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CERN COURIER

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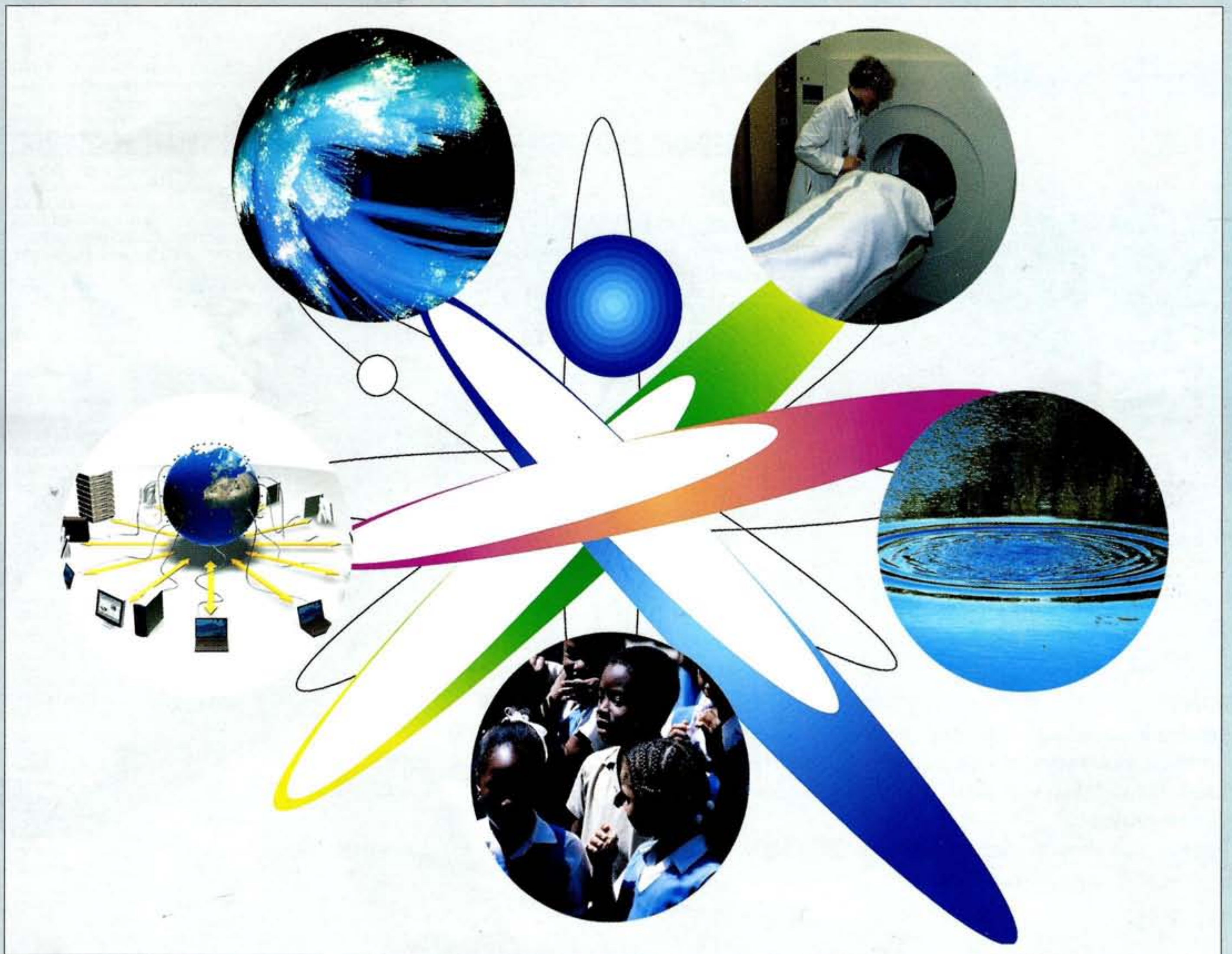

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Covering current developments in high-energy physics and related fields worldwide

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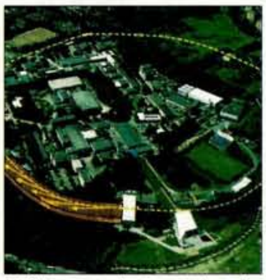
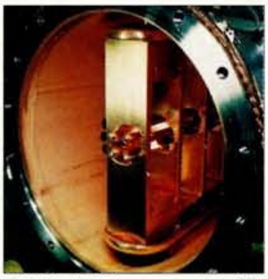
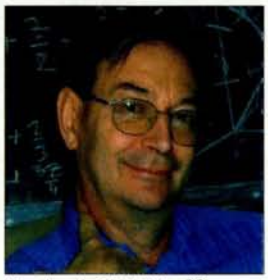


DESY to upgrade storage ring p7



LEAP looks to lower energies p29



New head of DAPNIA p33

Cover: CERN is hosting a meeting on The Role of Science in the Information Society, as a side event to the World Summit on the Information Society in Geneva in December (p27). Sessions will examine science's future contributions to information and communication issues in the areas of education, health care, environmental stewardship, economic development and enabling technologies.

ADSC

Quantum

CCD X-Ray Detectors

Quantum 315

Quantum 210

	Quantum 315	Quantum 210
Detector Type:	Array (3x3); 315mm x 315mm	Array (2x2); 210mm x 210mm
Number of Pixels:	6144 x 6144; 37.75 million	4096 x 4096; 16.8 million
Pixel Size at Detector Surfaces:	51 x 51 microns	51 x 51 microns
Phosphor (optimized):	1 X-ray Angstrom	1 X-ray Angstrom
Spatial Resolution FWHM:	90 microns; 1.76 pixels	90 microns; 1.76 pixels
Taper Ratio:	3.7 to 1	3.7 to 1
Optical Coupling (CCD to Taper):	Direct bond	Direct bond
CCD Type:	Thomson THX 7899	Thomson THX 7899
CCD Pixel Size:	14 x 14 microns	14 x 14 microns
Operating Temperature:	-50 degrees Celcius	-45 degrees Celcius
Cooling Type:	Thermoelectric	Thermoelectric
Dark Current:	0.015 e/pixel/sec	0.015 e/pixel/sec
Controller Electronics:	ADSC Custom	ADSC Custom
Readout Times (Full Resolution):	1 second	1 second
Read Noise (Pixel Rate):	(1 MHz): 18 electrons estimated	(1 MHz): 18 electrons typical
Full Well Depth (Full Resolution):	270,000 electrons typical	270,000 electrons typical
Dimensions:	34.7 in. L x 17.7 in. W x 18.1 in. H (880.6 mm x 450.0 mm x 460.0 mm)	31.7 in. L x 13.7 in. W x 12.4 in. H (804.5 mm x 346.8 mm x 315.6 mm)
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CERN

ATLAS cavern ready for its detector

The ATLAS cavern has become the first new experimental cavern for the Large Hadron Collider (LHC) to be handed over to CERN by civil-engineering contractors. On 4 June, this important milestone on the road to the planned start-up of the LHC in 2007 was celebrated in an official inauguration ceremony attended by Pascal Couchepin, president of the Swiss Confederation.

Some 35 m wide, 55 m long and 40 m high, the ATLAS cavern is literally the size of a cathedral – the nave of Canterbury Cathedral in the UK would fit neatly inside. Excavation of the cavern began in 2000 and has pushed civil engineering to new limits. Once the top part of the cavern had been excavated, it was concreted and the resulting vault suspended from 38 steel cables anchored in galleries 25 m above. Excavation of the remaining 28 m depth was then resumed and completed by the end of April 2002. The cavern has since been lined with concrete and services such as electricity, ventilation and water have been installed. The handover of the cavern to CERN signals the beginning of the installation of the 44 m long, 22 m high ATLAS detector, with the first components set to be lowered into the cavern later this year.

Inside the ATLAS cavern: manipulating shielding to fit within the beam tunnel.

Pascal Couchepin (right), president of the Swiss Confederation, and Carlo Lamprecht (left), Geneva state councillor, inside the ATLAS cavern with CERN's director-general, Luciano Maiani (behind centre).

CERN confirms LHC start-up in 2007

On 20 June, in its 125th session, the CERN Council received confirmation that the LHC and its detectors are on schedule for start-up in 2007, and that the LHC Computing Grid (LCG) project is about to reach a major milestone. CERN's director-general, Luciano Maiani, presented a comprehensive review of the status of the LHC project, which he underlined by saying that management is more committed than ever to the current LHC schedule. Maiani said that the major difficulties with the accelerator and detectors have been resolved, and that there is now a clear path to the project's completion. "All of the problems we encountered in 2002 have been overcome," he said, "although there remain hurdles to overcome, there is no showstopper. We can confirm with fewer reservations than last year that the LHC will start-up in spring 2007."

LHC dipole magnet cold masses awaiting installation into their cryostats at CERN.

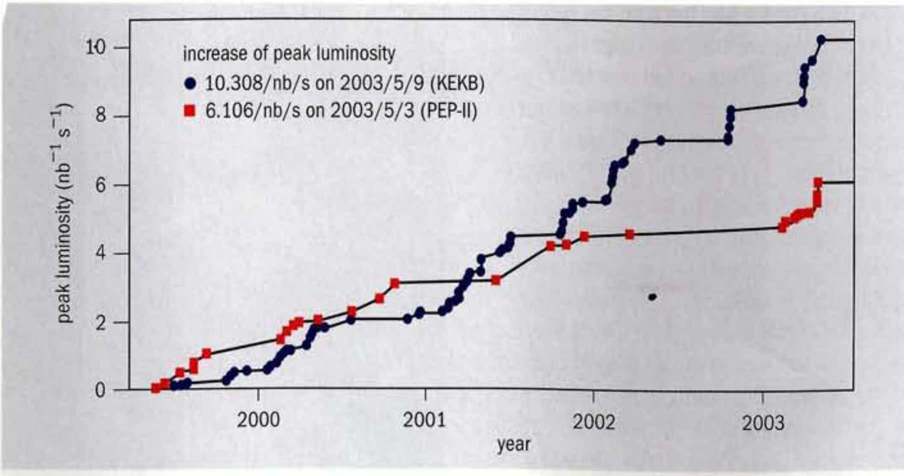
Maiani also drew attention to the LCG project, which will make an important step forward in distributed computing technology on 1 July when it deploys an operational computing Grid for the LHC. Negotiations are also underway with the European Union for the "Enabling Grids for E-science in Europe" (EGEE) project, which aims to create a Europe-wide Grid infrastructure by combining the many Grid initiatives across the continent.

The Council also heard from Robert Aymar, CERN's director-general elect, who presented his proposal for a new organizational structure for the laboratory. His plans are based on a recommendation by the External Review Committee that he chaired in 2001 and 2002. The new structure is intended to ensure continuity and build on existing strengths at CERN, while at the same time implementing changes at the higher levels appropriate to CERN's current objectives. The main features of the new structure are short lines of management and a restricted directorate consisting of the director-general (Aymar), a chief scientific officer, with the functions of deputy director-general, and a chief financial officer. Jos Engelen, currently director of NIKHEF, has been named as the chief scientific officer. CERN's current divisions will be regrouped into a smaller number of departments, while functions including safety, technology transfer and public communication will be moved into the director-general's office.

PARTICLE FACTORIES

KEKB scales peak in luminosity

On 9 May, the KEKB accelerator achieved a major breakthrough by being the first colliding-beam facility to reach a peak luminosity above 10^{34} cm^{-2} s^{-1}, a long-sought milestone in accelerator physics. This accomplishment will boost KEK's programme of investigating CP violation and searching for beyond-the-Standard-Model effects in the $\bar{B}$–B system. Almost all such studies require the largest possible samples of B-meson pairs, so the single most important factor in their success is high luminosity. A luminosity of 10^{34} cm^{-2} s^{-1} corresponds to a B-meson pair production rate of 10 per second, and under normal operating conditions this would yield approximately 100 million B-meson pairs per calendar year.



The increase in peak luminosity of KEKB and PEP-II after the 1999 start-up.

In order to increase the luminosity, the intensity of both the electron and positron beams must be increased, and each must be squeezed to the smallest possible size. Achieving these two conditions simultaneously presents a severe technological challenge to the accelerator design team. To tackle these problems, the KEKB group, which started construction of their machine in 1994, incorporated a number of new technologies. Among them are finite-angle crossing for the collision region, a lattice design with a 2.5π phase advance per cell, superconducting RF cavities that can tolerate large beam currents, and normal RF cavities coupled with attachments that have 10 times more energy-storage capacity than the accelerating cavity proper (called ARES cavities). The luminosity target set for KEKB at the outset was 10^{34} cm^{-2} s^{-1}, which at the time was considered by many to be an unrealistically ambitious goal.

The commissioning of KEKB was reasonably smooth, with the luminosity reaching 20% of its design value in one and a half years. This was already highly successful in comparison with many past accelerator projects, where progress in the early stages could be laboriously slow. KEKB's luminosity has steadily increased ever since, as the KEKB team have worked to solve the many problems they have encountered along the way.

Three categories of problems have been the most persistent and difficult to overcome. The first class of problems is related to the high beam currents. KEKB has frequently experienced serious trouble such as the breakdown and heating of the vacuum components. Vacuum chambers in the interaction region and beam abort sections, movable masks (for removing beam tails) and bellows, etc, were broken several times due to higher order mode (HOM) power from the beams, synchrotron radiation, or simply being hit by the beams themselves. The KEKB team solved these problems one by one, by developing revised versions of the components, reinforcing the cooling power and protection mechanisms, and by taking other counter-measures.

The second category of problems was a nagging blowup of the positron beam, believed to be caused by a photoelectron cloud. In the end, the KEKB team covered 2300 m (more than 90% of the free region) along the 3000 m positron ring with a solenoid winding that was designed to produce a small axial magnetic field to disperse the cloud.

The third problem category was beam blowup due to the beam–beam effect. This is a well known and common problem in colliding beam accelerators, and a huge amount of effort has been devoted since the design phase of KEKB to mitigate this blowup. The most important progress at KEKB on this issue is a special choice of betatron tunes. It turned out that making the horizontal tunes of both rings approach half-integer resonance was very effective in raising the luminosity. This effect is explained as a dynamic focusing effect by the beam–beam interaction, and is well reproduced by the beam–beam simulations. To enable this very close approach to the half-integer resonance, corrections for machine errors were crucially important.

Reaching the 10^{34} design luminosity in four years is a remarkable achievement. KEKB operates with 1284 bunches in both electron and positron rings, with averaged bunch spacing of 3.77 RF buckets. The currents are 1.5 and 1.1 A for the positron and electron beams, respectively, and these correspond to 58 and 100% of the design currents. Vertical beta functions at the interaction point are 5.8 and 7 mm for the positron and electron rings, respectively, which are even smaller than the design value of 10 mm. The vertical beam–beam parameters are 0.066 and 0.050 for the positron and electron beams, respectively, which are very close to (or higher than) the design value of 0.052. The fractional part of the horizontal tunes are 0.506 and 0.513 for the positron and electron beams, respectively.

The remarkable success of the KEKB project is an indication of not only the highest level of achievement in KEK's accelerator technology, but also of the highest levels in numerous branches of industry that support KEK. The experience gained in the KEKB project will be of great value in the development of a future linear collider.

SYNCHROTRON RADIATION

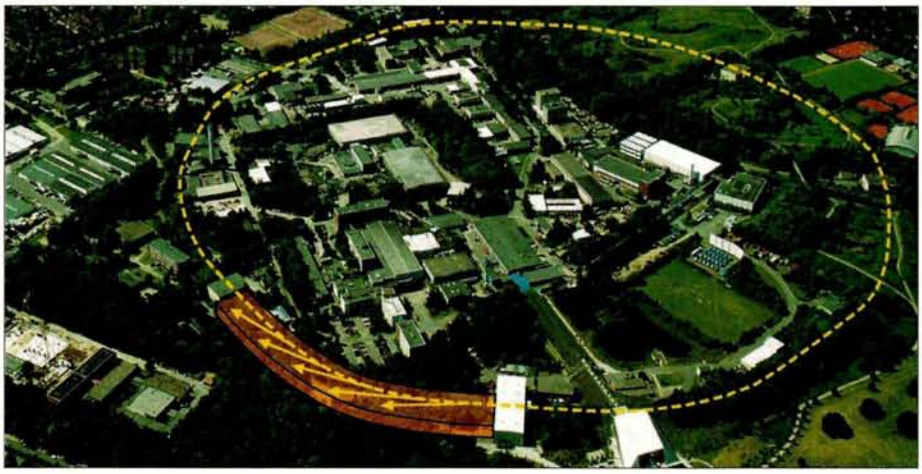
Brilliant future for PETRA III

DESY is to convert its storage ring PETRA into one of the most modern third-generation X-ray sources in the world. "PETRA III" is expected to provide the highest brilliance of any storage ring-based X-ray source until the first linac-driven sources begin operating.

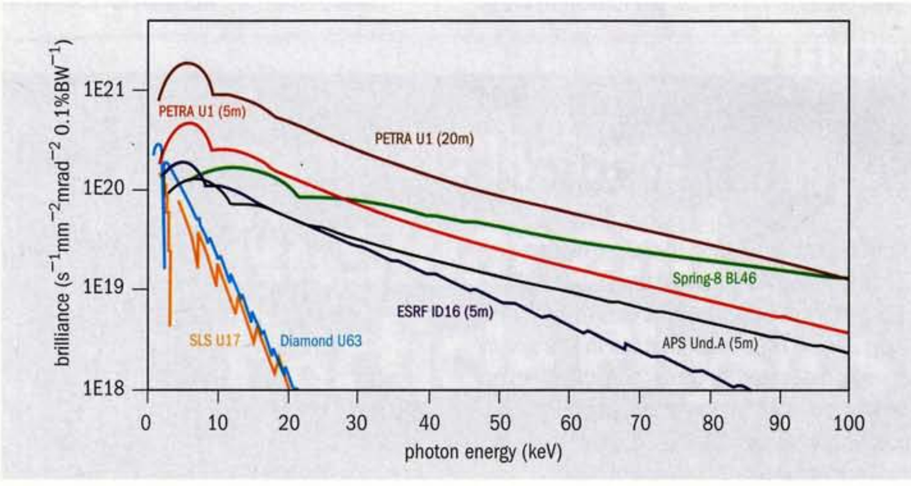
At present, more than 2000 physicists, chemists, biologists, geologists, and researchers working in the fields of materials science or life sciences, use the facilities at DESY's Hamburg Synchrotron Radiation Laboratory, HASYLAB, for experiments with soft and hard X-ray radiation in basic and applied research. As a second-generation synchrotron radiation source, however, DESY's current "workhorse", DORIS III, is not comparable in terms of brilliance with modern third-generation hard X-ray sources such as the ESRF in Grenoble, APS in Argonne or Spring-8 in Japan. In order to remain competitive in the synchrotron radiation sector, DESY has therefore decided to convert PETRA as soon as the HERA physics programme is completed, from 2007 onwards.

PETRA was successfully used for particle physics from 1978 to 1986, and since then, as PETRA II, it has been part of the injector chain for DESY's HERA collider. In addition, it also supplies intense X-ray light from one undulator to three experimental test stations. The upgrade of PETRA will require the total rebuilding of one-eighth of the storage ring to provide the electron-beam optics for nine straight sections, each of which will offer space for one 5 m long or two 2 m long insertion devices – "wiggler" and "undulator" magnets in which synchrotron radiation of high brilliance will be generated. Depending on the exact outline of the beamlines, about 13 experimental stations with independently tunable insertion devices will become available.

A positron energy of 6 GeV is currently predicted, with a beam current of at least 100 mA. This means that the energy of the synchrotron radiation photons will reach up to more than 100 keV. The installation of a number of damping wigglers, with a total length of 100 m in the empty long straight sections of the storage ring, will allow the upgraded facility to provide an emittance as small as 1 nm rad.



An aerial view of the DESY site, with the PETRA storage ring shown as a dashed line and the planned hall for synchrotron radiation experiments sketched out.



A comparison of the brilliance of two typical PETRA III undulators with those of other third-generation synchrotron radiation sources.

Such a small emittance is essential for the generation of highly brilliant high-energy photons in arrangements of undulator magnets. Compared with a number of other synchrotron radiation storage rings, an upgraded PETRA storage ring with damping wigglers offers the best basis for a low-emittance, high-brilliance synchrotron radiation source at higher particle energies. Only the "Ultimate Storage Ring" study carried out by the ESRF machine group, which describes an ideal storage ring-based light source and energy recovery linac-driven sources at high particle energies will be able to provide smaller emittances.

To ensure reliable machine operation and a beam lifetime limited only by intrinsic positron beam parameters, PETRA's existing vacuum system and a large portion of the infrastructure have to be replaced, and planning for a detailed layout of the new experimental hall is currently underway. The German federal government approved the PETRA upgrade project in February 2003 and agreed to finance it with €120 million. A formal proposal for the upgrade will be completed by the end of 2003, after the input of a series of workshops with potential users, so that reconstruction can begin as planned in January 2007.

SYNCHROTRONS

CERN establishes formal links with SESAME

A memorandum of understanding that provides for co-operation between the new international centre for Synchrotron light for Experimental Science and Applications in the Middle East (SESAME), CERN and Jordan has been signed. During the visit of King Abdullah II of Jordan to the laboratory on 12 June, Luciano Maiani, CERN's director-general, Herwig Schopper, president of the SESAME Council, and Khaled Toukan, Jordanian education minister, signed the memorandum, which covers the exchange of scientific personnel, fellows and equipment.

The organizational structure of SESAME is based on the model of CERN. At the suggestion of Schopper – who is a former director-general of CERN – SESAME was created under the umbrella of UNESCO in the same way that CERN began some 50 years ago. The SESAME Council now comprises nine founder members: Bahrain, Egypt, Iran, Israel, Jordan, Palestinian Authority, Pakistan, Turkey and the United Arab Emirates – who will fund the centre's annual budget. Other states are expected to join in the coming months. The Jordanian government will provide $12 million for the construction of the centre.

There are close to 50 synchrotron radiation sources in the world, but very few are located in developing countries. SESAME, which is being built on the site of the Al-Balqa Applied University, 30 km from Amman in Jordan, will be the Middle East's first synchrotron. Based on components from the BESSY 1 synchrotron in Berlin, SESAME should be up and running in 2006. It will produce synchrotron radiation over a broad range of wavelengths from the infrared to X-rays, and will therefore have various fields of application. The facility, which should attract scientists from numerous disciplines and nationalities, is a good example of collaboration between countries in the grip of political tensions. As Schopper underlines, SESAME is opening the way for technological progress and peaceful scientific development in the Middle East.

