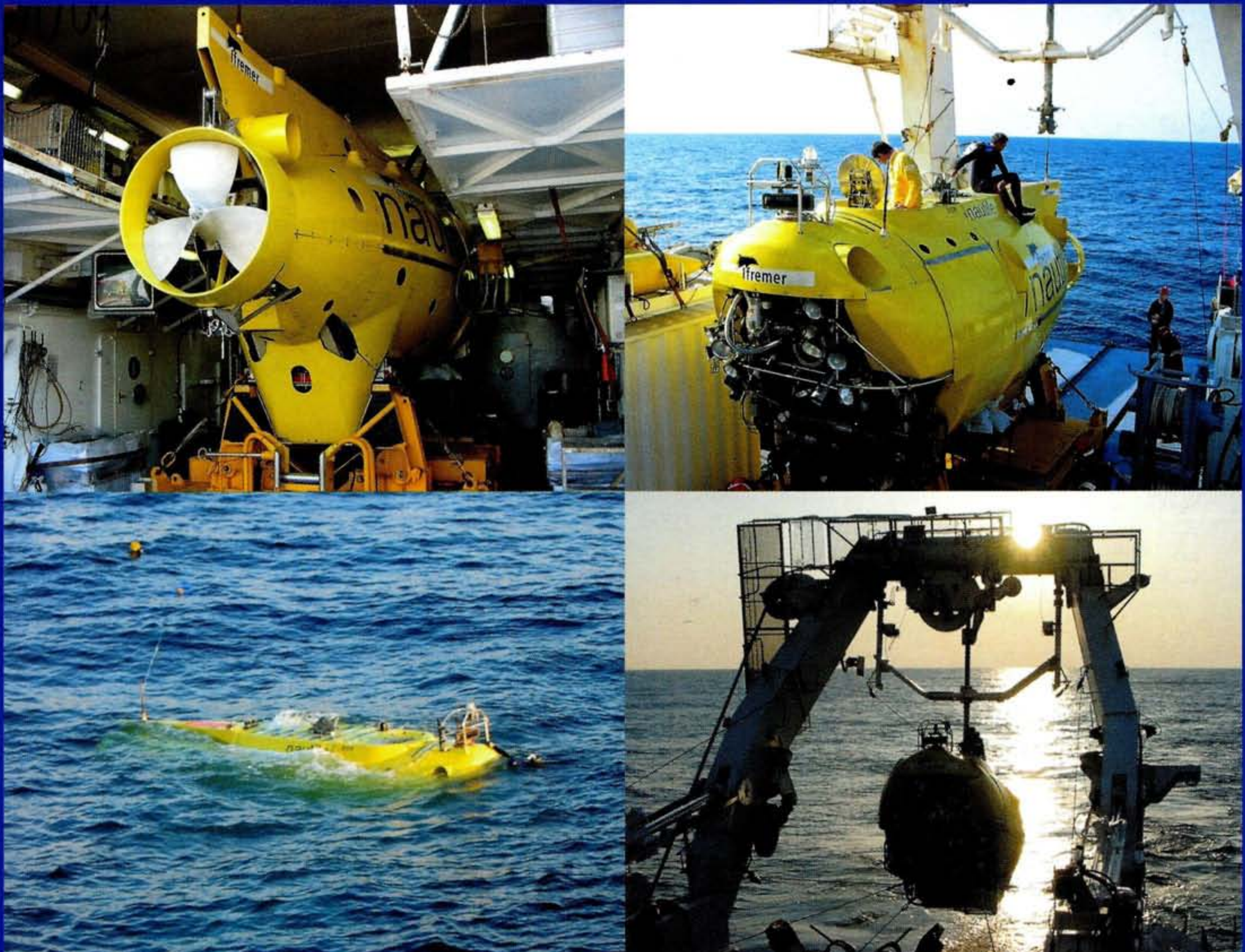
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

# CERN COURIER

VOLUME 43 NUMBER 5 JUNE 2003



# ANTARES' deep-sea connections

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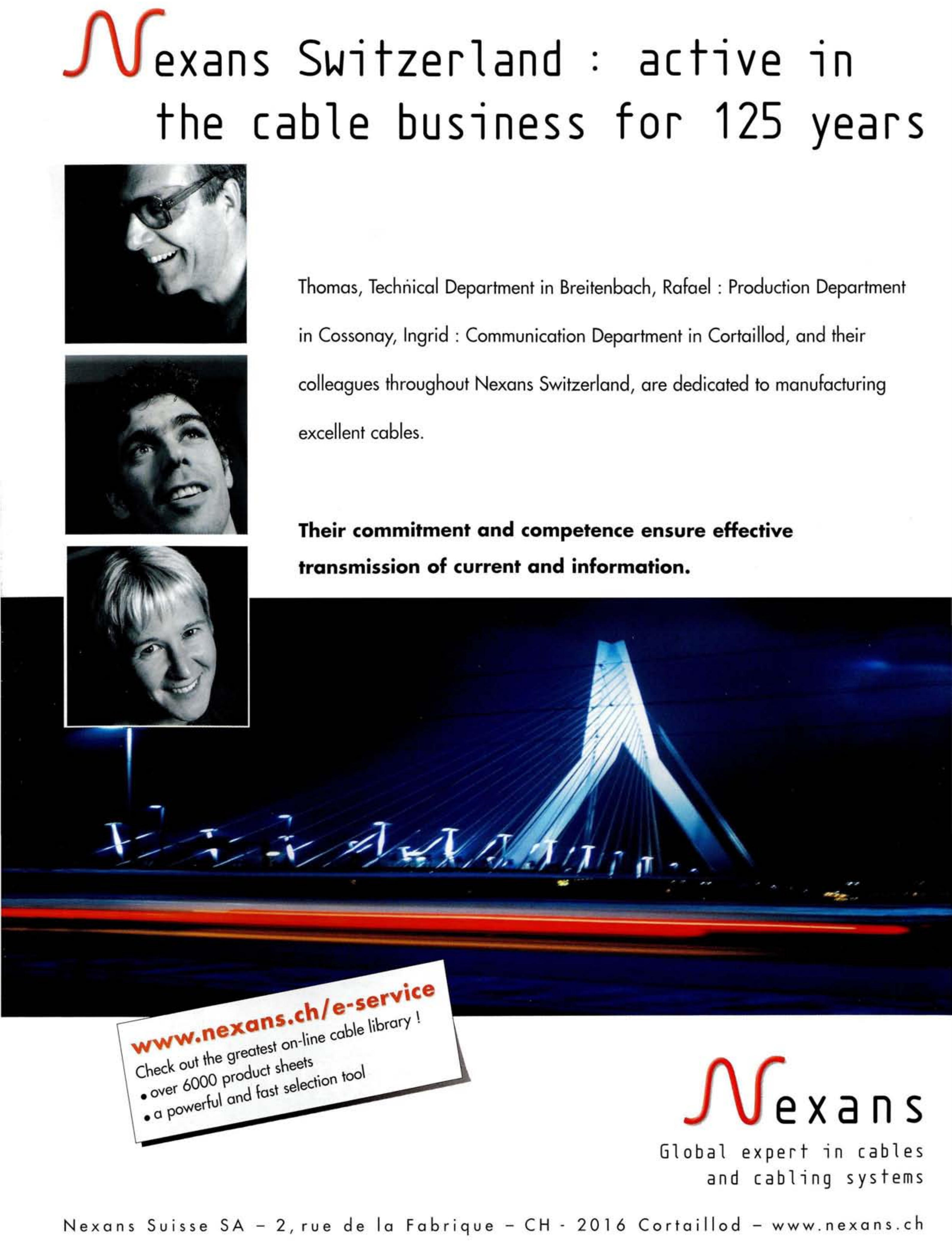

Covering current developments in high-energy physics and related fields worldwide

*CERN Courier* (ISSN 0304-288X) is distributed to member state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August, in English and French editions. The views expressed are not necessarily those of the CERN management.

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**US/Canada** Published by *Cern Courier*, 6N246 Willow Drive, St Charles, IL 60175. Periodical postage paid in St Charles, IL. Fax: 630 377 1569. E-mail: vosses@aol.com. Postmaster: send address changes to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174

**Published by** European Organization for Nuclear Research, CERN, 1211 Geneva 23, Switzerland. Tel: +41 (22) 767 61 11
Telefax: +41 (22) 767 65 55

**Printed by** Warners (Midlands) plc, Bourne, Lincolnshire, UK

ISSN 0304-288X

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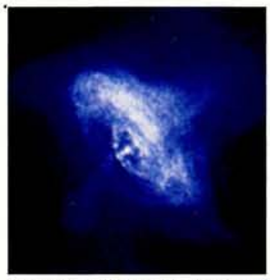
The origin of gamma-ray bursts **p5**


The work of Charles Peyrou **p25**


Egypt looks to halt brain drain **p29**

## Features

**Cover:** The deployment of the IFREMER submersible *Nautile* from the support ship *l'Atalante* to make the deep-sea connections for the ANTARES neutrino telescope (p22).
Top left: *Nautile* in its hangar on board *l'Atalante*. Top right: *Nautile* ready for winching into the sea. Bottom right: *Nautile* begins the 2400 m dive to the sea-bed. Bottom left: Recovery of the submersible at dusk. (Photos courtesy of IFREMER and ANTARES (Bertin, CNRS/IN2P3).)

