 events above 3 EeV. Above this energy, the full geometrical area of the detector, defined by the layout of the water tanks, is sensitive so that determination of the flux of events is relatively straightforward. The calibration of the tank signals against the fluorescence detector currently contains relatively large systematic uncertainties (about 30% at 3 EeV and around 50% near 100 EeV), which arise from statistical limitations and uncertainties in the fluorescence yield. The former issue will improve as more data are analysed, while the absolute value of the fluorescence yield is being measured in accelerator laboratories by a small team from the collaboration. Just as with a calorimeter operating in a particle-physics detector, missing energy must be taken into account: although the estimate of this is model- and mass-dependent, the systematic uncertainty in the correction is understood at the 10% level.

The spectrum from the Auger data is shown in figure 5 (p14), where it is compared with those from AGASA, HiRes in the US, and the Yakutsk Extensive Air Shower Array in Russia. The general form is similar but, even allowing for the systematic uncertainties still ▷

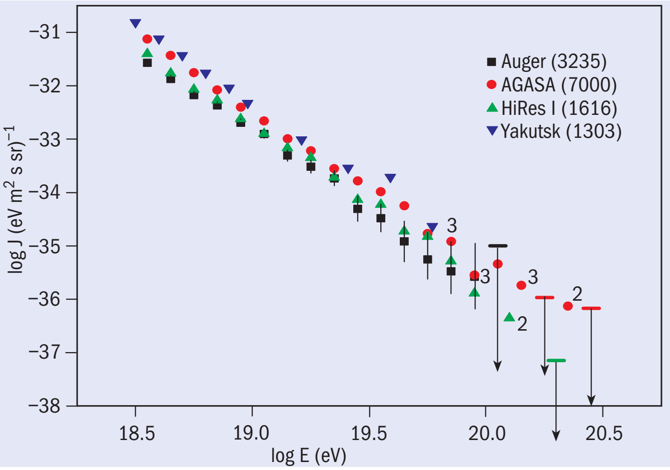


Fig. 5. The air-shower energy spectrum for very-high-energy events less than 60° measured by the Pierre Auger Observatory and the AGASA, HiRes and Yakutsk arrays.

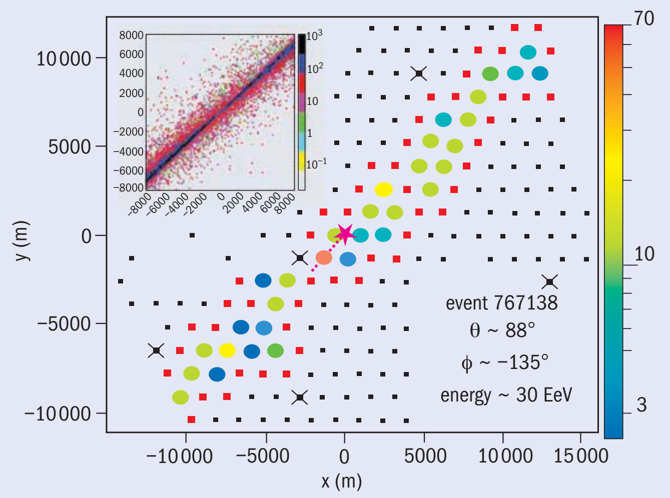


Fig.6. A 30 EeV event at a zenith angle of about 88°. The inset shows a simulation of an event of the same energy and angle.

present, it appears that at the highest energies significantly fewer events are seen than expected from the AGASA analysis. The claim of the HiRes team that the spectrum steepens at the highest energies can neither be confirmed nor denied with the present exposure. One event was recorded in April 2004 for which the fluorescence reconstruction gives an energy greater than 140 EeV, but the particle array was small at that date and the shower core fell outside of the fiducial area. Details of the spectrum will be greatly clarified with the data that have been accumulated since June 2005.

A further key quantity at the highest energies is the mass of the primary cosmic-ray particles. This is a significant challenge because of the uncertainties in our understanding of hadronic interactions. Showers produced by iron nuclei will contain more muons than protons, but the magnitude of the difference is relatively small, muons are expensive to identify and model predictions are uncertain. A practical approach is to study the change of the depth of shower maximum as a function of energy. Again it is necessary to make comparisons with models, but here an additional variable – the magnitude of the fluctuation in the depth of shower maximum – is probably less sensitive to details of different models. The fluctuation in the position of shower maximum is smaller for iron nuclei than for protons. To increase statistics, it is desirable to find a parameter measurable with the surface detectors, so the researchers are exploiting both the fall-off of signal size with distance, and features of the time structure of the tank signals measured with 25 ns flash ADCs.

The collaboration has also developed techniques to search for the photon flux that is expected if the highest-energy cosmic rays arise from the decay of super-heavy relic particles, such as cryptons or wimpzillas, which some theorists speculate were produced in the early universe. On average, showers generated by photons are expected to have maxima deeper in the atmosphere by around 200 g/cm^2. However, account has to be taken of the orientation of the photon with respect to the Earth's magnetic field, as electron-pair production is possible and this elevates the depth of maximum. The Landau–Pomeranchuk–Migdal effect must also be accounted for as it leads to significant fluctuations in the shower maximum. A first study has established a limit of 16% above 10 EeV with only 29 events. This limit is not yet very discriminatory, but the technique has significant potential and the result has been submitted to *Astroparticle Physics*.

Another goal is to search for anisotropies in arrival directions with detection of point sources being the "Holy Grail". Claims of significant effects at high energies have never been confirmed by independent work with higher statistics. So far, the analysis of data from the Pierre Auger Observatory repeats that story. A search for anisotropies associated with the galactic centre near 1 EeV claimed by the Adelaide group in a re-analysis of material from the Sydney array and by the AGASA group has failed to provide confirmation. Searches at the highest energies have so far been similarly unrewarding.

The Pierre Auger Collaboration is developing the study of inclined events, and showers with zenith angles above 85° have been seen. This was expected as they had been detected long ago with much smaller arrays, but the richness of the new data is impressive. Figure 6 shows an event at about 88° with 31 detectors, and even the present array is too small to contain it. A preliminary estimate of its energy is around 30 EeV. An understanding of these events will lead to additional aperture for collection of the highest-energy particles and also give additional routes to understanding the mass composition. Further, these events form the background against which a neutrino flux might be detectable. There is an exciting future ahead.

Résumé

Un ciel dégagé pour le Laboratoire Pierre Auger

En 1938, Pierre Auger et ses collègues ont découvert que les gerbes de rayons cosmiques pouvaient s'étendre sur de vastes zones. Actuellement, dans les plaines de l'ouest de l'Argentine, l'Observatoire Pierre Auger analyse les grandes gerbes atmosphériques engendrées par des particules d'énergies beaucoup plus élevées que celles que peuvent leur conférer les accélérateurs construits par l'homme. La stratégie adoptée consiste à mesurer l'énergie des gerbes à la fois en détectant les particules, à l'aide d'une batterie de 1600 détecteurs Chérenkov à eau, et en captant l'émission de lumière fluorescente, en utilisant quatre stations équipées chacune de six télescopes.

Alan Watson, *Leeds University.*

COMPASS homes in on the nucleon spin

In continuing CERN's long tradition in investigating and unravelling the spin structure of the nucleon, the COMPASS experiment is also pioneering new detection techniques.

The concept for the COmmon Muon and Proton Apparatus for Structure and Spectroscopy (COMPASS) experiment first appeared on paper in a proposal submitted to CERN in 1996. A decade later, COMPASS has reached maturity, and is again taking data after the shut-down of most of the CERN accelerator complex during 2005. The year-long break provided the opportunity to carry out important upgrades to the experiment's spectrometer, and the configuration is now very close to the one first envisaged 10 years ago. The first years of running have in the meantime already shed important light on our understanding of spin in the proton and neutron.

The goal of the COMPASS experiment is to investigate hadron structure and spectroscopy, both of which are manifestations of non-perturbative quantum chromodynamics (QCD). At large scales, QCD appears as a simple and elegant theory. However when it comes to hadrons, it is difficult to link some of their fundamental properties to quarks and gluons. Questions such as "How is the proton spin carried by its constituents?" and "Do exotics, non-$q\bar{q}$ mesons or non-qqq baryons exist?" still do not have clear answers. In this article we will focus on the contribution of COMPASS to the problem of nucleon spin, as it follows in the footsteps of earlier experiments at CERN.

Investigations of the spin structure of the nucleon are best performed by measuring double spin asymmetries in the deep inelastic scattering (DIS) of polarized leptons (electrons or muons) on polarized proton and neutron targets. These measurements allow the spin-dependent structure function $g_1(x)$ for the proton and for the neutron to be extracted.

The first measurements of polarized electron–proton scattering were performed at SLAC in the 1980s by the E80 and E130 Collaborations, and yielded results that were consistent with the Ellis-Jaffe sum rule. The comparison with the Bjorken sum rule is particularly important, but could not be performed at the time as the SLAC experiments did not measure the neutron. Derived as early as 1966 using current algebra tools, this sum rule relates the difference of the first moments of g_1 for the proton and the neutron to G_A/G_V, that is, to fundamental constants of the weak interaction.

A breakthrough occurred when the European Muon Collaboration (EMC) at CERN extended these measurements to a much larger kinematic range. Using a polarized muon beam with an energy 10 times higher than at SLAC, and the largest solid polarized target ever built (about 2 l), in 1988 the collaboration reported a significant violation of the Ellis–Jaffe sum rule for the proton. In the context of the quark–parton model this implied that the total contribution of the quark spins to the proton spin is small – a major surprise that soon came to be known as the "spin crisis". Soon after, the Spin Muon Collaboration (SMC) experiment was proposed to CERN, with the aim of improving the measurement of g_1 for the proton and performing the same measurement with a polarized deuteron target.

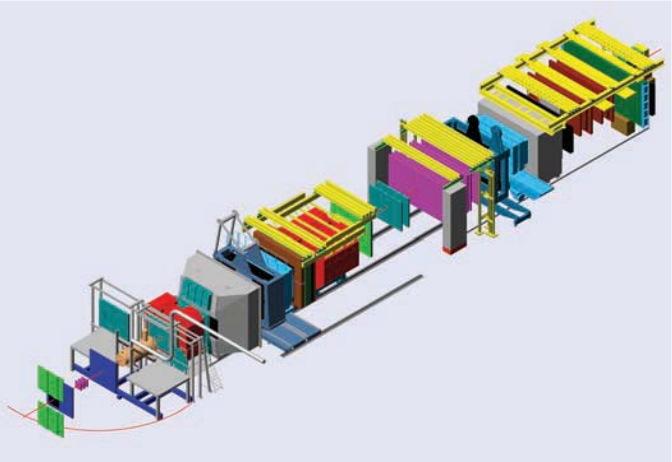


Fig. 1. The COMPASS spectrometer. The beam enters from the lower left corner into the cylindrical target solenoid, downstream of which the final state is analysed by the 60 m spectrometer.

Early results

SMC soon achieved a major accomplishment with the first measurement of g_1 for the deuteron in 1992. The result, when combined with the EMC result, was in agreement with the Bjorken sum rule, and implied that the Ellis–Jaffe sum rule was also violated for the neutron. This result was particularly important because the first evidence from a competing experiment at SLAC (E142) was quite different, which suggested that either the EMC result or the Bjorken sum rule was wrong. Given the extremely sound theoretical foun- ▷

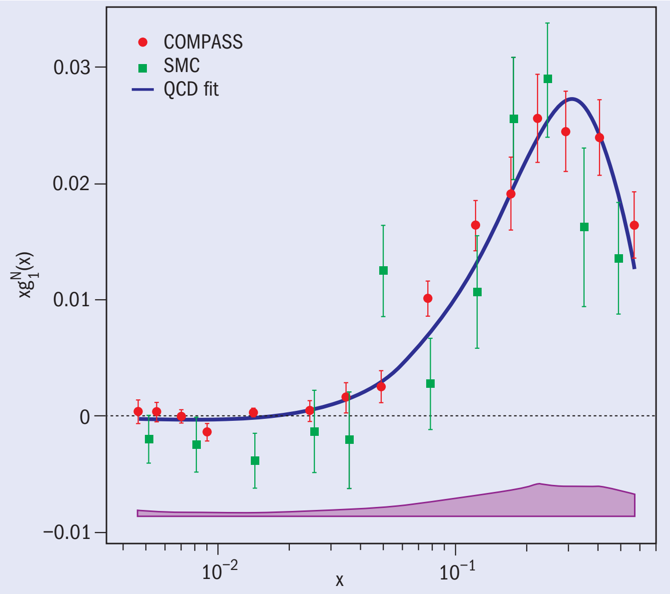


Fig. 2. The new preliminary data from COMPASS. The nucleon structure function $g_1^N = \frac{1}{2}(g_1^p + g_1^n)$ as a function of x.

dations of the Bjorken sum rule, the obvious inference was that experimental finding at CERN was wrong.

However, this was not the case. Both the EMC and the SMC experiments were right, and the original discrepancy with E142 turned out to be mostly driven by higher-order QCD corrections. So it was already safe to conclude in 1993 that the spin crisis was a well-established phenomenon for both the proton and the neutron, and that it occurred within the boundaries given by the Bjorken sum rule.

The SMC experiment also provided another important result, determining for the first time the separate contributions of the valence and sea quarks to the nucleon spin via semi-inclusive DIS measurements. Given the large range in x covered by the measurement, the polarized quark distributions could be integrated to obtain the first moments, $\Delta q = \int_0^1 x\Delta\, q(x)dx$, with resulting values $\Delta u_v = 0.77 \pm 0.10 \pm 0.08$, $\Delta d_v = -0.52 \pm 0.14 \pm 0.09$ and $\Delta\bar{q} = 0.01 \pm 0.04 \pm 0.03$ (Adeva 1998). The polarization of the strange sea could not be accessed as this requires full particle identification, which the SMC spectrometer could not provide.

Several experiments at SLAC (E143, E154, E155, E155x), and more recently HERMES at HERA, have confirmed the results from SMC on the structure functions g_1. The HERMES Collaboration has also recently reported results on the strange sea polarization (*CERN Courier* April 2006 p26).

All these measurements accurately determine $\Delta\Sigma$, the contribution of both valence and sea quark spins to the nucleon spin, to be only 20%. However it was already clear in the mid-1990s that a better understanding of nucleon spin structure demanded separate measurements of the missing contributions, i.e. the gluon polarization $\Delta G/G$ and the orbital angular momentum of both the quarks and the gluons. In particular, several theoretical analyses suggested a large contribution ΔG as a solution to the spin crisis.

Progress required a new experimental approach, namely semi-inclusive DIS with the identification of the hadrons in the current jet, because the determination both of Δq and $\Delta\bar{q}$ and of ΔG requires a flavour-tagging procedure to identify the struck parton. A suggestion to isolate the photon–gluon fusion (PGF) process and measure ΔG directly had been put forward several years previously, and implied measuring the cross-section asymmetry of open charm in DIS. A new experiment, with full hadron identification and calorimetry, therefore seemed to be necessary.

At the same time, transversity, an interesting new physics case for semi-inclusive DIS measurements, was also developing rapidly. To specify the quark state completely at the twist-two level, it was realized that the transverse spin distribution $\Delta_T q(x)$ has to be added to the momentum distribution q(x) and to the helicity distribution $\Delta q(x)$. The $\Delta_T q(x)$ distribution is difficult to measure because, owing to its chiral-odd nature, it cannot be measured in inclusive DIS processes. A possible way to access $\Delta_T q(x)$ is via the Collins asymmetry, that is, an azimuthal asymmetry of the final hadron with respect to the direction of the transversely polarized quark (*CERN Courier* October 2004 p51).

Today transversity is a big issue and is a major part of the programme of many experiments. Originally the idea was much debated in the US, where it was largely responsible for the Spin Project at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven. In Europe, a few enthusiasts met at a workshop in March 1993, organized by the late Roger Hess of the University of Geneva, and set down the case for a proposal (called HELP). This was submitted to CERN in the autumn, but was not accepted. However, the physics case was not given up, and, together with the measurement of ΔG, it became one of the important goals laid down in the proposal for a new experiment, COMPASS.

The COMPASS two-stage spectrometer, with particle identification and calorimetry, and the capability to handle a muon beam rate of $10^8\, s^{-1}$, was proposed for hall 888 at CERN, after completion of the SMC experiment. Submitted in March 1996, the proposal was fully approved in October 1998 with the first physics run in 2002.

The COMPASS spectrometer

The ambitious goals of the COMPASS experiment required an entirely new spectrometer, making use of state-of-the-art detector technology and data-acquisition systems. A huge step forward had to be made in statistical accuracy and particle identification. In comparison with the SMC experiment, the incident muon flux was increased by a factor of five and a deuteron target material (^{6}LiD) with a dilution factor roughly two times better was chosen, together accounting for a 20 fold improvement with respect to SMC. The angular acceptance for particles produced at the primary vertex was increased from ±70 mrad to ±180 mrad by a new superconducting target magnet system. The 3 m long COMPASS solenoid, with a 60 cm diameter, provides a magnetic field with a homogeneity of $\pm 3 \times 10^{-5}$ over the 1.3 m long target volume; it is being used for the first time in the 2006 run. Oppositely polarized target sections permit a direct measurement of the cross-section asymmetry.

The large acceptance requires a two-stage spectrometer. Figure 1 (p15) shows an artistic view of the apparatus, which including the beam detection fills the 100 m long experimental hall. Particles with large angles and relatively low momentum are detected in the first stage, while the fast, more central particles are analysed in the second stage, which comprises a spectrometer magnet with a stronger field and a smaller gap.

A ring imaging Cherenkov (RICH) detector provides charged particle identification. This has 116 UV-reflective mirrors forming upper and lower spherical surfaces, which focus the photons onto the upper and lower photon detectors. These detectors are multiwire proportional chambers (MWPCs) with CsI photocathodes and 80 000 pixelized read-out channels. With an area of 5.3 m^2, they represent the largest such system ever deployed. A new dead-time-less APV-based read-out system for the MWPCs will be in operation for the 2006 run, while the central quarter of the system has been replaced by multi-anode photomultipliers, each with an individual lens system. This technique, which has developed enormously since the RICH was originally designed, will considerably improve background rejection and rate capability.

Photons, and therefore also neutral pions, are analysed in two electromagnetic lead-glass calorimeters, one in each spectrometer stage. The larger one, ECAL1, is being used for the first time in the 2006 run. Two hadron calorimeters reinforce particle identification and support the formation of the trigger, which is based on an array of scintillator hodoscopes and is formed in the 500 ns following the interaction. For the detector control the supervisory control and data-acquisition system selected for the LHC was chosen (*CERN Courier* June 2005 p20). Here as in many other areas COMPASS has done pioneering work that will benefit the LHC.

The high particle rates in COMPASS present a real challenge for the central particle tracking, as conventional tracking detectors would suffer from big inefficiencies. COMPASS has therefore turned to novel technologies, using micromesh gaseous structure (Micromegas) and gaseous electron-multiplier (GEM) techniques in large sizes and in large quantities for the first time. Both techniques are based on the concept of minimizing the distance that positive ions can travel by confining the gas amplification region to 50–100 μm (*CERN Courier* June 2006 p37). The Micromegas technology is based on an idea by Nobel Prize winner Georges Charpak, while the GEM is a development by Fabio Sauli's group at CERN. Both detector types have been operating for three years in the intense muon beam of COMPASS without any sign of deterioration. Another new concept, to be employed when COMPASS uses a hadron beam, concerns cold silicon-strip detectors, which reduce the aging effect to a large extent.

To complete the overall detector assembly, precise timing information is provided by scintillating fibre trackers placed throughout the spectrometer close to the beam region. In the more peripheral region multiwire proportional chambers, drift chambers, drift tubes and straw chambers perform the large-angle particle tracking.

To cope with the high data rate arising from 250 000 read-out channels at a trigger rate of up to 20 kHz, the data acquisition has also had to enter new territory. Once the trigger is formed, the data are taken from the memory of custom-made front-end electronics, transferred to the event-building computers and stored on tape, at a rate of about 5 TB/day. Data storing and handling represent a challenge in themselves. The offline system is dealing with a raw data size of 400 TB/year, and once again COMPASS has been the guinea pig for the future experiments at the LHC (*CERN Courier* September 1999 p22). In the first three years of operation 20 billion events have been put on tape and processed several times.