Left to right: King Abdullah II of Jordan visiting CERN with Luciano Maiani, director-general of CERN, Maurice Bourquin, president of the CERN Council, and Herwig Schopper, president of the SESAME Council.

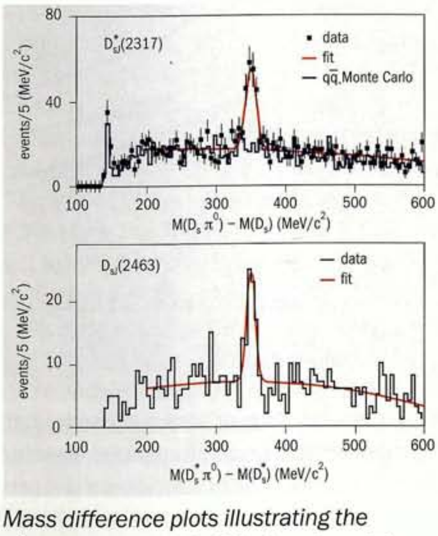
CORNELL

CLEO discovers second D_{sJ} particle

The CLEO collaboration has discovered a new particle, tentatively named the $D_{sJ}(2463)$, which decays to $D_s^*\pi^0$ with a decay width less than 7 MeV. The search that led to this discovery was motivated by BaBar's discovery of an unexpected new narrow state called $D_{sJ}^*(2317)$ (*CERN Courier* June 2003 p6), which decays to $D_s\pi^0$. CLEO has also confirmed the existence of the $D_{sJ}^*(2317)$.

In the simplest interpretation of these results both particles are excited bound states of a charm quark, c, and a strange antiquark, $\bar{s}$. It was thought that such states would be massive enough to decay to a D or D^* meson and a K meson. The biggest surprise of the D_{sJ}^* is that it is too light to decay via any of these modes. The decay of D_{sJ}^* to $D_s\pi^0$ is suppressed because it violates isospin symmetry, leading to the small decay width observed. Such suppressed isospin violating decays are not unknown in the c–$\bar{s}$ system – in 1995 CLEO found that about 6% of the decays of the D_s^* are to $D_s\pi^0$, instead of the dominant $D_s\gamma$ mode. On the other hand, the D_{sJ} is above the thresholds for decay to DK and $D_s\pi^0$, but apparently does not decay through either mode. If the spin parity of the D_{sJ} is 1^+, these modes would be forbidden and $D_s^*\pi^0$ would be allowed but also suppressed by isospin, again leading to a small decay width.

The analysis that determined the existence of the second state was complicated by an unusual kinematic property of the two states – the two new particles and the D^* are narrow and the mass difference between the D_{sJ} and D_s^* is essentially identical to the mass difference between the D_{sJ}^* and the D_s (see figure). Since the dominant decay mode of D_s^* is $D_s\gamma$, a real D_s^* decay can appear as a D_s if the photon from the D_s^* decay is lost, and a real D_s and random photon can appear as D_s^*. This means that the two states can "feed into each other" as photons are missed or randomly acquired. The observed $D_s\pi^0$ signal thus has a background from real $D_s^*\pi^0$ events and vice-versa, so separating the two sources requires careful and subtle analysis. CLEO found that multiple analysis techniques applied to the $D_s\pi^0$ and $D_s^*\pi^0$ signals led to the conclusion that both states exist and resulted in consistent measurements of their masses and widths.



Mass difference plots illustrating the $D_{sJ}^*(2317)$ and $D_{sJ}(2463)$ signals and the fact that the mass differences of the two signals are essentially equal.

The preferred spin parity of the D_{sJ}^* is 0^+ because it decays into $D_s\pi^0$ not $D_s^*\pi^0$. Predating the discovery of the D_{sJ}^* and D_{sJ}, there were at least two theoretical models that coupled heavy quark effective theory with chiral symmetry and predicted light c–$\bar{s}$ states. In these models the mass difference between a 1^+D_{sJ} and the $1^-D_s^*$ would be equal to the difference between a $0^+D_{sJ}^*$ and the 0^-D_s, in accord with CLEO's observation.

Further reading

D Besson *et al.* http://arxiv.org/abs/hep-ex/0305100.

DETECTORS

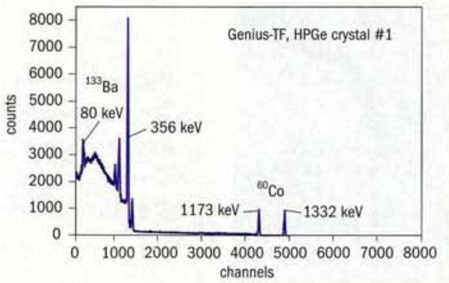
'Naked' crystals go underground

On 5 May, four "naked" high-purity germanium detectors were installed in liquid nitrogen in the GENIUS Test Facility (GENIUS-TF) at the Gran Sasso Underground Laboratory. This is the first time this novel technique for background reduction in searches for rare decays is being tested under realistic background conditions.

The goal of the GENIUS-TF, led by Hans Volker Klapdor-Kleingrothaus of Heidelberg, is to test detector techniques for the GENIUS project, which will search with extreme sensitivity for cold dark matter, double beta decay and low-energy solar neutrinos (*CERN Courier* December 1997 p19). In its dark-matter version, GENIUS will operate 40 naked germanium crystals (100 kg) in a 12 × 12 m tank of liquid nitrogen.

In the test facility the naked crystals sit on a plate made from a special type of Teflon, within a thin-walled copper box filled with 70 litres of purified liquid nitrogen. The copper is thermally shielded by 20 cm of special low-activity Styropor, surrounded by a 15 tonne shield of electrolytic copper (10 cm thick) and 35 tonnes of lead (20 cm thick). The complete set-up has a neutron shield of 10 cm boronpolyethylene. A digital data acquisition system allows the simultaneous measurement of energy, pulse shapes and other parameters of individual events.

The four naked germanium crystal detectors.



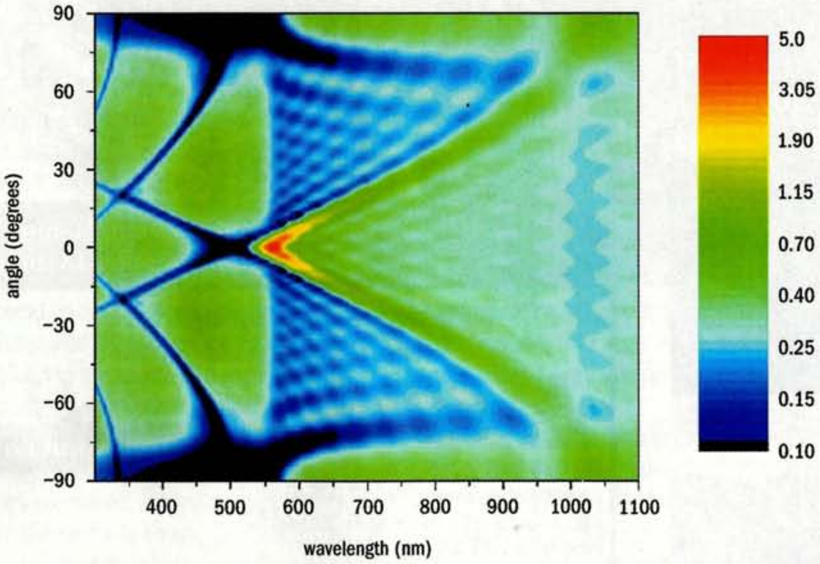
A spectrum measured for one of the detectors with ^{60}Co and ^{133}Ba sources. The other detectors show the same quality.

On the day they were installed, the four detectors – a total of 10 kg of high-purity natural germanium – were tested with radioactive sources of ^{60}Co and ^{228}Th. They showed good energy resolution and it was found that microphonics in the liquid nitrogen is not a problem.

Besides testing construction parameters, one of the first goals of GENIUS-TF will be to investigate the signal of cold dark matter reported by the DAMA collaboration in 1999 (*CERN Courier* June 1999 p17), which could originate from the modulation of the WIMP flux by the motion of the Earth relative to the Sun.

Edited by Steve Reucroft and John Swain

Diffraction is defeated



Intensity of light as indicated by colour plotted as a function of angle (y-axis) versus wavelength (x-axis). The angle is measured from the normal behind a narrow slit in a silver film surrounded by a grating that has 10 grooves on each side. Each of the grooves in the grating is 40 nm wide and 100 nm deep, and separated by 500 nm. The small red region in the image represents a tightly collimated beam close to zero degrees – that is, straight through the slit – for wavelengths around 550 nm.

It is well known that waves that strike a narrow slit diffract – i.e. they spread out as they emerge – but now it seems there could be exceptions to this rule. Thomas Ebbesen, of the Louis Pasteur University in Strasbourg, France, and colleagues have backed up earlier experimental work with calculations showing that light that hits a narrow metal slit can interact with electrons in the metal to produce a narrow beam. This surprising work could lead to a new generation of optical elements, with applications from computing to telecommunications.

Further reading

L Martin-Moreno *et al.* 2003 *Phys. Rev. Lett.* **90** 167401.

Heaviest isotope lives the longest

Radioactive substances now have a new record holder for longevity. Noel Coron and colleagues at the Institut d'Astrophysique Spatiale in Orsay, France, have shown that bismuth-209, which has long been thought to be the heaviest stable isotope that occurs in nature, has a half life of about 20 billion billion years. This is greater than the age of the universe by a factor of about one billion.

Further reading

P de Marcillac *et al.* 2003 *Nature* **422** 876.

Two teams discover currents of pure spin

In attempts to control the flow of information carried by the spins of electrons, it had been thought that a flow of the electrons themselves was needed, but two groups have now shown that it is possible to have a current of pure spin. A team led by Martin Stevens and Arthur Smirl of the University of Iowa and one led by Jens Hübner and Wolfgang Rühle of the University of Marburg, Germany, have shown that a combination of two polarized laser beams can coax electrons with different spins to flow at equal but opposite speeds in a semiconductor. The result is that although no net electrical current is present, there is a flow of spin. So far, the currents only travel a few nanometres so practical applications may still be some way off.

Further reading

M J Stevens *et al.* 2003 *Phys. Rev. Lett.* **90** 136603.

J Hübner *et al.* 2003 *Phys. Rev. Lett.* **90** 216601.

Noise aids perception

Stochastic resonance – the phenomenon whereby adding noise can make a signal easier to detect – can also be used to make the human eye more sensitive to light. Keiichi Kitajo of the University of Tokyo, Japan, and the University of British Columbia, Canada, and colleagues have shown that when exposed to a flickering random light, the eye can become sensitive to light at levels that would not otherwise be consciously detectable. The effect is the same even if only one eye tries to perceive the dim light while the flickering light is received by the other, so it is not simply a case of the eye "adding up" signals.

Further reading

K Kitajo *et al.* 2003 *Phys. Rev. Lett.* **90** 218103.

Edited by Marc Türler

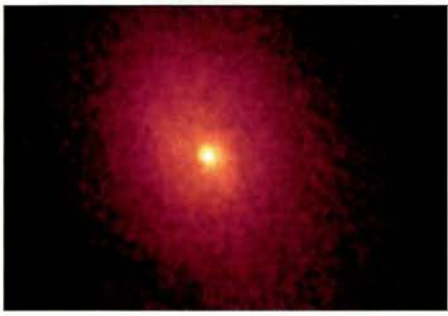
Hot gas reveals cold dark matter

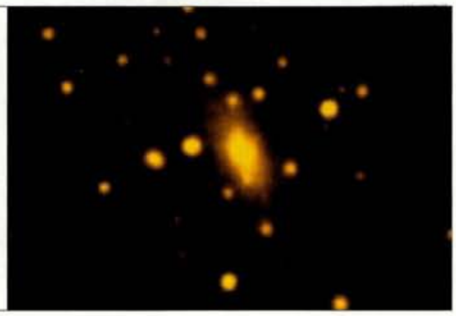
The long controversy between cold-dark-matter and hot-dark-matter models is rapidly nearing an end. A recent study of the X-ray emission of hot gas in a massive cluster of galaxies has allowed astronomers to determine the distribution of its dark-matter content. The density of dark matter appears to increase towards the centre of the cluster in agreement with cold-dark-matter predictions.

The discovery that the dark-matter distribution could be tightly constrained is due to the high resolution of NASA's Chandra X-ray observatory and to the choice of a regular and undisturbed galaxy cluster called Abell 2029. This cluster is located about a billion light-years from Earth, and is composed of thousands of galaxies enveloped in a gigantic cloud of hot gas. At the centre is an enormous elliptical galaxy that is thought to have been formed from the merging of a number of smaller galaxies.

Hot gas is held in the cluster by gravity, but the mass of the galaxies in the cluster is not enough to explain the presence of this gas. Huge amounts of additional, invisible matter are needed for gravity to balance the pressure of the gas, which is at a temperature of more than 10 million degrees. This missing mass of unknown nature is what we call dark matter.

It seems the distribution of hot gas is mainly determined by that of the dark matter, rather than by the distribution of visible matter in the galaxies. Therefore, by precisely measuring the distribution of X-rays from the hot gas, Aaron Lewis of the University of California and colleagues were able to make the best measurement yet of the dark-matter distribution in the inner region of a galaxy cluster. The X-ray data show that the dark-matter density increases smoothly all the way into the central galaxy of the cluster. This agrees with the predictions of cold-dark-matter models and is contrary to other dark-matter models that predict a constant dark-matter density in the centre of the cluster.





Analysis of Chandra's X-ray image (left) of the galaxy cluster Abell 2029 (optical image, right) reveals that the density of dark matter increases uniformly to the central galaxy of the cluster. (X-ray image: NASA/CXC/UCI/A Lewis et al.; *Optical image: Pal. Obs. DSS.)*

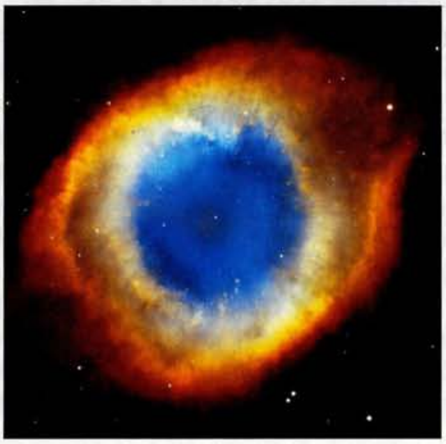
Dark-matter particles must have the property of interacting with each other and with "normal" baryonic matter only through gravity. These so-called weakly interacting massive particles are difficult to detect and have been elusive until now. Massive neutrinos are a possible dark-matter candidate, usually referred to as hot dark matter because they travel at close to the speed of light. Due to this high speed, hot-dark-matter models of the early universe create big structures of the size of galaxy clusters first, which then fragment to form galaxies. By contrast, the slower cold-dark-matter particles cannot travel as far and so form small galaxies first, which then merge to form bigger structures such as clusters of galaxies.

In the past few years there has been growing evidence in favour of the cold-dark-matter model. The Wilkinson Microwave Anisotropy Probe showed that "normal" baryonic matter only accounts for 17% of the matter content of the universe, the rest being cold dark matter of unknown nature (*CERN Courier* April 2003 p11). The study presented here supports this by determining the distribution of this matter in clusters of galaxies, but astronomers are still waiting for particle physicists to determine the nature of the elusive cold-dark-matter particles.

Further reading

A D Lewis *et al.* 2003 *ApJ* **586** 135.

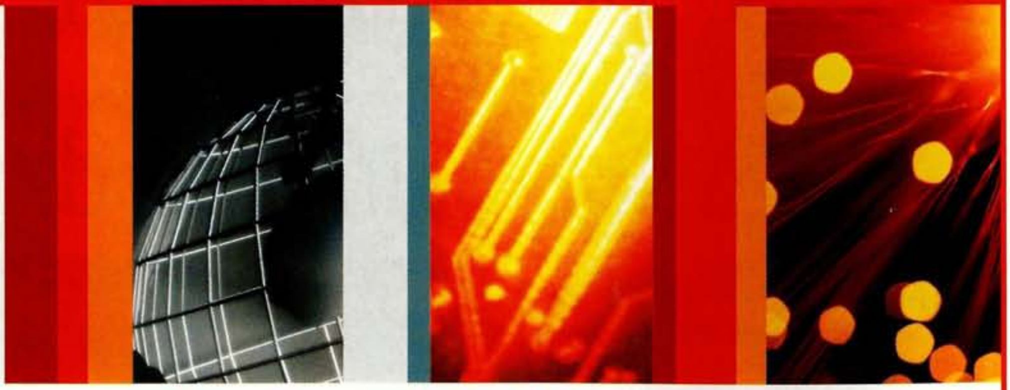
Picture of the month



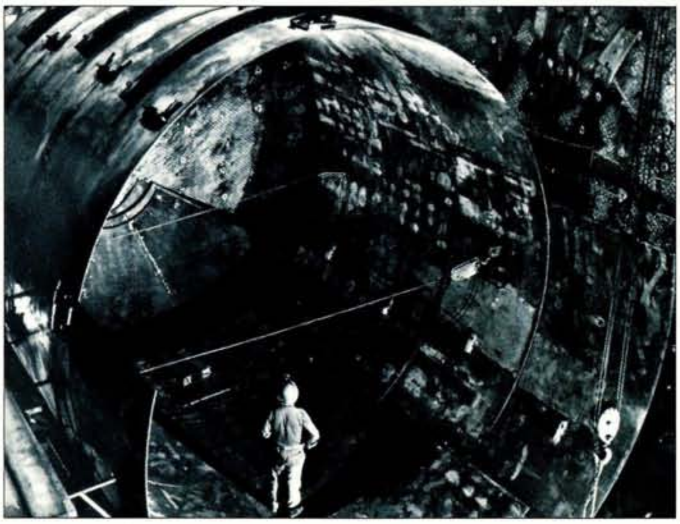
This picture from the Hubble Space Telescope is one of the most detailed celestial images ever produced. To capture most of this nearby planetary nebula – which appears in the sky as about half the diameter of the Moon – several shots were taken using the Advanced Camera for Surveys. These were then combined with a photo taken by Kitt Peak's Mosaic Camera.

This so-called helix nebula is popular among amateur astronomers. Viewed through binoculars, it appears as a ghostly, green-coloured cloud in the constellation Aquarius, which is 650 light-years away. Larger amateur telescopes can resolve the ring-shaped nebula, but only the largest ground-based telescopes can resolve the radial streaks. Astronomers have concluded that this nebula is a cylinder that happens to be pointing towards Earth, rather than a bubble.

Planetary nebulae have nothing to do with planet formation, but get their name because through a small telescope they look like planetary discs. They appear during the final stage in the life of a Sun-like star. The outer layer of the star is expelled and a white-dwarf star remains at the centre of the nebula. (NASA, NOAO, ESA, Hubble Helix Nebula team, M Meixner (STScI), T A Rector (NRAO).)

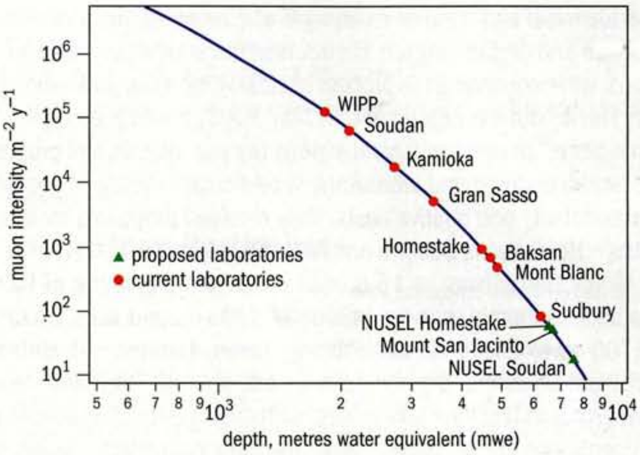


Decision to flood hits US underground science plans



The original installation of a physics experiment in the Homestake mine saw the construction of the tank for Raymond Davis's solar neutrino detector, seen here in 1966. (Brookhaven National Laboratory.)

The announcement that pumping will stop at the Homestake mine has clouded the future of the favoured site for a proposed major underground laboratory in the US.



The variation of muon flux with overburden, in metres water equivalent, for existing and proposed laboratories.

On 30 May, the US National Science Foundation (NSF) issued its site panel report concerning potential sites for a deep underground science and engineering laboratory for the US. The panel concluded that by far the most favourable among the proposed sites was the Homestake mine in South Dakota. However, on 2 June, the first working day after the NSF announcement, the company that owns the mine announced that the following week it would turn off the pumps that prevent the mine from flooding. Despite intense "scientific diplomacy" – including a letter to the company from Nobel prize-winning scientists – the pumps were turned off on 10 June. Now state officials are continuing their negotiations with the mine's owners, who estimate that complete flooding could take as long as 25–30 years. Meanwhile, the underground laboratory community in the US is pursuing several options.

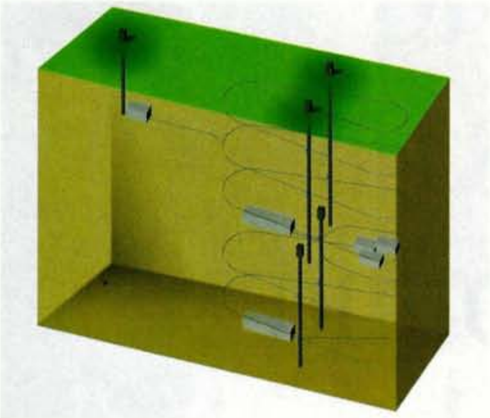
The idea of a National Underground Science and Engineering Laboratory (NUSEL) in the US first gathered momentum after the Homestake Mining Corporation announced the closure of the mine in autumn 2000. The Homestake mine housed the original large solar neutrino detector built by Raymond Davis, then at Brookhaven National Laboratory. At a meeting of 200 neutrino physicists in Seattle to discuss the future US Long Range Plan for Nuclear Physics, Kenneth Lande of the University of Pennsylvania, Davis's successor as leader of the Homestake experiment, proposed taking over the entire mine for science and engineering studies. This idea was ultimately strongly endorsed in the US Long Range Plan for Nuclear Physics and by several other US national advisory committees. Other groups also identified different possible sites for a national underground laboratory, including Mount San Jacinto in California, the Waste Isolation Pilot Plant (WIPP) in New Mexico and the Soudan Laboratory in Minnesota. However, because of its extreme depth – nearly 2500 m – and well-characterized rock integrity, most attention focused on Homestake.