Announcement

THE X$^{th}$ VIENNA CONFERENCE on INSTRUMENTATION

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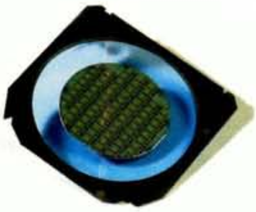

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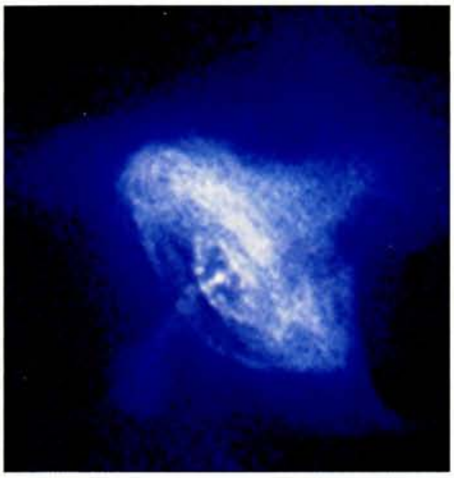
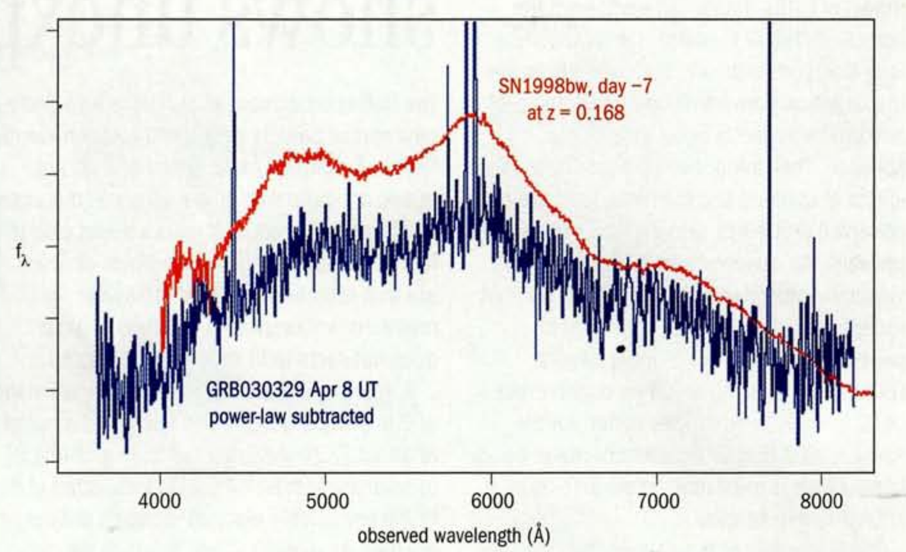
**ASTROPARTICLE PHYSICS**

# Gamma-ray bursts made by supernovae



*The Crab Nebula, the most intensively studied object beyond our solar system in all possible wavelengths, is the remnant of a supernova explosion in AD 1054. Chinese observers that year reported a brilliant "guest star" that appeared suddenly and remained visible for weeks, even during daylight hours. (NASA/CXC/SAO.)*



*The supernova component of the spectrum of GRB030329, obtained by subtracting a scaled version of the afterglow's power-law spectrum of April 4.27 UT from that of April 8.13 UT, shows a clear resemblance to the spectrum of SN1998bw at the same time after their respective explosions. The narrow emission lines belong to the host galaxy of SN2003dh, the supernova at the location of GRB030329. (P Garnavich* et al.*)*

On 8 April, astronomers using the 6.5 m Multiple Mirror and Magellan telescopes discovered supernova SN2003dh, at the location of the gamma-ray burst GRB030329 (P Garnavich *et al.* 2003). The GRB had been spotted 10 days earlier by NASA's High-Energy Transient Explorer satellite, on 29 March – the estimated time at which the supernova exploded. The association between these two phenomena may now have brought to a close the quest for what it is that generates gamma-ray bursts (see also p12).

Gamma-ray bursts (GRBs) are flashes of gamma rays that reach us about once a day from deep space. They were serendipitously discovered in 1967 by US military satellites that were intended to monitor nuclear tests occurring above ground, in violation of the nuclear-test-ban treaty. For decades the origin of the GRBs was a complete mystery.

The first indication that GRBs are of cosmological origin was obtained in 1991 by NASA's Compton Gamma Ray Observatory, which determined that their sources are isotropically distributed in the sky. It was also found that there are two GRB populations: "long-duration" GRBs lasting for more than 2 seconds, and "short" ones lasting less than this. The cosmological origin of GRBs, if the emission is isotropic, implied such a fast and huge energy release that it was even speculated that GRB explosions may involve new physics.

The cosmological origin of long-duration GRBs was first confirmed on 28 February 1997. The BeppoSAX satellite provided the approximate sky position of the long GRB970228 and discovered that it was followed by an "afterglow" – a continuous emission of radiation at longer wavelengths that lasted for a much longer time. This and following observations of the afterglow of long GRBs allowed their precise localization. They occur in distant galaxies in star-formation regions, which hints at their association with the explosive death of massive stars.

On 28 April 1998, ESO's New Technology Telescope discovered the supernova SN1998bw close to the spiral arm of the nearby galaxy ESO 184-G82. The supernova was within the error box of GRB980425, spotted 2.4 days earlier with the wide-field camera of BeppoSAX. The temporal and directional coincidence of the two objects suggested that they may be physically associated. The distance to SN1998bw is a mere 39 megaparsecs (redshift $z = 0.0085$), a trifle compared with the gigaparsec distances to other GRBs located at much larger redshifts. Yet the gamma-ray flux from GRB980425 was comparable to that of others and not orders of magnitude larger, as would be expected from a spherical emission from the nearby location of SN1998bw. This led the GRB community to conclude that either GRB980425 and SN1998bw were not physically associated, or if they were, the pair belonged to a rare class of GRBs produced by a new type of gigantic "hypernova".

The measured spectra of the recent supernova, SN2003dh, looks amazingly similar to that of SN1998bw, as the figure above shows. This may be a problem for the generally accepted "fireball" model of GRBs, in which the emission is spherical or due to a "firecone" directed towards the observer, but GRB980425 (coincident with SN1998bw) is a "one of its kind", extremely underluminous exception, while GRB030329 (coincident with SN2003dh) is a very bright conventional GRB at a relatively small but

▷

▷ nonetheless "cosmological" redshift, z = 0.1685. So why should their associated supernovae look so similar?

A group from the Technion Institute in Israel and CERN has long advocated a "cannonball" model of GRBs, totally different from the accepted fireball models. In this model the long-duration GRBs and their afterglows are the radiation from relativistic "cannonballs" emitted by supernovae as their cores collapse. The cannonballs are similar to the ejecta of quasars and microquasars; their observed properties also depend on the angle between the observer and the cannonballs' velocity vector. Hence, GRB980425 was not exceptional, it was simply viewed at an uncommonly large angle. More distant GRBs can only be seen if their cannonballs point towards the observer better, for the same reason that an accelerator-made beam of neutrinos is most intense close to its source and to its axis.

The advocates of the cannonball model have sufficient confidence in their understanding of GRBs to have correctly predicted, on three prior occasions, when the declining GRB afterglows become dim enough for the associated supernovae – whose light curves first rise with time and then fall again – to be observable. In the case of GRB030329, the team posted a paper on 6 April in the Web "Archives" (S Dado *et al.* 2003), correctly predicting that "10 days after burst, the AG of GRB030329 should begin to reveal the light curve, spectrum and polarization of an underlying supernova, akin to SN1998bw."

Whether this model will survive tests of the rest of its very specific predictions remains to be seen. But the discovery of SN2003dh may dispel the doubts that long-duration GRBs are produced by highly collimated radiation from core-collapse supernovae. If so, GRBs are not the long advocated "biggest explosions after the big-bang", but simply supernovae "playing high-energy accelerator physics", that is, spending a modest fraction of their energy budget in the acceleration of matter to relativistic speeds. Precisely how they do it, particle physicists and astrophysicists alike would very much like to know.

**Further reading**

P Garnavich *et al.* 2003 International Astronomical Union Circular No. 8114.
Shlomo Dado, Arnon Dar and Alvaro de Rujula 2003 www.arxiv.org/abs/astro-ph/0304106.

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**SLAC**

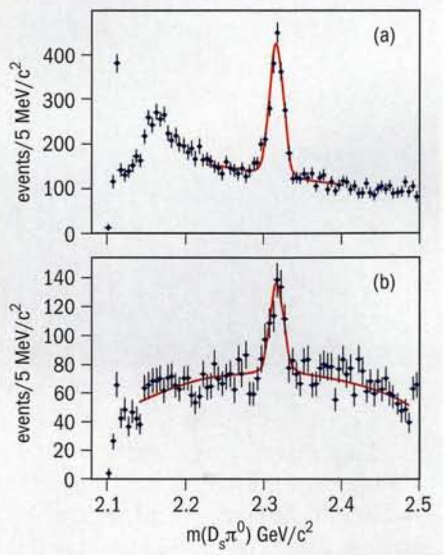
# BaBar's new particle shows unexpected traits

The BaBar experiment at SLAC has revealed a new narrow particle state that has been identified as a charmed meson, that is, a charm quark, c, bound with an antiquark, in this case a strange antiquark, $\bar{s}$. It joins a select club of four such states, only two members of which are well established. While additional members were expected, the new particle does not seem to fit in quite as predicted.

A member of the BaBar team, Antimo Palano of Bari University and INFN, first found a bump at about 2320 MeV after combining $\pi^0$ and $D_s^+$ in an analysis of 91 $fb^{-1}$ of data collected at the PEP-II asymmetric electron–positron collider at energies around 10.6 GeV. The $D_s^+$ is the ground state of the $c\bar{s}$ system and therefore might be expected to figure in the decays of excited $c\bar{s}$ states. However, both the $\pi^0$ and the $D_s^+$ decay quickly, and by using the decay vertex information are reconstructed from their decay products. The BaBar analysis team looked for the $D_s^+$ by combining charged particles corresponding to $K^+K^-\pi^+$, while photons were paired together to yield potential $\pi^0$s.

After applying various selection criteria, to home in on the desired $D_s^+$ and $\pi^0$ particles, the team calculated the mass for the $D_s^+\pi^0$ pairs to obtain a mass distribution. A clear peak appears both for events where $D_s^+ \rightarrow K^+K^-\pi^+$, and also for events where an additional $\pi^0$ appears to come from the same decay vertex, corresponding to the decay $D_s^+ \rightarrow K^+K\pi^+\pi^0$. The peak occurs at a mass close to 2.32 GeV/$c^2$, and its width is narrow, consistent with the resolution of the BaBar detector.

The charm quark is much heavier than the strange quark, so the spectroscopy of the $c\bar{s}$ system can be thought of in terms of the total angular momentum (spin plus orbital) of the light quark coupled with the spin of the heavy quark. The ground state, $D_s^+$, has zero orbital angular momentum ($L = 0$), and the spins are antiparallel ($^1S_0$ in spectroscopic notation). In the only other well-established state in the spectrum, $D_s^*(2112)^+$, the spins are parallel and $L = 0$ again ($^3S_0$). Excited states should also occur with $L = 1$, which combines with spin 1/2 to give a total angular momentum for the light quark of 3/2 or 1/2. When this is in turn combined with the spin 1/2 of the heavy quark, the result is an overall angular momentum $J = 2$, 1, or 0. With $L = 1$ all these states will have positive parity.