The first important results have already been obtained from the huge amount of data collected by COMPASS. The g_1 structure function of the deuteron has been measured with unprecedented accuracy in the low-x region, improving by at least a factor of six the precision of the SMC measurement (Ageev *et al.* 2005). Essential

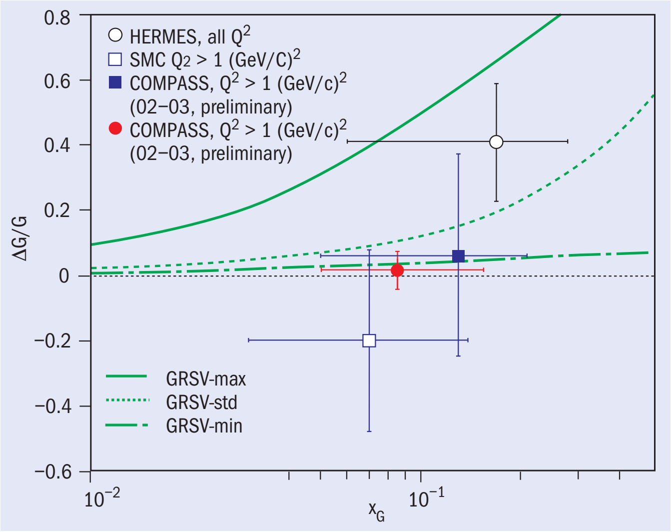


Fig. 3. Direct measurements of the gluon polarization ΔG/G from photon–gluon fusion. The data points are evaluated in leading order, while the three theoretical curves are in next-to-leading order (Glück et al. *2001).*

data for g_1 come from SLAC and HERA (and recently from Jefferson Lab), but the CERN experiments are unique at low x, giving an invaluable contribution to the evaluation of the first moment of g_1 and thus ΔΣ, which requires the data to be extrapolated to x = 0. The Q^2 evolution of g_1 also contains important information on ΔG. Here the COMPASS data have a particular impact, since they lie at the high-Q^2 end of the available experimental information. The new preliminary COMPASS data are shown in figure 2, together with the SMC data and the result of a recent QCD fit to the world data set comprising 230 data points. Recent fits now suggest rather small values for ΔG.

Competition breeds innovation

Direct measurements of ΔG are particularly important. In this field COMPASS is in competition with the experiments at RHIC, which look at the cross-section asymmetry of prompt photons or π^0s produced in collisions between polarized protons to estimate ΔG. Three independent measurements have been performed by COMPASS using the cross-section asymmetry of (i) open-charm production (detecting either D or D^* charmed mesons); (ii) high-p_T hadron pairs in DIS events ($Q^2 > 1$ GeV^2); and (iii) high-p_T hadron pairs in photoproduction ($Q^2 < 1$ GeV^2). In all these processes, the PGF contribution is important, but the background is different. COMPASS is unique in the open-charm measurement. The high-p_T hadron-pairs method was invented within the COMPASS Collaboration while setting up the experiment, and has already been applied to estimate ΔG by HERMES (all Q^2) and SMC ($Q^2 > 1$ GeV^2).

The COMPASS results (Ageev *et al.* 2006) are shown in figure 3 together with the results from the other collaborations and next-to-leading order QCD fits corresponding to a first moment of ΔG at $Q^2 = 3$ GeV^2 of 2.5, 0.6 and 0.2 for the maximum, standard and minimum scenarios, respectively. Small values for ΔG are favoured, and method (iii) from COMPASS now provides fairly precise information.

Another prime objective of COMPASS is the investigation of transverse spin effects. The transversity distributions are difficult to measure because they can be obtained from the transverse spin ▷

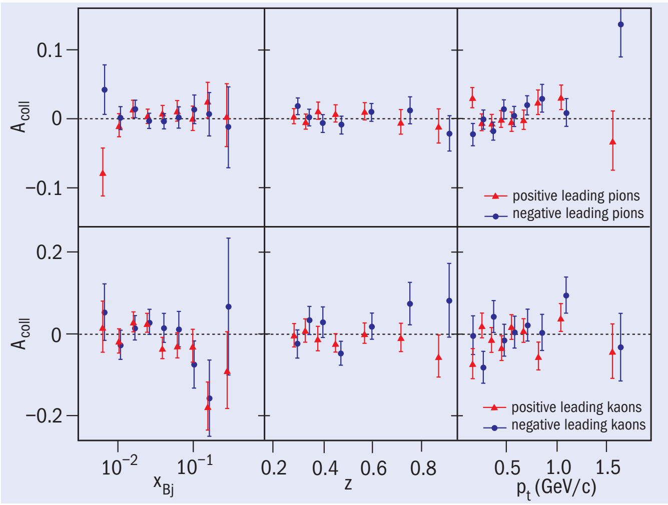


Fig. 4. Preliminary Collins asymmetries for identified pions (top) and kaons measured with the deuteron target in 2003/4.

asymmetries only after unfolding the Collins effect. This requires a global analysis of transverse spin asymmetries of several identified hadrons produced in semi-inclusive DIS, as well as the analysis of spin asymmetries in $e^+e^- \rightarrow 2$ hadrons, as currently measured by the BELLE Collaboration. In this worldwide effort, COMPASS has provided the first asymmetry data for the deuteron. The measured asymmetries are very small (Alexakhin *et al.* 2005) (figure 4). Taking into account the fact that the HERMES Collaboration has measured non-zero Collins asymmetries on a transversely polarized proton target, the COMPASS result very likely points to a cancellation between proton and neutron, much as for the longitudinal case where g_1 for the neutron has the opposite sign to g_1 for the proton. Further investigations of transverse-spin effects are related to ongoing measurements of the Sivers asymmetry, the two-hadron interference function and the Λ polarization transfer.

The search continues

The COMPASS analysis group is currently investigating many more physics channels. The wealth of data allows for the search for new states in quasi-real photoproduction; the recently announced pentaquark states $\Theta^+(1530)$ and the $\Xi^-(1860)$ have been looked for here, but so far with negative results. Very large samples of Λ hyperons allow the study of reaction mechanisms and polarization transfer. In a similar way, the measurement of the spin density matrix of vector mesons (φ, ρ, ρ') provides stringent tests on reaction mechanisms, such as s-channel helicity conservation; a phase-shift analysis of the $\pi^+\pi^+\pi^-\pi^-$ has recently begun.

Running-in the new spectrometer has taken some time. Owing to the non-availability of the COMPASS polarized-target magnet, the experiment has until now used the SMC target system, which has a much smaller acceptance. Physics data were collected in 2002, 2003 and 2004, doubling the amount of data each year, thanks to several improvements in the apparatus. This should again be the case for the 2006 run, when the new COMPASS polarized-target magnet is used for the first time.

COMPASS is scheduled to take data until the end of the decade both for its hadron programme and for its muon programme with a polarized proton target. An Expression of Interest has been put forward for a new experimental programme, based on an upgraded COMPASS spectrometer (COMPASS-II) and an even higher beam flux. The emphasis of the future programme will be on the still unknown orbital angular momentum of the partons inside the nucleon. This will be addressed in two different ways, first by the measurement of generalized parton distributions in deeply virtual Compton scattering and in hard exclusive meson production processes, and second by a precise determination of the first moments of the transversity distributions that are linked to the orbital angular momentum via the Bakker–Leader–Trueman sum rule. Of course, an important part of the COMPASS-II programme will still be spectroscopy, where many open questions remain.

Further reading

B Adeva 1998 *Phys. Lett. B* **420** 180.
E S Ageev *et al.* 2005 *Phys. Lett. B* **612** 154.
E S Ageev *et al.* 2006 *Phys. Lett. B* **633** 25.
V Yu Alexakhin *et al.* 2005 *Phys. Rev. Lett.* **94** 202002.
M Glück *et al.* 2001 *Phys. Rev. D* **63** 094005.
For a review of nucleon-spin physics see S Bass 2005 *Rev. Mod. Phys.* **77** 1257.

Résumé

COMPASS centré sur le spin du nucléon

Dans le prolongement de la longue tradition du CERN de recherche sur la structure en spin du nucléon, l'expérience COMPASS inaugure de nouvelles techniques de détection. Son spectromètre à deux étages, avec identification des particules et calorimétrie, peut faire face à un faisceau de 10^8 muons par seconde dans son acceptance angulaire qui atteint ±180 mrd grâce au système magnétique supraconducteur entourant la cible polarisée. Après les travaux importants d'amélioration menés au cours de l'année 2005, l'expérience saisit à nouveau des données en utilisant pour la première fois l'aimant de la cible polarisée. Entre-temps, les premières années de fonctionnement ont déjà permis des avancées considérables dans notre compréhension du spin des protons et des neutrons.

Franco Bradamante, *INFN Trieste and University of Trieste;* **Alain Magnon**, *CEA/DAPNIA Saclay; and* **Gerhard Mallot**, *CERN.*

Let there be axions

Konstantin Zioutas reports on the first Joint ILIAS–CAST–CERN Axion Training workshops, which covered a wide range of studies, from experiments at nuclear reactors to investigations of the roles of axions in solar physics and cosmology.

Axions bridge the gap between theory and observation of the strong interaction, and have also inspired the artist Evdoxia Kyrmanidou.

One of the biggest mysteries of science is the nature of dark matter, which first became apparent as astronomer Fritz Zwicky's "dunkle Materie" in 1933. The two leading particle candidates for this "missing matter" are weakly interacting massive particles (WIMPs) and axions – hypothesized uncharged particles that have a very small but unknown mass, which barely interact with other particles. To bring together the widespread axion community, the Integrated Large Infrastructure for Astroparticle Science (ILIAS), the CERN Axion Solar Telescope (CAST) collaboration and CERN have organized a series of training workshops on current axion research, including open discussions between theorists and experimentalists. The first two of these were held at CERN in November and at the University of Patras in Greece, in May. This article highlights the presentations at both meetings.

The idea of the axion has been around for some 30 years, proposed as a solution to the strong charge-parity (CP) problem in quantum chromodynamics (QCD), the theory of strong interactions. According to the basic field equations of QCD, strong interactions should violate CP symmetry, rather as weak interactions do. However, strong interactions show no sign of CP violation. In 1977, Roberto Peccei and Helen Quinn suggested that to restore CP conservation in strong interactions, a new symmetry must be present, compensating the original CP-violating term in QCD almost exactly – to at least one part in 10^{10}. The breakdown of this gives rise to the so-called axion field proposed by Steven Weinberg and Frank Wilczek, and the associated pseudo-scalar particle – the axion. Appropriately, Peccei, from the University of California Los Angeles, gave the first lecture of the workshop series and described the theoretical *raison d'être* of the Peccei–Quinn symmetry.

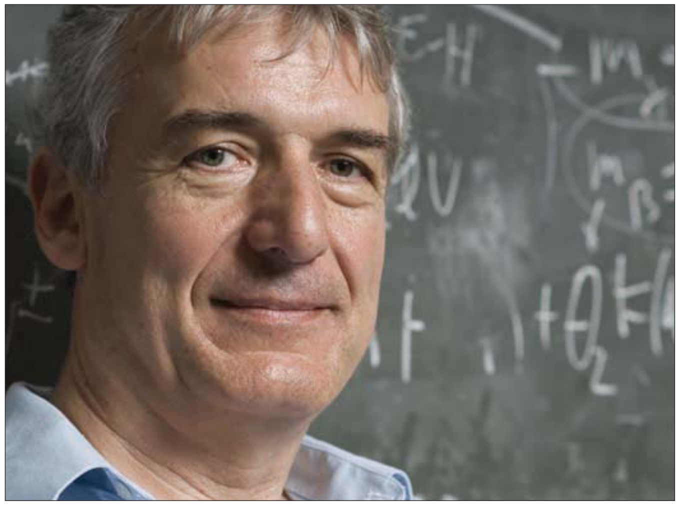
Evidence for strong CP violation should in particular appear in an electron dipole moment (EDM) for the neutron, but this has not yet been detected. Instead, we know from a high-precision measurement using polarized ultracold neutrons at the Institut Laue Langevin (ILL) in Grenoble that the neutron EDM is at least some 10 orders of magnitude below expectation. Peter Geltenbort of ILL presented the recently announced limit of 3×10^{-26} e cm (*CERN Courier* April 2006 p6). This is part of a series of experiments started by Nobel laureates Norman Ramsey and Edward Purcell in the 1950s, which continues today with the ambitious goal of reaching 10^{-28} e cm by the end of the decade. Other proposed neutron EDM experiments include those at the Paul Scherrer Institut and at the Spallation Neutron Source in Oak Ridge with goals of 10^{-27} e cm and 10^{-28} e cm, respectively. A new technique with the deuteron may provide the route for the next sensitivity scale, reaching 10^{-29} e cm, as Yannis Semertzidis of Brookhaven explained.

Stars and dark matter

CP violation seems to be necessary to explain the survival of matter at the expense of antimatter after the Big Bang. Thus the creation of relic axions shortly after the dawn of time could have been enormous, perhaps amounting to some six times more in mass than ordinary matter. In addition to the scenario of relic axions, Georg Raffelt, an axion pioneer from the Max Planck Institute, introduced the connections between astrophysics and axions, with the stars as axion sources as his central topic. The effect of such an energy-loss channel on stellar physics provides constraints on the interaction strength of axions with ordinary particles. The Sun, our best known star, should be a strong axion source in the sky, allowing a direct search for these almost-invisible particles.

This is precisely the objective of the CAST helioscope at CERN, which searches for solar axions using a recycled LHC test dipole magnet pointing at the Sun for some three hours a day. The signal of solar axions will be an excess of X-rays detected during solar tracking. While the relic axions are expected to move slowly at about 300 km/s, those escaping from the solar core must be super relativistic, despite their assumed kinetic energy of only about 4 keV. CAST is the first helioscope ever built with an imaging X-ray optical system, whose working principle was explained by Peter Friedrich from Max-Planck-Institut für extraterrestrische Physik and Regina Soufli from Lawrence Livermore National Laboratory (LLNL) in their lectures on X-ray optics. For axion detection, the X-ray optics act as a concentrator to enhance the signal-to-noise ratio by focusing ▷

Participants of the first axion training workshop visiting the experimental area of the CERN Axion Solar Telescope (CAST).



Sikivie Pierre Sikivie from the University of Florida invented the working principle of all magnetic axion telescopes, such as CAST.

the converted solar X-rays into a small spot on a CCD chip or a micromesh gaseous structure (Micromegas), as developed by Yannis Giomataris and Georges Charpak (*CERN Courier* June 2006 p37). CAST has been taking data since the end of 2002 and has already published first results.

The possible existence of axions in the universe means that they are a candidate for (very) cold dark matter, as another axion pioneer, Pierre Sikivie, from the University of Florida explained. He also described the technique that he invented in 1983 for detecting axions. The idea is that axions in the galactic halo may be resonantly converted to microwave photons in a cavity permeated by a strong magnetic field. The expected signals are extremely weak, measured in yoctowatts, or 10^{-24} W. The same holds also for the solar axions inside the CAST magnet, whose energies of a few kilo-electron-volts (keV) are several orders of magnitude higher. The process depends on various parameters, such as the magnetic-field vector and size, the plasma density, the (unpredictable) axion rest mass and the photon polarization – all of which provide the multi-parameter space in which axion hunters search for their quarry.

Sikivie also described the search for relic axions at LLNL, the topic of the CERN seminar at the start of the first workshop, presented by Karl van Bibber from LLNL. The Axion Dark Matter eXperiment (ADMX), which uses a microwave cavity to look for axionic dark matter as proposed by Sikivie, has been taking data for a decade. It is now undergoing an upgrade to use near-quantum-limited SQUID amplifiers. In his review, van Bibber also described CARRACK, a similar experiment in Kyoto, which uses a Rydberg-atom single-quantum detector as the back-end of the experiment.

The axion, together with the Higgs boson – another so-far undetected particle required by theory – may contribute not only to dark matter but also to dark energy, as Metin Arik from Istanbul explained. This leads to the question of why the dark-energy density is so small.

Light polarization

Giovanni Cantatore presented the Polarizzazione del Vuoto con LASer (PVLAS) experiment at the INFN Legnaro National Laboratory, which has recently caused a stir in the axion community. In a recent paper in *Physical Review Letters*, the PVLAS collaboration reports that a magnetic field can be used to rotate the polarization of light in a vacuum (*CERN Courier* June 2006 p11). The detected rotation is extremely small, about 0.00001°. The slight twist in the polarization, the result of photons of a given polarization disappearing from the beam, could suggest the existence of a light, new neutral boson, as the signal strength observed by PVLAS is much larger than would be expected on the basis of quantum electrodynamics alone.

The particle suggested by PVLAS is not exactly the expected axion; its coupling to two photons is so strong that experiments searching for axions, such as CAST, should have seen many of them coming from astrophysical sources. It would need peculiar properties not to conflict with the current astrophysical observations, but there is no fundamental reason barring it from having such properties. Eduard Masso from the University of Barcelona reviewed the theoretical motivation for axions and the importance of an axion-like coupling to photons, and addressed the apparent conflict between the PVLAS results and CAST and the astrophysically derived bounds.

Andreas Ringwald from DESY pointed out that the possible interpretation of the PVLAS anomaly in terms of the production of an axion-like particle has triggered a revisit of astrophysical considerations. Models exist in which the production of axion-like particles in stars is suppressed compared with the production in a vacuum. In these models, the bounds derived from the age of stars or from CAST may be relaxed by some orders of magnitude. The workshop participants agreed unanimously that the PVLAS result needs direct confirmation of the particle hypothesis with laboratory-based experiments.

Semertzidis spoke about a PVLAS-type experiment that was performed at Brookhaven more than 15 years ago, with most of the PVLAS collaborators as major players. They also observed large signals, which they attributed however to the laser light motion at the magnet frequency. He went on to suggest that laser motion at the magnet rotation frequency might also produce signals at the second harmonic that would look like axion signals. The PVLAS collaboration has spent five years looking for a systematic artifact that might explain their observations, and plans to attempt to settle the question in a new photon-regeneration experiment. Here, any particles produced from photons in a first magnet, would propagate into a second magnet blocked to photons, where they would convert back into photons.

Detection of such regenerated photons would provide a very robust confirmation of the particle interpretation of the PVLAS result, and similar regeneration experiments are in preparation elsewhere. Keith Baker presented the plans by the Hampton University–Jefferson Lab collaboration to use the world's highest-power tunable free-electron laser (FEL), in the LIght Pseudoscalar–Scalar Particle Search (LIPSS) experiment, which will run during the coming months. As Ringwald pointed out, there are a number of experiments based either on photon polarization or on photon regeneration measurements that should soon exceed the sensitivity of PVLAS. At DESY, there is a proposal to exploit the photon beam from the Free-electron LASer in Hamburg (FLASH) for the Axion Production at the FEL (APFEL) experiment, which will take advantage of unique properties of the FLASH beam. The available photon energies (around 40 eV) are just in the range where photon regeneration is most sensitive to masses in the milli-electron-volt range. In addition, the tuning possibilities of FLASH will allow a mass determination, and the pulsed nature of the photon beam allows noise reduction by timing.

Two linked experiments to search for axions proposed by a team from CERN and several other institutes are also well advanced. These were presented by Pierre Pugnat from CERN, who explained how this approach allows for simultaneous investigations of the magneto-optical properties of the quantum vacuum and of photon regeneration. The team could start next year to check the PVLAS result. The two experiments are integrated in the same LHC superconducting dipole magnet and so can provide solid results via mutual cross-checks.

Carlo Rizzo from Université Paul Sabatier/Toulouse presented a different detection concept in the Biréfringence Magnétique du Vide experiment at the Laboratoire National des Champs Magnétiques Pulsées in Toulouse. The goal is to study quantum vacuum magnetism and the experiment will be in operation this summer to test the PVLAS result.

Frank Avignone from South Carolina reviewed possibilities that go beyond the current experimental searches for axions, such as the use of coherent Bragg–Primakoff conversion in single crystals, coherence issues in vacuum and gas-filled magnetic helioscopes, and novel proposals to detect hadronic axions with suppressed electromagnetic couplings. Emmanuel Paschos of the University of Dortmund addressed possible coherence phenomena in low-energy axion scattering and its potential use for axion detection. This could be an important application of light-sensitive detectors used in underground dark-matter experiments, where they may allow the first low-energy axion searches, as reported by Klemens Rottler from the University of Tübingen and the CRESST dark-matter experiment. After all, the solar-axion energy range less than 0.5–1 keV remains a challenging new territory.

From the Sun and beyond

The signatures of axions are not confined to the solar system, and there were a number of interesting presentations on searches for axions or axion-like particles with telescopes on the ground or in orbit. A cosmologically interesting topic concerns axion–photon conversion induced by intergalactic magnetic fields, which offers an alternative explanation for the dimming of distant supernovae, without the need for cosmic acceleration. However, the same mechanism would cause excessive spectral distortion of the cosmic microwave background (CMB). Alessandro Mirizzi of Bari concludes that owing to the spectral shape of the CMB, photon–axion oscillation can play only a relatively minor role in supernova dimming. Nevertheless, a combined analysis of all the observables affected by the photon–axion oscillations would be required to give a final verdict on this model.

In related work, Damien Hutsemékers from the University of Liège has investigated the potential for photon–axion conversion within a magnetic field over cosmological distances, as it can affect the polarization of light from distant objects such as quasars. He reported on the remarkable observation, using the ESO telescopes in Chile, of alignments of quasar polarization vectors that might be due to axion-like particles along the line of sight.