The Homestake proposal was based on utilizing the attributes of the existing Homestake mine. It is the deepest existing site in the US, and provides a variety of levels and great flexibility in optimizing sites for experiments. Its massive shafts and hoists provide dual access to every level, which would allow the immediate initiation of a research programme simultaneously with the construction of a new laboratory. The site is also ideal for earth sciences as it provides 3D access to approximately 9 km^3 of well-characterized and interesting rock. The current proposal includes a comprehensive earth-science research programme called EarthLab, which includes studies of microbial life, fluid flow and rock deformation. Homestake also has sufficient distance (about 2000 km) from existing accelerators in the US to allow for precision studies of neutrino properties.

The proposed new layout for Homestake foresees development along the main drift at 1480 m (4400 metres water equivalent, or mwe), with existing shafts providing direct access to the surface. This is the level recommended for construction of a "megadetector" and ▷

for other experiments wanting to simplify construction and transport, while requiring moderate overburdens. The deep level at 2250 m (6500 mwe), also accessed by existing shafts, is the choice for experiments needing greater overburdens.

Despite significant efforts, progress at Homestake has been slow. Although initial talks with the US-based Homestake Mining Company were very encouraging, negotiations stalled after the Barrick Gold Corporation, a Canadian mining firm, purchased Homestake Mining Company. Intense discussions between officials of Barrick, national and local political leaders, and the NUSEL–Homestake group of scientists led by Wick Haxton of the University of Washington, failed to produce any universally agreed solutions to the technical and political challenges of converting the mine into a science and engineering lab. Barrick rejected several proposed solutions, while continuing the process of closing the mine and removing the Davis neutrino experiment. In May 2003, the NSF convened a "site panel" of seven technical experts to evaluate different proposals for an underground laboratory, in particular in terms of geological suitability and relative costs. They received proposals for three sites – Homestake, Soudan and Mount San Jacinto.



An isometric view of the conceptual design for the Soudan NUSEL. The existing mine shaft and laboratories are at left. The new race-track spiral decline, access shaft, ventilation shaft and new laboratories at 1450 and 2500 m are at right.

Mount San Jacinto, a 15 minute drive from the centre of Palm Springs, California, has an altitude of 3293 m, and rises 2400 m (6700 mwe) above the surrounding desert. Located in high-tech southern California, the site enjoys close proximity to many major research and teaching universities, with their assets of researchers, students and trained support staff. The proposal for this site, led by Henry Sobel of the University of California Irvine, foresees the construction of a complex of underground chambers accessed by one or two tunnels starting near the mountain's base. The sides of the mountain rise so steeply that an 8 km horizontal tunnel could access a laboratory almost 2 km underground. One advantage of Mount San Jacinto is that, unlike Homestake and Soudan, the site is unaffected by previous operations as a mine or laboratory. It offers the opportunity of a clean start, albeit with the concomitant costs associated with the lack of an existing underground infrastructure.

The Soudan Laboratory in northeastern Minnesota is currently the largest, deepest, most active and most experienced underground laboratory in the US. It houses the Cryogenic Dark Matter Search (CDMS 2) detector and the 5500 tonne "far detector" for the Main Injector Neutrino Oscillation Search (MINOS) experiment. MINOS will use the Neutrinos at the Main Injector (NUMI) neutrino beam from Fermilab, due to start up in 2005, which is likely to be the only long baseline beam in the US and one of only three in the world, at least for the next 10 years. NUSEL at Soudan would therefore start with existing laboratories, an existing research programme and experienced staff.

The proposed design for Soudan envisages the construction of a new 17.5 km long tunnel, with a one in seven decline from the surface to the deepest new laboratories 2500 m underground. The tunnel, which is modeled on the access to the Pyhäsalmi mine in Finland, would be in the form of a race-track spiral, about 800 by 400 m in cross-section, making seven complete turns from top to bottom. Trucks driving down the incline would deliver large instrumentation and equipment to the existing laboratories 710 m underground, and to new laboratories at 1450 and 2500 m (4350 and 7500 mwe). An elevator shaft tangential to the helix would allow easy entry for staff and small items of equipment.

The NSF panel came to the conclusion that "Homestake is by far the most favourable site for an underground laboratory", stating that the existing deep access, infrastructure and proven ability to excavate large caverns at relatively low cost, made it "an obvious choice". Soudan was considered a "possible back-up" site, but was not the first choice of any of the panelists, due in part to the need to develop ramps and shafts for deep access. San Jacinto was the least favourable site, and indeed considered "not a viable candidate", due to local geology uncertainties, the potential for permission problems due to environmental issues and high relative cost.

The San Jacinto proponents disagree with the report and the process behind generating it, and have sent a letter to the NSF stating their concerns. The group feels many of the panel's statements misrepresent the site and its benefits. There was in fact no opportunity for them to interact with the panel and correct these misconceptions.

The Homestake NUSEL collaboration intends to submit an updated project book to the NSF in the next few weeks. The collaboration was in the process of completing this more detailed proposal when the decision to flood was reached. But considering the potential delays and corresponding uncertainties associated with the flooding, the collaboration has also announced its intent to consider alternative sites, including potential new horizontal access sites in the western US.

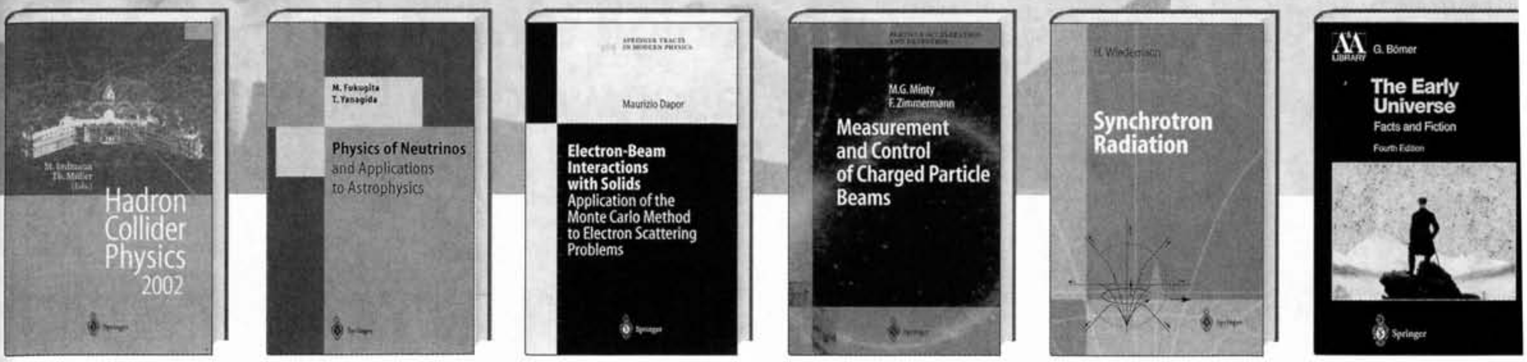
What happens next is still unclear. The key to the future of Homestake is for political leaders to find an acceptable legal framework to facilitate the transfer of the mine by Barrick Gold. A horizontal access laboratory at Mount San Jacinto or another mountain site in the western US requires additional studies to identify and document the site. The Soudan Laboratory proponents plan to focus on the existing programme of MINOS and CDMS 2, while continuing geological and environmental studies to keep Soudan ready if Homestake falters.

Further reading

NSF site report: http://mocha.phys.washington.edu/nusel/nsf_report.pdf.
NUSEL Homestake proposal: http://mocha.phys.washington.edu/nusel/proposal.html.
NUSEL Soudan full proposal: http://www.sudan.umn.edu/NUSEL.

Marvin Marshak, *University of Minnesota, and*
John Wilkerson, *University of Washington.*

New books from Springer



G. Altarelli, K. Winter (Eds.)

Forthcoming

TOC

Neutrino Mass

After an overview of the theory of neutrino masses and mixings, detailed accounts are given of the laboratory limits on neutrino masses, astrophysical and cosmological constraints on those masses, experimental results on neutrino oscillations, the theoretical interpretation of those results, and theoretical models of neutrino masses and mixings. The book concludes with an examination of the potential of long-baseline experiments.

2003. Approx. 210 p. 50 illus. Also available online. (Springer Tracts in Modern Physics, Vol. 190) Hardcover **€ 119.95**; sFr 194; £ 84 ISBN 3-540-40328-0

M. Erdmann, T. Müller (Eds.)

TOC

Hadron Collider Physics 2002

Proceedings of the 14th Topical Conference on Hadron Collider Physics, Karlsruhe, Germany, September 29-October 4, 2002

2003. XXXIV, 527 p. 298 illus. Hardcover **€ 189**; sFr 305.50; £ 132.50 ISBN 3-540-00995-7

M. Fukugita, T. Yanagida

Physics of Neutrinos

and Applications to Astrophysics

This book provides a survey of the current state of research into the physics of neutrinos. The reader finds here a global view of the areas of physics in which neutrinos play important roles, including astrophysics and cosmology. Starting from the standard theory of electroweak interactions, the key notions are explained in detail and the fundamental equations are derived explicitly to enhance understanding of their precise content. Prime emphasis is given to the mass of neutrinos and its implications.

2003. XII, 593 p. 111 illus. (Texts and Monographs in Physics) Hardcover **€ 69.95**; sFr 116.50; £ 49 ISBN 3-540-43800-9

M. Dapor

TOC

Electron-Beam Interactions with Solids

Application of the Monte Carlo Method to Electron Scattering Problems

2003. X, 106 p. 27 illus. Also available online. (Springer Tracts in Modern Physics, Vol. 186) Hardcover **€ 79.95**; sFr 133; £ 56 ISBN 3-540-00652-4

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M.G. Minty, F. Zimmermann

Measurement and Control of Charged Particle Beams

After a review of linear optics, the text addresses basic and advanced techniques for beam control, plus a variety of methods for the manipulation of particle-beam properties. In each case, specific procedures are illustrated by examples from operational accelerators. Problems and solutions are included.

2003. XX, 364 p. 172 illus. (Particle Acceleration and Detection) Hardcover **€ 69.95**; sFr 116.50; £ 49 ISBN 3-540-44187-5

H. Wiedemann

TOC

Synchrotron Radiation

In this book the characteristics of synchrotron radiation, including insertion device radiation, are described and derived from first principles. The reader is first introduced to the subject in an intuitive way in order to gain familiarity with the underlying physical processes. A rigorous mathematical derivation of the theory follows. Since the characteristics of synchrotron radiation are intimately connected with the parameters of the electron beam and its accelerator, a basic introduction to electron beam dynamics and accelerator design is included.

2003. XIV, 274 p. 96 illus., 100 Exercises and 55 Selected Solutions (Advanced Texts in Physics) Hardcover **€ 89.95**; sFr 149.50; £ 63 ISBN 3-540-43392-9

H. Wiedemann

Particle Accelerator Physics

SPRINGER STUDY EDITION

Volume I and II (study edition)

2nd ed. 2001. 2nd printing 2003. LVI, 908 p. (2-volume-set, not available separately). (Advanced Texts in Physics) Softcover **€ 79.95**; sFr 133; £ 56 ISBN 3-540-00672-9

G. Börner

TOC

The Early Universe

Facts and Fiction

In the center of this textbook are the connections between particle physics and cosmology: the standard model, some basic implications of quantum field theory, and the questions of structure formation.

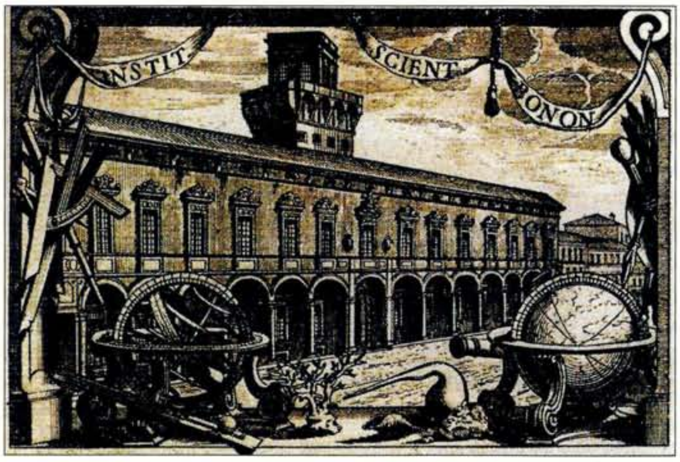
4th ed. 2003. XVIII, 586 p. 203 illus., 39 in color. (Astronomy and Astrophysics Library) Hardcover **€ 74.95**; sFr 124.50; £ 52.50 ISBN 3-540-44197-2

TOC

Complete Table of Contents (PDF) available online! Simply visit the Springer website and enter the ISBN number into the search facility. Then click on the title's catalogue entry and go to the "Table of Contents".

Springer

The legacy of the bubble chamber



The Bologna Academy of Sciences, as it appears on the front of the academy's journal Commentarii, *one of the famous scientific journals of the 18th century.*

A recent one-day meeting in Bologna looked back on the era of the bubble chamber, and recalled its technical achievements and main discoveries, as well as the sociology behind its development.

Detail from the ceiling of the "Sala Ulisse", where the meeting was held, showing Ulysses blinding Polyphemus.

The bubble chamber, which was invented by Donald Glaser in 1952, made its major contributions to particle physics over three decades, from the late 1950s until the 1980s. This period saw chambers of increasing size, particle beams of increasing energy, more and more automatic measuring machines, and increasingly powerful computers. The initial era was pioneered by groups in the US, in particular the Alvarez group at the Lawrence Berkeley Laboratory. Later, major contributions came from European groups, with CERN playing a central role. In Italy the bubble-chamber technique provided the opportunity to revitalize the field of particle physics, bringing together a large number of physicists from many Italian universities. This was coordinated by INFN, which also created a national centre called the Centro Nazionale Analisi Fotogrammi (CNAF) in Bologna.

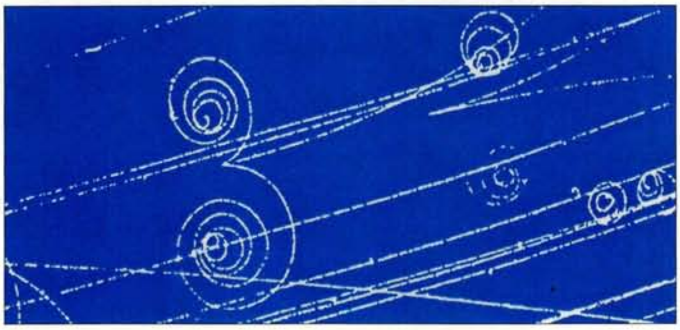
It was against this background that the Bologna Academy of Sciences organized a meeting on 18 March entitled "30 years of bubble chamber physics". Around 100 physicists from 28 different institutions attended the meeting, which was sponsored by the Bologna Academy of Sciences, the University of Bologna and the Department of Physics, and the INFN (CNAF and Sezione di Bologna). The programme included talks on the beginning of bubble chambers, the first instruments and the first results, the impact of bubble chambers on particle physics, and hydrogen, helium and heavy-liquid bubble chambers.

The early bubble chambers were very small, but over the years they increased in size by a factor of around one million, with the largest chambers containing 40 m^3 of liquid. More than 100 bubble chambers were built throughout the world, and more than 100 million stereo pictures were taken. The 80 cm Saclay bubble chamber at CERN, the 2 m CERN bubble chamber and the Big European Bubble Chamber (BEBC) took more than half of these pictures.

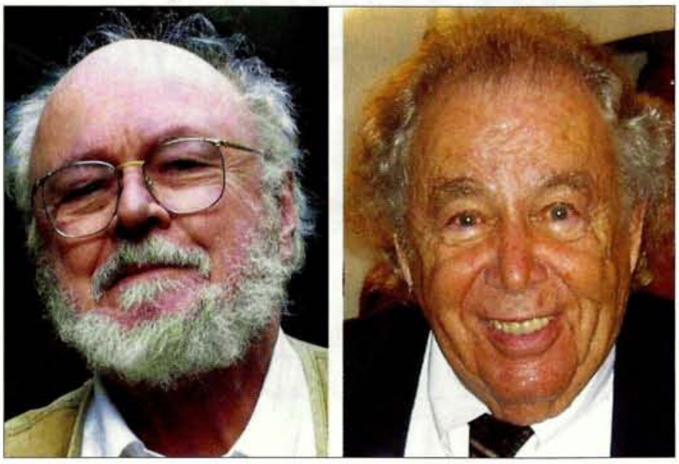
The sociology of bubble-chamber collaborations is an interesting one. In the initial period, many small chambers took pictures that were analysed by in-house groups. Later, bigger bubble chambers were built and run by experts in large laboratories using refined beams at accelerators of increasing energy. These chambers were considered facilities that could be used by internal and external groups, and this increased the number of international collaborations, with several groups from different countries and around 20–50 physicists per experiment. The role of large laboratories like CERN was always a central one.

One of the earliest bubble-chamber papers, "Demonstration of parity non conservation in hyperon decay", which was published in 1957, was signed by physicists from four teams: the Columbia–BNL team that was headed by Jack Steinberger, the Bologna team headed by Giampietro Puppi, the Pisa team headed by the late Marcello Conversi and the Michigan team led by Donald Glaser (F Eisler *et al.* 1957).

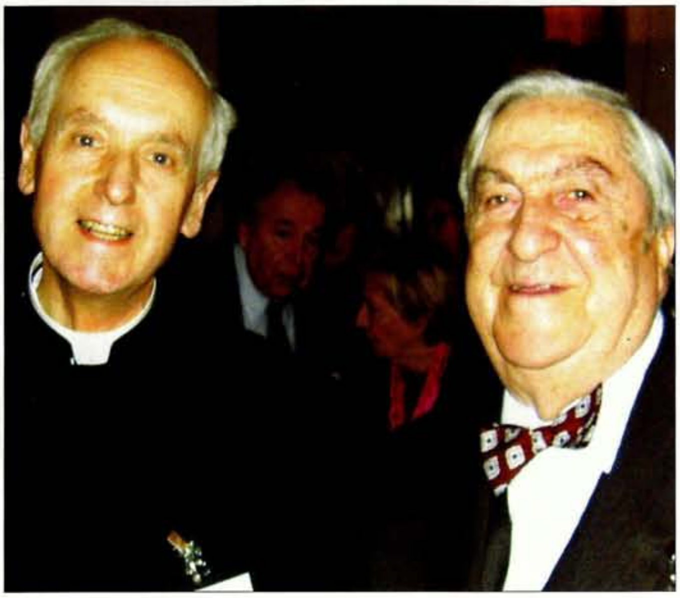
It is worth recalling that in the beginning every team had to scan and measure bubble-chamber photographs with very primitive equipment. Eventually, digitized tables were made and one started to ▷



This bubble-chamber event shows the creation of a positron–electron pair (the linked spirals) by a photon in the Coulomb field of an electron. The electron is ejected from the atom and creates the third track that connects to the two spirals. After about 1 cm the electron emits a gamma ray, which then converts into an electron–positron pair with straighter tracks. (Lawrence Berkeley Laboratory.)



Pedro Waloshek (left) of DESY and Martin Block of Northwestern University, US, were nominated corresponding foreign members of the Bologna Academy of Sciences during the meeting.



Vittorio Zoboli (left), the first student of the Bologna bubble-chamber group in 1957, and now a Catholic priest, with his tutor and group leader Gianni Puppi.

hear of "Mangiaspagos" in Italy, of more elaborate semiautomated or fully automated "Frankensteins" and "PEPRs" in the US, and of "MYLADYs" and "HPDs" in Europe. A large number of scanners was needed to cope with the increasing number of photographs, making measurements and pre-measurements more precise.

Computer technology grew in parallel with the increase in size and automation of the bubble chambers. At the beginning of the bubble-chamber era, slide rules and electromechanical calculators were used. But soon the IBM650 computer began to be used, and this was followed by even more powerful machines. Similarly, the measured co-ordinates of points along the tracks were initially punched onto cards manually, but then semiautomatic projectors took over this task. The installation of mainframe computing capacity was driven by the demands of bubble-chamber physics. For example, the CERN mainframe central computers increased their speed and capacity by a factor of more than 1000 during the bubble-chamber era.

The meeting also reviewed several areas of physics where bubble chambers have had an impact, for example, parity violation in hyperon decay, the weak neutral current, baryon resonances, charm particles and multihadronic production. In the round-table discussion on "The legacy of 30 years of bubble chamber physics", several participants completed the overall view of the field, with an emphasis on topics such as the neutrino field and some of the special bubble chambers.

The main scientific legacy of the bubble chamber towards our understanding of the microworld of particle physics forms an impressive list that includes: strange particles, such as the omega–minus; meson and hadron resonances, leading to the hadron spectrum, SU(3) and constituent quarks; neutral weak currents and electroweak unification; and scaling in neutrino–nucleon deep inelastic scattering, leading to partons and therefore to dynamical quarks ("Bubbles 40" 1994).

The final session at the meeting dealt with particle physics and society, and with the popularization of science. In this respect, selected bubble-chamber pictures can provide a global and intuitive view of particle-physics phenomena. They allow an untutored audience to realize that our field is based on simple and intelligible experimental facts. A large number of photographs of bubble-chamber events was on show to participants as part of a small historical exhibit, which included an early propane chamber that was built in Padova in 1955, early instruments and the central part of a Mangiaspago measuring projector.

Further reading

For more information about the meeting, see the website at: www.bo.infn.it/~spurio/bubble.htm.

F Eisler *et al.* 1957 *Phys. Rev.* **108** 1353.
"Bubbles 40" 1994 *Nuclear Phys. B* (Proc. Suppl.) **36**.

Fabrizio Fabbri, **Giorgio Giacomelli**, **Federico Ruggieri**, **Maurizio Spurio** *and* **Pedro Waloshek**.

Testing times for strings

The "hidden" dimensions of string theory may be much larger than was previously thought and may soon come within experimental reach, together with the strings themselves. **Ignatios Antoniadis** gives an introduction to string physics and describes how it may soon be testable at particle colliders.

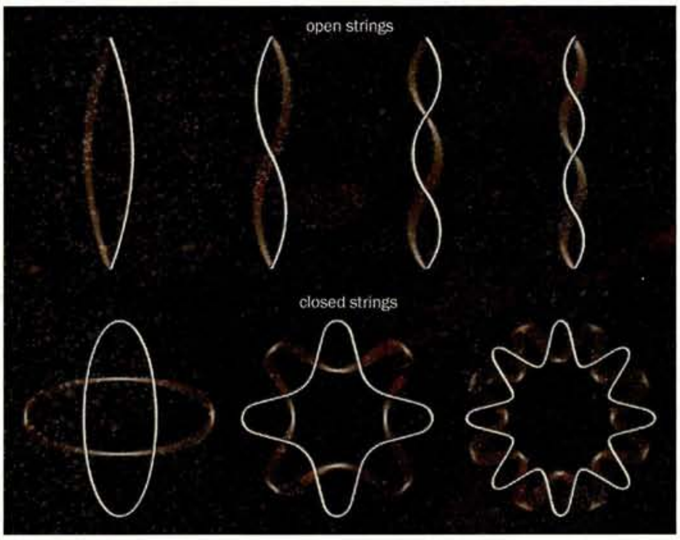


Fig. 1. In string theory, the elementary constituent of matter is a minuscule string with vanishing width but finite size. It can be open with free ends (top row), or closed (bottom row). Its vibration modes, like the ones shown here, correspond to various elementary particles.