*The $D_s^+\pi^0$ mass distribution for the decay $D_s^+ \rightarrow K^+K^-\pi^+$ (a) and the decay $D_s^+ \rightarrow K^+K^-\pi^+\pi^0$ (b) clearly show the new narrow particle state near 2.32 GeV/$c^2$.*

To conserve parity in its decay to $D_s^+\pi^0$, the new state, which has been designated $D_{sJ}^*(2317)^+$ by the BaBar team, must have spin-parity $J^P$ in the series ($0^+$, $1^-$ $2^+$...). The low mass compared with previously observed related states, which have masses of around 2.5 GeV/$c^2$, suggests that the new state corresponds to $J^P = 0^+$. If this is correct, the narrow width and relatively low mass of the state are not in line with theoretical models, which predict masses between 2.4 and 2.6 GeV/$c^2$ with large widths. In this case, the unexpected characteristics of the new particle suggest that the models will need to be changed – or maybe the state is something entirely new, for example consisting of four quarks.

**Further reading**

B Aubert *et al.* 2003 www.arxiv.org/abs/hep-ex/0304021.

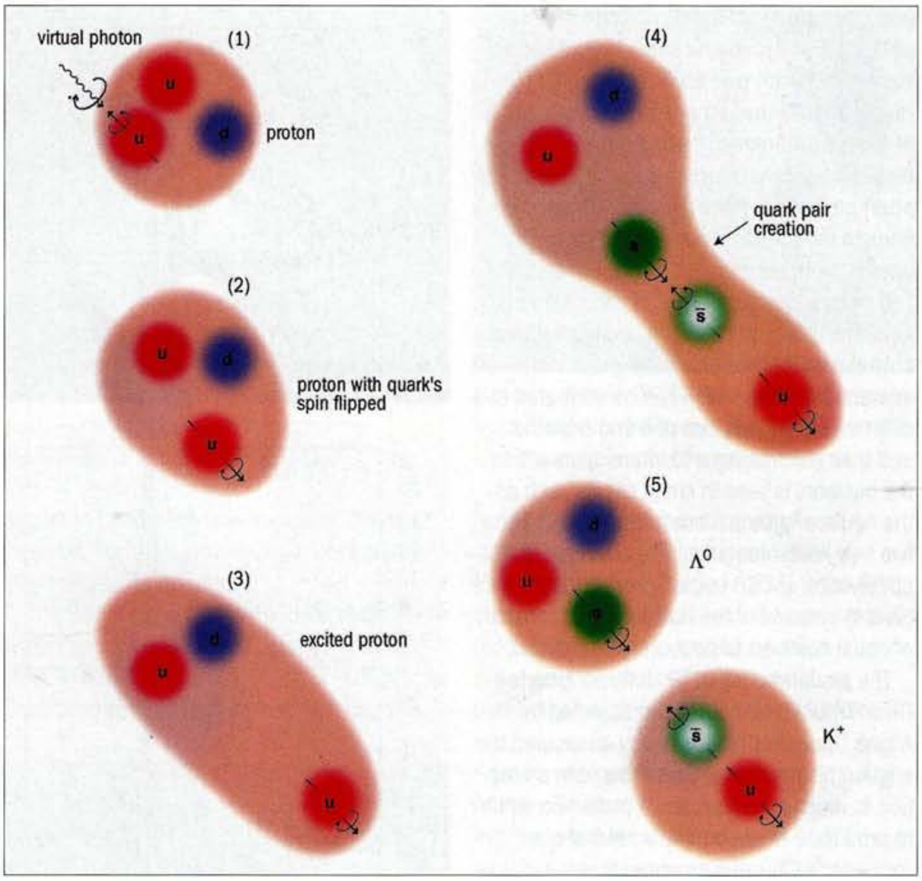
**QUARK DYNAMICS**

# JLab results put new spin on the vacuum

New measurements from the US Department of Energy's Jefferson Lab (JLab) in Virginia are challenging existing ideas on how quark–antiquark pairs are produced from "nothing" – that is, the vacuum. Members of the CEBAF Large Acceptance Spectrometer (CLAS) collaboration have studied the spin transfer from a polarized electron beam to a produced lambda particle, with surprising results.

The experiment recorded collisions between a 2.567 GeV longitudinally polarized electron beam and a proton target in which the electron emerges together with a polarized lambda ($\Lambda^0$) and a kaon ($K^+$). The large acceptance of CLAS enabled the team to detect the outgoing electron and the kaon, as well as the proton from the decay of the lambda, over a wide range of scattering angles – in effect, a wide range of momentum transfer from the electron to the quark system. The team was thus able to measure the angular dependence of the lambda polarization.

At the quark level, the reaction studied corresponds to the creation, from the available kinetic energy, of a strange quark–antiquark pair, in addition to the original quarks in the proton. In a simple model of the reaction dynamics, a circularly polarized virtual photon (emitted by the polarized electron) strikes an oppositely polarized up quark inside the proton. The spin of the struck quark flips in direction and the quark recoils from its neighbours, stretching a flux-tube of gluonic matter between them. When the stored energy in the flux-tube is sufficient, the tube is "broken" by the production of a strange quark–antiquark pair.



*In a simple model of the reaction, a circularly polarized virtual photon strikes an oppositely polarized up quark inside the proton (1). The spin of this quark flips (2) and the quark recoils from its neighbours, stretching a gluonic flux-tube between them (3). When the stored energy is sufficient, the tube breaks and a strange quark–antiquark pair is produced (4, 5).*

Using this simple picture, the CLAS team found that they could explain the measured angular dependence of the lambda polarization if the quark pair is produced with the spins in opposite directions, or anti-aligned. This is unexpected because according to the popular triplet-P-zero ($^3P_0$) model, a quark–antiquark pair is produced with vacuum quantum numbers, and that means their spins should be aligned. The new results imply that the $^3P_0$ model may not be as widely applicable as was previously thought.

Winston Roberts, a theorist at JLab and Old Dominion University, finds the CLAS measurement very interesting. "If they are right, it means we have to rethink what we thought we understood about our models for baryon decays," he said. "The CLAS results may also be saying something about what we understand of baryons themselves – our knowledge of how to describe scattering processes such as the one they measure, or even that there may be oddities or peculiarities, dare I say 'strangeness', in the way strange quark–antiquark pairs are produced."

The CLAS team itself expects further reaction from theorists. "Polarized lambda production is obviously sensitive to the spin dynamics of quark–pair creation," said Mac Mestayer of JLab. "We eagerly await confirmation, or refutation, of the conclusions of our simple model by realistic theoretical calculations." Meanwhile, the collaboration is planning further experiments, as Daniel Carman of Ohio University and lead author of the recent paper explains. "Our group is continuing this exciting research by extending our arguments to test our picture of the dynamics in different reactions."

The results certainly show that we still do not fully understand the basic structure of the vacuum. Twentieth-century quantum field theories filled the once-empty space with virtual particles. Now JLab physicists are working to measure the spin of those particles, helping us to understand the vacuum better as well as the matter that populates it.

**Further reading**

D S Carman *et al.* 2003 *Phys. Rev. Lett.* **90** 131804.

### CHARGE SYMMETRY

# TRIUMF and IUCF provide new results on CSB

Two separate experiments in North America - at TRIUMF in Vancouver and at the Indiana University Cyclotron Facility (IUCF) in Bloomington - have made new observations of charge symmetry breaking (CSB). The results have brought fresh input to theoretical attempts to determine the different contributions to the phenomenon, including effects due to the mass difference between quarks.

If charge symmetry were an exact symmetry, neutrons and protons would be indistinguishable except for their electromagnetic interactions. CSB, which can be attributed to a difference in the masses of u and d quarks and their electromagnetic interactions within the nucléon, is seen in small effects such as the neutron-proton mass difference $A_N$. The two new measurements have extended the observation of CSB to pion-production reactions in systems of few nucléons that consist of equal numbers of neutrons and protons.

The group working at TRIUMF, an Alberta-Ohio-TRIUMF-UNBC collaboration led by Aliéna Opper of Ohio University, measured the angular distribution of deuterons from a reaction in which a neutron and a proton combine to produce a deuteron and a neutral pion (np-»djr°). CSB was expected to appear as a small difference in the numbers of deuterons emitted in the forward and backward hemispheres of the centre-of-mass system. At a neutron beam energy of 279.5 MeV (« 0.8 MeV FWHM), just 4 MeV above threshold, the deuterons emerged within 30 mrad (lab angle) of the beam direction. This made it possible to detect the complete centre-of-mass angular distribution with one field setting of the SASP magnetic spectrometer. The experiment accumulated more than 6 million good events during 10 cycles of production and calibration runs. The observed events were compared with simulated events to account for energy loss and multiple scattering of deuterons in the liquid-hydrogen target, and the spectrometer's acceptance.

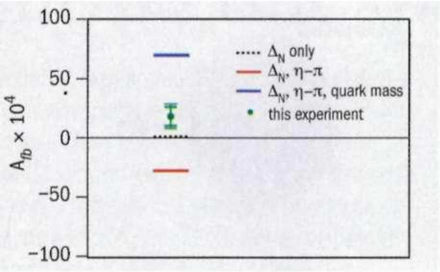


*Fig. 1. The forward-backward asymmetry* $A_{ft}$ *measured for the np^dn°* *reaction at TRIUMF, compared with various theoretical estimates as described in the text.*

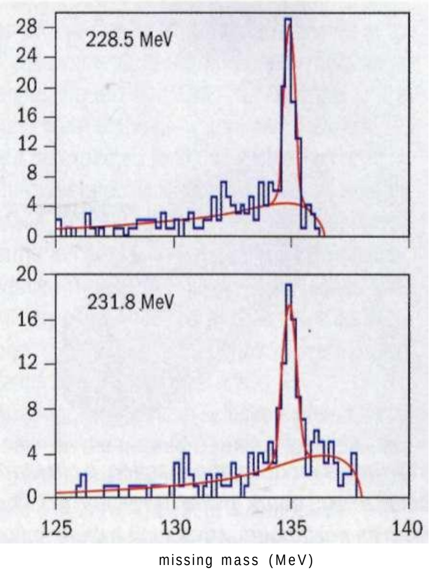


*Fig. 2. Missing-mass spectra measured for the dd-*an° reaction at the IUCF.*

The results can be expressed in terms of the difference in the numbers of deuterons in the forward and backward hemispheres divided by their sum: $A_{fc}$ = 17±8(stat)±5.5(sys) x 10"$^4$. For comparison, a theoretical calculation of $A_{ft}$ identified contributions from the n-p mass difference, from ***r\-n*** mixing, and from JT° rescattering effects, which are due to the d-u quark mass difference and electromagnetic interactions between the quarks (J A Niskanen 1999, U van Kolcketa/. 2000). The solid blue line of figure 1 indicates the shift in the calculated value of $A_{ft}$ when a "large but still reasonable" value for jt° rescattering is included. To reconcile this prediction with the data for $A_{ft}$ and the neutron-proton mass difference would require a quark mass difference within the chiral effective field theory that is less than 2 MeV. Large uncertainties remain, however, because neither the strength of T|-JT° mixing northe T J - N coupling is well known.