Rizzo also discussed potential axion signatures in astrophysical observations, presenting an impressive movie. He reported that axion and quantum vacuum effects have been studied in the double neutron-star system J0737-3039. Astrophysical observations of such effects will be possible in 2007 with the ESA XMM/Newton and NASA GLAST telescopes in orbit.

Coming nearer to Earth, Hooman Davoudiasl from the University of Wisconsin-Madison showed that solar axion conversion to photons in the Earth's magnetosphere can produce an X-ray flux, with average energy about 4 keV, which is measurable on the dark side of the Earth. (The low strength of the Earth's magnetic field is compensated for by a large magnetized volume.) The signal has distinct features: a flux of X-rays coming from the dark Earth, pointing back to the core of the Sun, with a thermal distribution characteristic of the solar core, and orbital as well as annual modulations. For axion masses less than 10^{-4} eV, a low-Earth-orbit X-ray telescope could probe ▷

From a student's perspective

The two axion meetings offered an immense variety of talks that were especially meant to help PhD students in the axion field to get to know more about both theory and other axion-related topics and experiments. The workshops were a perfect opportunity to meet the experts and ask questions. It has been very motivating training, although it was not always easy for us to remember all the new information.
Julia Vogel, PhD student, University of Freiburg.

Axion community support open access

Publications are the major output of scientific research and should be made available in their final form to the widest possible audience. In his talk Jens Vigen, CERN's head librarian, underlined the importance of the axion community's decision to challenge the current publishing paradigm that is based on publication behind toll barriers, and supported unanimously the open-access initiative advocated by CERN. For example, *Living Reviews in Solar Physics*, published by the Max Planck Society, is an interesting new title published as open access. Vigen appreciated the willingness of the CAST collaboration to make data from the experiment freely available worldwide (*CERN Courier* May 2003 p50).

ESA's SMART-1 mission to the Moon (left), which will run until late 2006, and the 1 m^3 DRIFT dark-matter detector that is operating in the Boulby Mine in the UK can both search for the radiative decay of massive axions. (Photos courtesy ESA and PPARC.)

the axion–photon coupling well below the current laboratory bounds, with a few days of data-taking. Also, the question was discussed as to whether axion–photon oscillations occur inside solar magnetic fields, sufficient to give the enhanced X-ray emission from places such as in sunspots.

Another possibility is the detection of the radiative decay of massive axions, predicted in extra dimensional models, which change drastically their mass, lifetime and detection, as Emilian Dudas from Ecole Polytechnique argued. In this context, Juhani Huovelin from Helsinki Observatory presented space-borne X-ray observations of the Sun and the sky background with ESA's SMART-1, the first European mission to the Moon, which began operation in 2004 and will continue data-taking until September 2006. The important instruments onboard for axion research are an X-ray camera from CCLRC Rutherford Appleton Laboratory in the UK, and the X-ray Solar Monitor (XSM) from the University of Helsinki. The XSM measures solar X-ray spectra with high time resolution in the 1–20 keV energy range.

Extensive data have already been accumulated, including a series of lengthy observations of the X-ray Sun during quiescence and flares, as well as various observations of the background sky. Preliminary analysis of the data indicates possible residual emission at several intervals in the 2–10 keV range after fitting known solar and sky-background emission components. A future more-refined analysis will show whether the residual emission is statistically significant, and possibly related to X-rays from the decay of gravitationally trapped massive axions. The NASA solar mission RHESSI has also entered this kind of research, with the aim of detecting the same sort of particles near the surface of the Sun, as we published with Luigi di Lella at CERN five years ago. SMART and RHESSI use the Moon and Sun respectively to block out the background sky, thereby creating a large fiducial volume to search for axion radiative decay. The 1 m^3 DRIFT detector operating in the Boulby Mine in the UK provides a similar capability in an underground experiment, as Eirini Tziaferi and Neil Spooner from Sheffield explained.

The friendly atmosphere of the two workshops saw plenty of fruitful discussions in which new ideas could emerge. For example, Ringwald has recently suggested a laboratory photon-regeneration experiment with X-rays. It seems that the ESRF at Grenoble offers one of the best opportunities worldwide for such an experiment, with photon energies in the 3–70 keV range. Also, as Sikivie highlighted, there is strong scientific interest in building a next-generation microwave cavity embedded in a large-bore superconducting solenoid to detect galactic-halo axions. CERN, together with several collaborating institutes, for example, could build a microwave cavity of around 1 m^3 integrated inside a 8–10 T magnetic field.

The workshop participants unanimously concluded with a call to CERN to become a focal point for axion physics. There will be more ideas and new results by the next workshop in June 2007 in Patras.

Further reading

For more information on the two workshops see http://agenda.cern.ch/fullAgenda.php?ida=a056218 and http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=1743.

Résumé

Que les axions soient

Plusieurs particules pourraient constituer la mystérieuse matière noire de l'Univers et l'axion est l'un des plus sérieux candidats. Imaginé afin de résoudre le problème dit de CP forte, l'axion serait une particule sans charge de masse très faible mais inconnue, interagissant très peu avec les autres particules. Pour rassembler la communauté dispersée des chercheurs spécialisés dans ce domaine, une série d'ateliers de formation ont été organisés sur les recherches actuelles concernant l'axion. Des débats ouverts entre les théoriciens et les expérimentateurs ont eu lieu et ont traité d'un large éventail d'études allant des expériences auprès des réacteurs électronucléaires et en orbite terrestre aux théories sur le rôle des axions dans la physique solaire et la cosmologie.

Konstantin Zioutas, *University of Patras.*

Ettore Majorana: genius and mystery

Antonino Zichichi provides a dual insight into Ettore Majorana: the genius of his many contributions to physics, and the mystery that surrounds his disappearance.

Ettore Majorana was born in Sicily in 1906. An extremely gifted physicist, he was a member of Enrico Fermi's famous group in Rome in the 1930s, before mysteriously disappearing in March 1938.

The great Sicilian writer, Leonardo Sciascia, was convinced that Majorana decided to disappear because he foresaw that nuclear forces would lead to nuclear explosives a million times more powerful than conventional bombs, like those that would destroy Hiroshima and Nagasaki. Sciascia came to visit me at Erice where we discussed this topic for several days. I tried to change his mind, but there was no hope. He was too absorbed by an idea that, for a writer, was simply too appealing. In retrospect, after years of reflection on our meetings, I believe that one of my assertions about Majorana's genius actually corroborated Sciascia's idea. At one point in our conversations I assured Sciascia that it would have been nearly impossible – given the state of physics in those days – for a physicist to foresee that a heavy nucleus could be broken to trigger the chain reaction of nuclear fission. Impossible for what Enrico Fermi called first-rank physicists, those who were making important inventions and discoveries, I suggested, but not for geniuses such as Majorana. Maybe this information convinced Sciascia that his idea about Majorana was not just probable, but actually true – a truth that his disappearance further corroborated.

There are also those who think Majorana's disappearance was related to spiritual faith and that he retreated to a monastery. This perspective on Majorana as a believer comes from his confessor, Monsignor Riccieri, who I met when he came from Catania to Trapani as Bishop. Remarking on his disappearance, Riccieri told me that Majorana had experienced "mystical crises" and that, in his opinion, suicide in the sea was to be excluded. Bound by the sanctity of confessional, he could tell me no more. After the establishment of the Erice Centre, which bears Majorana's name, I had the privilege of meeting Majorana's entire family. No one ever believed it was suicide. Majorana was an enthusiastic and devout Catholic and, moreover, he withdrew his savings from the bank a week before his disappearance. The hypothesis shared by his family and others who had the privilege of knowing him (Fermi's daughter Laura was one of the few) is that he withdrew to a monastery.

Ettore Majorana disappeared in 1938. This photograph was taken from his university card, dated 3 November 1923.

Laura Fermi recalls that when Majorana disappeared, Enrico Fermi said to his wife, "Ettore was too intelligent. If he has decided to disappear, no-one will be able to find him. Nevertheless, we have to consider all possibilities." In fact, Fermi even tried to get Benito Mussolini himself to support the search. On that occasion (in Rome in 1938), Fermi said: "There are several categories of scientists in the world; those of second or third rank do their best but never get very far. Then there is the first rank, those who make important discoveries, fundamental to scientific progress. But then there are the geniuses, like Galilei and Newton. Majorana was one of these."

A genius, however, who looked on his own work as completely banal: once a problem was solved, Majorana did his best to leave no trace of his own brilliance. This can be witnessed in the stories of the neutron discovery and the hypothesis of the neutrinos that bear his name, as recalled below by Emilio Segré and Giancarlo Wick (on the neutron) and by Bruno Pontecorvo (on neutrinos). Majorana's comprehension of the physics of his time had a completeness that few others in the world could match. ▷

Oppenheimer's recollections

Memories of Majorana had nearly faded when, in 1962, the International School of Physics was established in Geneva, with a branch in Erice. It was the first of the 150 schools that now form the Centre for Scientific Culture, which today bears Majorana's name. It is in this context that an important physicist of the 20th century, Robert Oppenheimer, told me of his knowledge of Majorana.

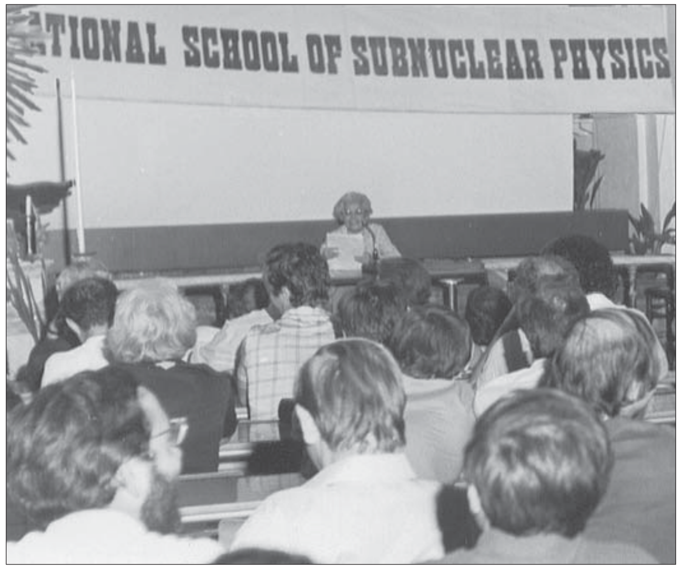
After having suffered heavy repercussions for his opposition to the development of weapons even stronger than those that destroyed Hiroshima and Nagasaki, Oppenheimer had decided to get back to physics while visiting the biggest laboratories at the frontiers of scientific knowledge. This is how he came to be at CERN, the largest European laboratory for subnuclear physics.

At this time, many illustrious physicists participated in a ceremony that dedicated the Erice School to Majorana. I myself – at the time very young – was entrusted with the task of speaking about the Majorana neutrinos. Oppenheimer wanted to voice his appreciation for how the Erice School and the Centre for Scientific Culture had been named. He knew of Majorana's exceptional contributions to physics from the papers he had read, as any physicist could do at any time. What would have remained unknown was the episode he told me as a testimony to Fermi's exceptional opinion of Majorana. Oppenheimer recounted the following episode from the time of the Manhattan Project, which in the course of only four years transformed the scientific discovery of nuclear fission into a weapon of war.

There were three critical turning points during the project, and during the executive meeting to address the first of these crises, Fermi turned to Eugene Wigner and said: "If only Ettore were here." The project seemed to have reached a dead-end in the second crisis, during which Fermi exclaimed once more: "This calls for Ettore!" Other than the project director himself (Oppenheimer), three people were in attendance at these meetings: two scientists (Fermi and Wigner) and a military general. After the "top secret" meeting, the general asked Wigner, who this "Ettore" was, and he replied: "Majorana". The general asked where Majorana was so that he could try to bring him to America. Wigner replied: "Unfortunately, he disappeared many years ago."

By the end of the 1920s, physics had identified three fundamental particles: the photon (the quantum of light), the electron (needed to make atoms) and the proton (an essential component of the atomic nucleus). These three particles alone, however, left the atomic nucleus shrouded in mystery: no-one could understand how multiple protons could stick together in a single atomic nucleus. Every proton has an electric charge, and like charges repel each other. A fourth particle was needed, heavy like the proton but without electric charge. This was the neutron, but no-one knew it at the time.

Then Frédérick Joliot and Irène Curie discovered a neutral particle that can enter matter and expel a proton. Their conclusion was that it must be a photon, because at the time it was the only known particle with no charge. Majorana had a different explanation, as Emilio Segré and Giancarlo Wick recounted on different occasions, including during visits to Erice. (Both Segré and Wick were enthusiasts for what the school and the centre had become in only a few years, all under the name of the young physicist that Fermi considered a genius alongside Galilei and Newton). Majorana had explained to Fermi why the particle discovered by Joliot and Curie had to be as heavy as a proton, even while being electrically neutral. To move a proton requires something as heavy as the proton, thus a fourth particle must exist, a proton with no charge. And so was born the correct interpretation of what Joliot and Curie discovered in France: the existence of a particle that is as heavy as a proton but without electrical charge. This particle is the indispensable neutron. Without neutrons, atomic nuclei could not exist.



Laura Fermi, in 1975, lecturing at the Subnuclear Physics School in Erice on her recollections of Ettore Majorana.

Fermi told Majorana to publish his interpretation of the French discovery right away. Majorana, true to his belief that everything that can be understood is banal, did not bother to do so. The discovery of the neutron is in fact justly attributed to James Chadwick for his experiments with beryllium in 1932.

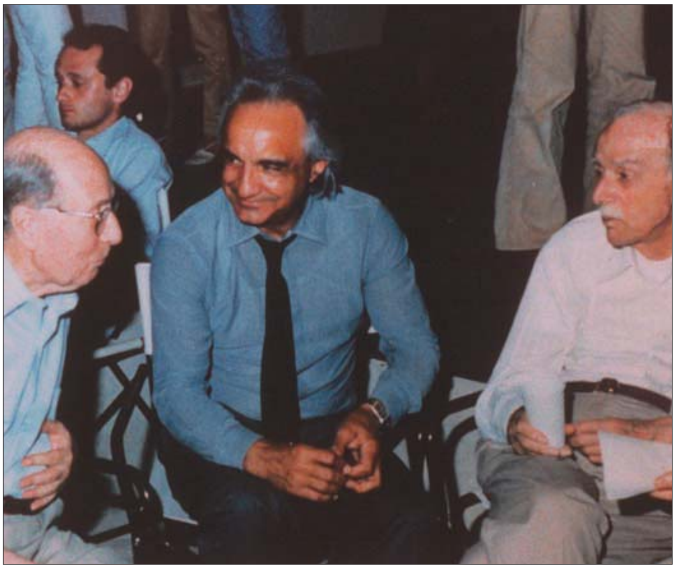
Majorana's neutrinos

Today, Majorana is particularly well known for his ideas about neutrinos. Bruno Pontecorvo, the "father" of neutrino oscillations, recalls the origin of Majorana neutrinos in the following way: Dirac discovers his famous equation describing the evolution of the electron; Majorana goes to Fermi to point out a fundamental detail: " I have found a representation where all Dirac γ matrices are real. In this representation it is possible to have a real spinor that describes a particle identical to its antiparticle."

The Dirac equation needs four components to describe the evolution in space and time of the simplest of particles, the electron; it is like saying that it takes four wheels (like a car) to move through space and time. Majorana jotted down a new equation: for a chargeless particle like the neutrino, which is similar to the electron except for its lack of charge, only two components are needed to describe its movement in space–time – as if it uses two wheels (like a motorcycle). "Brilliant," said Fermi, "Write it up and publish it." Remembering what happened with the neutron discovery, Fermi wrote the article himself and submitted the work under Majorana's name to the prestigious scientific journal *Il Nuovo Cimento* (Majorana 1937). Without Fermi's initiative, we would know nothing about the Majorana spinors and Majorana neutrinos.

The great theorist John Bell conducted a rigorous comparison of Dirac's and Majorana's "neutrinos" in the first year of the Erice

Bruno Pontecorvo, right, pictured talking with Antonino Zichichi in September 1978 about the Gran Sasso Project in Rome.



Eugene Wigner (left), during an animated discussion with fellow physicists Zichichi (centre) and Paul Dirac at Erice in 1980.

Subnuclear Physics School. The detailed version can be found in the chapter that opens the 12 volumes published to celebrate Majorana's centenary. These volumes describe the highlights leading up to the greatest synthesis of scientific thought of all time, which we physicists call the Standard Model. This model has already pushed the frontiers of physics well beyond what the Standard Model itself first promised, so now the goal is the Standard Model and beyond.

Today we know that three types of neutrinos exist. The first controls the combustion of the Sun's nuclear engine and keeps it from overheating. One of the dreams of today's physicists is to prove the existence of Majorana's hypothetical neutral particles, which are needed in grand unification theory. This is something that no-one could have imagined in the 1930s. And no-one could have imagined the three conceptual bases needed for the Standard Model and beyond.

Particles with arbitrary spin

In 1932 the study of particles with arbitrary spin was considered at the level of a pure mathematical curiosity, and Majorana's paper on the subject remained quasi-unknown despite being full of remarkable new ideas (Majorana 1932). Today, three-quarters of a century later, this mathematical curiosity of 1932 still represents a powerful source of new ideas. In fact in this paper there are the first hints for supersymmetry, spin–mass correlation and spontaneous symmetry breaking (SSB) – three fundamental concepts underpinning the Standard Model and beyond. This means that our current conceptual understanding of the fundamental laws of nature was already in Majorana's attempts to describe particles with arbitrary spins in a relativistically invariant way.

Majorana starts with the simplest representation of the Lorentz group, which is infinite-dimensional. In this representation the states with integer (bosons) and semi-integer (fermions) spins are treated equally. In other words, the relativistic description of particle states allows bosons and fermions to exist on equal footing. These two fundamental sets of states are the first hint of supersymmetry.

Another remarkable novelty is the correlation between spin and mass. The eigenvalues of the masses are given by a relation of the type $m = m_0/(J+½)$, where m_0 is a given constant and J is the spin. The mass decreases with the increasing value of the spin, the opposite of what would come, many decades later, in the study of the strong interactions between baryons and mesons (now known as Regge trajectories). As a consequence of the description of particle states with arbitrary spins, this remarkable paper also contains the existence of imaginary mass eigenvalues. We know today that the only way to introduce real masses without destroying the theoretical description of nature is through the mechanism of SSB, but this could not exist without imaginary masses.

In addition to these three important ideas, the paper also contributed to a further development: the formidable relation between spin and statistics, which would have led to the discovery of another invariance law valid for all quantized relativistic field theories, the celebrated PCT theorem.

Majorana's paper shows first of all that the relativistic description of a particle state allows the existence of integer and semi-integer spin values. However, it was already known that the electron must obey the Pauli exclusion principle and that it has semi-integer spin. Thus the problem arose of understanding whether the Pauli principle is valid for all semi-integer spins. If this were the case it would be necessary to find out the properties that characterize the two classes of particles, now known as fermions (semi-integer spin) and bosons (integer spin). The first of these properties are of statistical nature, governing groups of identical fermions and groups of bosons. We now know that a fundamental distinction exists and that the anti-commutation relations for fermions and the commutation relations for bosons are the basis for the statistical laws governing fermions and bosons.

The spin-statistics theorem has an interesting and long history, the main players of which are some of the most distinguished theorists of the 20th century. The first contribution to the study of the correlation between spin and statistics comes from Markus Fierz with a paper where the case of general spin for free fields is investigated (Fierz 1939). A year later Wolfgang Pauli comes in with his paper also "On the Connection Between Spin and Statistics" (Pauli ▷

1940). The first proofs, obtained using only the general properties of relativistic quantum field theory and which include microscopic causality (also known as local commutativity), are due to Gerhart Lüders and Bruno Zumino, and to N Burgoyne (Lüders and Zumino 1958; Burgoyne 1958). Another important contribution, which clarifies the connection between spin and statistics, came three years later with the work of G F Dell'Antonio (Dell'Antonio 1961).

It cannot be accidental that the first suggestion of the existence of the PCT invariance law came from the same people engaged in the study of the spin-statistics theorem, Lüders and Zumino. These two outstanding theoretical physicists suggested that if a relativistic quantum field theory obeys the space-inversion invariance law, called parity (P), it must also be invariant for the product of charge conjugation (particle–antiparticle) and time inversion, CT. It is in this form that it was proved by Lüders in 1954 (Lüders 1954). A year later Pauli proved that PCT invariance is a universal law, valid for all relativistic quantum field theories (Pauli 1955).

This paper closes a cycle started by Pauli in 1940 with his work on spin and statistics where he proved already what is now considered the classical PCT invariance, as it was derived using free non-interacting fields. The validity of PCT invariance for quantum field theories was obtained in 1951 by Julian Schwinger, a great admirer of Majorana (Schwinger 1951). It is interesting to read what Arthur Wightman, another of Majorana's enthusiastic supporters, wrote about this paper by Schwinger: "Readers of this paper did not generally recognize that it stated or proved the PCT theorem" (Wightman 1964). It is similar for those who, reading Majorana's paper on arbitrary spins, have not found the imprinting of the original ideas discussed in this short review of the genius of Majorana.