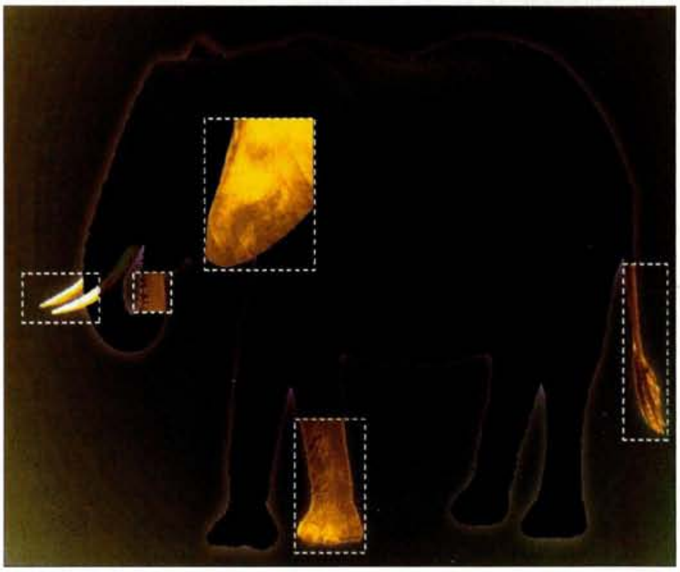


Fig. 2. How could you draw a picture of an elephant if you had only seen a few different parts of its body? In the same way, the five string theories describe only some of the parts of M-theory, most of which is not yet known.

Look in front of you. Now to your side. Next, up above. These are the known spatial dimensions of the universe: there are just three. Have you ever wondered about the origin of this number? Have you ever thought there might be new dimensions that escape our observation? In all physical theories, the number of dimensions is a free parameter that is fixed to three by observation – with one exception. This exception is string theory, which predicts the existence of six new spatial dimensions. At present, it is the only known theory that unifies the two great discoveries of the 20th century: quantum mechanics, which describes the behaviour of elementary particles, and Einstein's general relativity, which describes gravitational phenomena in our universe (M B Green *et al.* 1987).

String theory replaces all the elementary point particles that form matter and mediate interactions with a single extended object of vanishing width: a tiny "string". Thus, every known elementary particle, such as the electron, quark, photon or neutrino, corresponds to a particular vibration mode of the string, as shown in figure 1. The diversity of these particles is due to the different properties of the corresponding string vibrations. Until now there has been no experimental confirmation of string theory, and no-one has ever observed strings, not even indirectly, or the space of extra dimensions where they live. The main arguments in favour of the idea are theoretical, because this provides a coherent framework for the unification of all fundamental interactions.

For a long time string physicists thought that strings were extremely thin, having the smallest possible size in physics, associated with the Planck length, of 10^{-35} m. Recently, however, the situation has changed dramatically. It seems that the "hidden" dimensions of string theory may be much larger than we previously thought, and they may come within experimental reach in the near future, together with the strings themselves (I Antoniadis 1990, J D Lykken 1996, N Arkani-Hamed *et al.* 1998, I Antoniadis *et al.* 1998). These ideas are leading towards the experimental testing of string theory, which can be performed at Fermilab's Tevatron and the future Large Hadron Collider (LHC) at CERN.

The main motivation for these ideas came from the considerations of the so-called mass hierarchy problem: why does the gravitational force remain much weaker than the other fundamental forces (electromagnetic, strong and weak), at least up to the energies currently reached in high-energy physics? In quantum theory the masses of elementary particles receive important quantum corrections that are of the order of the higher energy scale present ▷

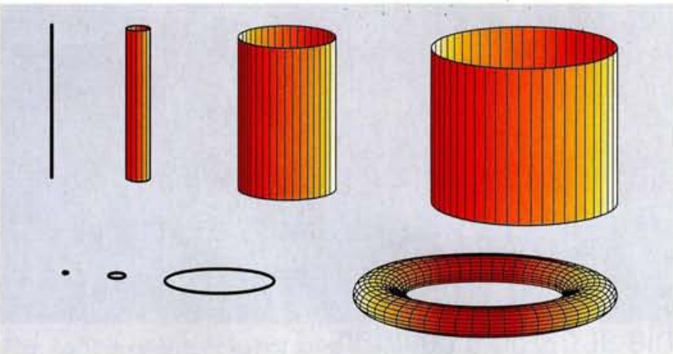


Fig. 3. Possible forms of small extra dimensions of space. Far away they are unobservable, but at distances comparable to their size we start feeling their existence and exploring their shapes.

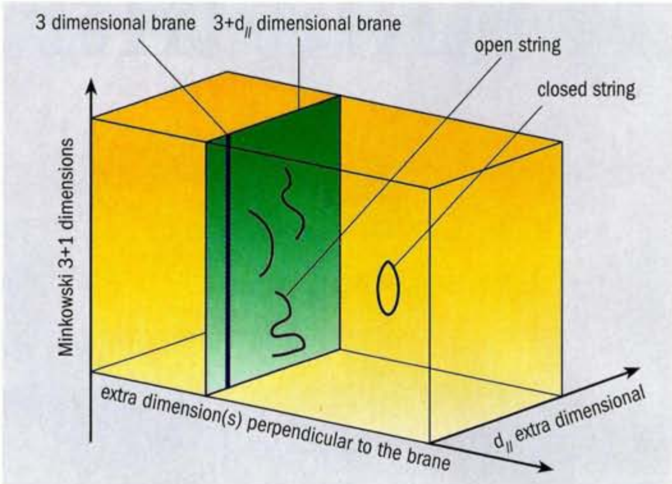


Fig. 4. In the type I string framework, our universe contains (besides the three known spatial dimensions; denoted by a single blue line) some extra dimensions ($d_{||}$ = p−3) parallel to our world p-brane (green plane), along which the light described by open strings propagates, as well as some transverse dimensions (yellow space), where only gravity described by closed strings can propagate. The longitudinal extra dimensions have a string size of about 10^{-18} m, while the size of the transverse dimensions varies between 10^{-14} m and a fraction of a millimetre.

in the theory. So in the presence of gravity the Planck mass (10^{19} GeV) pulls all the familiar particles of the Standard Model to be 10^{16} times heavier than we observe. To avoid this catastrophe the parameters of the theory must be adjusted by up to 32 decimal places, resulting in a very ugly "fine tuning".

A possible solution is provided by the introduction of a new fundamental symmetry of matter, called supersymmetry, at energies where electromagnetic and weak effects unite into electroweak interactions. One of the main predictions of supersymmetry is that every known elementary particle has a partner, called a superparticle. However, as none of these superparticles has ever been produced at an accelerator, they must be heavier than the observed particles. Supersymmetry must therefore be broken. On the other hand, protection of the mass hierarchy requires that its breaking scale – that is, the mass splitting between the masses of ordinary particles and their partners – cannot be larger than a few TeV. Such particles could therefore be produced at the LHC, which will test the idea of supersymmetry.

Alternatively, an idea proposed in the past few years solves the problem if the fundamental string length is fixed to 10^{-18} to 10^{-19} m (I Antoniadis *et al.* 1998). In this case, the quantum corrections are controlled by the string scale, which is in the TeV region, so they do not destabilize the masses of elementary particles. Moreover, the new idea offers the remarkable possibility that string physics may soon be testable at particle colliders.

The universe as a braneworld

How is it possible to lower the string scale from the Planck scale of traditional quantum gravity to the TeV region without contradicting observations? In particular, why does gravity interact much more weakly with our world, what happens to the extra dimensions of string theory and why have they not been observed?

String theory has a long history. It was introduced about 40 years ago in order to describe strong interactions, and it took a decade to understand that it was a natural candidate for quantum gravity. Ten years later, it was realized that it can unify all fundamental forces, while in the past decade there has been a real breakthrough in understanding several aspects of its non-perturbative dynamics.

This breakthrough was not realized earlier because prior to 1994 most of the research was done in the context of the so-called Heterotic string theory, which initially looked more promising for physics and more attractive theoretically. In this theory, the string scale is fixed by the Planck mass and cannot be lowered. However, there were five consistent string theories in total, which created a problem as string theory was supposed to provide a unified framework of all physical theories. We now believe that every known string theory describes a particular limit of an underlying more general fundamental theory that can be defined in 11 dimensions of space, called M-theory, as illustrated in figure 2 (E Witten 1995).

A crucial role in these developments was played by the discovery of "*p*-branes", which are higher dimensional objects extended in *p* spatial dimensions, so generalizing the notion of a point particle ($p=0$) or a string ($p=1$). One of the main consequences of this discovery is that the string scale is, in general, a free parameter that can be dissociated from the Planck mass if the universe is localized on a *p*-brane and does not feel all the extra dimensions of string theory. The braneworld description of our universe separates the dimensions of space into two groups: those that extend along our *p*-braneworld, called parallel dimensions, and those transverse to it. Obviously the parallel ones must contain at least the three known dimensions of space, but they may contain more. If our universe has additional dimensions, we should observe new phenomena related to their existence. So why has nobody detected them until now?

A possible answer was given at the beginning of the 20th century by Theodore Kaluza and Oskar Klein (T Kaluza 1921, O Klein 1926), who said that we cannot detect the new dimensions because their size is very small, in contrast to the infinitely large size of the other three that we know. An infinite and narrow cylinder, for example, is a two-dimensional space, with one dimension forming a very small circle. While you can move infinitely far away along the axis, you return back to the same point when moving along the

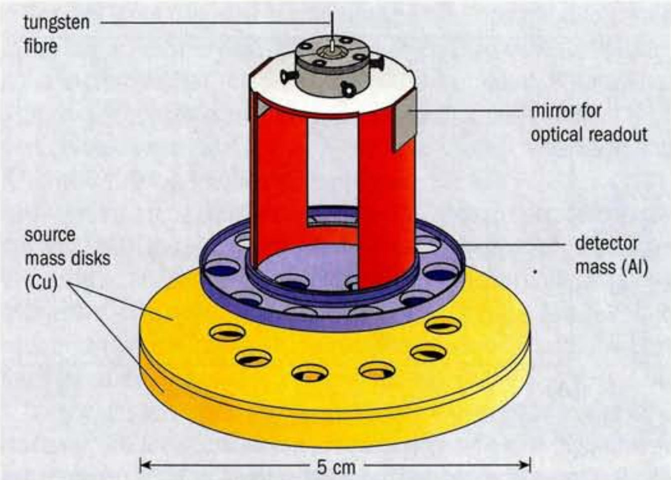


Fig. 5. The Eöt-Wash short-range torsion pendulum experiment has tested the validity of Newton's law down to 0.2 mm (Hoyle et al. *2001), thus constraining the size of gravitational extra dimensions. Improved sensitivity would reveal violations of Newtonian gravity at shorter distances, and the weakness of gravity complicates the experiments considerably. There are several sources of background noise due to other forces that must be eliminated, and at very short distances even the Casimir attraction due to vacuum fluctuations should be taken into account.*

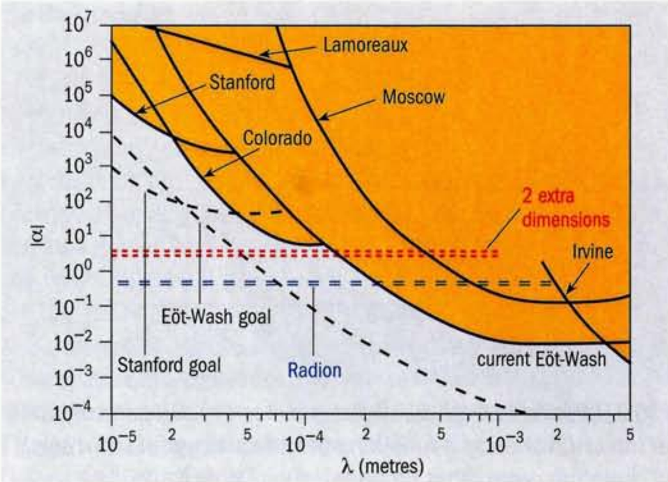


Fig. 6. The current limits on non-Newtonian forces at short distances. The excluded region is shown in yellow; the solid curves are associated with various experiments and the dashed lines correspond to future sensitivities.

orthogonal direction (see figure 3).

If one of the three known dimensions of space was small, say of millimetre size, we would be flat, and while we could move freely towards left or right, forward or backward, it would be impossible to go more than a few millimetres up or down where space would end. So extra dimensions along our universe escape observation if their size is less than 10^{-18} m, as they require energies higher than those we currently have at our disposal (I Antoniadis and K Benakli 1994, I Antoniadis *et al.* 1994, 1999).

The next question is how could we detect the existence of these extra dimensions if we did have sufficient energy to probe their size? (The minimum energy required is given by their inverse size and is called the "compactification scale".) The answer was again given by Kaluza and Klein, who stated that the motion of a particle in extra dimensions of finite size manifests itself to us as a tower of massive particles, called "Kaluza–Klein excitations". If for instance the photon propagates along an extra-compact dimension, we would observe a tower of massive particles with the same properties as the photon but with a mass that becomes larger as the size of the extra dimension decreases. It follows that for a size of the order of 10^{-18} m, an energy of the order of a few TeV would be sufficient to produce them.

The above analysis and bound on sizes does not apply, however, for dimensions transverse to our universe, as we cannot send light or any form of observable matter to probe their existence. The only way to communicate in this case is through gravity, which couples to any kind of energy density. However, our knowledge of gravity at short distances is much less than for the other interactions, allowing the sizes of such "hidden" dimensions to be as large as a millimetre, which is roughly the shortest distance at which Newton's law is tested in the laboratory.

The string scale at TeV energies

An attractive and calculable braneworld framework that allows the dissociation of the string and Planck scales without contradicting observations is provided by the so-called type I string theory. In this theory, gravity is described by closed strings, which propagate in all nine dimensions of space, while matter and all other Standard Model interactions are described by open strings that end on a particular type of *p*-brane, called a D-brane (where D stands for Dirichlet), as shown in figure 4 (J Polchinski 1995).

In the framework of type I string theory, the string scale can be lowered in the TeV region at the expense of introducing large transverse dimensions that are much bigger than the string length. Actually, the string scale fixes the energy at which gravity becomes coupled with a strength comparable to the other three interactions, thus realizing the unification of all fundamental forces at energies lower, by a factor 10^{16}, than we have previously thought. However, gravity appears very weak at macroscopic distances because its intensity is spread in the large extra dimensions known as the "bulk" (N Arkani-Hamed *et al.* 1998).

The basic relation between the fundamental (string) scale and the observed gravitational strength is: total force = observed force × transverse volume, thus expressing Gauss's law for higher dimensional gravity. In order to increase the gravitational force to the desired magnitude without contradicting current observations, one has to introduce at least two extra dimensions of a size that can be as large as a fraction of a millimetre. In the case of one transverse dimension, the required size is of astronomical distances, which is obviously excluded, while for more than two dimensions it should be smaller, down to the fermi scale (10^{-14} m) in the case of six dimensions. At distances smaller than the size of the extra dimensions, gravity should start to deviate from Newton's law, which it may be possible to explore in laboratory table-top experiments (see figure 5).

Type I string theory provides a realization of this idea in a coherent theoretical framework, where the string scale is fixed in the TeV ▷

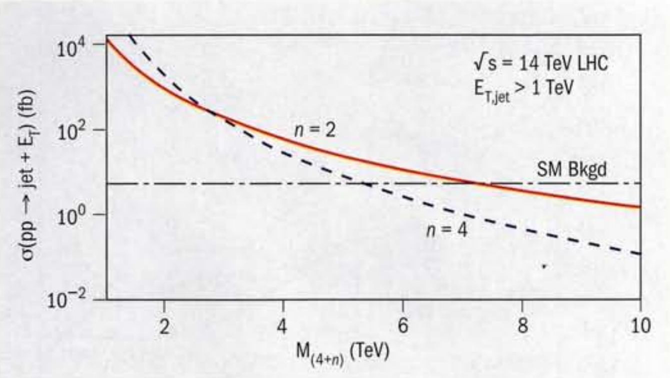


Fig. 7. Missing energy, E_T, due to graviton emission in collisions at the LHC varies as a function of the fundamental scale $M_{(4+n)}$ of quantum gravity that propagates in n *large transverse dimensions. The missing energy is produced together with a hadronic jet, which can be detected. The figure shows the expected cross-section for* n = 2 *and* n = 4 *extra dimensions, together with the background (horizontal dotted–dashed line) coming from other known sources (G F Giudice* et al. *1999, E A Mirabelli* et al. *1999).*

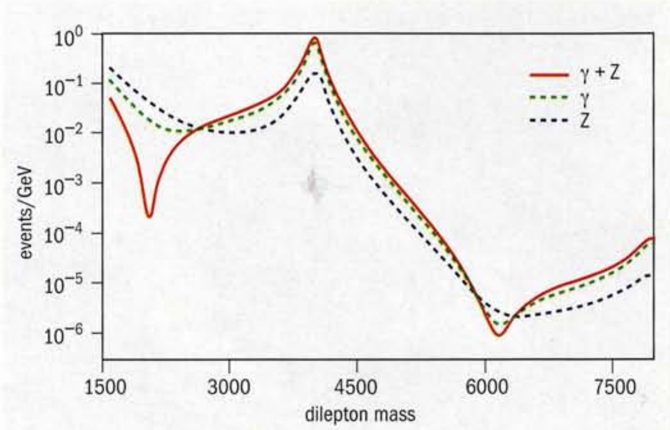


Fig. 8. If there is an extra dimension of the size 10^{-18} m felt by the electroweak interactions, then the LHC should produce the first Kaluza–Klein states of the photon and the Z boson. We can then detect the electron–positron pairs produced by the disintegration of these states. The number of expected events is computed as a function of the energy of the pair in GeV, with from highest to lowest, excitation of photon+Z, photon and Z boson.

region as required for the stability of the mass hierarchy, corresponding to a size of around 10^{-18} m. For the theory to be calculable, parallel dimensions should not be much bigger than the string length, while the size of transverse dimensions is fixed by the observed value of Newton's constant. This size should therefore vary from the fermi scale to a fraction of a millimetre, depending on the number of dimensions (varying from six to two, respectively). It is remarkable that this possibility is not only consistent with present observations, but also presents a viable and theoretically well motivated alternative to low-energy supersymmetry. It simultaneously offers a plethora of spectacular new phenomena, which can be tested in laboratory experiments and may provide surprises at the LHC and other particle accelerators.

String theory under experimental test

There are several tests of these new ideas, either in laboratory experiments that look for deviations of Newton's law at submillimetre distances, or at particle colliders. In microgravity experiments it is only possible to explore the case of two extra dimensions, because only in this case are deviations expected to appear at distances close to present limits. In fact the inverse square law of gravitational attraction, $1/r^2$, between two masses at a distance r should change to $1/r^{2+n}$ if there are n large extra dimensions. However, at distances of the order of the size of the extra dimensions, only the first Kaluza–Klein excitations of the graviton are probed, generating an extra Yukawa force of strength comparable to ordinary gravity and of a range equal to the size of the dimensions. The present experimental bounds on such forces are displayed in figure 6 as a function of their range λ (horizontal axis) and their strength relative to gravity α (vertical axis) (C D Hoyle *et al.* 2001, J C Long *et al.* 2002).

Besides the violation of Newton's law due to the presence of extra dimensions, there may be additional sources of new forces in a large class of models with supersymmetric bulk. In these models, motivated mainly from vacuum stability and model building, supersymmetry is not realized in our world because our brane universe is not supersymmetric, but it is present a millimetre away in the transverse dimensions of the closed string bulk. These models predict new forces at short distances mediated by superlight fields in the bulk, such as scalar or vector fields. The fields are massless in the absence of branes and acquire tiny masses due to non-supersymmetric radiative corrections from the branes, of the order of $\mathrm{TeV}^2/M_{\mathrm{Planck}} \approx 10^{-4}$ eV, corresponding to wavelengths in the submillimetre range. Such forces can be observable in microgravity experiments for any number of extra dimensions, in contrast to the deviation from Newton's law, which is testable only in the two-dimensional case. As an example, figure 6 shows the prediction for a hypothetical scalar universal force mediated by a particle known as the radion.

At particle colliders, there are generically three types of new phenomena associated with the existence of transverse and parallel dimensions, as well as with the string substructure of matter. Transverse dimensions are responsible for making gravity strong at TeV energies, and their main manifestation is through gravitational radiation in the bulk from any physical process that escapes detection and leads to events with missing energy (I Antoniadis *et al.* 1998, G F Giudice *et al.* 1999, E A Mirabelli *et al.* 1999). In contrast to microgravity experiments, high-energy particle accelerators, such as the LHC, are expected to produce a quasi-continuum of Kaluza–Klein excitations describing the propagation of the graviton to extra dimensions. Figure 7 shows the expected cross-section (number of events) at the LHC for the production of a single hadronic jet accompanied by missing energy due to graviton emission. Analysis of the angular distribution allows the spin of the unobserved graviton to be deduced, and these events to be differentiated from other possible sources of missing energy, such as the production of the lightest superparticle in supersymmetry.

Parallel dimensions of much smaller size, comparable to the string length, are manifest through the production of heavy Kaluza–Klein excitations for the photon and the mediators of the other Standard Model interactions. The LHC cannot miss these if their mass is below around 6 TeV, as figure 8 indicates (I Antoniadis and K Benakli 1994, I Antoniadis *et al.* 1994, 1999).

Finally, the string substructure of matter leads to spectacular new phenomena if the LHC centre-of-mass energy happens to be above the string scale. Some examples are the production of higher string excitations or even of micro-black holes weighing a few TeV. It is certain that in this case particle accelerators will become the best tools for studying quantum gravity in the laboratory.

Clearly, these theories exist only in our imagination at present. However, we look forward to the next generation of high-energy experiments and in particular to the most powerful machine, the LHC. I am convinced, as are the majority of my colleagues, that the LHC will play a very important role in the future of the high-energy physics of fundamental interactions. In fact, the LHC is designed to explore the origin of mass of elementary particles and in particular is designed to test the idea of supersymmetry, looking for the production of superparticles. We now hope that this accelerator may discover more spectacular and "exotic" phenomena, such as the existence of large extra dimensions of space and of fundamental strings.