The lUCF-Argonne-Hillsdale-Minnesota State-Western Michigan collaboration, led by Edward Stephenson, sought evidence for the reaction in which two deuterons combine to form an alpha particle and a neutral pion (dd-*ajt°). This reaction is forbidden by charge symmetry, so a non-zero cross section would indicate CSB. The group's method was to make deuterons circulating in the IUCF Cooler Ring collide with deuterons in a gas jet target, and then detect the resulting alpha particles in coincidence with the two gamma rays from the decay of the neutral pion. The challenge was to see a clean signal for the reaction - estimated to be as small as a few picobarns in cross section - in the presence of various backgrounds. The most troublesome background was expected to come from a reaction producing an alpha particle and two gamma rays, but without the formation of a pion - a reaction that is not forbidden by charge symmetry. The IUCF group was able to display the ayy events in terms of the missing mass, showing a clear peak at the mass of the pion on top of the double radiative capture continuum (figure 2). The cross section measured was 12.7±2.2 picobarns at a beam energy of 228.5 MeV and 15.1±3.1 pb at 231.8 MeV.

This non-zero result has provided fresh stimulus to a team of theorists whose goal is to relate the dd^ait° cross section, thought to be dominated by T | - j t mixing, to quark mass differences. The hope is that this cross section, when combined with the n-p mass difference and $A_{ffi}$ in np-*djt°, will help unravel the quark mass difference, electromagnetic and meson-mixing contributions to nuclear CSB.

These results and the related theoretical work were the focus of a special session of the April 2003 meeting of the American Physical Society in Philadelphia. See www.aps.org/meet/APR03/baps/tocC.html#SessC3.

### Further reading

J A Niskanen 1999 *Few-Body* Systems **26** 214.
U van Kolck, J A Niskanen and G A Miller 2000 *Phys. Lett.* **B493** 65.
http://www.physics.arizona.edu/~vankolck/coolerCSBtheory.html.

*David Hutcheon, TRIUMF, Aliéna Opper, Ohio University and Edward Stephenson, IUCF.*

LABORATORIES

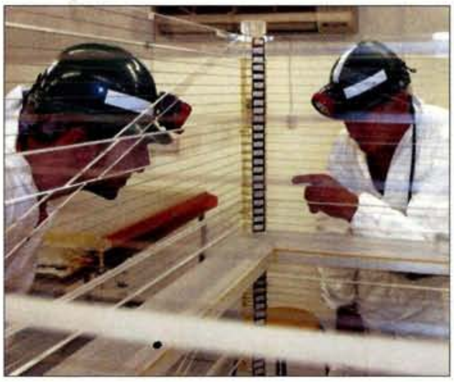
# Boulby extends the search for dark matter

On 28 April, the UK minister for science and innovation, Lord Sainsbury, opened a new research cavern at the Boulby Underground Laboratory for Dark Matter Research, at Boulby in North Yorkshire, UK. The Boulby lab is situated in a working salt and potash mine and houses experiments to detect weakly interacting massive particles (WIMPs), a prime candidate for dark matter in the universe. The laboratory has recently benefited from a £3.1 million Joint Infrastructure Award (JIF) from the UK Particle Physics and Astronomy Research Council, which has provided new enhanced underground laboratories and complementary surface facilities.

Situated more than 1 km beneath the Earth's surface within a salt and potash mine, the laboratory is isolated from interference from cosmic rays and benefits from an environment with low natural radioactivity. The laboratory operates on behalf of the UK Dark Matter Consortium – the University of Sheffield, the Rutherford Appleton Laboratory, the Imperial College of Science, Technology and Medicine, and the University of Edinburgh.

The Boulby lab currently houses three experiments to detect dark matter – NAIAD (NaI Advanced Array Detector), ZEPLIN I (from ZonEd Proportional scintillation in LIquid Noble gases, now operating with liquid xenon), and DRIFT (Directional Recoil Identification From Tracks). DRIFT is the first experiment to be installed in the new area of the laboratory and is unique because its aim is not only to detect WIMPS, but also to determine which direction they come from.

Looking along the new underground laboratory at Boulby, towards DRIFT.



Working on the DRIFT detector in the apparently contradictory environment of a cleanroom within a mine.

# Kavli Institute inaugurated at SLAC

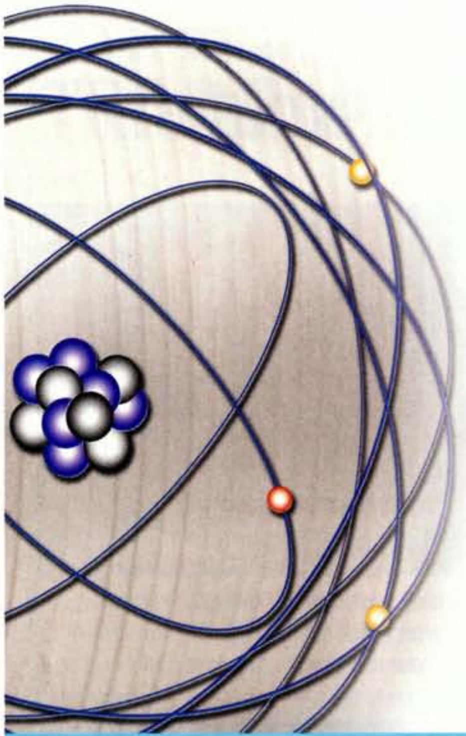
The new Kavli Institute for Particle Astrophysics and Cosmology has been inaugurated at SLAC. It is named after physicist and philanthropist Fred Kavli, whose Kavli Foundation pledged $7.5 million to establish the new institute. The institute, which will focus on recent developments in astrophysics, high-energy physics and cosmology, will eventually be located in a new building at SLAC between the research office building and the auditorium, and will open its doors in 2005. At the site of the future institute, Kavli unveiled a 2 m tall, steel and glass sculpture that incorporates a piece of SLAC history in the form of the window from the 1 m (40 inch) bubble chamber.

Roger Blandford, who will become the institute's director in October, was one of the speakers at the ceremony. He said that initially he intends to follow a roadmap that balances theory, computational astrophysics and phenomenology on one side, and experimental astrophysics and high-energy observing on the other. It will draw upon existing strengths in theoretical physics and astrophysics, gravitational physics and underground physics at Stanford. As Blandford noted, "Part of the excitement of the field is that it is impossible to predict where it will be in five years' time and what its scientific focus will be".

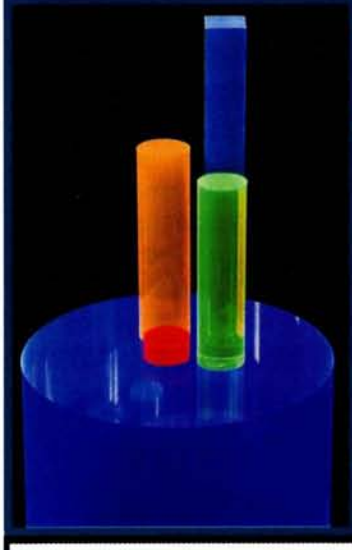
Fred Kavli unveils the sculpture at the site of the new Kavli Institute for Particle Astrophysics and Cosmology at SLAC, which is due to open in 2005. The sculpture, which contains the window from SLAC's 1 m (40 inch) bubble chamber was designed and fabricated entirely on site, mainly from recycled materials. The glass weighs 490 kg and still contains the fiducial marks used for the three-dimensional stereoscopic reconstruction of events in the chamber. (Kathy Bellevin, SLAC.)

**Correction**

In the April issue of *CERN Courier* on page 5, the first paragraph in the "HERA II puts collisions in a spin" news story was missing three key words. To be correct, the complete paragraph should have read: "With only days to go before a scheduled long shutdown began on 3 March, the upgraded HERA collider – HERA II – succeeded in running with *high-energy longitudinally* polarized positrons at three interaction regions, soon reaching a polarization of 50%. This is a first not only for DESY, the laboratory that is home to HERA, but also for the world."



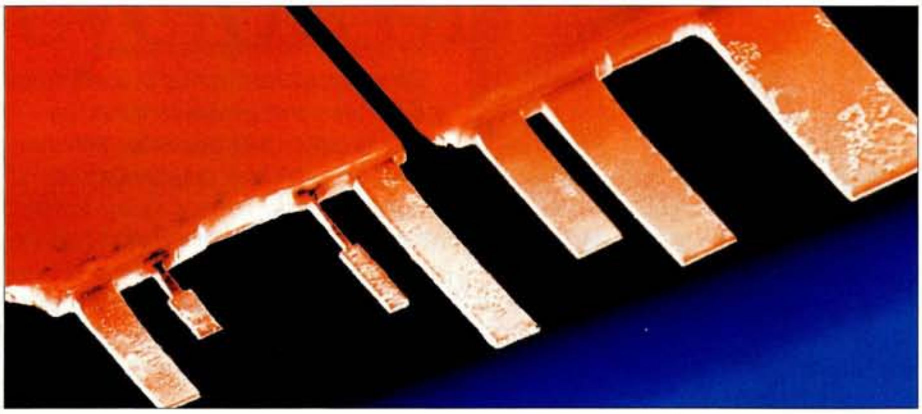




# PHYSICSWATCH

Edited by Archana Sharma

## Micro cantilevers weigh femto masses



*Silicon cantilevers of different sizes produced for detecting particles of differing masses. The largest strip at top right is 10 µm long and 3 µm wide. Particles that attach to the surface of the cantilevers change the resonant frequency in a measurable, mass-dependent way.*

A team at Oak Ridge National Laboratory has developed miniature cantilever oscillators that can detect masses on the scale of femtogrammes. Nickolay Lavrik and Panos Datskos have fabricated tiny silicon cantilevers as small as 2 µm long and 0.05 µm wide, and they use a diode laser to make them vibrate at MHz frequencies. When small particles are absorbed on the surface of the silicon, the resonance frequency changes in a measurable way. In one test, for example, an acidic substance was absorbed, giving a mass change at the level of 5 femtogrammes.