Further reading

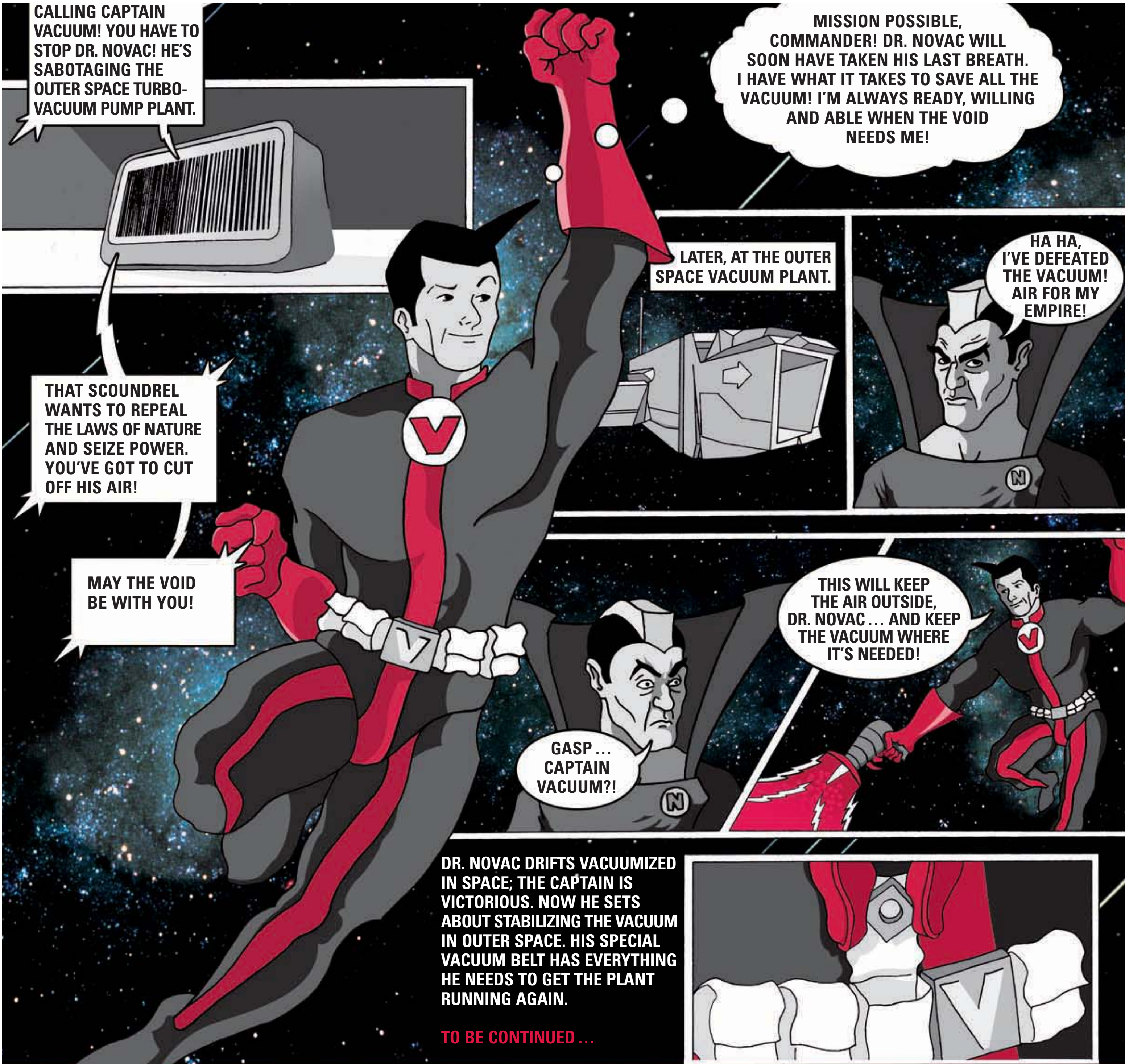
N Burgoyne 1958 *Nuovo Cimento* **8** 807.
G F Dell'Antonio 1961 *Ann. Phys.* **16** 153.
M Fierz 1939 *Helv. Phys. Acta* **12** 3.
G Lüders 1954 *Dansk. Mat. Fys. Medd.* **28** 5.
G Lüders and B Zumino 1958 *Phys. Rev.* **110** 1450.
E Majorana 1932 *Nuovo Cimento* **9** 335.
E Majorana 1937 *Nuovo Cimento* **14** 171.
W Pauli 1940 *Phys. Rev.* **58** 716.
W Pauli (ed) 1955 *Niels Bohr and the Development of Physics* (Pergamon Press, London).
J Schwinger 1951 *Phys. Rev.* **82** 914.
Arthur Wightman 1964 *PCT, Spin and Statistics, and All That* (Benjamin, New York).

Résumé

Ettore Majorana: génie et mystère

Ettore Majorana est né en Sicile en 1906. Physicien extrêmement doué, il faisait partie à Rome dans les années 30 du fameux groupe de Fermi avant de disparaître mystérieusement en mars 1938. Dans cet article, Antonino Zichichi jette un double regard sur Ettore Majorana: le mystère de sa disparition et le génie de sa contribution à la physique, en s'appuyant sur les souvenirs de grands physiciens comme Fermi et Oppenheimer.

Antonino Zichichi, *president of the Enrico Fermi Centre, Rome.*


CALLING CAPTAIN VACUUM! YOU HAVE TO STOP DR. NOVAC! HE'S SABOTAGING THE OUTER SPACE TURBO-VACUUM PUMP PLANT.
THAT SCOUNDREL WANTS TO REPEAL THE LAWS OF NATURE AND SEIZE POWER. YOU'VE GOT TO CUT OFF HIS AIR!
MAY THE VOID BE WITH YOU!
MISSION POSSIBLE, COMMANDER! DR. NOVAC WILL SOON HAVE TAKEN HIS LAST BREATH. I HAVE WHAT IT TAKES TO SAVE ALL THE VACUUM! I'M ALWAYS READY, WILLING AND ABLE WHEN THE VOID NEEDS ME!
LATER, AT THE OUTER SPACE VACUUM PLANT.
HA HA, I'VE DEFEATED THE VACUUM! AIR FOR MY EMPIRE!
GASP … CAPTAIN VACUUM?!
THIS WILL KEEP THE AIR OUTSIDE, DR. NOVAC … AND KEEP THE VACUUM WHERE IT'S NEEDED!
DR. NOVAC DRIFTS VACUUMIZED IN SPACE; THE CAPTAIN IS VICTORIOUS. NOW HE SETS ABOUT STABILIZING THE VACUUM IN OUTER SPACE. HIS SPECIAL VACUUM BELT HAS EVERYTHING HE NEEDS TO GET THE PLANT RUNNING AGAIN.
TO BE CONTINUED …

CMS closes up for magnet

Members of the CMS collaboration have spent much of this year preparing for crucial te

After many years of hard work and long hours, the team building the CMS detector at CERN will get the chance to test the giant magnet in the final stage of commissioning, together with pieces of all the sub-detectors, in the magnet test and cosmic challenge (MTCC). In mid-July the CMS superconducting coil, the barrel rings containing pieces of the inner detectors and the semi-equipped endcaps, were pushed together to be tested for the first time. CMS is unique among the experiments for the Large Hadron Collider (LHC) as it is being assembled on the surface at intersection point 5 in Cessy, France.

Meanwhile, a great opportunity exists for the collaboration to understand parts of the inner detector that have already been installed, including the hadronic calorimeter (HCAL – all of which is installed although only one section is being operated during the test), two supermodules of the electronic calorimeter (ECAL) and some pieces of the prototype tracker. These sub-detectors will be read out using the real data-acquisition system when cosmic muons are detected during the cosmic challenge. This "slice testing" will continue for two months to ensure the correct alignment and synchronization of the detectors, as well as to confirm that the event builder works as expected and that the software is flexible enough to make any changes needed.

Fig. 1. Members of the CMS Magnet and Integration Group and representatives from Saclay stand inside the cryostat of the giant superconducting solenoid during cooling to the interior operating temperature of 4.5 K.

Fig. 2. The firs

Step one: cooling the solenoid

The gigantic CMS solenoid has already been cooled to 4.5 K, the operating temperature reached on 25 February after cooling began 23 days earlier. The magnet will be operated at this temperature throughout the summer, while the magnet team commission it and test all the systems. The huge coil consists of 14.5 tonnes of niobium-titanium superconducting cables embedded in 74 tonnes of aluminium, with 126 tonnes of high-mechanical-strength aluminum alloy and 9 tonnes of insulation. The temperature is extremely well contained inside the outer covering, enabling engineers to stand within the solenoid during cooldown (figure 1).

After cooling the magnet, the next step was to turn on the current. However, before that could happen, the yoke had to be closed to channel the return flux. The CMS Magnet and Infrastructure Group tested the first low currents to check the control and safety systems before the yoke was closed. Final tests were then made on all auxiliary systems, including cryogenics, electronics and fine-tuning the control system and the power supply. During commissioning the current will rise from 1 kA to 19.5 kA before reaching the nominal magnetic field.

Fig. 3. The first two supermodules of the ECAL were installed into the barrel of the HCAL with the help of the CMS ECAL Group, CMS Integration and CEA-DAPNIA.

Fig. 4. On 19
complete slic

Step two: the hadronic calorimeter

At the beginning of March the first half of the barrel HCAL was tested using a radioactive source before insertion into the solenoid in early April (figure 2). The second HCAL half-barrel was inserted a month later. Both operations involved moving the HCAL pieces from their storage alcoves on an air-pad system and then sliding the halves onto rails welded to the inside of the solenoid. The HCAL comprises layers of brass interleaved with plastic scintillators embedded with wavelength-shifting optical fibres. The light is read out via hybrid photodiodes.

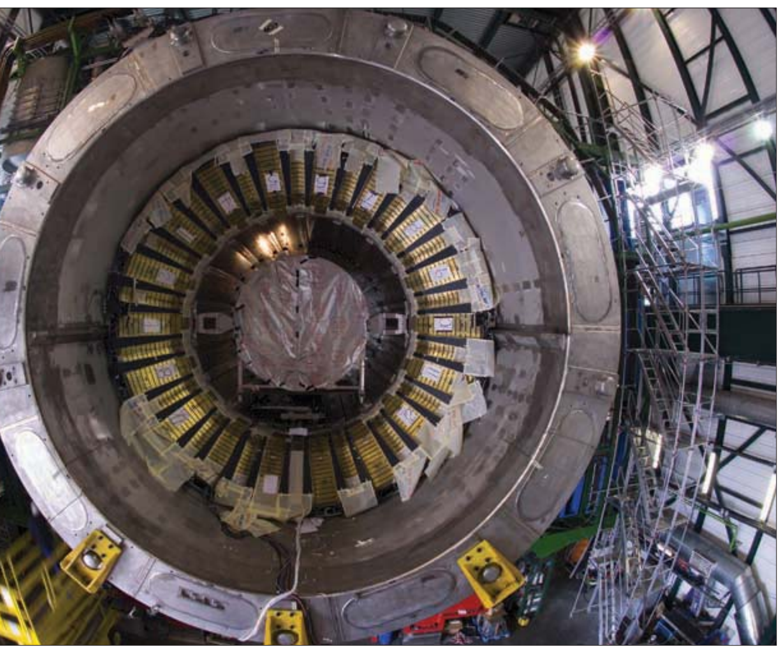
Step three: the ECAL supermodules

Two out of 36 supermodules that make up the barrel ECAL have been installed specifically for the MTCC using a rotatable insertion device known as the "squirrel cage". This is no easy task, as each

test and cosmic challenge

s before starting to lower the gigantic detector into the underground cavern in the autumn.

alf of the barrel hadronic calorimeter, ready for insertion into the magnet.



y, the successful central positioning of the prototype tracker meant that a f CMS was in place and ready for the magnet test and cosmic challenge.

section weighs more than 3 tonnes and is very delicate (figure 3). Inside each of these boxes lie 1700 lead-tungstate crystals inserted into glass-fibre "alveolar" structures. Scintillation light produced in the crystals by incident electrons and photons is detected by avalanche photodiodes glued to the back of the crystals. The supermodules also contain the associated front-end electronics, laser monitoring and cooling systems.

Step four: the prototype tracker

During the early hours of 19 May, a special climate- and humidity-controlled truck transported a prototype particle tracker to the CMS site. To avoid shocks to the delicate parts, the truck travelled at a maximum speed of 10 km an hour. Once it arrived, crews hoisted the 2 tonne apparatus up 10 m to the opening of the solenoid (figure 4). Surveyors then aligned the pieces, using the two supermodules of the ECAL for reference. While the prototype tracker is equipped with 2 m^2 of silicon sensors, the real tracker will comprise 16 000 strip sensors and about 900 pixel sensors – around 200 m^2 of sensors.

Once the MTCC is complete, CMS will be pulled apart in preparation for lowering the sections into the cavern (due to start in October/November). However, before the tracker is removed, an important test will be made of procedures to remove and replace one of the supermodules while the tracker remains inside. CMS plans to install all 36 supermodules into the HCAL on the surface before the real tracker is inserted, but if the schedule slips some supermodules may need to be installed underground with the tracker *in situ*. This is a demanding task, as neither piece can touch each other and there is only about a centimetre of clearance between them.

After the MTCC is complete, the team will remove the tracker and the ECAL, close CMS and conduct a magnetic-field map test. This will show how uniform the field is and where there are discrepancies. With this information, the differences can be incorporated into the operating software of the experiment.

The MTCC provides a unique opportunity for the CMS collaboration to test installation procedures and to commission a large fraction of the detector, including the data-acquisition and online-monitoring system. The lessons learned will be invaluable for the final push – the full installation of all elements for start-up in late summer 2007.

Résumé

Fermeture de CMS pour l'essai de l'aimant et le défi des cosmiques

De nombreux membres de la collaboration CMS ont passé une grande partie de l'année à préparer les essais cruciaux qui doivent avoir lieu avant que commence la descente de l'immense détecteur dans sa cavité souterraine à l'automne. L'équipe va mettre à l'épreuve l'aimant géant de CMS ainsi que des parties de tous les sous-détecteurs au cours d'un "essai de l'aimant et défi des cosmiques". En juillet, la bobine supraconductrice, les anneaux du tonneau contenant des parties des détecteurs internes ainsi que les bouchons à demi équipés ont été assemblés, en préparation des essais. La détection de muons cosmiques offrira la possibilité de mettre en service une grande partie du détecteur, y compris les systèmes d'acquisition des données et de surveillance en ligne.

Dave Barney *and* **Carolyn Lee**, *CERN.*

Pisa pushes new frontiers

The island of Elba, off the coast of Tuscany, hosted the 10th Pisa meeting on frontier detectors, a quarter of a century since the meetings began. **Giorgio Chiarelli** reports.

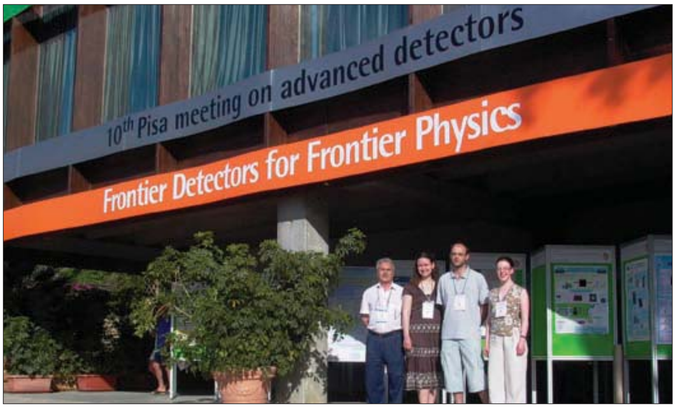
The Pisa meetings on Frontier Detectors for Frontier Physics (FD4FP) began 25 years ago as a small gathering in Tirrenia, near the INFN Pisa Laboratory. This year more than 300 participants from 21 countries attended the 10th in the series, held on Elba on 21–27 May. Lello Stefanini, chair of the FD4FP executive board, reminded the audience in his opening address that, after beginning in Pisa, the meeting moved to Castiglione della Pescaia in 1983 and 1986, and finally settled in La Biodola on Elba in 1989. This year it attracted about 200 selected contributions. As detector development and construction takes place in close collaboration with industries, hi-tech firms from all over the world displayed their products alongside presentations and direct interaction with researchers.

To mark the 10th meeting, there were two main modifications to the schedule. The first was a special session on experiments for the Large Hadron Collider (LHC) at CERN. Following an introduction by Michelangelo Mangano of CERN and John Carr of Centre de Physique des Particules de Marseille to the future of high-energy and astroparticle physics, a number of speakers described the main features and the status of the LHC detectors. After years of detector R&D and construction, four large devices are becoming reality and beginning to take data with cosmic rays in preparation for the real beams.

In a second innovation, day two of the meeting included a round table on strategies for future accelerators, chaired by Albrecht Wagner, chair of the International Committee for Future Accelerators and director of DESY. Fermilab's Jim Strait showed how the laboratory is running the Tevatron while broadening both its neutrino programme (with the MINOS and NoVA experiments) and its effort on the R&D for a future International Linear Collider (ILC).

During the round table, Jos Engelen of CERN stressed the importance at CERN of R&D for the Compact Linear Collider (CLIC) and SuperLHC studies while keeping the main focus of the laboratory on the start-up and the exploitation of the physics capabilities of the long awaited proton–proton collider, the LHC. Barry Barish, director of the ILC Global Design Effort, outlined how a triadic approach – with facilities for neutrino physics, an exploratory high-energy frontier with proton–proton colliders and a precision high-energy frontier with e^+e^- colliders – would address most of the open problems in particle physics. He also showed how the efforts of a large community that is gathered to design a baseline ILC are making progress towards a Reference Design Report to be available by the end of 2006.

Atsuto Suzuki of KEK showed the impressive results from the KEK-B facility and progress with the Japan Proton Accelerator Research Complex. The multipurpose accelerator complex is on schedule to provide beams to the users by 2008. At the same time the Japanese community is fully involved in the R&D for the ILC to be ready either to participate in an early built ILC or to upgrade the KEK-B facility. Finally in the round table, Roberto Petrozio, INFN president and chair of the



From left to right: Angelo Scribano, chair of the organizing committee of the 10th Pisa meeting, with Bilge Demirkoz, Nicola Cesca and Judith McCarron, recipients of the FD4FP Award.

Funding Agencies for the Linear Collider (FALC) committee, presented the INFN's strategies for future accelerators aimed mainly at e^+e^- (low and high energy) colliders, high-intensity radioactive beams for nuclear physics, and the exploitation of hadron beams for medical applications. He clearly indicated how the synergy among different projects is key to the approach. As chair of FALC, Petrozio later reported on recent discussions aimed at harmonizing and optimizing the human and financial resources in high-energy physics in the near future.

A discussion ended the round-table session, with several questions and comments raised from the floor, mainly aimed at understanding how the field will be able to widen the support for its projects and fulfil its promises with the resources available. There was a consensus that a successful start-up of the LHC will be a test-bed for the capability of the particle-physics community and might boost it to become bolder and seek even more ambitious goals.

The remaining sessions followed the established tradition, covering all aspects of design, development and running of detectors for high-energy physics. Topics ranged from calorimetry to gas detectors, from solid-state devices to electronics, from particle identification to devices designed for astroparticle physics and cosmology, in so many presentations that only a few aspects can be highlighted here.

Silicon represented the lion's share among the contributions. Over the years, the use of this material has extended from tracking detectors to calorimetry and particle identification, because the only limitation seems to be our own imagination. What was once used to miniaturize particle detectors and make them more compact is now the base for large-scale devices, for example for trackers for the LHC experiments and for the Gamma-ray Large Area Space Telescope. The need for a further reduction in the amount of material used and the requirements of the next generation of colliders demand an even ▷

closer integration of electronics and detectors, so more groups are now involved in developing and understanding monolithic devices.

Moving away from planar devices, 3D silicon detectors, presented at the ninth FD4FP meeting, are now better understood and seem able to provide detectors that are almost free from dead zones. At the ninth meeting, Valery Saveliev of Obninsk State University proposed silicon photomultipliers (SiPM). The past three years have seen a number of groups developing detectors based on this original R&D concept, so it is not surprising that several contributions presented results on SiPM or on devices based on similar concepts that are now being built by several firms around the world.

Several contributions focused on detectors based on gas, showing that they have a future besides the LHC, both on the ground and in space. Richard Wigmans of Texas Tech University presented the results of the dual read-out calorimeter project, DREAM. The separate measurement of the electromagnetic and hadronic component of a hadron shower seems the best way to a precise determination of its energy. It will be interesting to see whether in the near future an experiment will translate this R&D into a full-scale detector.