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Ignatios Antoniadis, *CERN*.

Developing countries and CERN

John Ellis looks at what CERN can offer scientists – and the wider society – in developing countries.

To paraphrase Tolstoy's introduction to *Anna Karenina*, every developing country is developing in its own way. It is for each developing country to define its own needs and set its own agenda. So in this context, what is, or what should be, the relationship of CERN to developing countries? In what ways do they already benefit from the work at CERN, and how might they benefit from further collaboration?

CERN's original *raison d'être* was to provide a vehicle for European integration and development, whilst also enabling smaller countries to participate in cutting-edge research, and to reduce the brain drain of young European scientists to the United States. Nowadays, CERN is internationally recognized for setting the standard of excellence in a very demanding field, and serves as a beacon of European scientific culture. CERN is open to qualified scientists from anywhere in the world, and beyond its 20 European member states currently has co-operation agreements with 30 countries. Prominent among these – beyond North America and Japan – are Brazil, China, India, Iran, Mexico, Morocco, Pakistan, Russia and South Africa, and more than 1000 people from these countries are listed in the database of scientists as using CERN for their experiments.

Govindrajan (left), director of the Electronics and Instrumentation Group at the Bhabha Atomic Research Centre, and Hans Hoffmann, CERN's director for technology transfer and scientific computing, sign an addendum to a co-operation agreement between CERN and India's Department of Atomic Energy that defines collaboration on software development for LHC computing.

Experimental groups from developing nations are not asked to make large cash contributions to the construction of detectors, but rather to produce components. These are valued according to European prices, and if the developing countries can produce them more cheaply using local resources, then more power to their elbows. In Russia's case, European and American funds were important in helping to convert military institutes into civilian work.

In addition to participating in experiments, some of these countries, notably Russia and India, have also contributed to the construction of accelerators at CERN. Russia and India are now making important contributions to the Large Hadron Collider (LHC) that is being constructed at CERN, and Pakistan has also offered to contribute. Again, CERN does not require these countries to pay any money towards the construction or operation of its accelerators. Indeed, CERN pays cash for the accelerator components that Russia and India provide, which these countries use to support their own scientific activities.

What, then, are the main benefits for developing countries in collaborating with CERN? It certainly provides them with a way to participate in research at the cutting edge, just as it always has for physicists from smaller European countries. In general, these users spend limited periods at CERN, preparing experiments, taking data and meeting other scientists. Thanks to the Internet, and to CERN's World Wide Web in particular, particle physicists were the first to make remote collaboration commonplace, and this habit has spread to many other fields beyond the sciences. It is now relatively easy for scientists working on an experiment at CERN to maintain contact with their colleagues around the world, and they can even contribute to software development, data analysis and hardware construction from their home institute. The Web has enabled Indian experimentalists to access LEP data, and their theoretician colleagues to access the latest scientific papers from around the world, all while sitting at their home desks.

CERN is now also a leading player in European Grid computing initiatives. These will benefit many other scientific fields, for which applications are already being developed. Grid projects involve

The Role of Science in the Information Society

On 10–12 December 2003, the first phase of the World Summit on the Information Society (WSIS) will take place in Geneva. The aim is to bring together key stakeholders to discuss how best to use new information technologies, such as the Internet, for the benefit of all. The International Telecommunications Union, under the patronage of UN secretary-general Kofi Annan, is organizing WSIS, and the second phase will take place in Tunis in November 2005.

The "information society" was made possible by scientific advances, and many of its enabling technologies were developed to further scientific research and collaboration. For example, the World Wide Web was invented at CERN to enable scientists from different countries to work together. It has gone on to help break down barriers around the world and democratize the flow of information.

For these reasons, science has a vital role to play at WSIS. Four of the world's leading scientific organizations: CERN, the International Council for Science (ICSU), the Third World Academy of Science (TWAS) and UNESCO, have teamed up to organize a major conference on The Role of Science in the Information Society (RSIS), as a side event to WSIS. The conference will take advantage of CERN's location close to Geneva to play a full role at the Summit.

Through an examination of how science provides the basis for today's information society, and of the continuing role for science, the conference will provide a model for the technological underpinning of the information society of tomorrow. Parallel sessions will examine science's future contributions to information and communication issues in the areas of education, healthcare, environmental stewardship, economic development and enabling technologies, and the conference's conclusions will be discussed at the UNESCO round table on science at the Summit itself.

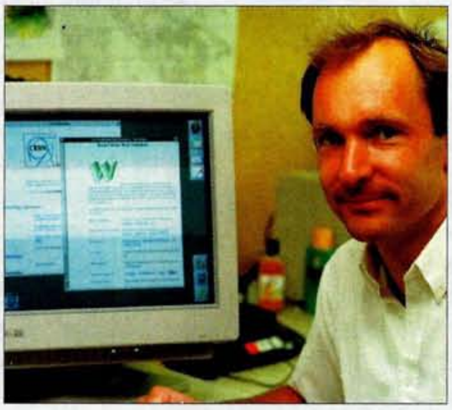
ICSU, TWAS and UNESCO have a long tradition of scientific, political and cultural collaboration across boundaries. CERN produces knowledge that is freely available for the benefit of science and society as a whole – the World Wide Web was made freely available to the global community and revolutionized the world's communications landscape. Working together, these organizations are providing a meeting place for scientists of all disciplines, policy makers and stakeholders to share and form their vision of the developing information society.

The RSIS conference will take place on 8–9 December. Its conclusions will feed in to the UNESCO round table at WSIS, and it will set goals and deliverables that will be reported on at Tunis in 2005. The scientific community's commitment is long-term.

Participation at the RSIS conference will be by invitation and is limited to around 400. However, anyone who feels they have something to contribute to the debate can do so via a series of on-line forums that are accessible through the conference website. These forums will have the same themes as the parallel sessions at the conference and will be moderated by the session convenors. Their conclusions will provide valuable input to the conference itself, and as an added incentive, CERN is offering up to 10 expenses-paid invitations to the conference for those making the most valuable on-line forum contributions.

For further information, see the conference website at http://cern.ch/rsis.

the role of science in the information society
CERN, Geneva, 8-9 December 2003



Combating the digital divide: Tim Berners-Lee, inventor of the World Wide Web, with the original Web browser.

writing a great deal of software and middleware, which is split up into many individual work packages. CERN is keen to share the burden of preparing the Grid with developing countries. For example, several LHC Grid work packages have been offered to India, and other countries such as Iran and Pakistan have expressed an interest and would be welcome to join. In this way, such countries can become involved in developing the technology themselves, thus avoiding the negative psychological dependency on technological "hand outs" (as in the "cargo cults" in New Guinea after the Second World War).

The everyday acts of collaborating with colleagues in more developed nations exposes physicists from developing countries to the leading global standards in technology, research and education. Collaborating universities and research institutes are therefore provided with applicable standards of comparison and excellence, as well as training opportunities for their young scientists. These may be particularly valuable when educational values are threatened by a combination of increasing demand, insufficient resources and inefficiencies. One country where this is currently a concern is Pakistan. Its chief executive, Pervez Musharraf, has clearly stated his interest in encouraging scientific and technological development in Pakistan, and has exhorted other Islamic countries to do likewise.

How might such "ISO 9000" educational and academic standards be transferred to the wider society? Their value is limited if only a few élite institutions in each country benefit from the international contacts and they are not available throughout the educational system. This is essentially an issue for the internal organization within the country concerned, but CERN is happy to help out. The laboratory has archives of lectures in various formats available through the Web, offering resources for remote learning.

In India, for example, the benefits of collaborating with CERN increase to the extent that physicists from smaller universities ▷

Malaysia is one country that is currently discussing a possible future collaboration with CERN. During a recent visit to Malaysia, Diether Blechschmidt (centre right), advisor to CERN's director-general, and his wife Britta Dezilli (left), attended an official dinner for CERN hosted by Datuk Abdul Rafie Bin Mahat (centre left), director-general of the Malaysian Ministry of Education. Also attending was Keith Lewin (right), director of the Centre for International Education at the University of Sussex, UK. The dinner offered an opportunity to establish first ties with Ministry officials, representatives of the Academy of Science of Malaysia and Malaysia's universities (standing).

HOPE for a partnership for health

Health is the second-most-searched-for subject on the Internet, which suggests that the Web should be an ideal tool to transmit health-related messages in a bid to reach some of the United Nations' Millennium Goals, such as reducing child mortality, improving maternal health and combating HIV/AIDS. CERN has therefore initiated a project to use short, simple, educational video clips to pass on important messages about primary health problems and issues such as HIV/AIDS, reproductive health and safe water. These clips are to be made available via the Web to lay people on five continents – in digital format and without copyright – using the Web-based delivery system set up by particle physicists.

Partners in the venture are two Geneva-based organizations, namely Project HOPE (Health Opportunities for People Everywhere), a not-for-profit medical-education organization, and the Ecole Supérieure des Beaux Arts, Geneva's prestigious and internationally recognized school for fine and audiovisual arts. The official launch of the first clip will be at the The Role of Science in the Information Society conference on 8–9 December (see p27). For further information on Project HOPE and the Ecole Supérieure des Beaux Arts, see www.projecthope.ch and www.hesge.ch/esba/htmfiles/accueil.html.

The first Iranian contribution to a particle-physics experiment, seen here with the team that designed and built it, was this table used to support the 240 tonnes of a forward hadron calorimeter for the CMS experiment at CERN.

outside the main research centres are brought into particle-physics research. In South Africa there are clear priorities in human development. However, a South African experimental group has joined the ALICE collaboration and CERN has welcomed a number of South Africans to its summer student programme, as well as a participant to its high-school teacher programme.

The information technologies that CERN has available should be of benefit to wider groups in developing societies. For example, could video archiving and data-distribution systems be used to disseminate public health information? This exciting idea was proposed to CERN by Rajan Gupta from the Los Alamos National Laboratory, and Manjit Dosanjh of CERN is now developing a pilot project in collaboration with the Ecole Superieure des Beaux Arts de Genève, supported by the foundation "Project HOPE" (see box above).

This project will be demonstrated at the conference on The Role of Science in the Information Society (RSIS) that CERN is organizing in December 2003 as a side event of the World Summit on the Information Society (WSIS) (see box p27). Other sessions at this event will explore the potential of scientific information tools for aiding problems related to health, education, the environment, economic development and enabling technologies.

In 1946 Abdus Salam left his native Pakistan to pursue his scientific dreams in the West – dreams that were more than fulfilled with the award of the Nobel Prize for Physics in 1979. However, his dream of bridging the gap between rich and poor through science and technology remained largely unfulfilled, as Riazuddin has described (*CERN Courier* April 2003 p46). If the world can develop its information society properly, a future Salam might not have to leave his – or her – country in order to do research in fundamental physics at the highest level. Moreover, a country's participation in research at CERN might benefit not only academics and students, but also the wider society at large.

John Ellis, *advisor for non-member states relations, CERN.*

The antiproton: a subatomic actor with many roles

From providing a window on fundamental symmetries to probing the strong interaction, LEAP'03 covered the many parts played by low-energy antiprotons from accelerators, as **John Eades** reports.

Participants at the LEAP'03 conference during a visit to the "Big Buddha" in Kamakura. (Masaki Hori.)

LEAP'03, the latest in the series of biennial low-energy antiproton-physics conferences, could not fail to be topical this year. Running from 3–7 March, it began with the latest news on the production of antihydrogen atoms at energies low enough to permit them to be studied by laser spectroscopy, and ended with progress reports on two new antiproton facilities (support for one of which had been announced by the German government just days before).

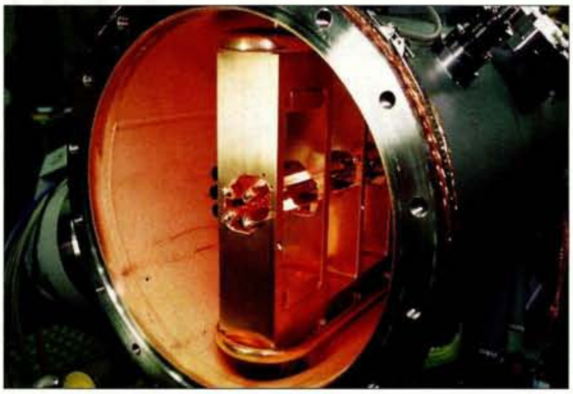
This somewhat unusual time of the year for LEAP – previous conferences in the series have always taken place in the Autumn of even years – is attributable to the frenzied activity at CERN's Antiproton Decelerator (AD), which now keeps many likely experimental participants busy between May and October. This year the meeting moved to Yokahama, where its packed programme more than compensated for the uncharacteristically wet and windy March weather. Some 60 talks reflected the recent surge of activity in what has become an exceedingly dynamic field.

An accelerator-produced antiproton normally spends only a brief instant in the world of matter. However, in this short time it can play many parts, from probing fundamental symmetry principles, to the study of atomic collisions, atomic bound states and nuclear physics. The initial session on discrete symmetries and antihydrogen was devoted to the current status of CPT invariance, the testing of which is perhaps the most powerful driving force behind current experimental activity in this field. Many particle physicists accept CPT invariance almost as an article of faith. They forget that, like Euclidean geometry, it is indeed a theorem, based on cherished but not entirely indispensable axioms such as Lorentz invariance (LIV), a feature the gravitational field only possesses locally. In his theoretical review, Nick Mavromatos of King's College, London, concentrated on the fact that gravitation has shown itself to be particularly resistant to quantization under the terms of the CPT theorem. Pointing out that it is not difficult to construct models containing parameters that violate LIV and other CPT axioms, he neatly connected ultra-high, Planck-mass scale energies with ultra-low ones, by suggesting that experiments on neutral mesons, slow neutrons and in particular antihydrogen atoms, can place bounds on these parameters. In a backward look at data from the KTeV, NA48 and CPLEAR collaborations, Yoshiro Takeuchi of Nihon University, Tokyo, analysed these in terms of CP- and T-violation parameters and limits on CPT violation, concluding that relative to the level of K^0–$\overline{K^0}$ mixing, CPT violation is currently constrained in the meson sector to a few parts in 10^5 at best.

A starring role

The spotlight then turned on the experimentalists and the antiproton's most recent starring role in the synthesis of large numbers of antihydrogen atoms. Nathaniel Bowden and Joseph Tan of Harvard brought participants up to date on the latest developments in antihydrogen synthesis from the ATRAP experiment. They reported on ATRAP's use of positrons in a nested Penning trap to cool antiprotons to the cryogenic energies necessary for the recombination reaction between the different particles to take place, and on the field ionization method used for detection. The latter makes it possible to observe antihydrogen atoms under background-free ▷

conditions and to measure, for the first time, the distribution of principal quantum numbers for the synthesized atomic states. Makoto Fujiwara of Tokyo and Germano Bonomi of CERN described the production, detection and temperature dependence of antihydrogen atoms in the ATHENA experiment, which uses a similar Penning trap but with a distinctive open and modular design. This allows, among other things, a buffer gas to be introduced on the positron side, in which continuously introduced positrons from ^{22}Na dissipate enough energy to prevent them re-emerging from the trap. Differential pumping then maintains a good-enough vacuum to ensure the survival of antiprotons for many hours on their side of the trap. ATHENA identifies antihydrogen events without ambiguity by detecting the simultaneous annihilation of their component positrons and antiprotons. New techniques for probing the positron plasma that rule out alternative but unlikely interpretations of the data have recently been introduced.



The decelerating radio-frequency quadrupole that is installed in the ASACUSA beamline at CERN's Antiproton Decelerator brings antiproton energies down to the keV range.

The mass and thermal model of the PAMELA experiment, inserted into the pressure vessel that will be attached to the Resurs-DK1 satellite, shows what this experiment to investigate antimatter in cosmic rays will look like when it is launched later this year. (PAMELA collaboration.)

Window on the world

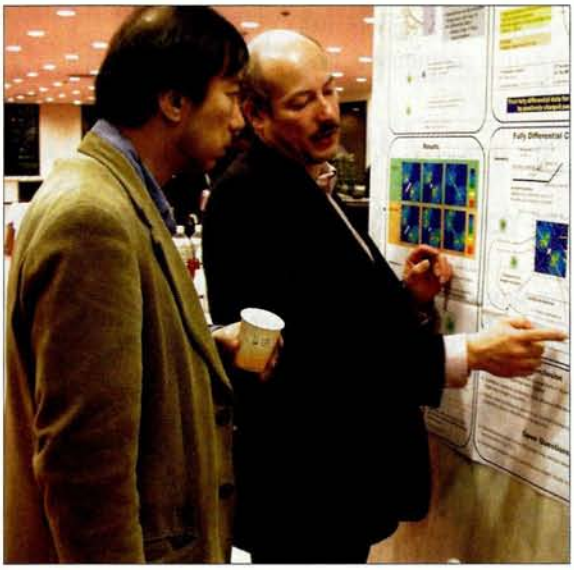
Antiproton beams have long provided a window on the shadowy world of glueballs, hybrids and quarkonia. In his review of this rich source of information on hadron physics, Ted Barnes from Oak Ridge looked both backward to LEAR and forward to future antiproton machines. Surviving glueball candidates from the era of LEAR, which ended in 1996, include the $f_0(1500)$ and, with less confidence, the $f_0(1710)$, while exotics include the $\pi_1(1400)$ and $\pi_1(1600)$. The advent of new antiproton sources at GSI and the Japan Proton Accelerator Research Complex (J-PARC; previously the Japan Hadron facility) now promises to open this window once again. Several more specific talks reviewed topics such as charmonium states from proton–antiproton annihilations in the Fermilab experiment E835, and the future Proton Antiproton Detector Array (PANDA) at GSI.

Low-energy antiproton beams can readily be stopped in matter targets. Before fully coming to rest, the antiprotons eject electrons from nearby target atoms and remain bound in their place. Once installed in this antiprotonic atom, they undergo complex cascades through electromagnetism-dominated states before coming within the range of strong interactions. However, it is only in antiprotonic helium that this cascade is known to last more than a few picoseconds. In this case, the microsecond-scale annihilation lifetimes of some atomic states fortuitously makes them accessible to laser spectroscopy, thus ensuring that antiprotonic helium can, in some respects, rival antihydrogen as a benchmark for studies of CPT invariance.

Attention on the second day, therefore, turned once again to the AD, with a session on the experimental and theoretical studies of antiprotonic helium. Masaki Hori of CERN reported on the limit on the antiproton charge and mass that can now be deduced from measurements of transition frequencies in the antiprotonic atom to a few parts in 10^7. The new limit results in part from the recent addition of a decelerating radio-frequency quadrupole (RFQD) to the ASACUSA beamline. This reduces the beam's kinetic energy from the MeV to the keV scale, and so allows the antiprotons to be stopped in very-low-density helium, with concomitantly smaller systematic corrections to the measured frequencies. Further impetus, expected from two-photon laser techniques and more advanced laser systems, may soon improve the precision of the frequency measurement to several parts in 10^9, and so also permit spectroscopy of the two-body antiprotonic helium ion ($\bar{p}\,He^{++}$). Jun Sakaguchi of Tokyo described the ASACUSA microwave-spectroscopy experiment on antiprotonic helium, which has allowed the antiproton orbital magnetic moment to be determined from the hyperfine splitting of atomic levels to a few parts in 10^5 (*CERN Courier* January/February 2003 p27). The QED calculations that make all the above interpretations possible, were described by Vladimir Korobov of JINR Dubna, and further talks dealt with the physical chemistry of the antiprotonic helium atom.

Antihydrogen experiments dominated again in the following session on the future programme for the AD. Cody Storry of Harvard introduced a novel antihydrogen production mechanism that is being considered by ATRAP. A beam of caesium atoms previously excited into Rydberg states by a laser beam passes through the positron cloud confined in a Penning trap, where they produce positronium atoms that are also in Rydberg states. These have a much higher recombination cross-section with trapped antiprotons than is the case for ground-state positronium. The next major goal for both ATHENA and ATRAP is to begin laser spectroscopy of cold antihydrogen atoms, and several different schemes, including laser-stimulated recombination and ionization, are being investigated. From ASACUSA, Yasunori Yamazaki of RIKEN and Tokyo presented the idea that positrons and antiprotons may be confined in the same region of a trap incorporating a magnetic field "cusp", while Eberhard Widmann, also from Tokyo, showed that a precision measurement of the ground-state hyperfine splitting in antihydrogen must now be seriously considered to fall within the AD's "line of sight". Throughout the history of modern physics, experiments with atomic beams have proved extremely fruitful in studying the hydrogen atom with high precision, and these latter two topics opened up the idea that the same can be true for antihydrogen.

Left to right: Hans Henrik Andersen of the Niels Bohr Institute, Yasunori Yamazaki of Riken and Tokyo, and Søren Pape Møller of Aarhus deep in conversation during the poster session. (Eberhard Widmann.)



Takashi Ishikawa (left) of Tokyo and Joachim Ullrich of MPI Heidelberg discuss one of the posters at LEAP'03. (Eberhard Widmann.)

The research arena then moved from earthbound laboratories to the atmosphere and space, where the search for cosmic antimatter has been under way for many years. Catherine Leluc of Geneva reviewed the status of the ALPHA Magnetic Spectrometer (AMS02). This is due for launch to the International Space Station in October 2005, but a pilot version (AMS01) has already been flown on the shuttle mission STS-91 in 1998. The AMS02 detector now incorporates improved acceptance and redundancy into its search for antimatter and dark matter in cosmic rays. The third-generation high-altitude balloon experiment BESS-Polar was discussed by Mitsuaki Nozaki of Kobe. This will be used to study low-energy cosmic-ray antiprotons in detail in a superconducting magnetic spectrometer, and is expected to have a 10–20 day flight through the top of the polar atmosphere in 2004. Finally, Piero Spillantini of Firenze described PAMELA, a successor to several balloon-borne experiments, which will be launched later this year into quasi-polar orbit on the Russian Resurs-DK1 satellite from the Baikonur Cosmodrome.

Before they can be captured into atomic states, antiprotons produced at accelerators must lose some nine orders of magnitude of kinetic energy, and as is the case for other particles, their interaction with matter over this range is of crucial importance. The fact that antiproton projectiles are both heavy and negatively charged has far-reaching consequences for their behaviour when passing through matter. Capture/loss processes and the excitation of target electrons drastically modify the Bethe–Bloch formula at the velocity scale of the electron orbitals in the target material. The RFQD installed in ASACUSA's beamline has shed new light on this experimentally dark area, and Ulrik Uggerhoj from Aarhus was able to report on the latest results on stopping-power measurements made with antiproton beams from 1 to 100 keV in C, Al, Ni, Au and LiF foils. The results of theoretical approaches to the understanding of collisions of antiprotons with hydrogen and helium atoms, ions and molecules, and to the explanation of ionization phenomena in the low-velocity domain, were presented by John Reading of Texas A&M and several other speakers.