The system works in ambient conditions, without the need for vacuum or cryogenic temperatures, and the Oak Ridge researchers believe that by raising the resonance frequency from around 2 MHz, as it is at present, up to 50 MHz they can increase the sensitivity to the level of molecules. The technique therefore offers the potential for detecting low-mass particles such as DNA, proteins, cells, or trace amounts of various chemical contaminants.

**Further reading**

Nickolay Lavrik and Panos Datskos 2003 *Appl. Phys. Lett.* **82** 2697.

## Novel photonic crystals can be tuned dynamically

Researchers working at Brown University in Rhode Island have succeeded in creating novel photonic crystals that can be modified in milliseconds. Usually the properties of photonic crystals – which can control the flow of photons – are fixed after they have been fabricated, but the new photonic crystals can be tuned dynamically in order to respond to different wavelengths of light.

The new tunable photonic crystals are made from materials known as holographic-polymer dispersed liquid crystals (or H-PDLCs). Jun Qi and colleagues expose this material to four laser beams, which create an interference pattern. Coherent interference results in the formation of liquid-crystal droplets, and it is these that form the photonic crystals.

The transmission spectrum of the photonic crystals that are made in this way can be varied by applying an electric field that changes the refractive index of the droplets. A wide spectrum of light can be affected, because the new photonic crystals can be built on a wide range of scales. The crystals can also reproduce the effects of structures such as diamond and anisotropic lattices.

The tunable photonic crystals should be useful as optical filters, and with further development may lead to novel lasers and optical waveguides.

## Magic numbers found to make 'super-alloys'

A group of "super-alloys", with properties such as ultra-high-strength, super elasticity and super plasticity, has been discovered by researchers at the Toyota Central Research and Development Laboratories and the University of Tokyo. The alloys show their "super" behaviour over a wide range of temperatures, including room temperature.

The researchers have used computational methods to find their way through a myriad of possible combinations of elements that could lead to useful alloys. In particular, they have found that three electronic "magic numbers" yield the super-alloys: an electron-to-atom ratio of about 4.24; a "bond order", which represents the bonding strength, of 2.87; and a d-orbital energy level, which represents the electronegativity, of about 2.45. The "super" properties arise only when all three numbers are satisfied.

The alloys found in this way are based on titanium, with additional amounts of tantalum, niobium, zirconium, vanadium and oxygen in a simple body-centred cubic structure. To exhibit their "super" properties, the alloys must first be "cold worked", but afterwards they show high strength, together with low expansion and no change in elasticity, over a temperature range of several hundred degrees.

**Further reading**

Takashi Saito *et al.* 2003 *Science* **300** 464.

# ASTROWATCH

Edited by Marc Türler

# The race to observe gamma-ray bursts

More and more astronomers are joining the race for the first optical images from gamma-ray bursts. After the precise localization of a new gamma-ray burst, several institutes try to obtain an image of its optical counterpart as quickly as possible. What makes this "sport" so exciting is that nobody knows when or where the next gamma-ray burst will occur. Luck plays an important role in the quest. Among the telescopes around the world that are ready to respond immediately to an alert, only a few are able to take advantage as the bursts occur during the night, well above the horizon and during good weather conditions.

The story of one of the most exciting of these races has recently been published in *Nature* (Fox *et al.* 2003). The starter's shot was the detection by NASA's High Energy Transient Explorer (HETE) satellite of a gamma-ray burst, named GRB021004, on 4 October 2002 at 12:06:14 UT. Just 193 seconds later, the Japanese Automated Response Telescope at the Institute for Physical and Chemical Research (RIKEN) pointed on the location sent out by HETE to make the first image of the burst. Sharper images were performed a few minutes later by the Near Earth Asteroid Tracking (NEAT) camera mounted on one of the Mount Palomar telescopes near San Diego, California. The fading afterglow of this burst was then followed, for several weeks, by some 40 optical telescopes around the world, as well as by six radio telescopes.

*An artist's impression of the Swift spacecraft – due for launch in December 2003 – observing a gamma-ray burst. Swift will be dedicated to observing bursts and their afterglows. (Spectrum Astro.)*

GRB021004 is the second gamma-ray burst, after GRB990123 in January 1999, to be observed in the optical less than 15 minutes after the burst. Although detected slightly later in the optical than GRB990123, it was the best-observed gamma-ray burst at that time. Now, however, all the attention is focused on GRB030329, which is on the way to take the lead over GRB021004. Detected by HETE on 29 March 2003, GRB030329 is one of the brightest and closest gamma-ray bursts on record. With a cosmological redshift of $z=0.17$, it is approximately two billion light-years away, as opposed to other bursts such as GRB021004 ($z=2.32$) that are located at more than 10 billion light-years away.

The unprecedented number of observations of these two recent gamma-ray bursts has tended to confirm their association with supernovae. The violent flash of gamma rays is thought to arise from ultra-relativistic particles thrown out by a cataclysmic event such as the collapse of a massive star – for example in the "cannonball" model (see p5). Such models apply to gamma-ray bursts lasting several seconds; bursts shorter than about 2 seconds are thought to be due to the coalescence of two neutron stars to form a black hole.

Currently, two satellites are able to provide and distribute accurate burst locations within seconds – HETE and INTEGRAL (*CERN Courier* March 2003 p13). In December 2003, NASA will launch the Swift spacecraft, which will have an even greater capability to detect and locate bursts, as well as on-board optical, ultraviolet and X-ray telescopes.

**Further reading**

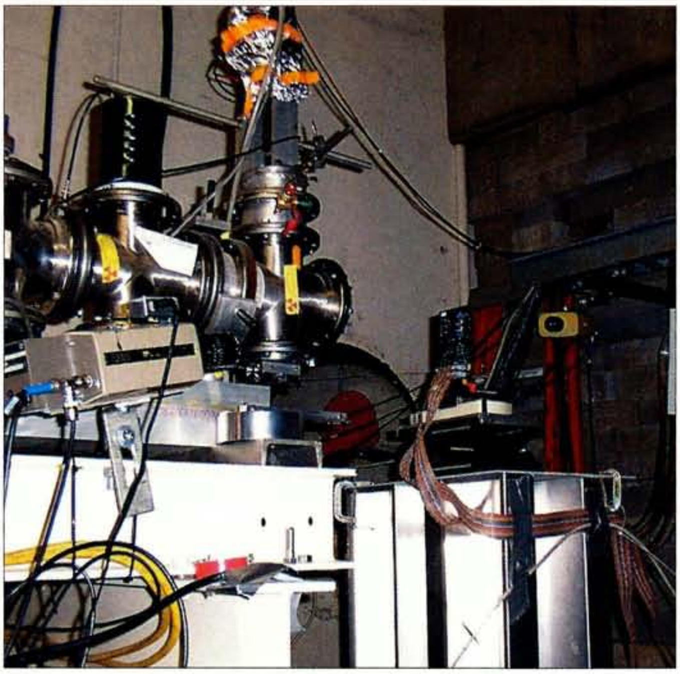
D W Fox *et al.* 2003 *Nature* **422** 284.

## Picture of the month

**In January 2002, the supergiant star V838 Monocerotis, located about 20 000 light-years away in the constellation Monoceros (the Unicorn), suddenly became 600 000 times more luminous than the Sun. This made it temporarily the brightest star in our galaxy. The light from this dramatic eruption created a unique phenomenon known as a "light echo" when it reflected off dust shells around the red star at the centre. This sequence of pictures from the NASA/ESA Hubble Space Telescope's Advanced Camera for Surveys, obtained between May and December 2002, shows apparent changes in the appearance of the circumstellar dust as different parts are illuminated sequentially. From the first to last image, the apparent diameter of the nebula appears to balloon from four to seven light-years. This creates the illusion that the dust is expanding into space faster than the speed of light. In reality the dust shells are not expanding at all, but it is simply the light from the stellar flash that is sweeping out into the nebula. (NASA, European Space Agency and H E Bond (STScI).)**

# A new life for Indiana's cyclotron

Built for research in nuclear physics, the cyclotron at Indiana University now has a new role, which includes radiation testing for high-energy particle physics.



*Component testing for CMS at the IUCF, with a multiple chip test board in the beamline. Monitoring and data-recording equipment are kept out of the radiation zone.*

The Indiana University Cyclotron Facility (IUCF) was originally built as a laboratory for medium-energy nuclear physics, and began operations in 1975. By the 1990s the research programme had begun to diversify, and in 1998 the National Science Foundation decided to discontinue funding of the cyclotron for basic research. Since then, the facility has undergone several dramatic changes, and a medical clinic for cancer treatment using the 205 MeV proton beam from the cyclotron is nearing completion. At the same time, the radiation effects research programme (RERP) is being expanded, and is proving valuable for testing detectors and components for high-energy particle physics.

The beginnings of the RERP at the IUCF go back to the early 1990s, when a group from NASA began to use the proton beam to simulate the space radiation environment. Since then, the radiation effects programme has grown steadily. Studies of single-event upsets (SEUs), displacement damage or other effects of radiation on micro- or opto-electronic devices are routinely conducted. Qualification of commercial-off-the-shelf (COTS) components for applications in space are also part of the radiation effects programme. In addition, the radiation hardness of materials, such as adhesives for use in high radiation environments, is being investigated.

So far, only one beamline has been available for research into radiation effects. However, about two years ago NASA chose the IUCF as their main test facility for the devices intended for use on the International Space Station. Subsequently, two new, state-of-the-art beamlines for radiation effects research were designed in collaboration with NASA and are now under construction. The first new radiation effects research station will become available in June, while the second will be operational later in the year. The radiation effects studies will be conducted concurrently with proton therapy operations.

At the IUCF, protons are extracted from the cyclotron at 205 MeV and delivered by a fast kicker system to both the medical facility and to each of the new radiation effects stations. The kickers deliver a 0.4 ns wide pulse every 100 ns. Beryllium degraders that are well upstream of the radiation effects stations may be used to degrade the beam energy to 40, 65, 90, 120 or 150 MeV. Momentum analysis downstream of the degrader guarantees nearly mono-energetic beams at the location of the device under test. The available fluxes are between $10^2$ and $10^{11}$ protons/s/cm$^2$. The new irradiation stations feature spot sizes between 2 and 40 cm in diameter, so whole laptops may be irradiated at the location of the largest beam spot. For each irradiation, the dose is automatically measured with a calibrated secondary electron monitor and then logged.