The growing application of high-energy physics techniques in other fields of research (mainly, but not exclusively, in medicine and biology) was well described in a dedicated session of posters and presentations. Reports on the results of two field studies in archaeological sites, at the Aquileia port near Udine and at the Traiano and Claudio port near Rome Airport, showed an intriguing use of muons, detected by scintillating fibres, for underground mapping.

Three young participants received the 2006 FD4FP Young Physicist Award for their work and presentations. Nicola Cesca, who has a fellowship at the University of Ferrara reported on the semiconductor small-animal scanner, SiliPET; Bilge Demirkoz, a graduate student at Oxford University, presented the ATLAS Semiconductor Tracker; and Judith McCarron, a graduate student at Edinburgh University, presented tests and results of the hybrid photon detector for the ring imaging Cherenkov detector of the LHCb experiment for the LHC.

Further reading

For electronic versions of the presentations, or to view the webcast, which was broadcast live, see www.pi.infn.it/pm/2006.

Résumé

Sur l'île d'Elbe, des physiciens tournés vers le futur

La dixième rencontre de "Pise" sur le thème Frontier Detectors for Fontier Physics (FD4FP) a eu lieu sur l'île d'Elbe du 21 au 27 mai. Quelque 300 participants étaient présents cette année et 200 contributions ont été sélectionnées. Les thèmes abordés allaient de la calorimétrie aux détecteurs à gaz en passant par les dispositifs à semi-conducteurs, l'électronique, l'identification des particules ou les appareils conçus pour l'astrophysique des particules et la cosmologie. Deux nouveautés étaient également au programme: une séance spéciale sur les expériences du Grand collisionneur de hadrons (LHC) et une table ronde sur les accélérateurs du futur. Des entreprises de haute technologie du monde entier ont également participé en exposant leurs produits et en présentant des exposés.

Giorgio Chiarelli, *INFN Pisa.*

ANNIVERSARY

LAL celebrates 50 innovative years

An aerial view of the Laboratoire de l'accelerateur lineaire on 5 October 1957.

Guy Wormser, LAL director (left), and Mario Calvetti, LNF director, with the plaque celebrating the first collisions between electrons and positrons with the ADA storage ring.

Celebrations to mark the 50th anniversary of the Orsay Linear Accelerator Laboratory (LAL) took place on 8–9 June, beginning with an opening ceremony attended by Michel Rocard, former prime minister of France and son of LAL's founder, Yves Rocard. The event featured an outstanding array of speakers and attendees with two Nobel laureates, the director and the president of the French National Centre for Scientific Research, and many directors of major particle-physics laboratories, including CERN, DESY, Fermilab, the Laboratori Nazionali di Frascati (LNF) and SLAC. Colleagues and former collaborators came from many parts of the world to congratulate LAL for its leadership in particle physics and its pioneering experimental work.

Construction of the linear accelerator at Orsay began in 1956 under the direction of Yves Rocard and Hans Halban. Designed by physicists of the Ecole Normale Supérieure and engineers of the Compagnie générale de télégraphie sans fil, it became one of the world's most powerful accelerators during the 1960s. The intense beam with its small spot size allowed studies of the structure of matter through electron-scattering experiments.

However, the accelerator's main role turned out to be as a powerful injector for e^+e^- storage rings, a story that began in 1962 when the AdA storage ring, built in Frascati under the visionary leadership of Bruno Touschek, arrived in Orsay. The following year, in December 1963, collisions between electrons and positrons were observed for the first time, a world premiere of great significance. A new ring, ACO, started operation at LAL in 1966, producing a large proportion of the early results on low energy e^+e^- collisions. It ceased functioning in 1988 and was transformed into a museum and registered on the inventory of historic buildings. ACO can be considered as the ancestor of the synchrotron light source SOLEIL, currently under construction at Saclay. An even larger ring, DCI, was constructed at LAL in 1976 and this hosted the DM2 detector, which for many years studied the largest J/ψ sample in the world.

During the 50th anniversary event, a plaque celebrating the first e^+e^- collisions was unveiled by Guy Wormser, director of LAL, and Mario Calvetti, director of the LNF. Also, a huge experimental hall was renamed Hall André Lagarrigue, commemorating the great scientist whose team discovered neutral currents in 1973 with the Gargamelle bubble chamber at CERN. Lagarrigue was LAL's director from 1969 until his untimely death in 1975. CERN has also renamed a road Route André Lagarrigue on its site at Prevessin.

Many other great achievements at LAL were discussed during the two-day event, including the construction of the LEP Injector Linac, the first accelerator at CERN entirely provided by another laboratory. LAL also participated in the discovery and the study of the W and Z bosons in the experiments UA2, ALEPH and DELPHI at CERN, and played a pioneering role in the BaBar experiment at SLAC, paving the way for much larger international participation there. As in many other laboratories in the world, in the 1990s physicists at LAL became keenly interested in experiments in astroparticle physics and cosmology, making key contributions to the VIRGO gravitational-wave interferometer in Cascina, Italy, and the Planck satellite to measure the cosmic microwave background with unprecedented accuracy.

The value of a fundamental research laboratory such as LAL in fostering innovation was a recurring theme of the anniversary celebration. As current director, Wormser's first priority now is to maintain and enhance the excellent international reputation of LAL. "In the next decade, we will have the very exciting opportunity of answering the fundamental questions raised in our field – 'What is the origin of mass?', 'What is dark matter and dark energy?', 'What is the number of space dimensions of the universe?' – with new tools such as the LHC [Large Hadron Collider] that offer unique possibilities to answer them. LAL will no doubt continue to play a pioneering role in this magnificent endeavour."

● For more information see www.lal.in2p3.fr/ and http://sciences-aco.lal.in2p3.fr.

NEUTRINOS

KM3NeT Collaboration gets going

Scientists from 37 research institutes in eight European countries gathered at the physics institute of the Friedrich-Alexander University of Erlangen-Nuremberg on 11–13 April to launch the three-year design study for a cubic-kilometre-scale neutrino telescope (KM3NeT) and platform for deep-sea sciences at a clear-water site in the Mediterranean. The €20 m design study, partly funded under the research infrastructure portion of the European Community's 6th Framework Programme, will finish in 2009 with a detailed technical design report allowing construction of the telescope to commence swiftly.

KM3NeT's mission is to detect high-energy neutrinos, which are expected to be created in a variety of astrophysical sources including active galactic nuclei, pulsars, supernova remnants, black holes and quasars. The detection of such neutrinos may be key to understanding the most violent objects in the universe and, in conjunction with experiments sensitive to charged cosmic rays and photons at a variety of wavelengths in the electromagnetic spectrum, will open the era of multi-messenger astronomy.

The detection of these neutrinos, which can travel intergalactic distances and pass through intervening dust clouds and magnetic fields without interaction or deflection, requires a huge detector target. KM3NeT will instrument at least 1000 megatonnes of deep-sea water with thousands of sensitive light detectors. Occasionally a neutrino will interact with an atomic nucleus close to the detector, producing a charged muon. Moving through the water at close to the speed of light, the muons will generate a detectable blue wake of Cherenkov radiation.

KM3NeT will complement the sky coverage of the IceCube cubic-kilometre-scale telescope currently deployed in the deep Antarctic ice (*CERN Courier* May 2006 p24). It will be sensitive to the region of the sky containing the galactic centre and galactic plane, in which many exciting ultra-high-energy gamma-ray sources have recently been detected by the HESS imaging air Cherenkov telescope in Namibia (*CERN Courier* January/February 2005 p30).

The KM3Net collaboration reflects a convergence of effort from the three smaller-scale Mediterranean projects: ANTARES near Toulon (*CERN Courier* June 2003 p22), NEMO near Catania and NESTOR near Pylos (*CERN Courier* May 2003 p5). In addition to their role as pilot neutrino-telescope projects, these sites will form part of the proposed ESONET/EMSO chain of sea-floor observatories.

The infrastructure of KM3NeT will provide an instrumentation platform for ocean sciences that include marine biology, geology and geophysics. These sciences will benefit from long-term fixed-site measurement of deep-sea environmental parameters such as water purity, undersea currents, bioluminescence, biosedimentation studies and sea-floor seismometry.

There has been strong support for KM3NeT, which promises an eventful future, from the European Community, the University of Erlangen-Nuremberg (which is the project coordination centre for the design study) and a growing community of participating institutes.

EXHIBITION

Science unites nations in Geneva

Alexei Sissakian, director of JINR, speaking at the opening of the exhibition in Geneva.

The Science Bringing Nations Together exhibition was on display in the Palais des Nations of the UN office in Geneva on 25–28 April to celebrate the 50th anniversary of the establishment of the Joint Institute for Nuclear Research (JINR), Dubna, on 26 March 1956. The poster exhibition developed jointly by CERN and JINR has previously been displayed in Oslo, Paris, Brussels, Moscow, Bucharest, Dubna, Yerevan and Thessaloniki.

The scientific activities of the two international centres, CERN and JINR, their collaboration in global projects on modern elementary-particle physics and the application of high-energy physics in various aspects of life were main themes of the event.

Addressing a press conference before the opening of the exhibition, CERN's director-general Robert Aymar and JINR's director Alexei Sissakian, spoke about scientific research at JINR and CERN, including joint projects and future experiments in high-energy physics at the Large Hadron Collider at CERN. At the opening event, Sergei Ordzhonikidze, UN director-general in Geneva, and Valery Loshchinin, the Russian Federation ambassador to the UN in Geneva, as well as Aymar and Sissakian, addressed the delegates.

The exhibition covered the achievements of joint research in high-energy particle physics by CERN and JINR, as well as progress in nuclear physics, condensed-matter physics and applied research. A film was shown about the joint scientific programmes of the two organizations, and booklets and souvenirs for JINR's 50th anniversary were also available.

AWARDS

Markov prize goes to Lake Baikal physicists

The Markov prize for 2006 has been awarded to Grigory Domogatsky and Christian Spiering for their leading roles in creating the Lake Baikal neutrino telescope, NT200+, and for their outstanding contributions to high-energy neutrino astrophysics. Grigorij Domogatksy started his career in theoretical astroparticle physics and has been held the position of spokesman of the Baikal collaboration since 1980. Christian Spiering led significant German contributions to the Baikal project from 1988 and is currently spokesman for the IceCube collaboration.

The Baikal telescope was the first successful realization of an idea proposed by Moisey Alexandrovich Markov more than 40 years ago: the exploitation of water in oceans or lakes for neutrino detection. NT200+ is the second-largest existing neutrino telescope, after AMANDA at the South Pole. Both detectors have pushed the limits on cosmic fluxes from diffuse or point-like sources of energetic neutrinos to more than an order of magnitude below earlier results from underground detectors. AMANDA is currently being incorporated in the cubic-kilometre array, IceCube, which has nine of its 80 strings already deployed (*CERN Courier* May 2006 p24). There are also plans to expand NT-200+ to the gigatonne scale, to observe regions of the sky not observable by IceCube, with a much better sensitivity than the present NT200+ detector.


Grigorij Domogatsky, left, and Christian Spiering during their lectures at the Markov award ceremony, which took place in May.

The prize diplomas were handed to the laureates on the occasion of the Markov Readings, held in Moscow on 11–12 May. This annual mini-conference commemorates Markov, the outstanding Russian scientist who initiated and promoted many lines of research in elementary-particle physics, gravitation and cosmology. The readings were organized by the Lebedev Physical Institute, the Institute for Nuclear Research, the Petersburg Institute for Nuclear Physics and the Joint Institute for Nuclear Research, Dubna – all institutions where Markov worked for many years.

ATLAS collaboration rewards top suppliers

In a ceremony on 5 May, three companies showing excellence in mechanics, electronics and cryogenics received awards for their contributions to the ATLAS experiment.

Alu Menziken Industrie AG of Switzerland was honoured for the production of 380 000 aluminium tubes for the monitored drift tube (MDT) chambers, which were delivered on time with an extraordinary quality and precision. Between October 2000 and January 2004 1300 km of tubes were supplied in time for the production of the MDT chambers. The average straightness, even for the long tubes, is around 0.05 mm, never exceeding 0.15 mm.

Representatives of the three award-winning companies, alongside members of ATLAS.

The Franco-Italian firm STMicroelectronics was rewarded for developing and producing about 40 000 radiation-hard voltage regulators for different ATLAS subsystems. The regulators are used mainly in the liquid-argon front-end electronics and in the power distribution of the pixel detector and the transition radiation tracker. ATLAS required radiation-hard voltage regulators able to deliver a sufficient current, but there was no such component available on the market. A collaboration between CERN and STMicroelectronics was thus initiated. Despite several subtle technical problems linked to transistor modelling, STMicroelectronics completed the project very successfully.

SB Verksted AS of Norway received its award for supplying four 50 000 l cryogenic-liquid storage tanks and two valve boxes for the ATLAS liquid-argon calorimeters. The work was supported financially by the Norwegian ATLAS project and by a technical collaboration between the Norwegian University of Science and Technology, SB Verksted and CERN. Two of the high-pressure tanks are situated on the surface at the ATLAS experimental area and the other two in the cavern. The design of the argon tanks was completed within stringent safety, installation and operating conditions and met a high purity level.

Japan commends KEK induction acceleration team

A research group led by Ken Takayama was awarded the Commendation for Science and Technology from the minister of education, culture, sports, science and technology in a ceremony in Japan on 18 April. The award was presented to recognize the group's "research on induction acceleration in a high-energy circular accelerator". This was developed at the Japanese High Energy Accelerator Organization, KEK, originally for the experimental demonstration of an induction synchrotron.

Left to right: Kunio Koseki (KEK), Akira Tokuchi (Nichicon Kusatsu Co), Ken Takayama (KEK), Kota Torikai (National Institute of Radiological Sciences) and Yoshito Shimosaki (KEK).

HERA theses win DESY prizes

Ingo Bloch, left, and Ulrike Elschenbroich, after receiving their prizes earlier this year.

The 2006 PhD prize of the Association of the Friends and Sponsors of DESY goes to Ulrike Elschenbroich of Geneva University and Ingo Bloch of Hamburg University, for their theses on research at DESY's electron–proton collider, HERA.

Elschenbroich's thesis describes work with the HERMES experiment. She was the first to succeed in gathering detailed information about the transverse spin effects and structures that allow a better understanding of the role of the orbital angular momentum of the quarks in the proton – a milestone in the understanding of the proton structure.

In his PhD thesis, Bloch developed for the first time at HERA a largely model-independent analysis of the production of heavy beauty quarks, leading to a better understanding of the discrepancy between experiment and theory. Also, his investigation of the background radiation in the ZEUS detector contributed to solving the background problems in runs at HERA, making possible more-efficient experiment operation.

Bogoliubov Prize seeks candidates

The Joint Institute for Nuclear Research (JINR) announces the competition for the 2006 N N Bogoliubov Prize for Young Scientists. The prize, established in 1999 in memory of the eminent physicist and mathematician Nikolai Nikolaevich Bogoliubov, is awarded to young researchers (up to 33 years old) for outstanding contributions in theoretical physics related to Bogoliubov's scientific interests – nonlinear mechanics, statistical physics, quantum field theory and elementary-particle theory.

The prize is awarded to a scientist who has shown early scientific maturity and whose results are recognized worldwide. Applicants should try to emulate Bogoliubov's skill in using sophisticated mathematics to attack specific physics problems.

To take part in the competition, send a curricilum vitae and a one- to two-page abstract of submitted papers in electronic form to V I Zhuravlev, scientific secretary in the Directorate of the Bogoliubov Laboratory of Theoretical Physics of JINR (Joliot-Curie str. 6, 141980 Dubna, Moscow Region), e-mail: bltp@theor.jinr.ru, not later than 10 September 2006. The winners of the competition will be announced on 3 October during the seminar dedicated to the 50th anniversary of the Laboratory of Theoretical Physics.

ART AND SCIENCE

Breathing Room exhibition looks into the relationship between the body and space

An exhibition at the Galerie Thaddaeus Ropac in Paris by British sculptur Antony Gormley opened on 31 March with a discussion on mathematics, physics and philosophy. The exhibition featured a major new installation by Gormley called *Breathing Room*. Created specifically for this show, it is constucted from square aluminium tubing formed into seven interlocking space frames that the viewer can enter, thereby activating the space and turning the viewer into part of the artwork.

Gormley's interest in the relationshp between the internal state of the human body and the infinity of space provided the background for the discussions, which involved particle physicist Michael Doser from CERN, as well as Gormley himself and Catherine Ferbos, art historian and curator.

Sculptor Antony Gormley (left) , with Catherine Ferbos, and Michael Doser (right) at the round-table discussion, with Gormley's installation, Breathing Room*, visible in the background.*

OUTREACH

Discovering the Quantum Universe: 21st-century particle physics for non-experts

The High Energy Physics Advisory Panel in the US has launched a new publication to explain the excitement of 21st-century particle physics to audiences who are not science experts. *Discovering the Quantum Universe* describes the role of particle colliders, nowadays the basic tools of particle physics, in answering fundamental questions about the universe. It is a companion publication to the earlier report, *Quantum Universe* (2004).

In short chapters and with an attractive layout, the report presents mysteries and discovery scenarios in simple language. Copies may be ordered or downloaded for free online at www.quantumuniversereport.org.

NEW PRODUCTS

e2v scientific instruments is launching SiriusSD, a new product range in X-ray detection. SiriusSD is an electrically cooled solid-state silicon drift chamber with a new electronic design. Directly compatible with existing systems, the range includes designs for integration with scanning electron microscopes and X-ray fluorescence systems. For further information see www.e2v.com.

Hiden Analytical Ltd has introduced the HPR 20 QIC Plus gas analysis system to the QIC series which offers fast response, sensitivity, stability and flexibility. The system is PC operated and handles all features, including data acquisition, gas stream switching and calibration. For more details tel: +44 1925 445225, e-mail: info@hiden.co.uk or see www.HidenAnalytical.com.

Kulite has announced the world's smallest combined pressure and temperature sensor, the HKL/T-1-235 (M). The high-pressure transducer (covering 1.7 to 250 bar) and platinum RTD temperature sensor (covering −55 to +175 °C) are designed to operate independently. The devices weigh 15 g without cable. For further information contact Stéphane Beaufront, +33 472 83 90 83, email: stephane@kulite.fr or visit www.kulite.com.

Lake Shore Cryogenics has introduced the Model 325, the latest in its line of dual-channel temperature controllers. The Model 325 can support nearly any diode, RTD or thermocouple temperature sensor, allowing accurate measurement and control of temperatures from 1.4 K to more than 1500 K. It includes both IEE-488 and serial (RS-232C) computer interfaces. For more details tel: +1 614 891 2244, e-mail: info@lakeshore.com or see www.lakeshore.com/325.html.

OBITUARIES

Yuval Ne'eman 1925–2006

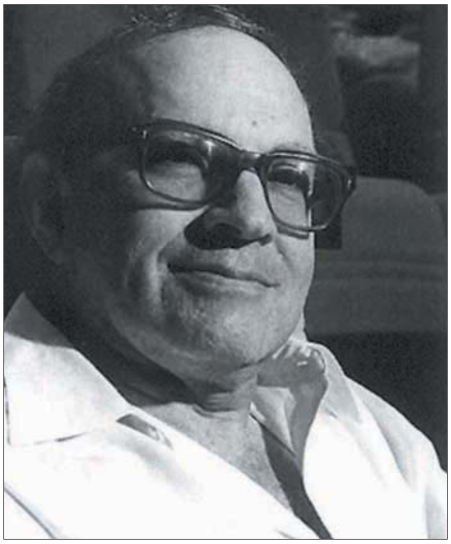
Yuval Ne'eman, the pioneer of particle physics in Israel died on 26 April 2006 in Tel-Aviv. During the course of a life shaped by the extraordinary times in which he lived, Yuval in turn also shaped events in a career that was a mixture of physics research and public life.

Yuval was born on 14 May 1925 in Tel-Aviv, to a family that had lived in the country since 1803. At 15 he finished high school and soon enrolled in engineering studies at the Technion in Haifa as one of its youngest students ever. He graduated in 1946. His original intention was to join the family pump factory, however the tides of the time made him enlist in the Haganah, the organization that later became the nucleus of Israel's army. Eventually Yuval postponed all of his plans for studying physics and mathematics for full-time service in the Israeli Army, through the war of 1948. After the war he served in several top-level positions, culminating in 1955 as acting chief of military intelligence.

In late 1956 Yuval felt it was his last chance of becoming a scientist. Moshe Dayan, the then army chief of staff, suggested that he could pursue his goal by becoming defense attaché in London, at that time a mostly ceremonial job, which should have left him enough time to pursue his graduate studies. Dayan gave him a strong letter of recommendation and he was accepted in 1958 to join Abdus Salam's group at Imperial College.

Events in 1958 made the attaché job more demanding than was anticipated, so in May 1960, at the age of 35, Yuval chose to quit the army and became a full-time graduate student. By October he had achieved his first major result: the discovery of the "eightfold way", utilizing the adjoint representation of the SU(3) group as a classifying symmetry of hadrons. Simultaneously and independently Murray Gell-Mann came up with the same classification. Yuval loved to classify everything, so classifying hadrons came naturally to him.