The final curtain

The life of an antiproton ends when it comes within range of the strong interaction, either after an atomic cascade or (occasionally) by a direct in-flight hit on the nucleus. It is then that it plays its final research role, as a nuclear probe. The AD as presently constituted is not easily adaptable for such studies, but with GSI and J-PARC now on the horizon, Josef Pochodzalla of Mainz was able to look forward to using antiprotons from these machines for the large-scale production of single and double Λ-hypernuclei. The weak decays and gamma-ray spectra of these hypernuclei can elucidate hyperon–hyperon and hyperon–nucleon interactions, measure fundamental properties of the hyperons themselves, and produce genuine hypernuclear states with symmetry properties unavailable to ordinary nuclei. These antiprotons that have suffered atomic capture can eventually de-excite to atomic ground states that "graze" the nucleus, so their annihilation constitutes an effective probe of the nuclear surface. This aspect occasioned both backward and forward glances in reports on new analyses of data from the PS209 experiment at LEAR and the possibility of similar studies at ASACUSA. ▷

The final day of the LEAP'03 conference was appropriately devoted to the current and future antiproton facilities. The morning session opened with a review by Tommy Eriksson from CERN of the present status of and future prospects for the AD machine, where the name of the game is "ever lower energies". The AD is now operating close to its design specifications, with pulses containing 10^7 antiprotons being reliably delivered at an energy of 5.3 MeV every 100 seconds. Research at even lower (keV) beam energies has now been strongly boosted by the RFQD, which has permitted several million antiprotons to be captured in the Tokyo Penning trap and cooled to cryogenic energies. Naofumi Kuroda of Tokyo discussed their extraction in the form of a beam of antiprotons with kinetic energies on the eV scale. A new feature of the AD programme, which was described by Carl Maggiore of Pbar Medical, is an investigation with a 300 MeV/c (25 MeV) beam of a possible therapeutic role for antiprotons. This beam, astronomically high in energy for most other physicists, will soon be used to investigate the relative biological effect of antiprotons on biological cell samples.

In the final session on the topic of future antiproton facilities, Walter Henning, GSI's director, described the laboratory's new project and its potential for antiproton physics. The large-scale expansion of the GSI-Darmstadt laboratory, the funding of which has only very recently been agreed by the German federal government, will be carried out in two stages, with a 25% external contribution. One of its key elements will be the provision of antiproton beams below 15 GeV. Shoji Nagamiya, director of the J-PARC project, outlined progress on this new Japanese accelerator complex, centred on a 50 GeV proton synchrotron at Tokai, 150 km north-east of Tokyo. Planning has been under way since 2001 and is now rapidly gathering momentum. With financing amounting to some ¥134 billion (€98 billion), Phase 1 is expected to produce its first beams in 2008. An opening ceremony was held in October 2002, and 30 letters of intent had been received by the end of December 2002, one-third each from Japan, Europe and North America. Both GSI and J-PARC now actively encourage the voice of antiproton users to be heard in the planning of their experimental programmes.

The best yet

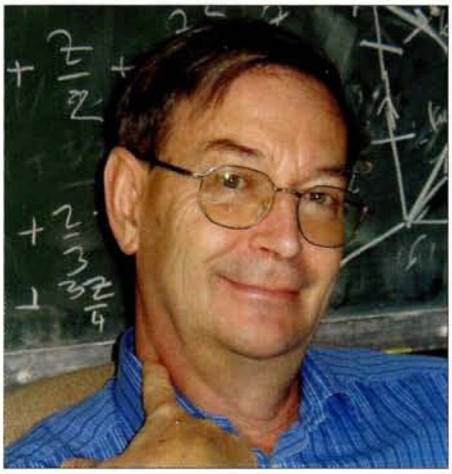
The smooth organization of LEAP'03 largely resulted from the efforts of Eberhard Widmann and Ryugo Hayano of Tokyo University, with financial assistance being provided by RIKEN, KEK and the Antimatter Science Project at the University of Tokyo. Viewing the busy and spectacular Yokohama bay through the Sangyo Boeki Centre's windows during the coffee breaks, the 100 participants could all agree that the form and content of the conference programme was the best yet.

John Eades, *Tokyo.*

APPOINTMENTS

Zinn-Justin becomes head of DAPNIA

Jean Zinn-Justin has succeeded Michel Spiro as head of the Department of Astrophysics, Particle Physics, Nuclear Physics and Associated Instrumentation (DAPNIA) at the Saclay laboratory of the French Atomic Energy Commission (CEA).

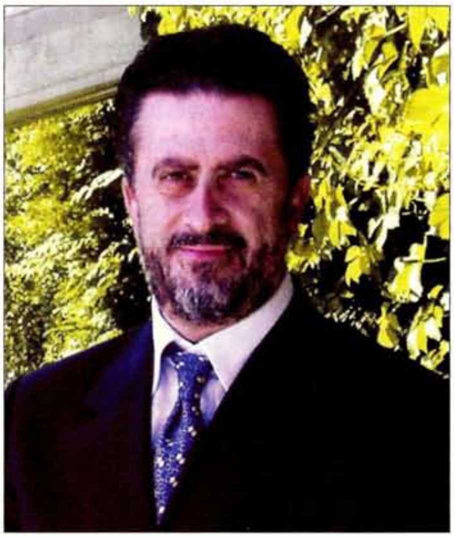


A theoretical physicist, who joined the theoretical physics service of the CEA in 1965, Zinn-Justin has worked principally on quantum field theory and its applications in particle physics and in the statistical mechanics of phase transitions. He led the theoretical physics service from 1993 to 1998.

Zinn-Justin has been a visiting scientist in many research centres and universities, including CERN, MIT and the universities of Stony-Brook, Princeton and Harvard. He is editor of several scientific journals and is a member of numerous scientific committees, both in France and elsewhere. As a teacher, between 1987 and 1995, he was director of the Les Houches Summer School and co-organizer of the courses.

Zinn-Justin is the first theoretician to become director of DAPNIA. However, having participated on scientific committees for the astrophysics and particle physics services of DAPNIA for many years, he will be working with the department's experimenters in an environment he knows well.

New director for the INFN Gran Sasso National Laboratory...



Eugenio Coccia is the new director of the INFN National Laboratory of Gran Sasso, the world's largest underground laboratory for astroparticle physics. Coccia, who is full professor of gravitational physics at the Physics Department of the Faculty of Science of the University of Rome Tor Vergata, succeeds Alessandro Bettini at the end of his six-year mandate. Coccia has carried out research mainly at CERN and the INFN National Laboratories of Frascati, working on the realization of the cryogenic detectors EXPLORER and NAUTILUS, which are currently the most sensitive gravitational wave detectors in continuous operation. Prior to this appointment, he was chairman of the Scientific National Committee for Astroparticle and Neutrino Physics of the INFN, and is the current president of the Italian Society of General Relativity and Gravitational Physics. Coccia, who took over on 16 June, will be director at Gran Sasso for the next three years.

...and for the Instituto de Fisica at UNAM

Arturo Menchaca, a leading Mexican experimentalist and member of the ALICE collaboration at the Large Hadron Collider, has recently been appointed as director of the Instituto de Fisica of the Universidad Nacional Autonoma de Mexico (UNAM). The Instituto de Fisica at UNAM has the largest concentration of physicists in Mexico, with approximately 100 post-docs and around 115 graduate students, and plays an essential role in the education and training of the country's physicists.

Willibald Jentschke commemorative issue

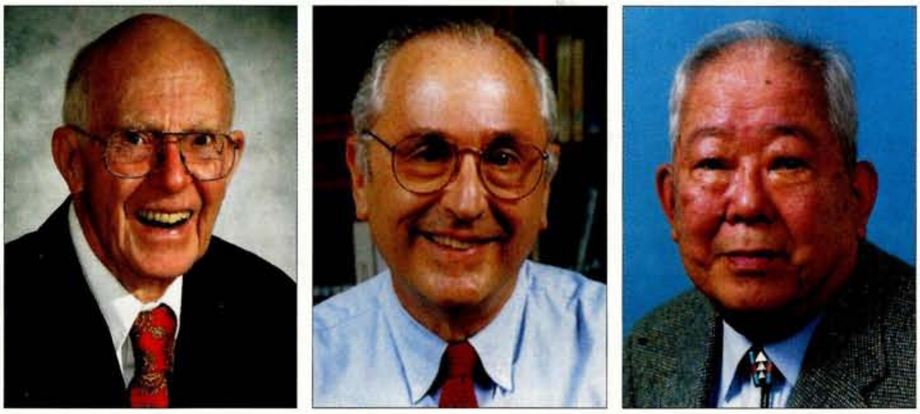
A special issue of *CERN Courier*, dedicated to the memory of Willibald Jentschke, has just gone online at the *CERN Courier* website (www.cerncourier.com – click on "Special Issues"). A limited number of paper copies will be available on a first-come first-served basis from the CERN library. To request a copy, fill in the form at: http://weblib.cern.ch/publreq.php, or write to CERN Scientific Information Service, CERN, 1211 Geneva 23, Switzerland.

PRIZES

Neutrino physicists pick up awards

The Franklin Institute in Philadelphia has awarded its 2003 Benjamin Franklin Medal in Physics to three pioneers of solar neutrino physics. John Bahcall of the Institute for Advanced Study, Princeton, Raymond Davis of the Brookhaven National Laboratory and the University of Pennsylvania, and Masatoshi Koshiba of the University of Tokyo, have received the medal for work that led to an understanding of neutrino emission from the Sun. Bahcall performed some of the earliest research in this area and provided the theoretical basis for the experimental work of Davis, in his pioneering detector in the Homestake gold mine, and then Koshiba, who led the design and construction of the Kamiokande neutrino observatory. Bahcall is also a winner of the 2003 Dan David prize. The prize, which is funded by auto photo-booth developer Dan David, makes awards for past, present and future "time dimensions". Bahcall's award is in the Future Time Dimension category, in the field of cosmology and astronomy.

On 13 May, the Markov prize was presented to Tom Bowles from Los Alamos National Laboratory, and Vladimir Gavrin and Vadim Kuzmin, both from the Institute for Nuclear Research (INR) of the Russian Academy of Sciences. The Markov prize was established last year by the INR as a memorial to Moisey Alexandrovich Markov, one of the founders of the INR, with its Baksan and Baikal neutrino observatories. This year the prize was presented in acknowledgement of contributions to research on the solar neutrino problem.



Medal winners Raymond Davis (left), John Bahcall (centre) and Masatoshi Koshiba.

Markov prize winners (from left) Vadim Kuzmin, Tom Bowles and Vladimir Gavrin, together with the first director of the INR, Albert Tavkhelidze, and its current director Victor Matveev.

Gavrin and Bowles are, respectively, the Russian and American co-principal investigators of SAGE (Soviet–American Gallium Experiment), which has been in operation at Baksan since 1987, while Kuzmin was, in the 1960s, the first person to suggest gallium as a target for solar neutrinos produced in proton–proton fusion reactions.

NEW PRODUCTS

Integrated Engineering Software (IES) has recently unveiled the V6.1 release of its two-dimensional low-frequency electric and magnetic field solvers, which now incorporate new technology solvers that are based on FEBEM, a hybridized finite element (FEM) boundary element (BEM) method. Users can select between FEM, BEM or the FEBEM hybrid mode. For further information, tel: +1 204 632 5636, fax: +1 204 633 7780, or e-mail: info@integratedsoft.com.

Thales Computers has announced a new PCI mezzanine card, the PMC-PIO. The card provides 64 channels of 3.3 V (5 V compatible) parallel I/O, which can be independently programmed as input or output. The company is also offering a new shortform catalogue. For more details and a free copy of the catalogue, see www.thalescomputers.com, tel: +1 800 848 2330, or fax: +1 919 231 8001.

Acqiris has introduced a new 21-slot crate that enables high-speed digitizer systems with up to 80 channels to be configured in a single 19" wide, 9U high rack. Acqiris has also developed a new family of PCI 12-bit ADC digitizer cards that feature a high level of throughput. The DP310 has a sampling rate of up to 400 MS/s, while the DP306 and DP308 sample at up to 100 and 200 MS/s, respectively. More details are available at www.acqiris.com.

FIZ Karlsruhe has launched a new defensive publication database on the online service STN International. RDISCLOSURE contains over 27 000 records, with full text and images, and covers inventions from all areas of science and technology since 1960. For further information see www.fiz-karlsruhe.de.

PRIZES

DESY acknowledges young physicists

David Milstead from the University of Liverpool has received the DESY communication award, which was presented to him on 23 April by Erich Lohrmann. Milstead won the €1000 prize for the film "Chasing the Magnetic Monopole" that he produced last year in collaboration with a BBC television team. The film provides an insight into Milstead's life as a young physicist looking for magnetic monopoles at the H1 experiment at HERA. The award is presented by the Association of Friends and Sponsors of DESY to young scientists who have an excellent capability to give an understanding of their work to a scientifically interested audience.

DESY's PhD thesis prize has this year been awarded, for work carried out at HERA, to Lara De Nardo and Oscar González López. De Nardo, from the University of Alberta, received the prize for her thesis on "Measurement of the structure function g_1^d at HERMES and extraction of polarized parton distributions", which was carried out at the HERMES experiment at HERA. On the basis of her measurement of the spin structure function of the deuteron – the most precise so far – De Nardo carried out an impressive theoretical analysis of all previous measurements and came to the conclusion that the gluons very probably contribute a large positive amount to the spin of the proton. González López from the Universidad Autonoma de Madrid was awarded the prize for his thesis on "Precise determinations of the strong coupling constant at HERA". This was based on a new, precise measurement of the coupling constant carried out at the ZEUS experiment, which provides a very precise and methodically "clean" verification of quantum chromodynamics.

David Milstead (left) receives the DESY communication award from Erich Lohrmann.

DESY's PhD thesis prize winners Lara De Nardo (left) and Oscar González López (right) with Erich Lohrmann.

CERN

LHC suppliers receive Golden Hadron awards

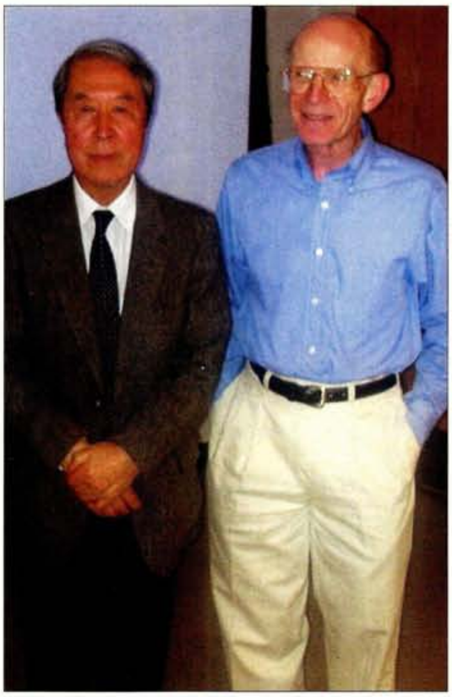
In a ceremony at CERN on 16 May, three companies received CERN's "Golden Hadron" awards for 2003. The awards, for the LHC project's best suppliers, were presented not only for technical and financial achievements, but also for compliance with contractual deadlines. The Furukawa Electric Company from Japan won its award for delivering some 575 km of superconducting outer cable, representing a whole octant of the LHC ring. The Belgian firm JDL Technologies distinguished itself by developing a cable inspection system by image analysis, which detects the slightest defect in a cable in real time. IHI (Japan)–Linde Kryotechnik (Switzerland) received its award for manufacturing four 1.8 K refrigeration units for the LHC cryogenic system. Based on a unique advanced cold-compressor technology, each unit has a cooling power of 2400 W.

Representatives of the companies who have received the 2003 Golden Hadron awards, together with Lyn Evans (centre), the LHC project leader, who made the presentations.

'Wallyfest' in Maryland and 'Joefest' in Syracuse

To celebrate the 70th birthday of O W "Wally" Greenberg (right of picture) on 9 May, the University of Maryland hosted a "Wallyfest", a symposium on "Quarks, Statistics and Colour". Speakers included Dan Zwanziger, on non-perturbative QCD; Carl Bender, on PT symmetry in quantum mechanics; Gabriel Karl and Yoichiro Nambu (left of picture) on colour and related topics; Alan Kostelecky, on Lorentz and CPT violation; and Masud Chaichian, on non-commutative quantum field theory.

Meanwhile, the University of Syracuse celebrated the 65th birthday of Joe Schechter with a "Joefest" on 13–15 May, which was attended by many distinguished theoretical physicists, including Robert Jaffe, Susumu Okubo and Lincoln Wolfenstein, as well as many of Schechter's former students, post-docs and friends. Schechter is well known for his contributions to several areas of particle physics, in particular the origin of neutrino masses, QCD-effective Lagrangeans and current algebra.



TRIUMF's new ISAC-II building, funded by the government of British Columbia, Canada, was formally opened by the premier of British Columbia, **the Honourable Gordon Campbell** (left), on 11 June. The ISAC-II accelerators, now under construction with funding from the Canadian government, will increase the maximum energy of the radioactive ion beams from 1.5 MeV/u to at least 6.5 MeV/u, and their mass range from A < 30 to A < 150 (*CERN Courier* January/February 2003 p30). Campbell is seen here with **Alan Shotter**, director of TRIUMF. Photo credit: Hapke, TRIUMF.

The Portuguese minister for science and higher education, **His Excellency Pedro Augusto Lynce de Faria** (right), visited CERN on 6 May. He toured various LHC and ATLAS installations, including the hall where the hadron calorimeter is being assembled. Here, the minister shares an amusing moment with **Peter Jenni** (left), spokesman for ATLAS, and **Ana Maria Henriques Correia**, the tile calorimeter group leader at CERN.

On 30 April, **Bjørn Haugstad**, the state secretary of the Norwegian ministry of education and research, paid a visit to CERN, where he toured various installations including the LHC test facility and the ATLAS assembly areas. He also learned about initiatives from CERN and the European Union on Grid technology, in particular CERN's openlab for Grid applications. Here, he is seen (left) at a luncheon given in his honour, hosted by **Carlo Wyss**, CERN's director for accelerators (standing right).

Technology transfer from CERN to medicine was the theme for two visits hosted by **Hans Hoffmann**, director for technology transfer and scientific computing. **Octavi Quintana Trias**, director of the health directorate of the European Commission's Directorate-General for Research, visited on 14 May, and heard about the application of CERN's technologies in medical imaging and hadron therapy. He is seen seated in the left-hand picture with Hoffmann (standing right) and **Juan Antonio Rubio**, CERN's Education and Technology Transfer Division leader. On 19 May, **Maria Rauch-Kallat** (right-hand picture), Austria's minister of health and women's issues, also heard about the spin-offs from CERN for medical applications and toured the assembly areas for the ATLAS experiment.

Members of the Swedish Research Council and the Scientific Council for Natural and Engineering Sciences visited CERN on 26 May. The visit included tours of the LHC magnet test facility, the ISOLDE facility and the ATLAS assembly areas, where there was time for a group photo in front of one of the vacuum vessels for the ATLAS toroid magnet.

MEETINGS

The ICFA Future Light Sources Sub-Panel's **Mini-Workshop on Start-to-End Simulations of X-Ray FELs** will take place at DESY–Zeuthen, Berlin, on 18–22 August. The purpose of this workshop is to discuss and compare results of start-to-end simulations of specified benchmark scenarios. Attendance is by invitation only. For further information, see www.desy.de/s2e.

The International Workshop on Astroparticle and High Energy Physics (AHEP-2003) will take place in Valencia on 14–18 October. The meeting forms part of the activities of the European Science Foundation Neutrino Astrophysics Network, aimed at fostering collaboration on neutrino physics and astrophysics. For further details and online registering, see the conference website at http://nac15.ific.uv.es/conference/.

LETTERS

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

Charmonium revisited

We were very pleased to read the article "The eventful story of charmonium singlet states" by André Martin and Jean-Marc Richard (*CERN Courier* April 2003 p17), because we have ourselves been involved in this search for more than a decade. We unsuccessfully searched for the η'_c in our $p\bar{p} \rightarrow \gamma\gamma$ measurements at Fermilab (T A Armstrong *et al.* 1995), and then in the DELPHI $\gamma\gamma \rightarrow$ hadrons measurements at CERN (P Abreu *et al.* 1998). However, we are happy to report that we finally succeeded in our recent measurements of the reaction $\gamma\gamma \rightarrow K_sK\pi$ at Cornell. In two independent measurements – 13.5 fb^{-1} of e^+e^- data using the CLEO II/II.V detector, and 9.2 fb^{-1} data using the CLEO III detector – we successfully identified the η'_c. Our mass for the η'_c is 3643±4(stat)±4(syst) MeV, which makes its hyperfine splitting a bit less drastic than the larger of the two Belle results suggests, but it is still quite unexpected. This result was presented by Z Metreveli at the Philadelphia meeting of the American Physical Society in April (Z Metreveli, CLEO Collaboration 2003). We expect to be able to submit our results for publication soon. Until then, they will of course carry the caveat of "preliminary".

Further reading

P Abreu *et al.* 1998 *Phys. Lett.* **B441** 479.
T A Armstrong *et al.* 1995 *Phys. Rev.* **D52** 4839.
Z Metreveli, CLEO Collaboration 2003 *Bull. Am. Phys. Soc.* **48(2)** 12–17; www.lns.cornell.edu/public/TALK/2003/TALK 03-8/aps_talk.ps.

Z Metreveli, K K Seth and A Tomaradze, Northwestern University, Evanston, Illinois.

CORRECTION

An error crept into the caption to the picture of particle tracks on page 26 of the June issue. It should have said that the image shows "multiparticle production by 24 GeV/c protons".

OBITUARIES

Vernon Hughes 1921–2003

Vernon W Hughes, well known for his work on precision measurements of elementary particles and the use of polarized electrons and muons in particle physics, passed away on 25 March 2003.

Born in Kankakee, Illinois, on 28 May 1921, Hughes attended Columbia University, where he received an AM degree in 1941. During the Second World War he helped develop radar at the MIT Radiation Laboratory and was one of the co-editors of a volume of the *MIT Radiation Laboratory Series* entitled "Waveforms" – a volume that has been of major significance to the development of the US electronics industry. Hughes then returned to Columbia and received his PhD in 1950. This early work – and in fact much of his life's work – involved investigations of the effects of the interaction of radiation with matter, and in 1950 he and his colleagues discovered the first two-photon transition in atomic spectroscopy.