### Tests for CMS

Although traditionally associated with space applications, radiation hardness assurance is becoming crucially important for detector components for high-energy collider experiments. It is a particular concern for all the teams that are building detectors for CERN's Large Hadron Collider (LHC) where the proton beams will cross each other 40 million times per second; at the highest luminosity ($10^{34}$ cm$^{-2}$ s$^{-1}$) 25 proton–proton collisions per crossing are expected. To this end, Fermilab has established a programme at the IUCF for the radiation qualification of the electronics it is developing for the Hadron Calorimeter (HCAL) for the CMS experiment.

The CMS HCAL is a sampling calorimeter, composed of brass absorber and scintillating tile with embedded optical fibre readout, which is used to determine the energy of an event. Its front-end electronics accounts for approximately 10 000 of the CMS detector's 16 million readout channels. During 10 years of CMS operation, the front-end components are expected to be exposed to a total ionising dose of approximately 300 Rad, and a neutron fluence of $1.3 \times 10^{11}$ n/cm$^2$.

Although not considered a high radiation region within CMS, the performance of radiation-sensitive devices can degrade in the HCAL environment. Radiation-induced pathologies include non- ▷

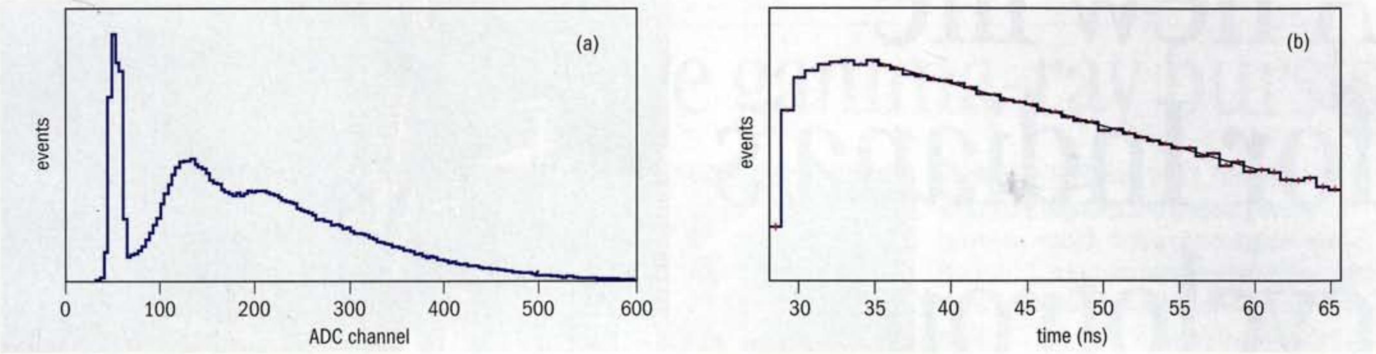


*Fig. 1. The ADC (a) and time (b) distribution of scintillation light from protons in a sample of pure mineral oil for MiniBooNE. The incident proton energy is 205 MeV. The pedestal, first, and second photoelectron peaks are visible in the ADC distribution.*

destructive effects such as SEUs that cause data corruption due to bit-flips and potentially catastrophic failures such as latch-up, which can cause over-current damage to chips. Both effects are caused by single-particle interactions in a device.

A key to determining the radiation specifications for a component is understanding its function in the system. An error rate of 1 SEU per day for a chip may not seem like a large figure, but multiply this by 10 000 channels and the impact can be quite significant. Because designing redundancy into the system is not always practical, it becomes important to select components that can survive in a radiation environment carefully.

The HCAL front-end readout and control monitoring boards have approximately 20 different components that need to be radiation qualified. Several of these are custom-designed chips, but the majority are COTS components, ranging from temperature sensors to field programmable gate arrays (FPGA). Radiation-hard versions of the COTS chips are sometimes available, but at a cost that is prohibitively expensive. Fermilab's strategy is to purchase non-radiation-hard versions and validate them. The combination of rigorous testing at proton beam facilities such as the IUCF and designing for radiation tolerance is expected to yield reliable electronics for the HCAL that will survive 10 years of operation in the LHC environment.

The majority of radiation assurance testing for the CMS HCAL front-end electronics has taken place at the IUCF, where the 205 MeV proton beam is ideal because the protons are of high enough energy to induce single-event effects. Cumulative damage can also be studied. The programme of tests has been conducted over a period of 2.5 years, and has yielded many interesting results (Whitmore *et al.* 2002). For example, FPGA testing revealed SEU susceptibility, and consequently the FPGA programming was modified to allow for triple redundancy in critical elements of operation. Tests of clock distribution chips showed that certain logic families were more sensitive to radiation conditions than others, and tests of shift registers revealed that SEU-tolerant cell layout was required for the design of the digital sections of the custom-designed chips. The results from prototype HCAL system board tests look promising, with no indication of latch-up problems at exposures up to 50 times that expected in 10 years of CMS operation. The final board tests, including monitoring of SEUs, were scheduled for March 2003 at the IUCF.

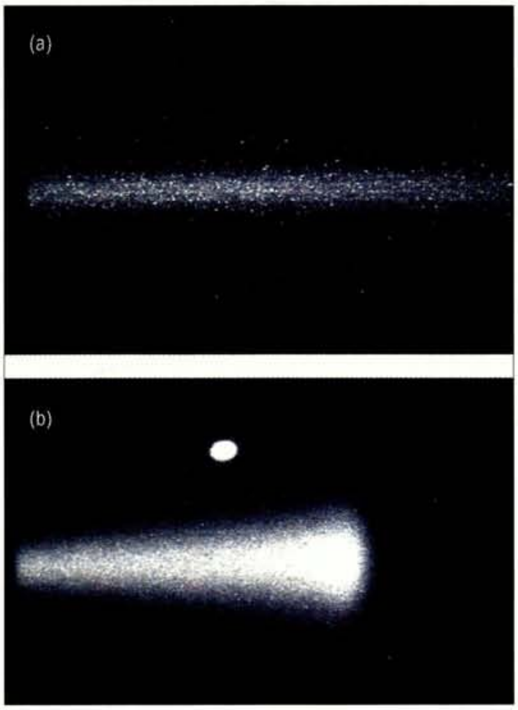


*Fig. 2. Images of an ensemble of protons with 205 MeV (a) and 135 MeV (b) incident energy through a liquid scintillator. The pictures were obtained using an image-intensifier/CCD camera system. The imaged area is 14 cm wide. The bright spot in (b) is due to a calibration LED. Note that the 135 MeV protons range out in the liquid scintillator.*

## MiniBooNE oil

Aside from applications that investigate the potentially damaging effects of ionizing radiation, the RERP beamline may also be used to test the overall performance of detectors and detector components. For example, the neutrino physics group at the IUCF has used the RERP beamline for tests of the scintillation properties of mineral oil and for prototype detector studies. The beam current can be reduced so that the proton rate is quite low (~1 kHz), and tests requiring single proton tracks can be conducted.

The recently commissioned MiniBooNE neutrino experiment at Fermilab uses 800 tonnes of mineral oil as a neutrino detector medium. Charged particles in the mineral oil predominantly produce Cerenkov light. However, a small amount of scintillation light is also produced. It is important to quantify the amount and time distribution of the emitted scintillation light in order to understand the detector response to charged particles, especially particles with velocities below the Cerenkov threshold.

The tests at the RERP facility measured the strength and time distribution of the scintillation light emitted from the MiniBooNE mineral oil. Since the cyclotron beam energy is well below the threshold for Cerenkov light production ($T_{th} = 341$ MeV), any light emitted from proton tracks in the oil sample must be due to scintillation. Instead of the usual electronic components, a beaker containing the oil was placed in the beam. Scintillation light from the oil was detected using a Burle 8850 photomultiplier tube submersed in the oil. This particular photomultiplier tube was chosen because it is capable of detecting single photoelectrons.

The tests showed that about five photoelectrons are generated per MeV of proton energy loss. The pedestal, the first, and the second photoelectron peaks are visible in figure 1a. A fit to this distribution determines the average number of photoelectrons detected. The time distribution of the scintillation light is well fitted by a single exponential distribution (figure 1b), with a characteristic time of around 19 ns.

New neutrino detector schemes are also being studied using the RERP facility. During one such test, a small prototype of a liquid scintillation imaging detector was placed in the beam and illuminated with protons. Images of ensembles of protons were obtained using an image-intensifier/CCD camera system. Two of these images are shown in figure 2. Future tests to determine whether single particle tracks can be reconstructed using an array of CCD cameras are planned.

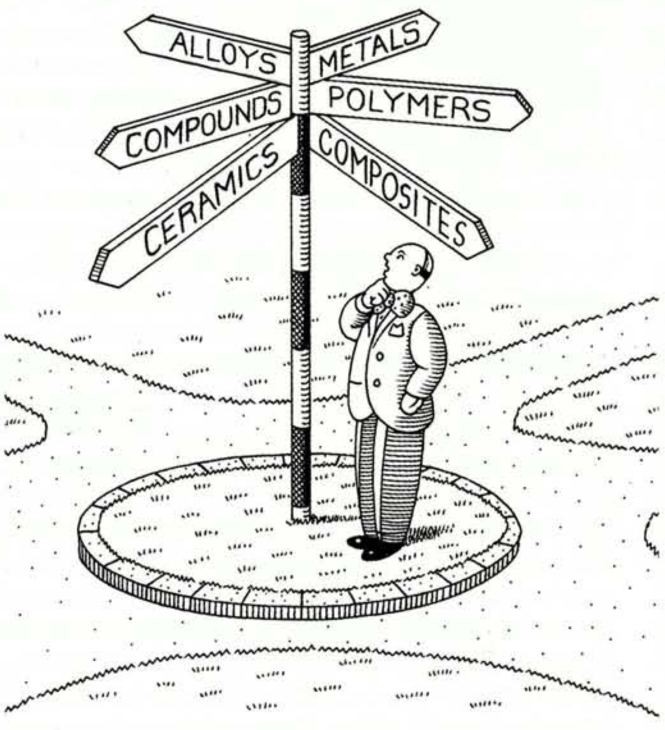
As the size of electronic components continues to decrease into the "nano" regime, the sensitivity of these components to single-event errors increases. Here, the response of certain components to single events triggered by neutrons is particularly interesting. Moreover, neutron scattering is also a valuable tool in materials science, so a low-energy neutron scattering facility (LENS), has been proposed. This would produce copious numbers of neutrons from 11 MeV protons impinging on a production target, and would be accompanied by a neutron irradiation facility (RERPIII). If funding for LENS and RERPIII is granted, the IUCF will be able to provide neutron beams for radiation effects research and materials science by 2005.