According to the SU(3) multiplets of Gell-Mann and Ne'eman, the nucleons were members of an octet representation, rather than the defining triplet. In addition to the octet, higher-mass multiplets also contained several yet to be discovered states, including



the illustrious Ω^- in the decuplet. Its discovery in 1964 with the predicted properties provided a triumphant validation of the SU(3) classification scheme and particle physicists then rushed to study group theory.

So began Yuval's impressive contribution, spanning more than 45 years, to a large number of aspects of theoretical physics, from high-energy, through supersymmetry, supergravity, astronomy and cosmology. He collaborated with many physicists, from all over the world and in many cases was a visionary ahead of his time.

A prescient paper in *Nuovo Cimento* in 1963 with H Goldberg-Ophir was the first to suggest that an operator with baryon number 1/3 plays an essential role in constructing hadron representations. Yuval also realized that SU(3)-breaking cannot be due to the strong interaction. In today's language, this is the observation that QCD forces are flavour-blind. A year later, Yuval was already toying with the application of the Kaluza–Klein approach to several problems in hadron physics. He continued his excursions into algebraic applications with the introduction of spectrum generating algebras with the late Y Dothan and Gell-Mann.

The geometrization of physics fascinated Yuval. He was very fond of the non-Riemannian alternative model that he had introduced to advance his quantum-gravity work. Very early on, he and collaborators also identified the enormous potential of the rich structure of space–time supersymmetry. Subsequently Yuval played an important role in the early stages of supergravity research. He also had a deep interest in history and philosophy of science and published on numerous subjects, from foundations of quantum physics to the role of science in the evolution of human societies.

Yuval set up theoretical high-energy physics in Israel, founded the physics department at Tel Aviv University in 1963, started the first astrophysics research group in Israel and created the Wise Observatory in the Negev in 1971. He also played a key role in building research in other Natural Sciences at Tel Aviv University. Early on he was a very strong supporter of Israel's involvement in CERN and established the Israeli Committee for High Energy Physics for that purpose.

Furthermore, Yuval was deeply involved in the struggle of Jewish scientists in USSR for the right to emigrate.

Yuval was also involved in scientific administration and in Israeli politics. In particular, he served as Tel-Aviv University president (1971–75), minister of science (1982–84, 1990–92), minister of energy (1990–92) and chair of Israel's Space Agency (1983–2005).

He had an insatiable curiosity and thirst for knowledge. For example, he found that the first scientific grant awarded to a scientist by the society in which he lived was awarded by the citizens of Abdera to the particle physicist Democritos. According to Socrates' student Anisthenes, the amount of the grant was truly staggering – 500 talents, which was equivalent to $75 million in 1990.

Yuval saw himself as a disciple of the Pythagorean tradition in theoretical physics. Pythagoras had discovered that frequencies of a vibrating string are described by a series of integers. Yuval saw this discovery as a manifestation of the "Music of the Spheres", a belief that he held dear – that physical phenomena can be described by simple and beautiful mathematics. Yuval's own work is a prime example of the strength of this principle.

Yuval's friends.

Sergei Slavatinsky 1927–2006

Sergei Slavatinsky, a renowned leader in cosmic-ray and high-energy physics, died on 13 February 2006 aged 78. For many years, as leader of the Pamir International Collaboration and chair of the International Emulsion Committee of the IUPAP Cosmic Ray Commission, he played a prominent role in developing emulsion-chamber experiments, studying very-high-energy cosmic-ray interactions at mountain altitudes.

Slavatinsky was born in Moscow in 1927 and entered Moscow State University in 1944. Near the end of his course Slavatinsky studied cosmic rays and in 1947 he visited the new Pamir high-altitude scientific station of the Lebedev Physical Institute in Chechekty in the Eastern Pamirs. There he joined extensive air-shower experiments being conducted by D V Skobeltsyn, N A Dobrotin and G T Zatsepin, among others. This research established the major role of nuclear cascades in the formation of extensive air showers and led to the discovery of several laws of multi-particle production in high-energy cosmic-ray interactions.

Slavatinsky proved to be a talented student, contributing to his first scientific paper in 1949. The following year he began the postgraduate course of the Lebedev Physical Institute and joined the group of N G Birger, G B Zhdanov and others involved in cosmic-ray studies using cloud chambers. Full of enthusiasm, Slavatinsky spent several winters in high isolated mountains, increasing his skills in experimental techniques and novel instrumentation. Slavatinsky's PhD thesis in 1953 contained data on energy spectra and effective cross-sections of secondary particles, as well as an analysis of neutral V-shaped events, later attributed to Λ-hyperon production.

In 1960 the group moved from the Pamirs to the Tien Shan where a new high-altitude scientific station was under construction. As first director of the station, Slavatinsky exhibited a remarkable organizing talent managing the construction and installation of numerous facilities in extreme conditions. The main experimental set-up combined a large cloud chamber ($100 \times 50 \times 40$ cm^3) in a 0.7 T magnetic field with an ionization calorimeter. This unique arrangement allowed important

observations at primary proton energies in the range 0.1–1.0 TeV. Slavatinsky also observed a significant fraction of asymmetric showers favouring the hypothesis of the production of massive mesonic fireballs in the pionization region accompanied by baryonic (nucleonic) clusters in the fragmentation region.

To meet the challenge of colliders and to continue pioneering studies of cosmic-ray interactions at higher energies, in the early 1970s Slavatinsky and Dobrotin initiated an ambitious project using large X-ray emulsion chambers (XRECs) at high mountain altitudes. These proved effective in studying cosmic-ray interactions at energies above 10 TeV. The project required emulsion chambers up to 1 km^2.

In 1971 Slavatinsky and colleagues returned to the Eastern Pamirs to set up an experimental site near a high mountain pass, Ak-Arkhar. There they deployed the world's largest array of XRECs and initiated the Pamir emulsion-chamber experiment to study interactions of hadrons with light nuclei in the atmosphere over an energy range of 100 TeV–100 PeV. Slavatinsky became the leader of the large Pamir Collaboration of 10 scientific institutions from Russia, Georgia, Kazakhstan, Tajikistan, Uzbekistan and Poland, and managed to maintain a collaborative spirit despite divergent opinions and conflicting ethnic ambitions.

In 1980 Japanese physicists were invited to the annual Pamir Collaboration workshop to discuss recent emulsion-chamber results with respect to progress in high-energy accelerator physics. Thus a biennial symposium series was launched, bringing together cosmic-ray and accelerator physicists. The symposia, later expanded to include frontier subjects of astrophysics, are now held under the auspices of the Cosmic Ray Commission of IUPAP.

During the 1980s a series of successful joint exposures at both the Pamirs and Mt Chacaltaya in Bolivia led to the formation of the Pamir-Chacaltaya Collaboration. Slavatinsky played a decisive role in setting up this collaboration, which promoted emulsion-chamber experiments and yielded many results that are still difficult to interpret within the Standard Model. More recently he channelled much energy into a challenging new project at the Tien Shan High Altitude Station, involving a new hybrid arrangement combining emulsion-chamber techniques with the observation of extensive air-showers using electronic detectors.

Slavatinsky was also an exceptional mentor of young scientists, greatly appreciated as a teacher. He leaves behind a generation of young physicists inspired by his all-embracing devotion to science, his enthusiasm and his profound vision of physics problems. Late in his life he became an honorary professor of the Moscow Institute of Physics and Technology. In 1993 he was elected a member of the Russian Academy of Natural Sciences.

Slavatinsky is remembered by his many friends and colleagues for his cheerful character, as well as for his kindness. He possessed a wide spectrum of interests, being fond of the arts, classical music and poetry. He also enjoyed mountain skiing and canoeing along Russian rivers and lakes.

A S Borisov and colleagues, P N Lebedev Physical Institute.

Karen Avetovich Ter-Martirosyan 1922–2005

Karen Avetovich Ter-Martirosyan, who died on 19 November 2005, was an outstanding theoretician. He spent most of his scientific career at the Institute of Theoretical and Experimental Physics (ITEP) in Moscow, where during five decades, he made remarkable contributions to our understanding of high-energy physics phenomena. He also created new trends in the theory of strong interactions, and founded the Elementary Particle Physics chair of the Moscow Institute of Physics and Technology and the Laboratory of Hadron Physics at ITEP.

Born in Tbilisi, Karen graduated from Tbilisi State University in 1943 and, after two years of teaching physics at the Tbilisi Railroad Institute, started postgraduate studies at the Leningrad Physico-Technical Institute (now the A F Ioffe Physico-Technical Institute in St Petersburg). He completed his candidate's (PhD) thesis under the supervision of Yakov Frenkel and in 1949 accepted a position in the Theory Division, where he met Lev Landau. Their very active working relationship continued in Moscow, when Karen moved in 1955 to join the Theory Division of ITEP led by Isaak Pomeranchuk. Two years later Karen received the Doctor of Science (professor's) degree in theoretical physics.

In his scientific work, Karen frequently selected problems that others had not worked on and gave correct, straightforward and useful solutions. He attacked each problem in his own way, which soon became the standard way.

In 1952 he created a theory of the Coulomb excitation of atomic nuclei, which led to the discovery of nonsphericity in certain heavy nuclei. Soon after, in 1952–54, he solved the quantum-mechanical three-body problem with a point-like interaction; the Skornyakov–Ter-Martirosyan equation was later generalized by L Faddeev and became a major tool in nuclear and atomic physics. In quantum field theory he formulated, together with I Dyatlov and V Sudakov, the method of parquet equations for summing planar diagrams.

Karen Ter-Martirosyan (right), pictured celebrating his 80th birthday with Michael Danilov.

Karen invested a tremendous amount of effort in the theory of high-energy hadron interactions. In the 1960s, together with Vladimir Gribov and Pomeranchuk, he developed the theory of branch points in the complex angular-momentum plane. He also discovered processes with multi-reggeon kinematics and set down the theoretical description of rising cross-sections. Together with A Migdal and A Polyakov he developed a theory of critical and supercritical pomerons. In these investigations of high-energy interactions, a profound theoretical understanding comes together with the analysis of the bulk of experimental data from the new big accelerators, including the rise of total cross-sections. For self-consistency, theory had to comprise multi-particle processes as well, and Karen created a theory of the hadron multiplicity distribution at high energy.

In the 1980s Karen developed a model of quark–gluon string production and fragmentation, which became the basis for a realistic theory of particle production in hadron–hadron and hadron–nuclear collisions. It provided a high-precision description of all available experimental hadron-inclusive spectra and to this day remains the valid phenomenological theory of hadron interactions at high energy, naturally incorporating ideas in QCD.

Karen received his most recent honour in 1999 with the award of the Pomeranchuk Prize, and in 2000 he was elected a corresponding member of Russian Academy of Sciences. B-meson physics and Standard Model extensions were a recent major focus of his interest, and his last talk at the ITEP seminar, in 2005, concerned neutrino physics.

A gifted teacher, Karen loved teaching and his students, to whom he was available no matter how busy he was, loved him. Karen and M Voloshin co-authored the textbook *Gauge Theory of Elementary Particle Interactions*, which remains a delight and inspiration to students and established theorists alike.

Never short on new insights, Karen did much to launch international contacts for Soviet physics. It was on his initiative that the ITEP Theory Division began collaborations with Oxford and Orsay, and in the 1960s he organized famous International Schools in Nor-Hamberd and Yerevan in Armenia.

Karen remained active and surrounded by talented young physicists until his last days. Perhaps his most lasting legacy will be in the many scientists who struggled to meet his exacting standards and who now populate elite research centres worldwide.

His friends from ITEP and from CERN.

MEETINGS

The **Hadronic Shower Simulation Workshop** will take place on 6–8 September at the Fermi National Accelerator Laboratory. The aim for the workshop is to bring together world experts in a collaborative effort that will lead to a better understanding and simulation of hadronic showers for hadron calorimetry at the ILC and Large Hadron Collider, neutrino fluxes and atmospheric showers. For further information and details about registration (deadline 28 August) see http://conferences.fnal.gov/hss06/.

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Thomas Jefferson National Accelerator Facility (Jefferson Lab), located in Newport News, VA, USA, is a world-class scientific laboratory centered around a high-intensity, continuous wave electron beam, which provides a unique capability for nuclear physics research. The lab is managed for the Department of Energy by Jefferson Sciences Associates.

Jefferson Lab is currently seeking exceptional candidates for an SRF accelerator scientist position to provide support to all ongoing SRF institute activities as required by the institute directorate, which may include operational support of CEBAF and the FEL, cavity and cryomodule R&D and production. The incumbent will be expected to take the initiative in solving complex problems, lead small multi-disciplinary teams and prepare reliable budgets and schedules for new activities. The incumbent is expected to lead the analysis and development of new or improved SRF accelerating structures for particular needs, explore and develop new and improved superconducting RF surface preparation techniques for optimized performance and reliability, and perform general SRF analysis.

MINIMUM QUALIFICATIONS

PhD. in Physics or an appropriate discipline and seven years relevant experience. Must have direct experience designing, constructing, processing, and testing niobium superconducting cavities for accelerator applications. Experience with RF characterization of SRF structures via both bench measurements and state-of-the-art simulation software required. Demonstrated track record of successful completion of projects desired. Experience designing, constructing, debugging, and commissioning integrated SRF cavity/cryomodule systems for accelerator use is highly desirable, with some experience of SRF accelerator construction, commissioning or operations. Visual acuity sufficient to use RF design software, operate test equipment and perform bench experiments.

For prompt consideration, apply on-line at: **www.jlab.org/jobline**

An Equal Opportunity/Affirmative Action Employer

Staff Physicist - Accelerator Physics

The Stanford Linear Accelerator Center (SLAC) is seeking an experienced Staff Physicist to work in the Beam Physics Department. SLAC's research program covers a wide range of accelerator physics as applied to linear colliders, storage rings, synchrotron radiation and free electron laser devices. In this position, the candidate will participate in many of these research activities concerning accelerator lattice design and linear and nonlinear single-particle dynamics. A Ph.D. or equivalent is required. Qualifications include experience in accelerator lattice design, demonstrated knowledge in accelerator linear and nonlinear dynamics, proficiency in scientific programming and numerical modeling/simulation.

Applicants should send a letter, a brief summary of accomplishments, a curriculum vitae and a list of publications to Professor Alex Chao, Mail Stop 26, Stanford Linear Accelerator Center, P.O. Box 20450, Stanford, CA 94309, USA, or by e-mail to **achao@slac.stanford.edu**. Three letters of recommendation should also be sent. All materials should be received on or before August 31, 2006.

STANFORD LINEAR ACCELERATOR CENTER

Stanford University is an Affirmative Action/Equal Opportunity Employer.

INFN Istituto Nazionale di Fisica Nucleare

POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS

IN THE FOLLOWING RESEARCH AREAS
THEORETICAL PHYSICS (N. 10)
EXPERIMENTAL PHYSICS (N. 20)

The INFN Fellowship Programme 2006-2007 offers 30 (thirty) positions for non Italian citizens for research activity in theoretical or experimental physics.

Fellowships are intended for young post-graduates who are under 35 years of age by October 20, 2006.

Each fellowship, initially, is granted for one year and then, may be extended for a second year.

The annual gross salary is EURO 28.000,00.

Round trip travel expenses from home country to the INFN Section or Laboratory will be reimbursed, also lunch tickets will be provided for working days.

Candidates should submit their application form, a statement of their research interests and enclose three reference letters.

Candidates should choose at least two of the following INFN sites, indicating their order of preference.

- INFN Laboratories:
  Laboratori Nazionali di Legnaro (Padova), Laboratori Nazionali del Gran Sasso (L'Aquila), Laboratori Nazionali del Sud (Catania), Laboratori Nazionali di Frascati (Roma);
- INFN Sections in the universities of:
  Torino, Milano, Padova, Genova, Bologna, Pisa, Napoli, Catania, Trieste, Firenze, Bari, Pavia, Cagliari, Ferrara, Lecce, Perugia, Roma "La Sapienza", Roma "Tor Vergata", "Roma Tre".

The research programs, must be focused on the research fields of the Section or Laboratory selected (http://www.infn.it).

Applications must be sent to the INFN no later than October 20, 2006.

Candidates will be informed by May 2007 about the decisions taken by the INFN selection committee.

Fellowships must start from September to December 2007. Requests for starting earlier accepted.

Information, requests for application forms, and applications should be addressed to Istituto Nazionale di Fisica Nucleare, Direzione Affari del Personale, Ufficio Borse di Studio - Casella Postale 56 - 00044 Frascati (Roma) Italia.

ISTITUTO NAZIONALE DI FISICA NUCLEARE
IL PRESIDENTE
(Prof. Roberto Petronzio)

Indiana University Cyclotron Facility

is seeking to fill the following positions:

Mechanical Engineering Division Head #000019699
RF Electrical Engineering Specialist #00023003
Electronic Engineer Position # 00007577
Electrical Engineer, DC Power Control, AC Distribution Position # 00014901
Director of Operations #00029110
Controls Specialist-High Speed Data Acquisition # 00030122
Operations and Maintenance Manager #00028744

Indiana University Cyclotron Facility (IUCF) is a growing accelerator based facility with an operating proton therapy clinic (MPRI), a Low Energy pulsed Neutron Source (LENS), a Radiation Effects Research Program (RERP) and thriving nuclear physics and material science research groups.

Indiana University is an Equal Opportunity Affirmative Action Employer.
For more information about these and other positions at IUCF browse to:

http://www.iucf.indiana.edu/jobs/

UNIVERSITY OF ROCHESTER

TENURE TRACK FACULTY POSITION IN EXPERIMENTAL PARTICLE PHYSICS

University of Rochester
Department of Physics and Astronomy

The Department of Physics and Astronomy at the University of Rochester invites applications for a tenure-track position in experimental particle physics, with the appointment to begin on
July 1, 2007 or earlier. Appointments at higher levels might be considered based on the applicant's qualifications.

We seek outstanding candidates to either strengthen or complement our current activities in experimental particle physics, which include programs within the CDF, D0, CLEO, Minerva and CMS (LHC) experiments.

The successful candidate is expected to initiate an independent research program, either within these collaborations, or in experiments not currently pursued by Rochester faculty. Candidates should have outstanding records in research, and strong commitments to excellence in undergraduate and graduate teaching. To ensure full consideration, applications should be received before November 1, 2006.

Salary will be competitive, and applications from women and members of underrepresented minority groups are encouraged. Applicants should submit a curriculum vitae, a list of publications, and a description of their proposed research, and should arrange for at least five letters of recommendation to be sent to:

Professor Arie Bodek, Chair, Department of Physics and Astronomy, University of Rochester, Rochester, New York 14627-0171, USA

Applications may also be submitted by email sent to shirl@pas.rochester.edu with the subject line
"HEP faculty position."

The University of Rochester is an equal opportunity/affirmative action employer and encourages applicants from members of minority groups and women All applications are considered without regard to race, sex, age, religion or national origin.

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

The U.S. Department of Energy
Office of Science
Office of Nuclear Physics, Facilities & Project Management
is recruiting for a
Physicist, GS-1310-15
with the salary range from $107,521.00 to 139,774.00

This position is located in Germantown, Maryland. The incumbent of this position serves as a recognized scientific authority and expert in the area of instrumentation in nuclear physics program maintaining a high level of knowledge of the status of instrumentation in nuclear physics research, and as such has the responsibility to plan, coordinate, implement, and evaluate research programs and projects in this field on a national and international level.

Submit a narrative statement responding to the knowledge, skills and abilities (KSAs) identified in the announcement. This information will be used to determine your eligibility and/or rating and is required.

For more detailed information on this position and filing instructions, please go to the website: **http://jobsearch.usajobs.opm.gov** At this website you can do a search by job (Physicist) or by agency (Department of Energy). The announcement number is 06PN-SC26-001, and closes August 16, 2006.

You must be a U.S. citizen to qualify for this position

Mail your applications so it will be postmarked by closing date (August 16, 2006). If hand delivered, be sure your application is received by closing date.

Universität Karlsruhe (TH)

Forschungsuniversität · gegründet 1825

The **Centre for Elementary Particle Physics and Astroparticle Physics CETA** has an open position for one

Postdoc in Astroparticle Physics: The KASCADE-Grande experiment

The interdisciplinary research center CETA in Karlsruhe includes about 150 scientists at Karlsruhe University and Forschungszentrum Karlsruhe. We take leading positions in particle phenomenology, collider experiments, the German center for grid computing GridKa, and in an extensive astroparticle physics programme to which this announcement is directed.

Our main activities are the study of galactic and extra-galactic cosmic rays with the KASCADE-Grande detector and the Pierre Auger Observatory, the investigation of the absolute neutrino mass scale with the Karlsruhe Tritium Neutrino Experiment KATRIN, and the search for dark matter with the EDELWEISS-2 detector.