Hughes' career involved a broad spectrum of studies of physical phenomena, ranging in energy from the very low to the very high. But he consistently maintained the theme of understanding the physics of elementary particles and their interactions at the most fundamental level. He measured the sum of the difference in magnitude between the electron and proton charges to be one part in 10^{19}, and the electric charge on the neutron to be zero, with similar precision.

One area for which Hughes is particularly well known is the study of atomic physics by means of experiments with the most elementary particles. For 30 years he studied the helium and positronium atoms, and made the first observation of the muonium atom in 1960. The latter evolved into precision measurements of the properties of the atom, eventually leading to hyperfine measurements.

These 35 years of experimentation, verifying to a high precision that the muon is indeed a "heavy electron", provided new avenues into the experimental study of quantum electrodynamics and created a tool to probe the highest energy scales of elementary particle physics.

Hughes was the originator of another field of great importance: the use of polarized electrons in high-energy accelerators. His interest in polarized electron beams began in 1959 and he developed the first polarized source for SLAC. His vision and perseverance led to the first measurements of the spin-dependent structure of the proton and to the historic observation of parity non-conservation in electron scattering from nucleons. More recently, the success of the SLAC Linear Collider experiments in probing the electroweak interaction with polarized electrons colliding with positrons are directly traceable to Hughes' seminal work.

His pioneering work also opened up the field of nuclear physics to investigations with polarized electrons at low-energy accelerators. The first such experiment in the US was performed by Hughes and his collaborators at the Bates linear accelerator, where they observed parity violation in polarized electron–carbon elastic scattering.

Extending the reach of deep inelastic polarized lepton scattering from nucleons, Hughes led a large collaboration at CERN in investigations that employed polarized muons scattering from polarized neutrons and protons. This work was stimulated by the "proton spin crisis", first observed by Hughes and his group, and led to a more complete understanding of the relationship between the nature of the constituents of the proton and its spin.

Most recently, he conceived and led an experiment at the Brookhaven National Laboratory to greatly improve the measurement of the muon anomalous magnetic moment (g–2). This quantity embodies our knowledge of the interactions of elementary particles in one parameter, and has long served as a crucial parameter with which we can test new ideas in particle physics.

Hughes was on the Yale University faculty from 1954 until his retirement in 1991, and was Sterling professor, the highest honour Yale can bestow. He was also chairman of the Physics Department from 1961 to 1966 and presided over a large expansion of the department. Hughes received many honours in his lifetime, including membership of the National Academy of Sciences, an honorary doctorate from the University of Heidelberg, and both the Davisson-Germer Prize in Atomic Physics and the Tom R Bonner Prize in Nuclear Physics of the American Physical Society.

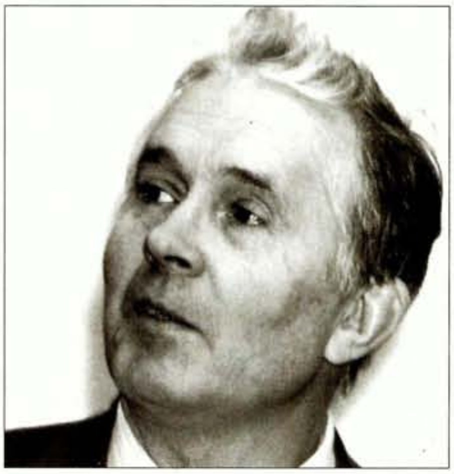
Hughes' focus was always on the most fundamental questions in physics, and his development of ultra-precise experimental techniques allowed him to establish several of the fundamental constants that characterize our universe and all its wonderful phenomena.

Never satisfied until he fully understood the phenomenon he was studying, Hughes educated a generation of students who have become leaders in the international scientific community. He will be much missed by all his friends and collaborators worldwide, and especially by his colleagues at Yale.

Robert K Adair and Michael E Zeller, Yale University.

OBITUARIES

Grigory Silvestrov 1934–2003



Grigory Silvestrov, one of the outstanding disciples of Gersh Budker, passed away on 22 April.

In 1958, after graduating from Moscow University, Grigory joined the team working on the realization of Budker's original ideas. During his first years at the Institute of Nuclear Physics he constructed transport channels from synchrotrons to electron–electron colliders (VEP-1) and to electron–positron colliders (VEPP-2 and later VEPP-4). Pulsed power supply, for which he was always an enthusiast, was employed for the magnets and lenses in these channels and allowed a smaller size and lower energy consumption. Quadrupole lenses and septum magnets, which he constructed using skin formation of the field profile, were widely used. Grigory's development of parabolic and cylindrical lithium lenses, and their use to obtain positron beams at VEPP-2 and VEPP-2M colliders, is well known. The next generation of these lenses, designed to obtain antiproton beams, served as a prototype for devices later used at CERN and FNAL, a fact recognized in the *Encyclopaedia Britannica* in 1983.

The parabolic and cylindrical lenses Grigory created were very original devices, typical of his style. Supplied by mega-ampere sources, they could operate in environments of high radiation, heat and mechanical load. A natural way to obtain intensive secondary beams is to construct liquid metal lenses for converters and here, as in many other devices, Grigory showed his inventiveness and talent. Another branch of his activities was the development of pulsed high field magnetic elements in which fields up to 10 tesla can be created by iron poles and current buses. During the last years of his life, Grigory became interested in creating a powerful neutron source for boron–neutron capture therapy. He suggested an original system consisting of a 2.5 MeV tandem proton accelerator with vacuum insulation and a liquid lithium lens. Grigory gathered a team of enthusiasts and, supported by international grants, started active work on the project.

We will remember Grigory as a talented physicist, an optimist and a kind man.

A Skrinsky and G Tumaikin, Budker Institute.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
Tel: +44 (0)117 930 1028. Fax: +44 (0)117 930 1178. E-mail: sales@cerncourier.com.
Rates per single column centimetre: mono $66/€72/£44, single colour $69/€75/£46, full colour $72/€78/£48. Please contact us for more information about publication dates and deadlines.

EDITORIAL POSITION, PHYSICAL REVIEW LETTERS

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Physical Review Letters seeks a dynamic and personable colleague to join its editorial staff in Ridge, New York (near Stony Brook and Brookhaven).

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Joseph Ignacio, Director of Human Resources,
American Physical Society,
1 Research Road, Box 9000, Ridge, NY 11961,
e- mail: edresumes@aps.org, fax: 631-591-4155.

For general information about the American Physical Society and its journals, see www.aps.org.

RESEARCH SCIENTIST

TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, has an immediate opening for a Research Scientist to lead its current particle physics effort based upon its cyclotron. The initial focus will be the TRIUMF Weak Interaction Symmetry Test (TWIST), and for the longer term, the scientist will be expected to participate in the development of a major national data-handling centre for particle physics experiments, which is currently in the planning stages.

A recent PhD in experimental, nuclear or particle physics with strong abilities in detector technology and data analysis is required. In particular, the candidate will have a strong record in on-line/off-line data-handling, data analysis and software development involving large data-sets, and will have demonstrated the ability to carry out such tasks to the stage of publication of physics results. The initial appointment will be for a two-year renewable term, leading to a continuing appointment (tenure track) after five years. The successful candidate will be eligible to apply for NSERC peer-reviewed funding and will be encouraged to develop his/her own proposals.

The position will be based at **TRIUMF**, located in Vancouver, British Columbia. Applications from qualified candidates should include a detailed CV and three reference letters sent separately to the following address, or fax, prior to **September 30, 2003. TRIUMF Human Resources, Competition No. 907, 4004 Wesbrook Mall, Vancouver, B.C. V6T 2A3 Canada. Fax: (604) 222-1074. Please do not send electronic applications.**

In the event where two final applicants are equally qualified, preference will be given to a Canadian citizen or permanent resident. **EOE**

ASSISTANT PROFESSOR

EXPERIMENTAL PARTICLE ASTROPHYSICS

ENRICO FERMI INSTITUTE

The Enrico Fermi Institute is seeking applicants for a tenure-track position at the rank of Assistant Professor in the field of experimental particle astrophysics, or a closely allied field, commencing with the Autumn 2004 Quarter. Some of the present activities in this area within the Enrico Fermi Institute include the VERITAS high energy gamma-ray observatory and the Auger project for observations of ultra-high energy cosmic rays.

Qualified applicants in any area of experimental particle astrophysics are encouraged.

Interested candidates should send CV, statement of research interests and goals and arrange for 3 letters of reference to be sent to: Director, Enrico Fermi Institute, 5640 S. Ellis Av., Chicago, Illinois, 60637.

Applications and references should be submitted by October 15th.

The University of Chicago is an equal opportunity employer.

THE UNIVERSITY OF
CHICAGO

POSTDOCTORAL RESEARCH ASSOCIATE
KANSAS STATE UNIVERSITY
DEPARTMENT OF PHYSICS

Applications are invited for a Post-Doctoral Research Associate position with the experimental high-energy physics group of Kansas State University. Our group is currently active in the analysis of D0 data from the Fermilab Tevatron, in the D0 Run IIb upgrade, in the construction of the CMS silicon tracker. We are also launching new R&D efforts in e+e- linear collider and reactor neutrino physics.

The successful candidate will play a strong role in the analysis of D0 data and will seek leadership opportunities in linear collider detector R&D.

The position requires a Ph. D. in experimental particle physics. Applicants should send curriculum vita, a list of publications, and arrange to have three letters of recommendation sent to:

Professor Eckhard von Toerne,Department of Physics,
116 Cardwell Hall, Kansas State University, Manhattan, KS 66506-2601,
evt@phys.ksu.edu, phone 785-532-1644.

Screening of applications will begin July 31, 2003 and continues until the position is filled.

Kansas State University is an affirmative action/equal opportunity employer and actively seeks diversity among its employees.

Deutsches Elektronen-Synchrotron

Accelerator physics

DESY

DESY is one of the leading accelerator centers worldwide. The research spectrum ranges from elementary particle physics and solid state physics to molecular biology.

For the participation in the operation and development of HERA we are seeking a

PhD Physicist (m/f)

HERA is for the time being the only high energy particle collider in Europe and the only lepton-hadron collider in the world. For further improvement and development of this exciting machine, we are looking for a physicist with good general knowledge in physics for a postdoc position. Experience in accelerator physics is desirable but is no condition. The aim is to support the achievement of higher luminosity and higher degree of beam spin polarization. We expect the willingnes to work on new topics, to work in a team, and to support accelerator operation by the participation in scientist-shift services. Your health should also permit the use of a breath protection mask. If you fulfil all these requirements, please send your letter of application to our personnel department.

The position is limited to 2 years (postdoc position, a 1-year extension is possible).

Salary and benefits are commensurate with public service organisations. DESY operates flexible work schemes, such as flexitime or part-time work.

DESY is an equal opportunity, affirmative action employer and encourages applications from women.

Deutsches Elektronen-Synchrotron DESY
member of the Helmholtz Association
code: 25/2003 • Notkestraße 85 • D-22603 Hamburg • Germany
Phone +49 40/8998-3187 • www.desy.de
email: personal.abteilung@desy.de

Deadline for applicants: 30.09.2003

Massachusetts Institute of Technology

The Laboratory for Nuclear Science at MIT has two openings for postdoctoral research associate positions with the Medium Energy Physics Group.

This group is starting a new involvement in the spin physics program at RHIC at BNL within the STAR experiment. This effort focuses on the collision of polarized protons at center-of-mass energies from 200GeV to 500GeV to gain a deeper understanding of the spin structure of the proton in a new, previously unexplored territory.

The first polarized proton run in January 2002 is the beginning of a multi-year experimental program at BNL which aims to address a variety of topics related to the nature of the proton spin such as the gluon contribution to the proton spin, flavor decomposition of the quark and anti-quark polarization and the transverse spin dynamics of the proton.

The successful applicant is expected to take a leading role in data analysis and/or in detector development. Preference will be given to applicants with previous experience in C++ programming.

A Ph.D. in experimental high energy nuclear or particle physics is required.

Interested candidates should provide a curriculum vita, a brief description of research interests and arrange to have three letters of recommendation sent to:

Medium Energy Group, Professor Robert P. Redwine
Room 4-110 MIT, 77 Massachusetts Avenue
Cambridge, MA 02139-4307

MIT is an Affirmative Action/Equal Opportunity Employer and encourages applications from women and minorities. MIT is a non-smoking environment.

Deadline: August 30, 2003

PARTICLE PHYSICS DIVISION HEAD

Fermi National Accelerator Laboratory, dedicated to fundamental research in particle physics and related fields, and home to the world's highest energy accelerator, has an exceptional professional opportunity available to lead one of its four major scientific divisions.

The Particle Physics Division (PPD) Head will lead a staff of more than 550 physicists, engineers and technicians skilled in building and operating high energy particle physics experiments. Specific centers of excellence are the group that designs ASICs (application specific integrated circuit) for experimental physics and the SiDet (silicon detector) facility, which is unsurpassed in the design, construction and assembly of silicon microstrip and pixel detectors. Various research and development projects in the Divison advance new experimental initiatives or detector concepts for the longer future. The two excellent theoretical physics groups in the PPD, one in particle physics and one in astrophysics, have close connections with the experimental research program.

PPD is also responsible for the detector aspects of the CDF and DZero Collider experiments currently running at the Tevatron, for the neutrino experiments MiniBooNE and MINOS, and for a selective fixed target and test beam program based on the 150 GeV Main Injector accelerator. The PPD is also preparing to build the CKM and BTeV experiments to explore quark flavor physics at the end of the decade. In addition to these experiments associated with the Fermilab accelerator complex, the Division is host to the US component of the CMS (Compact Muon Solenoid) experiment at the Large Hadron Collider at CERN. Physicists in the particle Physics Division lead many of these experimental efforts.

The selected individual must have demonstrated ability to lead a large team in a research environment. The candidate should have a broad and deep understanding of the present state of particle physics, detectors and physics collaborations in order to participate in key decisions about directions for the Division and, more broadly, for the Laboratory. Fermilab is managed by the Universities Research Association for the US Department of Energy. Experience in managing within a government laboratory or a university to standards set by federal, state and local agencies is highly desirable. A PhD. or equivalent experience in particle physics is required. Reporting through the Associate Director for Research to the Laboratory Director, the PPD Head is responsible for maintaining very high safety standards in all work done within the Division.

Located 40 miles west of downtown Chicago, we offer a competitive salary and excellent benefits package. For consideration, please forward a curriculum vitae, the names of three references and a letter of interest to: **Dr. Hugh Montgomery, Associate Director for Research, MS 105, Fermi National Accelerator Laboratory, P.O. Box 500, Batavia IL 60510-0500, USA**. To access Employment Opportunities at Fermilab and a complete description of this position, our URL is **[http://fnalpubs.fnal.gov/employ/jobs.html]**. EOE M/F/D/V.

Fermilab

The Netherlands Organization for Scientific Research (NWO) promotes and supports research of high quality in the Netherlands, both fundamental and applied in all fields. International orientation is a key concern.

SKA

The Square Kilometre Array (SKA) is a visionary international project to develop a next-generation world radio telescope with a collecting area of one million square metres. An International SKA Consortium representing twenty-four institutes in eleven countries are partners in a cooperative research and development program toward construction of the SKA. In Europe, the partners in the different countries are organized in the European SKA Consortium.

ASTRON

ASTRON coordinates the Dutch involvement in the European SKA Consortium and through an early involvement in the study of the so-called Aperture Array concept, now adopted as the European SKA concept, is a key player in its further development. To lead these efforts, ASTRON is seeking an individual for the position of Program Manager within the Technical Lab. The position will be executed from ASTRON in the Netherlands and also involves coordination of the R & D SKA activities in the European Consortium.

ASTRON SKA Program Manager

for the International Square Kilometre Array Project

The ASTRON SKA Program Manager will
- lead the SKA program at ASTRON and coordinate these activities as part of the European SKA effort
- develop the scientific goals and requirements of the European effort in collaboration with the European SKA Consortium and the International SKA Project Office
- coordinate and stimulate European SKA activities to achieve a structured and efficient European development effort resulting in a competitive design concept that meet scientific, engineering, political, and cost goals. Suggest possible alternatives, in collaboration with the European SKA Consortium and the international SKA Engineering and Management Team
- lead generation and approval of the project plan for concept development including implementation.

Information on the SKA project can be found at http://www.skatelescope.org.

The appointment is funded by ASTRON and the European SKA Consortium for at least two years and the appointee is located in Dwingeloo as NWO employee. The Program Manager will report internally for the ASTRON activities and externally to the European SKA Steering Committee, which has ultimate responsibility for the European SKA development.
We are seeking an individual with a PhD in astronomy, astrophysics, physics or engineering, or equivalent experience, with proven management skills in an R&D environment, preferably with a record of achievement in radio astronomy instrumentation, and a flexible team player with good interpersonal and communication skills.

Applications for the position should be sent to Prof Dr H. Butcher, Chairman of the EuSKAC and Director of ASTRON, ASTRON, P.O. Box 2, 7990 AA Dwingeloo, The Netherlands. Applications received before August 1, 2003 will be given full consideration. Please mention the jobposition in the left corner of the envelope. Further information can be obtained from the Director of the ASTRON Technical Lab., ir. A. van Ardenne, e-mail: tlinfo@astron.nl.

Women in particular are encouraged to apply.

More information about NWO: http://www.nwo.nl

NWO

Institute of Physics
Bhubaneswar 751005, Orissa, India

Faculty Position - Theoretical Condensed Matter Physics Group

Institute of Physics, Bhubaneswar, an autonomous research institution under Department of Atomic Energy, Government of India invites applications for a faculty position at the level of Senior Lecturer in theoretical solid state physics in the scale of pay of Rs.10,000-325-15,200 per month plus other allowances. A Ph. D. Degree with 2-4 years of experience as a Post-doctoral Fellow is a necessary requisite. Applications may be sent to **Director**, in the above address by **31st July, 2003.** Details can be found at **http://www.iopb.res.in/~cmpth.**

Caltech Space Radiation Laboratory

Postdoctoral Position in Gamma-ray Detector Development and High-Energy Astrophysics

The X-ray/gamma-ray astrophysics group at Caltech's Space Radiation Laboratory invites applications for a postdoctoral position, available immediately, to develop imaging solid state X-ray and gamma-ray detectors. Applications for these sensors include balloon and satellite astrophysics missions, and radiation monitoring for homeland security.

The applicant must have a Ph.D. in physics, applied physics, or related field. Experience with low-noise electronics, solid state sensors, laboratory data acquisition systems, and computer programming is desirable.

Applicants should submit CV, publication list, and three letters of reference to **Prof. Fiona Harrison, c/o Stacia Rutherford, 1200 E. California Blvd, Mail Stop 220-47, Pasadena CA 91125, USA.**

Caltech is an Affirmative Action/Equal Opportunity Employer.
Women, Minorities, Veterans, and Disabled Persons are encouraged to apply.

DARESBURY LABORATORY

PHYSICIST (ACCELERATOR R&D)

An opportunity exists for a physicist to join the Accelerator Science and Technology Centre (ASTeC) within CCLRC. This Centre's role is to perform particle accelerator research and development and the team you would join are experts in the design, construction and development of advanced high-energy particle accelerators.

The Vacancy is in the Accelerator Physics Group at Band 5 or 6 for recent graduate physicists (depending upon experience) and at Band 4 for a recruit with several years relevant experience.

You would join a growing team of physicists whose work supports the design and development of a future linear collider accelerator. The work is carried out in close collaboration with University groups within the UK and as part of wider international collaborations.

We are looking for a highly motivated scientist with an independent outlook, but who must be able to work in or lead a team. You should have a willingness to take on a variety of tasks, both experimental and theoretical. Previous experience of the relevant areas, although welcome, is not essential as full training will be available. Career development opportunities will be available in this core professional activity of CCLRC.

You should have a good honours degree in physics (or an equivalent qualification) or a closely related subject. Both recent graduates and postdoctoral scientists are encouraged to apply. To merit a Band 4 position you should additionally have an established track record of achievement in accelerator physics. For all positions a willingness to travel within the UK and overseas is essential, as is the desire to participate in large multinational collaborations.

Starting salary for a Band 6 is up to £19,900 on a pay range from £15,920 to £22,420. Starting salary for a Band 5 is up to £25,790 on a pay range from £20,630 to £28,370 and for a Band 4 Starting salary is up to £32,740 on a pay range from £26,190 to £36,010 (pay award pending). A recruitment and retention allowance of up to £3000 will also be offered depending on Band. Salary on appointment is awarded according to relevant experience. An index linked pension scheme, flexible working hours and a generous leave allowance are offered.

For further information contact Susan Smith, Daresbury Laboratory, email S.L.Smith@dl.ac.uk or telephone (01925) 603260.

Application forms can be obtained from: Human Resources Division, Daresbury Laboratory, Daresbury, Warrington, Cheshire, WA4 4AD. Telephone (01925) 603114 or email recruit@dl.ac.uk quoting reference VND182/03. More information about CCLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by: 7 August 2003.

The Council for the Central Laboratory of the Research Councils (CCLRC) is committed to Equal Opportunities. CCLRC is a recognised Investor in People. A no smoking policy is in operation.

CCLRC
Daresbury Laboratory

INVESTOR IN PEOPLE

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The August issue of *PhysicsWorld* will feature a high-profile Medical Physics Special with editorial, dedicated recruitment pages and special show distribution.

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E-mail: jayne.purdy@iop.org

CHIEF SCIENTIST POSITION IN RIKEN

RIKEN (The Institute of Physical and Chemical Research) invites applications for the position of Chief Scientist to direct a new laboratory on Experimental Nuclear Physics. The successful candidate will be responsible for the overall management of the laboratory,research strategy and implementation of research projects to be carried out in the Radio-Isotope Beam Factory which is under construction in the RIKEN Wako Campus.

Applicants should have appropriate research experiences supported by relevant publications. The post is a permanent appointment, subject to RIKEN's mandatory retirement age of 60. Terms and conditions of employment shall include a director-level salary and shall be in accordance with RIKEN's procedures for appointing Chief Scientists.

The successful applicant will be expected to take up this position from April 1st, 2004.