## Further reading

J Whitmore *et al.* 2002 Radiation Validation for the CMS HCAL Front-End Electronics. *8th Workshop on Electronics for LHC Experiments* (Colmar, France) 433–438 (FERMILAB-CONF-02-224-E).

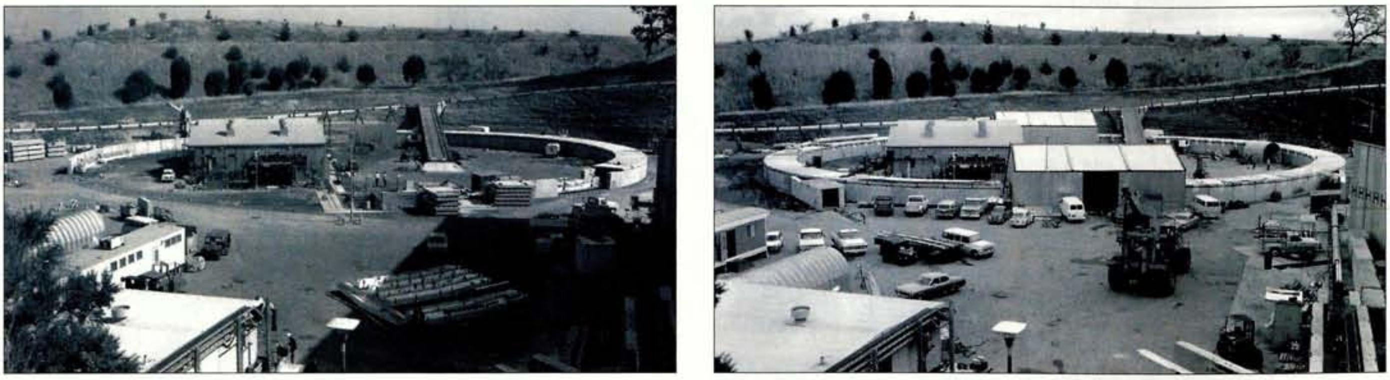
For more information on the IUCF, see www.iucf.indiana.edu/RERP.

**Barbara von Przewoski** *and* **Rex Tayloe**, *IUCF, and* **Julie Whitmore**, *FNAL.*



# The ring on the parking lot

Thirty years ago, a handful of tenacious physicists put up a $5 million storage ring on a parking lot at SLAC. Shawna Williams reflects on its glorious past and its promising future.



Progress in the construction of SPEAR on the parking lot in 1971 is shown in these views from 8 October (left) and 12 December.

In 1972, only 20 months after its construction had finally been agreed, the SPEAR electron–positron collider went into service on a parking lot at SLAC, and by spring 1973 had started to deliver its first physics data. From its humble beginnings, the machine went on to revolutionize particle physics, with two of the physicists who used it receiving Novel prizes. It also pioneered the use of synchrotron radiation in a variety of fields in scientific research. In March this year, technicians began upgrading SPEAR, and now only the housing and control room remain of the original machine. Burt Richter, whose dogged determination led to the machine's existence, likens SPEAR to a character in *Alice in Wonderland*. "It's like the Cheshire cat," he says, "there's nothing left but its smile."

SPEAR was elusive from the start. "The initial question was, how do you build such a machine?" says Martin Perl, who like Richter was to receive the Nobel prize for his work on the machine. "The idea of building an electron–positron collider was not in the mainstream back then." Richter and others at Stanford first proposed building the Stanford Positron–Electron Asymmetric Rings (SPEAR) in 1964, at a time when hitting a fixed target with a beam was the standard way of doing high-energy physics. From 1964 to 1970, annual requests for funding to the US Atomic Energy Commission (AEC) were repeatedly rejected, even though Richter slashed the application from $20 million to $5 million. During one of the revisions to the proposal, the two planned rings became one and SPEAR was no longer asymmetric; but the name stayed. Finally, in 1970, SLAC's director, W K H "Pief" Panofsky, spoke to the AEC's comptroller, John Abbadessa, who said that if SPEAR was an experiment with no permanent buildings, it could be built out of SLAC's normal operating budget.

Richter's team had hoped to build the collider in two years; they finished four months ahead of schedule. "It certainly was the most fun I'd ever had building a machine," says John Rees, one of the accelerator physicists involved. Moreover, the funding delay had actually worked to SLAC's advantage in some ways, since they now had other colliding-beam storage rings to look to. "By that time, we'd learned enough from other people to be able to build the best machine," explains Perl.

SPEAR had another advantage: a new kind of detector, called the SLAC-LBL Magnetic Detector or Mark I, which uniformly surrounded the interaction point. The design "flew in the face of conventional wisdom about how to build detectors for colliders," says Marty Breidenbach of SLAC, who was a post-doc at the time.

SPEAR had a second interaction point devoted to more specialized experiments than the Mark I. "We wanted to give more independent physicists an opportunity to use this new and unique facility, and they all worked," recalls Panofsky. "But they were basically less productive than the approach of having one detector looking at everything that came from the collisions and then later, whilst offline, unpickling everything to sort out what was important." Since then, says Panofsky, "colliding machines all over the world have followed the pattern set by the general-purpose, solenoidal-type magnetic detectors, which were the Mark I and Mark II."

From the beginning, some Stanford faculty members, including Sebastian Doniach, William Spicer and Arthur Bienenstock, realized SPEAR's potential to produce useful synchrotron radiation, so

*An early SSRP experimental station used a Sears "Garden Shed" mounted on the concrete roof of SPEAR. Ian Munro (third from right), a visitor for one year from Daresbury, was the key scientist in this development and provided haggis and drinks to celebrate the first light. On Munro's right are Ben Salzburg, Axel Golde, Sebastian Doniach (SSRP's first director) and George Brown.*

*A scene from 11 November 1974 showing (clockwise) Martin Breidenbach (seated), Gerson Goldhaber, Ewan Paterson, Herman Winick and Francois Vannucci in the SPEAR experimental control room, analysing the data that was rolling in.*

they asked Panofsky and Richter to devise a way to allow X-rays out of SPEAR. The X-ray synchrotron radiation emitted by the circulating beams in the machine was much higher in intensity than anything available for structural analysis in many areas of research, from semiconductor materials to protein molecules. So Richter's team attached an extra vacuum chamber to SPEAR and made provision for a hole in the shielding wall for the beamline. This was the start of the Stanford Synchrotron Radiation Project (SSRP).

### The revolution begins

In the spring of 1973, SPEAR began to gather high-energy physics data. By the next year, the machine was measuring very erratic values of R, the ratio of hadron production to lepton production. These were the first signs of a new particle, which Richter's team called the "psi" ($\Psi$). "Nobody dreamed that there was any state, particle, that was as narrow in width as the $\Psi$ turned out to be," says Richter. "So the first question was what the hell was wrong with the apparatus, is there something wrong with the computers, is there something wrong with the data taking?"

No-one could find any such errors, and some researchers on the Mark I collaboration pushed to rescan the region. But by this time SPEAR had been upgraded and Bob Hofstadter, who was running an experiment at SPEAR's other detector, wanted to move on to higher energies. Finally Richter decided to go ahead with rechecking the anomalous results, but only for one weekend in November 1974. At about 3.1 GeV the group began to see impossibly high particle production. "It didn't take very long before the control room started to fill up with people, because the yield of these particles kept going up and up and up as we made tiny little changes in the energy of the machine," recalls Richter. Word travelled fast. "We started getting calls from all over the country," says Breidenbach. "There was no need to check anything – the signal was beyond any statistics. It was there. No-one had ever seen anything like it."

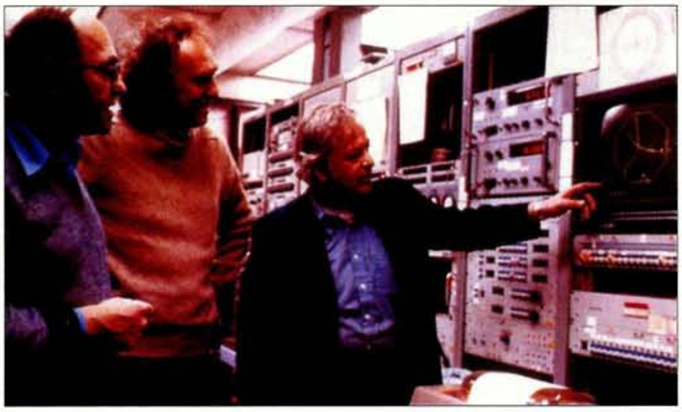
One of the first physicists outside SLAC to learn of the discovery was Sam Ting of Brookhaven National Laboratory, who happened to be visiting SLAC the day after the psi's discovery. Ting's lab, it turned out, had detected the same particle using a different method, but hadn't yet confirmed it to Ting's satisfaction. He called it the J. Whatever the name, Ting's results meant that the new particle had been observed in two experiments and the table of particles had to be revised. Around this time, Panofsky went to the AEC to see Abbadessa. "I said I wanted to announce the discovery of an unauthorized particle on an unauthorized machine," Panofsky recalls. "He liked that."

SPEAR meanwhile continued to yield breakthroughs. "We had a fantastic time for a year or so – we were writing close to a paper per week," Breidenbach remembers. Subsequent experiments revealed that the $J/\Psi$ was the bound state of a new quark – charm – with its antiquark. This was the first discovery of a new quark since Murray Gell-Mann and George Zweig had first put forward the ideas of the quark model in 1964, and it brought the number of known quarks to four. It also confirmed the theoretical ideas of Sheldon Glashow, John Iliopoulos and Luciano Maiani, which grouped four quarks in two "generations". This breakthrough came to be known as the November Revolution. "And then the next year Martin Perl changed the rules of the game again," Richter says.

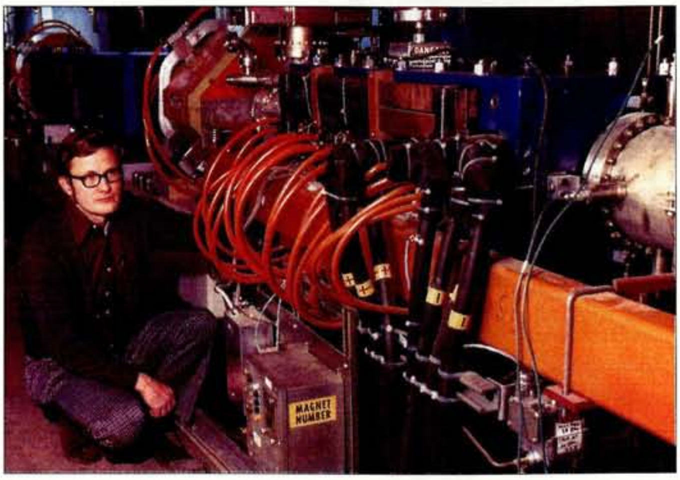
The tau was discovered soon after the $J/\Psi$ and with the same detector, but there the comparison ended. Perl wanted to test his idea that electrons and muons were just the beginning of a series of particles. Rather than designing an experiment to find the next-heaviest particle in the series, he teased out the tau from data recorded on Mark I during more general runs. The tau particle turned out to be part of a third generation of matter, which involves six quarks rather than the four known at the time. Richter and Ting won the Nobel prize in 1976, reflecting the physics community's swift acceptance of the $J/\Psi$. The third generation turned out to be harder to verify than the second, but Perl was finally rewarded with his Nobel prize in 1995.