We are now seeking an excellent scientist to work in the international KASCADE-Grande team, starting from September/October 2006. The main task will be the development of a multi-parameter analysis of the KASCADE-Grande data to unfold the composition and energy spectra of primary particles and the interpretation of results within astrophysical models.

Applicants must have a PhD or comparable degree in particle/astroparticle physics or astrophysics. We expect experience in software development and advanced analysis methods. Successful candidates will participate in teaching at Karlsruhe University.

The position is based at Karlsruhe University for a renewable two-year term; the salary corresponds to the German BAT IIa grade.

The working place will be at Forschungszentrum Karlsruhe. More details can be found at the internet addresses **http://www-ik.fzk.de/ik/jobs/d_stellen.html** (deutsch) or **http://www-ik.fzk.de/ik/jobs/e_stellen.html** (english).

Both institutions are equal opportunity employers and encourage applications from women. Handicapped applicants will be preferred if equally qualified.

The application must include a statement of research interests and experience, the curriculum vitae, a publication list and the name and addresses of two referees. Internet links to download recent publications will be appreciated. Please send **till end of August, 2006 one single email attachment in Adobe PDF Format to ik-sekretariat@ik.fzk.de or by mail to Professor Johannes Blümer, Institut für Kernphysik, Forschungszentrum Karlsruhe, Postfach 3640, D-76021 Karlsruhe.**

acqiris

YOUR STANDARD
FOR DATA CONVERSION

Acqiris is a Swiss company founded in 1998 by a group of dynamic individuals with extensive experience in the electronic test and measurement markets. We specialize in the development, design, and manufacture of high-speed and high-precision digitizers (8GS/s).
Since the introduction of its first products in 1999, Acqiris has entered market segments ranging from fundamental research to product development at laboratories, universities, industry, and OEMs.
As our customer base continues to grow, so does the demand for our expertise.
This creates an immediate opening in our Geneva headquarters for a

Analog Design Group Leader

. Enthusiasm for driving a small dynamic group of analog designers
· Higher degree in Electronic Engineering or equivalent
. Ability to generate new and innovative ideas
. Experience with analog RF hardware design (ADS software)
· Experience in high-resolution electronics would be an advantage
· Fluent in French and English

You are expected to become the reference for analog design questions and be in charge of achieving the design goals of the group.

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

Acqiris (Suisse) SA - Human Resources
18, chemin des Aulx CH-1228 Plan-les-Ouates-Switzerland
Email: human.resources@acqiris.com

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

GSI Darmstadt, member of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren e.V., is world-wide a leading research facility in the field of nuclear and atomic physics.

A new facility for antiprotons and ion research (FAIR) is planned together with international partners. Key instruments for the research are the new accelerators: two superconducting rapid cycling synchrotrons, two rings for accumulation of rare ions and antiprotons and two storage rings. High intensity beams, phase space cooled, of antiproton to Uranium will open fascinating research in nuclear structure and astrophysics, physics of dense plasma and atomic physics.

We are looking for several

Accelerator Physicists (Ph.D.)

Ref: 5000-06

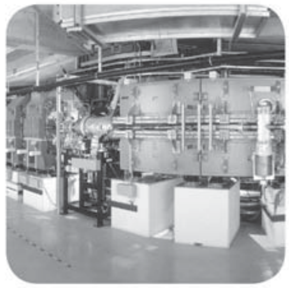
The job profile covers: development of optical layout, development of prototypes and specification of hardware components for synchrotrons and storage rings; project management and quality control in industry and together with our international partner institutes. You are an expert in accelerator physics. Further you have experience in the design and operation of accelerator components as magnets, RF cavities, cryogenics or pulsed power systems, than you should join the FAIR team.

The positions are limited to 3 years with the possibility of conversion into an unlimited contract. Salary and benefits are commensurate with German public service organisations. GSI is an equal opportunity, affirmative action employer and encourages applications from women. Handicapped applicants will be treated preferentially if equal qualified.

For further information, please contact Dr. P. Spiller,
tel.: +49 6159 71 2405.

Please send your complete application by indicating the reference code to our personnel department not later than **July 28th 2006** to:

GSI Darmstadt



Gesellschaft für Schwerionenforschung mbH
Personalabteilung
Ref.No. 5000-06
Planckstraße 1
64291 DARMSTADT
GERMANY

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

Max-Planck-Institute for Nuclear Physics
Attn. Prof. C. H. Keitel
Postfach 10 39 80
D-69029 Heidelberg
Germany
www.mpi-hd.mpg.de

Max-Planck-Institut für Kernphysik

MAX-PLANCK-GESELLSCHAFT

The Max-Planck-Institute for Nuclear Physics in Heidelberg, Germany, seeks applications for a

director position (W3)

in the area of Experimental Many-body Dynamics of Atoms and Molecules.

This includes high-precision experiments and quantum dynamics in storage rings and/or traps, strong laser-matter interaction and atmospheric molecular physics. We expect the successful candidate to develop collaborations within the institute and to build up research directions which are sufficiently distinct to those currently persued at the Max-Planck-Society.

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

Applications including curriculum vitae, a list of publications, 5 sample reprints and a brief outline of research plans at our institute are invited to be addressed within 6 weeks after posting to Prof. C. H. Keitel, chair of the Directorate.

The International Helmholtz Graduate School, funded by the Initiative and Networking Fund of the Helmholtz Association together with the

FIAS Frankfurt Institute for Advanced Studies

- *Frankfurt Institute for Advanced Studies (FIAS), Frankfurt,*

GSI

- *Gesellschaft für Schwerionenforschung mbH (GSI), Darmstadt,*

JOHANN WOLFGANG GOETHE UNIVERSITÄT FRANKFURT AM MAIN

- *Physics Department of the Johann Wolfgang Goethe University, Frankfurt,*

invites applications for

Ph.D. fellowships.

Up to 25 fellowships will be available for PhD students in the fields of experimental and theoretical physics. The research topics will be devoted to the physics of states of strongly interacting matter in the universe probed by relativistic heavy-ion collisions. Experimental and theoretical investigations of nucleus-nucleus collisions at high energy at the Large Hadron Collider LHC at the European Organization for Nuclear Research, CERN, in Geneva, will be an important subtopic of the Helmholtz Graduate School.

The Helmholtz Graduate School performs internationally oriented scientific research and graduate training at the highest level in heavy-ion and hadron physics at both the ALICE program at CERN's Large Hadron Collider, LHC, and at the future International Facility for Antiproton and Ion Research, FAIR, at GSI. Details on the Helmholtz Graduate School and its partners are available at **http://www.fias.uni-frankfurt.de/helmholtz**. The primary language of the Helmholtz Graduate School is English.

The fellowships in the PhD program are granted for a period of three years, which corresponds to the anticipated duration of the PhD work. The Helmholtz Graduate School will open September 2006.

Applicants with a solid education in experimental and theoretical nuclear physics holding a Masters degree in physics or equivalent (e.g. german "physics diploma" or french "DEA") with excellent grades are invited to send their curriculum vitae, list of publications, copy of their theses, past and present research interests, copies of masters/diploma certificates, and two letters of reference to:

Prof. Dr. Harald Appelshäuser
Director, Helmholtz Graduate School
Johann Wolfgang Goethe University
Max von Laue Str. 1
D-60438 Frankfurt am Main
Germany

or by electronic mail to: **appels@ikf.uni-frankfurt.de**. Women are especially encouraged to apply.

Electronic Engineer 4

Lawrence Berkeley National Laboratory (LBNL) is located in the San Francisco Bay Area on a 200-acre site in the hills above the University of California's Berkeley campus and is managed by the University. A leader in science and engineering research for more than 70 years, Berkeley Lab is the oldest of the U.S. Department of Energy's National Laboratories.

POSITION SUMMARY: The LBNL Engineering Division is seeking an **Accelerator Electronics Engineer** to join the Instrumentation section of the Advanced Light Source (ALS) Electrical Engineering (EE) Group.

DUTIES: The candidate must act independently on a broad range of electrical engineering projects of significant scope with responsibility for cost, schedule, design, and implementation. He/she will apply electronic engineering design expertise on a fully independent basis to meet the broadly based accelerator electronics requirements of the ALS. The candidate will interact with accelerator and beamline scientists effectively on a day-to-day basis to meet the systems needs of the scientific and accelerator physics programs.

QUALIFICATIONS: A B.S. degree or equivalent in Electrical Engineering is required. The candidate must possess significant design and hands-on expertise in one or more of the following areas: high-power DC magnet power supplies, high voltage ultra-high stability power supplies, accelerator timing systems, beam position monitor systems, DC beam current monitors, DCCT current monitors, stepper and servo motor control technology, and pulsed power techniques. It is essential that the candidate have broad knowledge in electrical engineering with demonstrated analog and digital circuit design and documentation skills including proficiency with modern computer aided design packages. Experience with general interfacing, control, and data acquisition techniques is necessary, as is demonstrated ability to work effectively in a team environment.

For fastest consideration, apply online at: **http://jobs.lbl.gov**, select "Search Jobs", and enter **018633** in the keyword search field. Enter "CERN Courier" as your source.

LBNL is an Affirmative Action/Equal Opportunity Employer committed to the development of a diverse workforce.

For more information about LBNL and its programs, visit **http:www.lbl.gov**.

BERKELEY LAB

GSI, the German National Laboratory for Heavy Ion Research, member institute of the Hermann von Helmholtz Association of German Research Centres, invites applications for the position of

Leading Scientist for Experimental Nuclear Physics

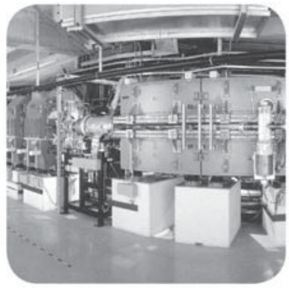
(Nuclear Structure and Reactions)

The successful candidate will be expected to develop a leading research program in the use of radioactive beams, lead experimental groups at GSI, and maintain and enhance the cooperation with German and foreign universities and research institutions.
The present research program of the experimental groups concerns reaction experiments with high-energy beams of unstable nuclei, focussing on nuclear structure, reaction dynamics and on nuclear astrophysics. GSI operates a facility for secondary beams of nuclei far away from stability and offers a wide spectrum of experimental possibilities with an advanced setup for external-target reactions and with a storage/cooler ring. The future accelerator facility FAIR (International Facility for Antiproton and Ion Research) at GSI will open unprecedented opportunities for nuclear structure experiments with new concepts and advanced technologies.

The position is a permanent one; the function of a Leading Scientist is initially for a five year term but may be extended. Salary will be commensurate with responsibilities. GSI's policy foresees the advancement of women in the scientific field and qualified women are encouraged to apply. Persons with disabilities will be given preference over other candidates with comparable qualifications.

Applications with curriculum vitae, list of publications, statements on teaching and research experience, and a brief outline of a research plan should be submitted by **August 15th 2006** to

GSI Darmstadt



Prof. Dr. W. F. Henning
Wissenschaftlicher Geschäftsführer
Gesellschaft für Schwerionenforschung mbH
Planckstraße 1
64291 Darmstadt/GERMANY

Max-Planck-Institut für Kernphysik

MAX-PLANCK-GESELLSCHAFT

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

We invite applications for a

W2 – Research Group Leader

(former C3 – Research Group Leader)

The Max-Planck-Institut für Kernphysik in Heidelberg, Germany, is seeking a young, experienced theoretical physicist with her/his main interests in the area of complex quantum dynamics. Favourable would be the interaction of complex atomic systems such as especially molecules or plasmas with laser fields, attosecond quantum dynamics and nuclear and/or high-energy reactions via very strong external fields.

The W2 appointment (succeeding the former C3 position) is limited to five years. The person is expected to build and lead an independent research group to obtain funding and to closely interact with other groups at the institute and the university. The initial appointment will be for two years with a possible extension for further three years. The candidate should have a PHD in physics, a "Habilitation" or a similarly adequate qualification and international reputation in laser physics. We provide excellent working conditions, an inspiring surrounding as well as intense exchange of ideas with the other groups in the division.

At equal level of qualification, candidates with disabilities are given preference. Women are encouraged to apply. Application with full CV, publication list and names and addresses of three referees should be sent to Prof. Dr. Christoph H. Keitel, Director at the institute (E-Mail: keitel@mpi-hd.mp.de, www.mpi-hd.mpg.de/keitel).

Max-Planck-Institut für Kernphysik
Attn. Prof. Dr. C. H. Keitel
Postfach 10 39 80
D-69029 Heidelberg
Germany
www.mpi-hd.mpg.de

CERN COURIER

The classified advertising section in *CERN Courier* is the perfect platform to promote important announcements including:

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E-mail: kathryn.zerboni@iop.org

US and ROW – Adam Hylands
Tel: +44 (0)117 930 1027
E-mail: adam.hylands@iop.org

UNIVERSITY OF OXFORD

Mathematical, Physical & Life Sciences Division
Department of Physics in association with Merton College & Hertford College

University Lecturerships in Experimental Particle Physics

Salary scale: up to £49,116 p.a. (under review)

Applications are invited for two University Lecturerships in the field of experimental particle physics. These are permanent posts (equivalent to Assistant Professorships) associated with Tutorial Fellowships at the above Colleges, under arrangements described in the further particulars.

The first position will be in the area of LHC physics using the ATLAS experiment; the second will be in the area of cryogenic experiments in the CRESST/CryoEDM group. You will be expected to play an important role in the Oxford effort in these areas, in both of which the Oxford groups have leading roles. The posts are available from 1st January 2007 and it is hoped that you will be able to take up the positions as soon as possible thereafter. Questions may be addressed to Prof. B Foster, Head of the Subdepartment of Particle Physics, b.foster@physics.ox.ac.uk

Further particulars of these posts and information on how to apply are available on http://www.physics.ox.ac.uk/pp/jobs/atlas-lect-fp.htm and http://www.physics.ox.ac.uk/pp/jobs/cresst-lect-fp.htm or from Mrs. Sue Geddes, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, UK, e-mail: s.geddes@physics.ox.ac.uk fax 0044 (0)1865 273417. The application deadline is 18th September 2006. It is intended to hold interviews on 23rd October 2006 (ATLAS) and 13th October 2006 (CRESST/CryoEDM). Candidates should keep the appropriate date free.

The University is an Equal Opportunities Employer.

www.ox.ac.uk/jobs

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Lawrence Berkeley National Laboratory.

Current online announcements on physicsweb

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UKAS
University of Sheffield
University of Strathclyde - Institute of Photonics
University of Wisconsin-Madison -IceCube

Institute *of* **Physics** PUBLISHING

Mechanical Engineers

Lawrence Berkeley National Laboratory (LBNL) is located in the San Francisco Bay Area on a 200-acre site in the hills above the University of California's Berkeley campus and is managed by the University. A leader in science and engineering research for more than 70 years, LBNL is the oldest of the U.S. Department of Energy's National Laboratories. We are currently seeking Mechanical Engineers to join our team.

Mechanical Engineers - 018920, 018973
POSITION SUMMARY: LBNL is looking for highly capable, experienced mechanical engineer/engineering scientists with a desire to work in an applied R&D National laboratory environment, using a broad array of analytical, computational, experimental, instrumentation, and hardware design skills to facilitate solving complex engineering programs of national importance within the Department of Energy complex. The positions provide opportunity for exposure to a wide variety of R&D programs and projects

QUALIFICATIONS: A B.S. or M.S. in Mechanical Engineering, Engineering Science, or a related field, or equivalent experience is required. A Ph.D. is preferred.

Accelerator Mechanical Engineer 5 - 018655
POSITION SUMMARY: LBNL seeks a highly capable Accelerator Engineer to work in an applied R&D National Laboratory environment. We seek an experienced Mechanical Engineer/Engineering Scientist with a broad array of accelerator engineering and physics core skills, including hardware design, vacuum systems, optics, cryogenics, and radiation safety, coupled with proven organizational, managerial, communication, and leadership abilities to facilitate operation and maintenance of the Advanced Light Source, a National Synchrotron User Facility. The position provides opportunity for exposure to a wide variety of R&D programs and projects.

QUALIFICATIONS: A B.S. in Mechanical Engineering, Engineering Science, Physics or equivalent knowledge and experience in a related field is required. Professional mechanical engineering experience is required.

NOTE: These are two to three-year term appointments with possible opportunities for a career appointment, contingent upon satisfactory performance, continued availability of work, and funding.

FOR MORE DETAILED INFORMATION ON EACH OF THESE POSITIONS PLEASE GO TO: http://jobs.lbl.gov . Go to "Search Jobs", and enter the appropriate job number in the keyword search field. To apply online, select the "Upload Your Resume" option, and follow the on-line instructions to complete the application process. As part of the online application process, please submit a single attachment that includes both your resume or CV and a statement of your research interests or cover letter. Be sure to indicate "CERN Courier" as your source. Feel free to apply to other posted positions that match your interest and skills.

Berkeley Lab is an Affirmative Action/Equal Opportunity Employer committed to the development of a diverse workforce.

BERKELEY LAB

cerncourier.com

BOSTON, MA 2006 MRS FALL MEETING
NOVEMBER 27 - DECEMBER 1

2006 MRS FALL MEETING

www.mrs.org/fall2006/

Meeting Chairs:

Babu R. Chalamala
Indocel Technologies, Inc.
Tel 919-244-1040
Fax 888-853-4407
chalamala@indocel.net

Louis J. Terminello
Lawrence Livermore National Laboratory
Tel 925-423-7956
Fax 925-422-0029
terminello1@llnl.gov

Helena Van Swygenhoven
Paul Scherrer Institute
Tel 41-56-310-2931
Fax 41-56-310-3131
helena.vs@psi.ch

For additional meeting information, visit the MRS Web site at

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SYMPOSIA

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F: Integrated Nanosensors
G: Fibrillar Aggregates as Materials—Assembly, Properties, and Applications
H: Biofilm-Material Interactions—New Tools, Technologies, and Opportunities

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K: Zinc Oxide and Related Materials
L: Group IV Semiconductor Nanostructures
M: Quantum Dots—Growth, Behavior, and Applications
N: Self Assembly of Nanostructures Aided by Ion- or Photon-Beam Irradiation—Fundamentals and Applications
O: Nanostructured and Patterned Materials for Information Storage
P: Nanoscale Magnets—Synthesis, Self-Assembly, Properties, and Applications
Q: Nanowires and Carbon Nanotubes—Science and Applications
R: Meta-Materials at the Milli-, Micro-, and Nanoscale
S: Organic Electronics—Materials, Devices, and Applications
T: Ferroelectrics and Multiferroics
U: Advances in *In Situ* Characterization of Film Growth and Interface Processes
V: Advanced Electronic Packaging
W: Heterogeneous Integration of Materials for Passive Components and Smart Systems
Y: Enabling Technologies for 3-D Integration

ENERGY STORAGE AND UTILIZATION

Z: Hydrogen Storage Technologies
AA: Solid-State Ionics
BB: Mobile Energy
CC: Solar Energy Conversion

MICROSTRUCTURE, MECHANICS, AND MODELING

DD: Mechanics of Biological and Bio-Inspired Materials
EE: Size Effects in the Deformation of Materials—Experiments and Modeling
FF: Processing-Structure-Mechanical Property Relations in Composite Materials
GG: Multiscale Modeling of Materials
HH: Thermodynamics and Kinetics of Phase Transformations in Inorganic Materials
II: Advanced Intermetallic-Based Alloys
JJ: Structural and Refractory Materials for Fusion and Fission Technologies

CHARACTERIZATION TOOLS AND TECHNIQUES

KK: Electron Microscopy Across Hard and Soft Materials
LL: Focused Ion Beams for Analysis and Processing
MM: Magnetic Resonance in Material Science

GENERAL INTEREST

X: Frontiers of Materials Research
NN: Scientific Basis for Nuclear Waste Management XXX
OO: Actinides—Basic Science, Applications, and Technology
PP: Materials Research at High Pressure
QQ: Solid-State Chemistry of Inorganic Materials VI

MEETING ACTIVITIES

SYMPOSIUM TUTORIAL PROGRAM

Available only to meeting registrants, the symposium tutorials will concentrate on new, rapidly breaking areas of research.

EXHIBIT

A major exhibit encompassing the full spectrum of equipment, instrumentation, products, software, publications, and services is scheduled for November 28–30 in the Hynes Convention Center. Convenient to the technical session rooms and scheduled to complement the program, the MRS Fall Exhibit offers everything you need all under one roof.

PUBLICATIONS DESK

A full display of over 915 books will be available at the MRS Publications Desk.

STUDENT OPPORTUNITIES

Graduate students planning to attend the 2006 MRS Fall Meeting are encouraged to apply for a Symposium Assistant position and/or a Graduate Student Award.

CAREER CENTER

A Career Center for MRS members and meeting attendees will be open Tuesday through Thursday.