Applicants should send: a complete curriculum vitae with a photograph; a list of publications; one copy each of five key publications; a statement explaining research experience, reasons for her/his application, and proposals for research at RIKEN (these should not exceed 5 pages of regular sized paper); and the names and addresses of three referees. All applications are to be received by **September 30th, 2003.** Email submission in PDF format is also accepted for applicants outside Japan. Address all correspondences to:

Dr. Hideto En'yo, Director of Radiation Laboratory,
RIKEN, Hirosawa 2-1, Wako-shi,
Saitama, 351-0198, JAPAN
Fax: +81-48-462-4641, E-mail: enyo@riken.go.jp

Information about RIKEN is available on Web site **(http://www.riken.go.jp/)**

RIKEN

POSTDOCTORAL POSITION

PARTICLE ASTROPHYSICS-GAMMA-RAY ASTRONOMY

University of California, Los Angeles

We invite applications for a postdoctoral research position in particle astrophysics at the University of California, Los Angeles (UCLA). UCLA is involved in two forefront experiments, STACEE and VERITAS, designed to detect GeV and TeV gamma rays. Located near Albuquerque, NM, STACEE is an operating atmospheric Cherenkov telescope sensitive to gamma rays of energies between 50 and 500 GeV. VERITAS is a major, future array of imaging telescopes with sensitivity between 50 GeV and 50 TeV. The successful candidate will have the opportunity to work on either of these experiments.

We encourage candidates with experimental backgrounds in particle/nuclear physics or astronomy/astrophysics to apply. A Ph.D., or equivalent degree, in physics or astronomy is required. Applicants should send a CV and arrange for three letters of recommendation to be sent to:

Prof. Rene Ong
Department of Physics and Astronomy
8371 Math Sciences Bldg.
University of California, Los Angeles
CA 90095-1562
Deadline for receipt of applications is September 1, 2003.

CERN COURIER RECRUITMENT BOOKING DEADLINE

September issue: 15 August

Publication date: 1 September

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HEAD OF ACCELERATOR SCIENCE AND TECHNOLOGY

CCLRC
Daresbury Laboratory

The Council for the Central Laboratory of the Research Council, CCLRC, is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide.

Its two main sites are the Rutherford Appleton Laboratory in Oxfordshire and the Daresbury Laboratory in Cheshire. A key part of its mission is the support for and provision of access to large-scale accelerator based facilities for UK scientists. As such CCLRC undertakes a significant programme of research, development and design in accelerator science and technology at both sites often in collaboration with Universities and other international Laboratories. It does this through its Accelerator Science and Technology Centre, with staff located at both sites.

A vacancy exists at Daresbury Laboratory for a Head of Accelerator Science and Technology. The primary purpose and objectives will be to provide leadership and direction to the Council's support of the UK science and engineering base in accelerator science and associated technologies. As such the successful candidate will provide direction and leadership to the work of ASTeC staff and develop in conjunction with stakeholders a strategic plan for programmes of research in accelerator science in CCLRC that meets the future research needs of the UK. Presently there are major areas of collaborative activities associated with Linear Colliders, Synchrotron Radiation Light Sources, High Intensity Proton Accelerators and Neutrino Factories. Close support and collaboration with the UK Diamond Light Source is a further important area of activity for ASTeC.

An outstanding international reputation and standing in the field of Accelerator Science is necessary. The post-holder will interact with a very broad national and international community and strong communication, interpersonal and negotiating skills are essential. The ability to manage staff with a wide range of skills and disciplines based at geographically separate sites is also required.

The successful candidate will hold a Chair in Accelerator Science within the Department of Physics at the University of Liverpool. The University is committed to exploring the possibility of adding to the resources available to the post-holder. The aim will also be to develop close relationships with all UK Universities involved in the field of accelerator science.

Starting salary will be in the region of £50,000, negotiable depending on the calibre of the successful candidate, an index-linked pension scheme and a generous leave allowance are also offered.

Application forms can be obtained from: Human Resources Division, Daresbury Laboratory, Daresbury, Warrington, Cheshire, WA4 4AD. Telephone (01925) 603114 or email recruit@dl.ac.uk, quoting reference VND181/03. More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 30 July 2003.

The Council for the Central Laboratory of the Research Councils (CCLRC) is committed to Equal Opportunities and is a recognised Investor in People. A no smoking policy is in operation.

INVESTOR IN PEOPLE

COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

Bergische Universität Wuppertal

Im Fachbereich 08 Physik ist folgende Stelle zu besetzen:

Universitätsprofessor/in C3 für Experimentelle Elementarteilchenphysik

Gesucht wird eine Persönlichkeit, die das Gebiet der experimentellen Elementarteilchenphysik an Beschleunigern in der Forschung vertritt. Die Wuppertaler Gruppe beteiligt sich gegenwärtig am D0 Experiment am Fermilab und am ATLAS Experiment am CERN. Eine Verstärkung dieser Aktivitäten sowie Initiativen für zukünftige Projekte in der beschleunigergebundenen Elementarteilchenphysik, z. B. in der Detektorenentwicklung sind erwünscht. Es wird erwartet, das der/die Kandidat/in Lehraufgaben in der Experimentalphysik übernimmt.

Von den Bewerbern und Bewerberinnen wird neben pädagogischer Eignung erwartet, dass sie ihre wissenschaftlichen Leistungen durch eine Habilitation oder eine äquivalente Leistung nachweisen.

Die Bergische Universität Wuppertal strebt an, die Unterrepräsentierung von Frauen abzubauen. Bewerbungen von Frauen sind daher besonders erwünscht. Bei gleicher Eignung werden Schwerbehinderte bevorzugt.

Bewerbungen, Lebenslauf, Zeugniskopien, Schriftenverzeichnis und ggf. Verzeichnis der bisher gehaltenen Lehrveranstaltungen sind **spätestens bis zum 29. August 2003** an den **Dekan des Fachbereichs Physik, Bergische Universität Wuppertal, D-42097 Wuppertal,** zu richten.

Associate Director
Caltech Optical Observatories
California Institute of Technology

Caltech has an opening for the position of Associate Director, Caltech Optical Observatories in Pasadena, California. The current Director is Richard S. Ellis, Steele Professor of Astronomy.

The Associate Director is responsible for budget planning, fiscal management, and coordinating the operation of those astronomical facilities for which Caltech is directly responsible. Project management responsibilities include major instrument contracts for the Palomar and Keck telescopes, instrument development and prototyping studies for the California Extremely Large Telescope (CELT) project now entering its preliminary design phase, high order adaptive optics development, CELT-specific AO studies, and mosaiced IR detector development. Operational management includes supervision of observatory staff, telescope scheduling and maintenance, and liaison with the astronomical observer community.

A Ph.D. in astronomy or a related scientific field is desired. The position requires good inter-personal and leadership skills, and proven success in project management.

Caltech offers an attractive salary and benefits package, including relocation allowance. Please apply electronically to position CIT10338JH at Caltech's on-line Employment Opportunities at **http://cit.hr.caltech.edu/Jobs-HTML/EO.htm**. Attach a complete resume including academic, professional and personal data, and contact information for at least three references.

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Applicants should submit a curriculum vitae, publication list, statement of current research interests and future plans, and should arrange for four letters of recommendation to be sent to: **Professor Michael E. Peskin, Theory Group, MS 81, SLAC, 2575 Sand Hill Road, Menlo Park, CA 94025-7015.** All material should arrive by **October 1, 2003**.

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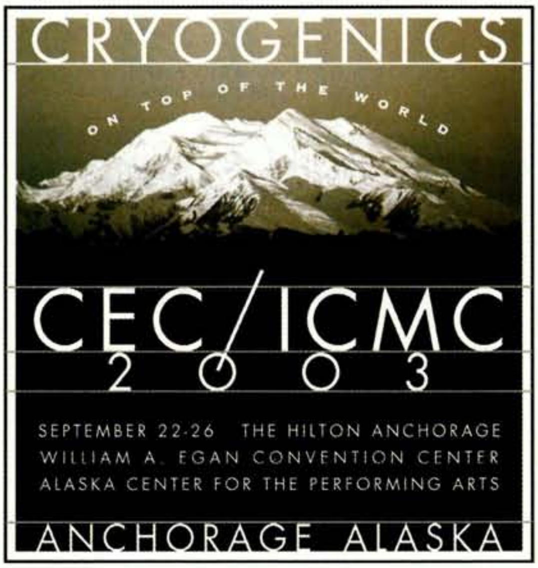

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Further information on the programme can be obtained from the Director of the School, Dr. Jens Jørgen Gaardhøje, the Niels Bohr Institute, Blegdamsvej 17, 2100 Copenhagen, Denmark (email: gardhoje@nbi.dk).

Information on the Danish Ph. D. programme and on the current activities within the above cited research fields may be found on the homepage for the school http://ntserv.fys.ku.dk/hco/Bestyrelse/IPhd Applications should be received no later than August 15, 2003 at the above address and should contain CV, copy of relevant Masters degree, list of publications, 3 letters of reference, and a proposal for a Ph. D. project. Ph. D. stipends are currently remunerated at a level of about 259.000 DKK/yr (approx. 35.000 €), liable to tax.

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BOOKSHELF

Current Aspects of Neutrino Physics by David Caldwell (ed.), Springer-Verlag. ISBN 3540410023, €79.95, £56.00.

When, almost 70 years ago, Wolfgang Pauli wrote "I have done a terrible thing, I have postulated a particle that cannot be detected," he could not have anticipated that even now that particle, albeit detected, would continue to be the most elusive, and also the most astonishing, paradoxical and intriguing of elementary objects. We now know that it appears as (at least) three different species, possibly some of them massive, all uncharged, spinning and blind to strong interactions, and all playing the most crucial role in modern theories of the history and structure of the universe – from the smallest to the largest scales.

Indeed, few things in recent years have had as much of an impact on our view of particle physics as the recent impressive developments in neutrino physics. Experiments in this field are challenging due to the very small neutrino interaction cross-section. As Haim Harari put it: "Neutrino physics is largely an art of learning a great deal by observing nothing." Today, new technologies and ideas have allowed us to conceive projects that may soon bring us to a much better understanding or even to a solution of the neutrino puzzle. Neutrino physics, interplaying between elementary particles and astrophysics, is currently one of the hottest subjects in physics.

The fast development of neutrino physics is – paradoxically – a reason for the small number of textbooks on the subject. Proceedings of conferences and schools are too advanced and detailed, and thus do not make up this deficiency, while standard textbooks on particle physics cannot afford to expand the subject of neutrinos. We are therefore left with a "literature hole", a hole that is well known to graduate and postgraduate university teachers. This book, edited by David Caldwell, seems to meet these needs. It comprises a set of purpose-written, up-to-date, advanced reviews, which also offer a comprehensive view of the field – a rare but fundamental feature of a textbook – and it is aimed at both specialists and beginners.

The book begins with a concise history of neutrino physics, and is followed by a theoretical discussion of the nature of massive neutrinos. The ensuing chapters review our experimental knowledge, interleaved with a guiding theoretical framework: measurements of the neutrino masses, their flux from the Sun and the atmosphere, studies of neutrinos at reactors and accelerators, and finally double beta decay searches. The next two chapters contain phenomenological and theoretical interpretations of this empirical knowledge, and the last three chapters refer to cosmological scales and review the neutrino's role in supernovae, in the early universe and finally in astronomy. Each chapter starts with a very good introduction and closes with a superb summary. Reference lists, compiled separately for each chapter, are extensive and up-to-date until the time the book was edited. They often contain popular and review articles.

The authors, one of whom is the editor, are recognized authorities on the topic of each chapter. The only surprise is their geographic bias: all 16 are from the United States and six of them come from California. A newcomer to the field may suspect that neutrino physics blossoms mainly along the west coast of America. The important role played by the neutrino experimental communities in Japan and Europe should have been better reflected in the choice of book contributors.

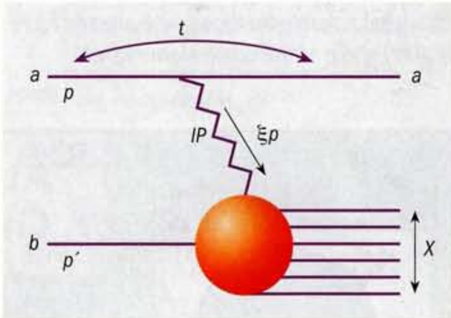
A more detailed presentation of forthcoming experiments and facilities, such as MINOS, ICARUS, OPERA, and neutrino factories, could have been included in the book. It is also unfortunate that the traditional role of neutrinos as probes of the structure of matter and interactions was completely neglected. The editor is aware of this shortcoming and states: "While they [neutrinos] have been important tools for studying particle properties, such as structure functions and the nature of weak interactions, at present this is not the thrust of most research and hence is not covered in this book." While this is indisputably true, a short account of those efforts could have been given for completeness; after all they are still being undertaken, for example in the CCFR and NuTeV measurements of $\nu(\bar{\nu})$–nucleon cross-sections. An appendix with Web addresses for databases or for websites where the reader can find updated or more detailed information would also be useful.

The book appears to have been carefully proofread, but the index is surprisingly poor. The names of future experiments and facilities discussed in the text are missing and some of the page numbers are wrong.

Most of the book was completed before the results of the SNO experiment were published in mid-2001, but because of their anticipated importance publication was delayed so that the results could be summarized in an addendum. Since then, KamLAND has confirmed the disappearance of the electron antineutrinos. There is always a risk that reviews have a short life-time, especially now in neutrino physics as it is developing rapidly. However, this book should be useful for a long time yet, both as a reference and a textbook, due to its comprehensive content, clear logic in ordering the material, and extremely good oversight of most aspects of neutrino physics.

Barbara Badelek, CERN.

Pomeron Physics and QCD by Sandy Donnachie, Günther Dosch, Peter Landshoff and Otto Nachtmann, Cambridge University Press. ISBN 052178039X, £70.



Pomeron physics: pomeron exchange in an inelastic diffractive event.

Just as in the diffraction of light, beams of elementary particles diffract off each other in scattering experiments at high energies. The resulting diffraction pattern contains crucial information on the nature of the strong force and, in particular, on the pomeron.

For more than 40 years now, particle physicists have been trying to understand the physics of particle scattering at high beam energies. Central to the theory is the notion of complex angular momentum pioneered by Tulio Regge, where single particle exchange is generalized to the exchange of a collaboration of many particles that collectively look like a single particle carrying complex angular momentum. The pomeron, named after Isaak Pomeranchuk, is the collective exchange that is dominant at high-enough beam energies.

This book carefully collects the key theoretical ideas and confronts them with the available data in a systematic way. Given ▷

that there is, as yet, no consensus on the exact nature of the pomeron and that the literature is often quite confused, such a well written and accessible book as this is most welcome. The authors present an approach based firmly on the theory of Regge and make very good use of both perturbative and non-perturbative QCD to help develop and support their ideas. The authors have considerable expertize and experience, which they particularly bring to bear when presenting their ideas on the use of non-perturbative techniques to study the pomeron. They are also the principal advocates of the idea that there may be two pomerons, with one pomeron dominant in soft interactions and the other dominant in hard interactions. Within this framework they succeed in presenting a rather coherent picture of the physics, notwithstanding that there are a few areas where the theory remains to be developed.

The book is quite pedagogical and is written at a level suitable for those who already have a good grasp of the basic elements of quantum field theory and elementary particle physics. There is a self-contained introduction to S-matrix theory and Regge poles, which provides the necessary foundation for the remainder of the book. Although there is a brief introduction to QCD, a prior exposure to QCD as a quantum gauge field theory would be helpful, particularly if one is to appreciate fully the sections that present the authors' ideas in non-perturbative QCD.

Over the past 10 years, data from the HERA and Tevatron colliders have allowed us to make substantial advances in our understanding of high-energy processes. Continued understanding can be expected in the light of data that will come from future colliders and this book will, I suspect, continue to provide an excellent introduction to the subject.

Jeff Forshaw, University of Manchester.

Books received

The Global Approach to Quantum Field Theory by Bryce DeWitt, Oxford University Press. Hardback ISBN 0198510934, £115.

This work in two volumes covers classical field theory, quantum mechanics and all major theoretical aspects of quantum field theory, and shows how they are related. Fields are viewed as global entities in spacetime, rather than as systems evolving from one instant of time to the next. The book should be particularly useful for quantum field theorists (especially students), theoretical physicists and mathematicians with an interest in physics.

Numerical Methods for Delay Differential Equations by Alfredo Bellen and Marino Zennaro, Oxford University Press. Hardback ISBN 0198506546, £59.95.

The latest in a series on numerical mathematics and scientific computation, this book by Bellen and Zennaro provides an introduction to the Cauchy problem for delay differential equations. It is aimed at mathematicians, physicists, engineers and other scientists interested in this area of numerical methods.

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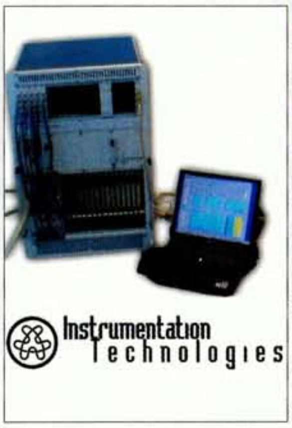

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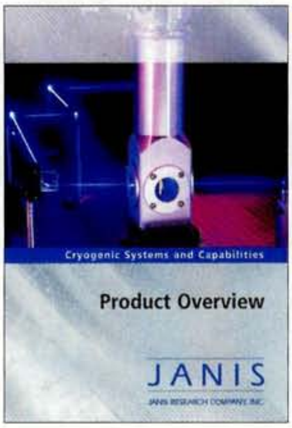

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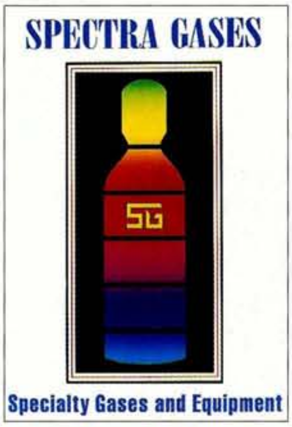

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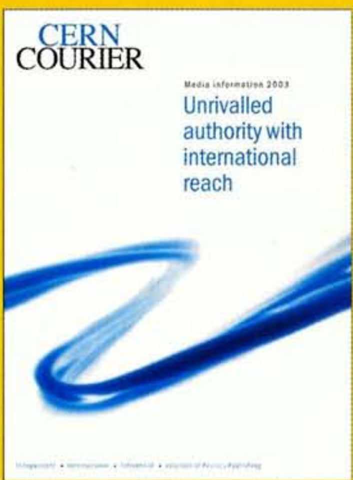

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Internet for the masses

Onno Purbo, a prominent Indonesian IT expert, sees a self-financed, bottom-up Internet infrastructure as the key to achieving a knowledge-based society in developing countries.

What if no telecommunications companies, no government and no World Bank involvement were necessary to develop and build an information and communication technology (ICT) infrastructure in developing countries? What if it cost only $0.50 (€0.43) per student per month to install such an infrastructure in schools in developing countries?

This may sound like an impossible dream for those who live in a developing country, as I do in Indonesia. But fortunately, in reality it can easily be done. It is not the equipment, nor the legislation, nor the investment that counts; it is the ability to educate a critical mass of people to gain the information and knowledge that are vital to the establishment of such an infrastructure.

It seems that the traditional Indonesian telecommunications companies (such as Telco) and the government believe that any ICT infrastructure requires highly skilled and trained personnel to run expensive, sophisticated equipment that can be funded only by multinational investors. This belief is embedded in all legal and policy frameworks within the Indonesian telecommunications industry.

Stronger, smarter and faster

However, let's take a closer look at ICT, and note a few important features of how it has developed. It has recently become more powerful, smarter and faster, and has greater memory requirements than ever before. Fortunately, all of these advanced features can now be obtained at much lower costs, and are also much easier to use, configure and control. ICT has become more user-friendly – with dramatic consequences.

The investment required in infrastructure can now be drastically reduced to a level that makes it affordable for a household or community to build and operate their own ICT system. Moreover, it can be operated by people with limited technical skills. This enables a community-based telecommunications infrastructure to be built by the people and run by the people, for the people.

It is a totally different concept and a significant paradigm shift away from the traditional telecommunications infrastructure, which is normally licensed by the government and built and run by the telecommunications operators for the subscribers. Unfortunately, most telecommunications policies and regulations, at least in Indonesia, cannot easily be adapted to accommodate such a shift.

After seven years of trying to educate the Indonesian government about the basic idea of a community-based ICT infrastructure, in 1996 I succeeded in having it partially written into some sections in the Indonesian National Information Infrastructure policy known as "Nusantara 21".

However, in February 2000, fed up with the lack of progress, I left my work as a civil servant to dedicate myself to becoming an IT writer, delivering ICT knowledge to Indonesians through various media, such as CD-ROMs, the Web, books, talk shows, seminars and workshops, as well as answering e-mails on more than 100 Internet mailing lists. Since then, experience has proved that a knowledgeable society with access to new ICT equipment can easily deploy a self-financed infrastructure, thus releasing its dependence on the telecommunications companies as well as on its own government.

Two major technologies are used as the backbone of this Indonesian bottom-up, community-based telecommunications infrastructure, namely wireless Internet (WiFi) and Voice over Internet Protocol (VoIP). WiFi-based systems, when run at 2.4 and 5.8 GHz and extended by simple external antennas, are quite good for 5–8 km links. This makes it possible to bypass the Telco system's "last mile" and enables the NeighborhoodNet Internet Service Provider to reduce access costs.

This infrastructure currently supports about 4 million Indonesian individuals, more than 2000 cyber cafés and more than 1500 schools on the Internet, running on more than 2500 WiFi nodes. It has increased dramatically in size in the past few years.

Building on the infrastructure

Because the Indonesian government is planning to increase phone tariffs in mid-2003, a free VoIP infrastructure, also known as Indonesian VoIP MaverickNet, was deployed on top of the Indonesian Internet infrastructure in early January 2003. Within around three months, we managed to deploy more than 150 VoIP gatekeepers based on www.gnugk.org freeware to handle approximately 1000 calls per gatekeeper per day for more than 3000 registered users and an estimated 8000 or more unregistered users.

Long-distance and local calls are routed through the Internet infrastructure without any Telco interconnection, via a VoIP MaverickNet area code, +6288, that has been specifically assigned to this task. Users can also be called and registered to the VoIP gatekeeper using their normal Telco number if they wish – this can easily be done, as the gatekeeper can recognize any form of number. This has the side-effect that people can be called on Telco's number at no charge via VoIP MaverickNet, thus avoiding using the expensive Telco infrastructure.

Tutorial files on implementing a bottom-up infrastructure can be downloaded free of charge from our website at www.apjii.or.id/~voipmerdeka/practical-guide. A community-based telecommunications infrastructure would not have been possible without the generous knowledge-sharing of many people on the Internet. I thank them all.

Onno W Purbo (onno@indo.net.id), former professor at the Institute of Technology in Bandung and self-confessed Indonesian ICT evangelist.

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