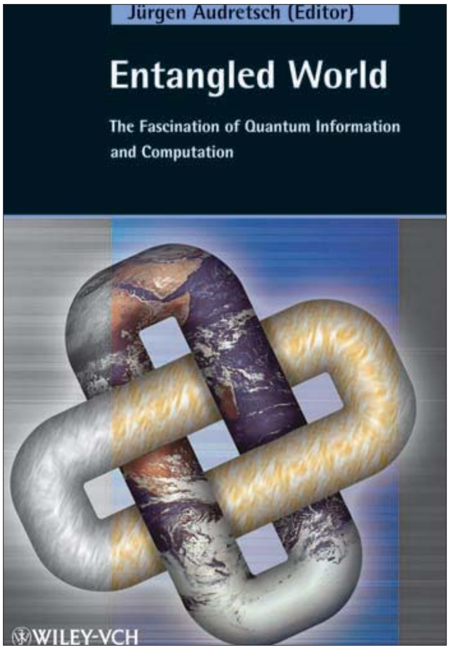
The 2006 MRS Fall Meeting will serve as a key forum for discussion of interdisciplinary leading-edge materials research from around the world.

Various meeting formats—oral, poster, round-table, forum and workshop sessions—are offered to maximize participation.

BOOKSHELF

Summer Bookshelf

Summer for physicists is the season of conferences as well as (or instead of!) well-earned holidays, perhaps providing more time for reading about topics away from mainstream particle physics. In this Bookshelf, some of our regular contributors review a selection of less-technical books for dipping into on the beach or on long plane journeys.



Entangled World. The Fascination of Quantum Information and Computing by Jürgen Audretsch (ed.), Wiley-VCH. Hardback ISBN 3527404708, £22.50 ($33.80).

Entangled World is a 2006 English translation of "*Verschränkte Welt – Faszination de Quanten*" (2002). Based on lectures about "physics and philosophy of correlated quantum systems" given at the University of Konstanz in the winter semester of 2000/2001, it presents a clear and simple overview of quantum mechanics and its applications (especially via entanglement) to novel technologies like quantum computing.

The lectures in the book are written in a clear and informal style, but are aimed at a level that is too high for an average non-physicist and too low for a practising physicist. Given that they are based on university lectures, this is perhaps not surprising and this book might best be thought of as supplementary reading for a proper quantum mechanics course.

For example, bra and ket notation are introduced, but you'd have to know what vectors and complex numbers are to follow the explanation. A discussion of Bell's inequality assumes that the reader knows what a probability density is, as well as what an integral means. Those who do not have a background in mathematics or physics would probably still find this an interesting read, but they would have to be willing to skip over many of the details; finding a simpler book might be a better idea for them.

A practising physicist who has not had time to keep up with recent advances in quantum computation and other fields dealing with quantum information may well find sections of this book useful as quick and painless introductions to emerging quantum technologies – ones that genuinely go beyond the possibilities offered by an arbitrarily large amount of classical hardware. Those with a philosophical bent are likely to find much of interest, as there is a fair amount of historical information and interesting quotes with emphasis on the thoughts of physicists rather than professional philosophers.

Although the lectures are by a number of different authors, the book flows well and the notation is consistent. With the slightly rough translation, one could easily think that this was written by a single author.

With respect to the translation, I am aware that it is all but impossible for anyone who is not a native speaker to make a perfectly smooth translation and in many ways the translation is quite good. That said, a final pass by a native English speaker would have been useful. The same criticism could be levelled at many publishers, but it doesn't seem unreasonable to ask for the same level of editing that goes into a book originally written in English. Even the short description of the book at www.wiley.com/WileyCDA/WileyTitle/productCd-3527404708.html is written in rather poor English. Come on publishers – there is no shortage of underpaid physicists who would make small corrections to translated texts for you!

Overall, I like the layout. Numerous illustrations help to make the text clear, and Erich Joos' chapter on decoherence has the useful feature of separating out material "for physicists" into shaded boxes, much as *New Scientist* used to do many years ago, so that a popular article could include a piece of higher-level information without disturbing the overall flow of the text. This has always seemed a great idea to me and I wish that it would come back into vogue.

A few interesting points are raised that would even be of interest to a relatively advanced physics student, especially with respect to decoherence, which receives little treatment, if at all, in most of the classic textbooks. Another noteworthy feature of this book is the inclusion of experimental information in the form of plots and sketches of how pieces of equipment are put together.

All in all the book has much to offer and is reasonably priced, but one should be aware of the level at which it is pitched.

John Swain, Northeastern University,

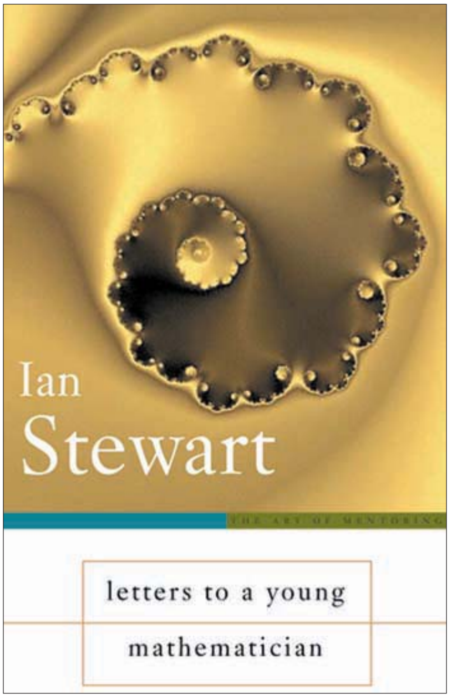
Letters to a Young Mathematician. The Art of Mentoring by Ian Stewart, Basic Books. Hardback ISBN 0465082319 £13.99 ($22.95).

"Our society consumes an awful lot of mathematics, but it all happens behind the scenes [...] You want your car navigation system to give you directions without your having to do the math yourself. You want your phone to work without your having to understand signal processing and error-connecting codes."

Letters to a Young Mathematician is a collection of letters addressed to "Meg", an imaginary young girl who already shows interest in mathematics at high school. The author follows Meg until university, gives her advice, talks to her about mathematics and its relation to society, family, work and careers. In this way, the reader learns more about the *raison d'être* of mathematics, its applications in our everyday life, its past, present and future.

I particularly liked the first half of the book in which the author talks about himself, his personal experience and his motivations for becoming a mathematician. In these first letters, the reader can really feel the author's enthusiasm and share with him the wonder of discovering mathematics everywhere, for example in the way roads are designed, in the sea's waves or in the colours that we see.

The narration then becomes more abstract and therefore less close to the reader. Here references to mathematicians of the past replace too often the personal experience of



the author and this makes the reading slower.

However, it never goes too far and links with real life can be found throughout the book. Often this is done by demonstrating how apparently abstract mathematical formulae are used in physics and hence in technology or computing.

The book is inspiring and full of interesting information without being boring. I wish a similar collection of letters could be written to a young physicist!

Antonella del Rosso, CERN.

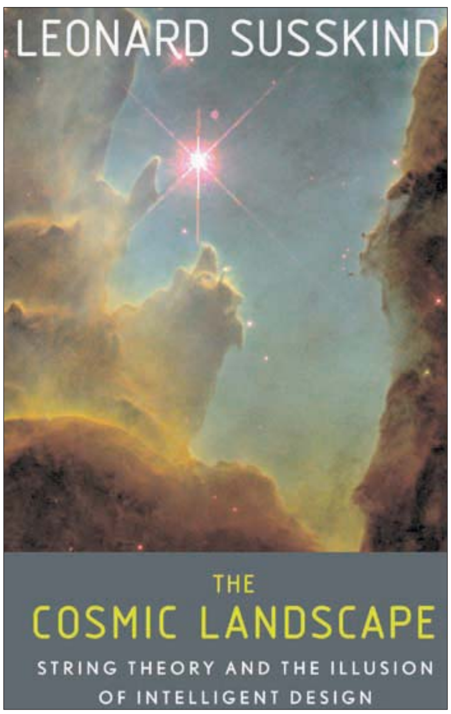
The Cosmic Landscape. String Theory and the Illusion of Intelligent Design by Leonard Susskind, Little Brown and Company. Hardback ISBN 0316155799, $24.95.

In some theoretical physics institutes, uttering the words "cosmic landscape" may give you the feeling of walking into a lion's den. Leonard Susskind courageously takes upon himself the task of educating the general public on a very controversial subject – the scientific view on the notion of intelligent design. The ancestral questions of "Why are we here?", "Why is the universe hospitable to life as we know it?" and "What is the meaning of the universe?", are earnestly addressed from an original point of view.

Darwin taught us that, according to the theory of evolution, our existence in itself has no special meaning; we are the consequence of random mutation and selection, or survival of the fittest. This is a baffling turn of the Copernican screw, which puts us even farther away from the centre of the universe. We live in the age of bacteria and we are nothing but part of the tail in the distribution of possible living organisms here on Earth.

A possible counter to this reasoning is the notion of a benevolent intelligence that designed the laws of nature so that our existence would be possible. According to Susskind, this is a mirage. Using current versions of string theory and cosmology he provides yet another turn of the Copernican screw. A good aphorism for this book can be found on p347 – the basic organizing principle of biology and cosmology is "a landscape of possibilities populated by a megaverse of actualities". This may sound arcane, but the book gives a consistent picture based on recent scientific results that support this view. This is no paradigm shift, but an intellectual earthquake.

The author masterfully avoids the temptation to give a detailed account of our understanding of particle physics and cosmology. Instead, he provides an impressionistic, but more than adequate, description of the theories that have inspired us over the past 30 years, some verified experimentally (such as the Standard Model) and some more speculative (such as string theory). A more accurate description may have kept many readers away from the book, yet enough information is given to grasp the gist of the argument.



The main theme is the understanding of the cosmological constant – Albert Einstein's brainchild, which later he called the biggest blunder of his life – the numerical value of which has been measured by recent astronomical observations. The numerical value of the universal repulsion force represented by this constant simply boggles the imagination. In natural units (Planckian units, as explained in the book) it is a zero, followed by 119 zeroes after the decimal point and then a one. Fine-tuning at this level cannot be explained by any symmetry or any other known argument. It is 120 orders of magnitude, something to make strong men quail.

We can appeal to the anthropic principle, but this is often taken as synonymous with the theory of intelligent design. Susskind avoids this temptation by turning to our best bet yet to unify, or rather make compatible, quantum mechanics and general relativity – string theory. Work from Bousso Polchinski and others implies that string theory contains a bewildering variety of possible ground states for the universe. In recent counts, the number is a one followed by 500 zeroes – a nearly unimaginably big number – and most of these universes are not hospitable to bacteria or us. However, the number is so big that it could perfectly accommodate some pockets where life as we know it is possible. No need then to fine-tune; the range of possibilities is so large that all we need is a procedure efficient enough to turn possibilities into actualities.

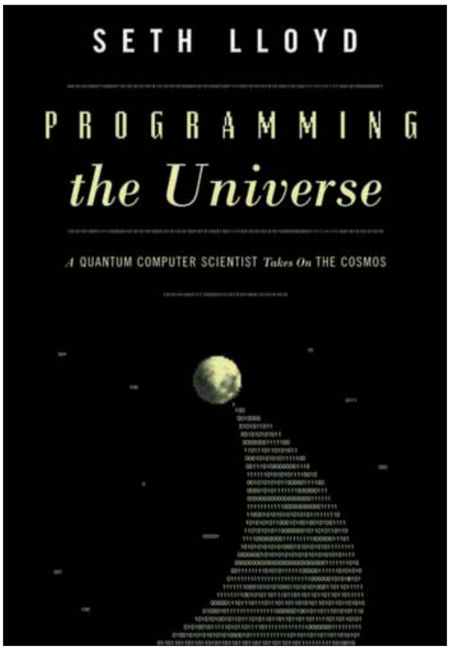
This is the megaverse provided by eternal inflation. The laws of physics allow for a universe far bigger than we have imagined so far and as it evolves it creates different branches, which among other properties contain different laws of physics, sometimes those that allow our existence.

This is radical, hard to swallow, and against all the myths that the properties of our observed and observable universe can be calculated by an ultimate theory from very few inputs – but it is remarkably consistent.

The topics analysed in this book are deep – it deals with many of the questions that humans have posed for millennia. It is refreshing to find a hard-nosed scientist coming out to address such controversial questions in the public glare, without fearing the religious or philosophical groups (or even worse, his colleagues), who for quite some time have monopolized the discussion.

Despite the difficult questions raised, when unfamiliar concepts are introduced, one finds a humorous punctuation based on the author's personal experience, which lets you recover your breath. Some will find the arguments convincing, some will find them irritating, but few will remain indifferent.
Luis Alvarez-Gaume, CERN.

Programming the Universe: A Quantum Computer Scientist Takes on the Cosmos by Seth Lloyd, Alfred A Knopf. Hardback ISBN 1400040922, $25.95.



I borrowed this book from my local library a couple of months ago and found it so irritating that I gave up after the first few chapters. When I agreed to review it I decided that I'd better read it a little more thoroughly – amazingly, this time I really enjoyed it.

Some of the anecdotes and name-dropping are rather annoying and I'm not sure that I can embrace the central thesis – that our universe is a giant quantum computer (QC) computing itself. (I would have thought that the inherent randomness of things argues against the universe as computer.) However, the book does contain an unusually informative and quirky account of the theory of our surroundings, from small to large, and it is very entertaining and easy to read.

As a sort of theoretical theory book, it is not real science that we are looking at here. It takes the current theories of particle physics and cosmology, assumes that they are all correct and then constructs a new all-embracing theory. Somewhere in the book a claim is made that there are predictions, but I didn't see any sign of them (theories that make no predictions are unfortunately getting more and more common these days).

Perhaps the book is way ahead of its time. The most important force in the universe is surely gravity, so when some future theorist has finally developed a quantum theory of gravity, then we might be ready for it.

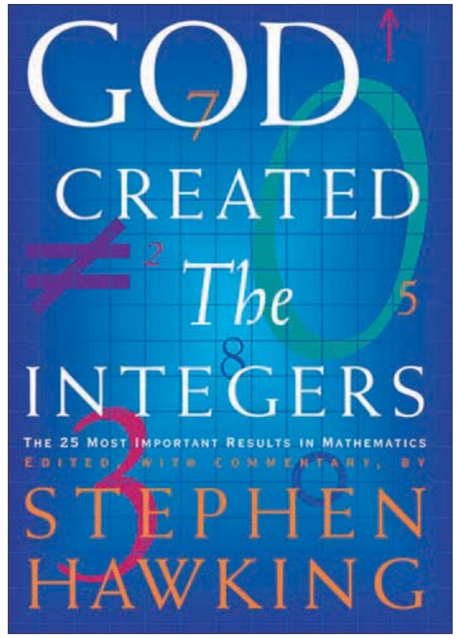
I have heard that the intelligent-design people are unhappy with this book, but they shouldn't be. Lloyd has presented them with a great opportunity: surely the hypothetical intelligent designer and the hypothetical programmer of the big hypothetical QC within which we live might be one and the same.

As alert readers of *CERN Courier* will already know, a recently published experimental result (O Hosten *et al.* 2006 *Nature* **439** 949) has confirmed theoretical speculation and demonstrated that QCs compute the same whether they are on or off. So here's an interesting thought: amazing as our universe is, if Lloyd is right it might not even have been turned on yet.

Indeed, it all reminds me a bit too much of *Deep Thought* and a misspent youth, but it's a fun book. I guess it takes a quantum-mechanical engineer to view things in such an odd manner. I do recommend this book, but urge that you don't take it too seriously. Also make sure that you read it twice and remember that the answer might well be 42.
Steve Reucroft, Northeastern University.

God Created the Integers. The Mathematical Breakthroughs that Changed History, edited, with commentary, by Stephen Hawking, Running Press. Hardback ISBN 0762419229, £19.99 ($29.95).

"God created the integers, all the rest is the work of Man," are the words of 18th-century mathematician Leopold Kronecker, whose thought-provoking statement makes a fitting title to this collection. Following on the path of his previous collection *Standing on the Shoulders of Giants*, Hawking has brought together representative works of the most influential mathematicians of the past 2500 years, from Euclid to Alan Turing.



(Incidentally, Kronecker did not make the cut to be included, but his best friend Karl Weierstrass did.)

The collection outlines the life of each mathematician before reproducing a selection of original work. The sections are self-contained so the book can be read over time or out of sequence. Reading it in one go has its advantages, however: the beautifully terse ancient Greek text contrasts well with the flowery style of George Boole, for instance. Also, there are recurrent themes, such as the problem of the continuity of a function, or David Hilbert's challenges, which are tackled by several mathematicians in this volume.

Each section starts with an introduction where Hawking's delightful pen takes us through the mathematician's biography and then patiently through the most important points of his works. Hawking's introductions are informative, understandable and in places amusing – for instance, the hilarious story of when Kurt Goedel is taken by his friend, Albert Einstein, for his US nationality hearings.

There is a wealth of information in the original works reproduced and I mention here a few points that I found interesting.

Euclid's *The Elements* concerns geometry, and number theory – geometry is the means of visualizing important proofs, such as the infinitude of prime numbers. Archimedes, although better known for his engineering skills, was one of the best mathematicians of antiquity. One of the works reproduced is *The*

Sand Reckoner, Archimedes' ambitious attempt to measure the mass of the visible universe using the measured size of the Earth and the Sun to arrive at his answer: 10^{63} grains of sand. What is interesting is his treatment of errors – although he knows the size of the Earth, he conservatively assumes a figure 10 times as big.

The collection covers another Greek, Diophantus, although he is perhaps best known from a footnote that the mathematician Pierre de Fermat (not covered) wrote in the margin next to one of his theorems, which became known as Fermat's last theorem. It puzzled mathematicians for many years until finally proved in 1992.

Isaac Newton has probably the shortest space allocated in the book, but quantity is not proportional to importance. Newton was not only a great physicist, but also a brilliant mathematician: he invented calculus. In another link between mathematics and physics, Joseph Fourier derived his trigonometric series while trying to solve a physics problem on heat transfer.

Carl Friedrich Gauss, a mathematical prodigy, is considered by many as the greatest mathematician of all time. Less well known is the fact that he worked for a period as a surveyor and that he achieved international fame when he calculated the position of asteroid Ceres in 1801.

Bernhard Riemann generalized geometry in a way that proved essential to Albert Einstein more than 60 years later. Ironically, Riemann was worrying about deviations from the Euclidian model for the infinitesimally small.

While Hilbert does not feature in this volume, his statement of the three most important challenges of mathematics inspired mathematicians who do appear. Goedel would prove the incompleteness and inconsistency of mathematics, whereas Turing would disprove the decidability of mathematics some years later.

When reading about the lives of the great men featured a few worrying recurrent themes appear, some in line with caricatures of mathematicians. Mental problems and an unfulfilled private life occur with alarming frequency. Less expected, perhaps, is the struggle for professional recognition.

Unfortunately, the book is not perfect and I do have a few gripes. The Greek text is deeply flawed and quite unacceptable for such a publication; the typesetting is appalling and proofreading evidently was non-existent. Running Press would do well to rectify this on future editions. Throughout the book, the hallmarks of a rushed job are everywhere. There are far too many typing errors, which is especially bad when formulae are concerned; it is not always clear if a footnote was from the original author, or inserted by the editor; and finally, some figures (the ones appearing in Henri Lebesgue's section) were of surprisingly low quality.

Even so, this is an impressive collection of works that are part of our intellectual heritage. It is an important addition to every library, but bedside (or poolside) reading it is not.

Mike Koratzinos, CERN.

Synchrotron and High Energy Physics

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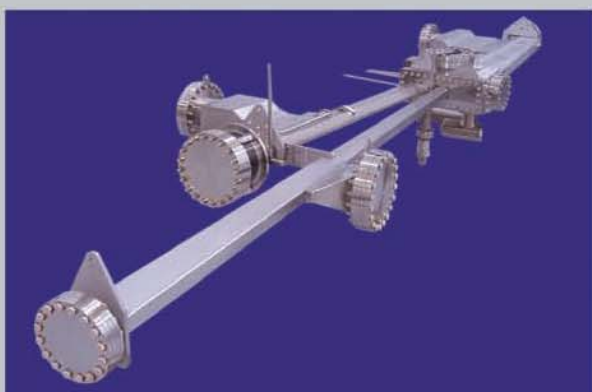

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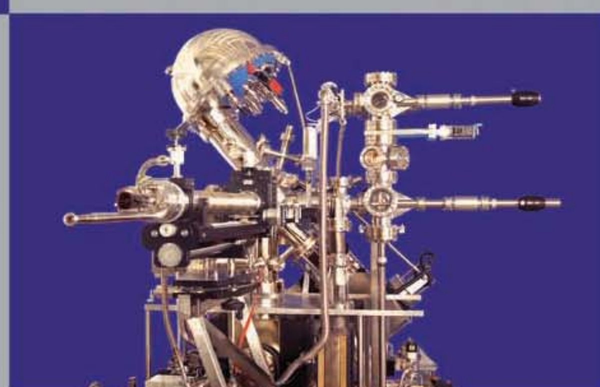

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