### Synchrotron radiation for all

Even though it began as a parasitic operation, synchrotron radiation represented an unparalleled opportunity. Use of the SSRP quickly expanded from materials science to chemistry to structural biology. "No-one had ever had effective access to a broad spectrum ranging from the deep ultraviolet into the hard X-rays from a multi-GeV storage ring for these kinds of experiments," says Keith Hodgson, now associate director of the SSRP's successor, the Stanford Synchrotron Radiation Laboratory (a division of SLAC). "This really was one of ▷



Gerson Goldhaber (left) of the Lawrence Berkeley Laboratory, Martin Perl (centre) and Burton Richter of SLAC meet in late 1974 in the control room of SPEAR. A psi decay in the Mark I detector traces an image of the Greek letter psi on the monitor at right.



James Spencer, the designer of the wiggler magnet, crouching next to the first wiggler in the SPEAR tunnel in 1978.

the first of the modern synchrotron radiation research user facilities." The National Science Foundation approved the SSRP grant proposal early in 1973, and soon a pilot beam was up and running. The SSRP team began accepting proposals for experiments, and recorded its first useable data in summer 1974.

The November Revolution later that year was a disaster for SSRP's users, because after that the high-energy physicists began doing experiments in the 3.1 GeV region or 1.55 GeV per beam, which was nowhere near the 2.4 GeV per beam that SPEAR was capable of. "We had what we called the X-ray drought," says Herman Winick, SSRP's first full-time employee and deputy director. In 1978, the group solved this problem by installing "wiggler" magnets in the storage ring, the first time such magnets were used in synchrotron radiation experiments. Wiggler magnets cause particles to wind sharply back and forth as they travel through a storage ring, emitting focused synchrotron radiation with every turn. Not only did the wigglers enhance synchrotron emission and extend it to higher energies, but they also boosted luminosity for the high-energy physicists.

A crane removes the "rafts" of SPEAR2 on 22 April this year, in preparation for the construction of SPEAR3.

By the decade's end, synchrotron radiation research was gaining the upper hand at SPEAR, with 50% of the machine experiment time devoted to X-ray research. In 1980 the Stanford Synchrotron Radiation Laboratory (SSRL), as the SSRP was by then known, received a National Institutes of Health grant to make its X-rays more accessible to structural biologists. Dramatic growth in demand and productivity was also seen in materials sciences and other areas, especially after SPEAR operation was transferred to the US Department of Energy (DOE) in 1982. In the following years, under the stewardship of the DOE Office of Basic Energy Sciences, the SSRL has grown to serve about 1800 users, who mount over 1000 individual experiments each year from a range of disciplines. In 1997 particle-physics experiments on SPEAR ended and the ring became devoted solely to synchrotron radiation research.

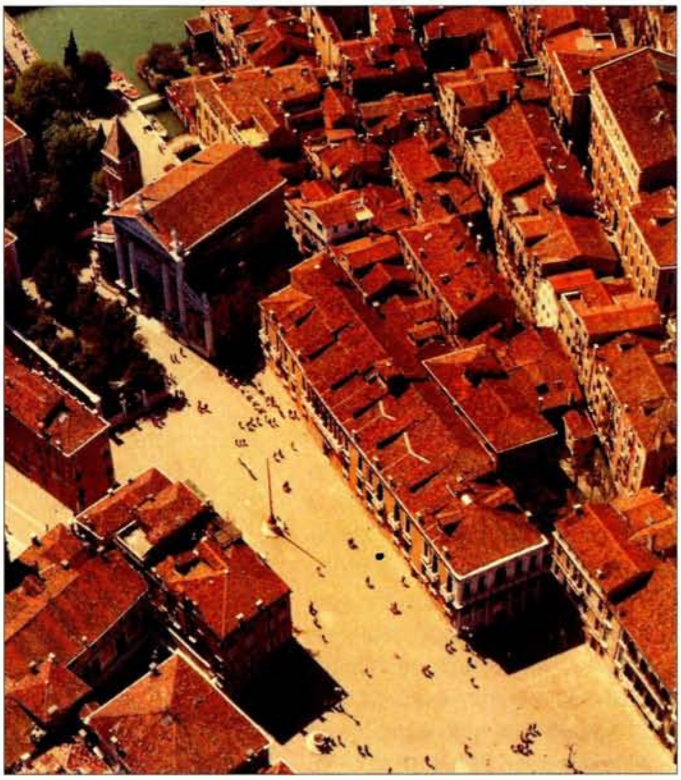
SPEAR revolutionized X-ray analysis just as it revolutionized high-energy physics. For example, to determine atomic structural information using crystallographic techniques, researchers must crystallize the material, record its diffraction pattern and invert that pattern to obtain the real space structure – all tricky endeavours. With the availability of SPEAR and synchrotron radiation, researchers began, for the first time, to use specific wavelengths of synchrotron radiation to directly solve the "phase" part of the experiment (the so-called "phase problem" in crystallography). This new technique, called multiple-wavelength anomalous dispersion phasing (MAD), has proved extremely valuable in solving large numbers of protein molecule structures, and today forms the basis of much of the work done in this field worldwide. X-rays from SPEAR found many other important applications, including solving the mysteries of unusual materials such as the high-temperature superconductors; identifying trace environmental contaminants, such as those found at the Rocky Flats Superfund site; and pinpointing the culprit in the eroding of the *Vasa* warship, a Swedish national treasure.

On 31 March 2003, the SSRL temporarily shut down as staff began stripping the historic ring of all its innards and replacing them with a third-generation machine that will take synchrotron radiation research to new heights. The upgrade will replace all storage ring magnets, the 235 m long vacuum system, 54 magnet support rafts, the RF system, power supplies, cable plant and floor foundation, and will result in significantly higher photon brightness and more stable photon beams. In the wonderland of science, SPEAR's smile will linger for years to come – just like that of the Cheshire cat in *Alice in Wonderland*.

**Shawna Williams**, *SLAC.*

# Neutrinos: universal messengers at all scales

The beautiful interior of the San Vidal church in Venice was the setting for a workshop on neutrino telescopes, which looked at the many messages neutrinos carry.



*The Santo Stefano square, Venice. The Palazzo Loredan, site of the Istituto Veneto delle Scienze, Lettere ed Arti, and the San Vidal Church, site of the workshop, can be seen to the right.*

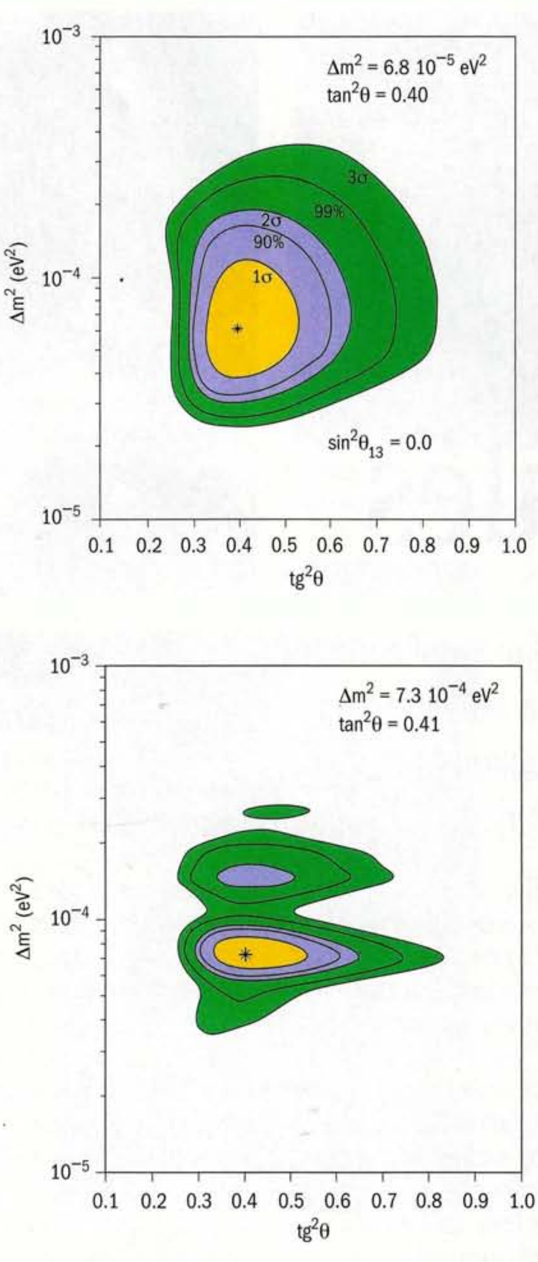
The 10th International Workshop on Neutrino Telescopes, held in Venice on 11–14 March, brought together particle physicists, astrophysicists and cosmologists, all captivated by the fascinating properties of neutrinos. A total of 142 participants attended the meeting, which was organized by Milla Baldo Ceolin of Padova University and co-sponsored by the Istituto Nazionale di Fisica Nucleare (INFN) and the Istituto Veneto delle Scienze, Lettere ed Arti. In her opening address, Baldo Ceolin recalled the recent death of George Marx, a leading figure in Hungarian astroparticle physics. Further reminiscences followed, with warm and affectionate recollections of Bruno Pontecorvo by Luigi Radicati di Brozolo from Pisa, who talked about Pontecorvo's deep human qualities and his invaluable scientific legacy, in particular regarding neutrinos.

The first two days of the workshop were devoted to neutrino oscillations, neutrino masses and mixing angles. John Bahcall of the Institute of Advanced Study, Princeton, began by reminding us of the tremendous challenge that the detection of solar neutrinos represented when it was first proposed. Like the Sun, which shone in Venice during most of the conference and dissolved the last of the winter fog, the joint effort of all experiments on solar neutrinos and solar physics has finally cast light on the long-standing solar neutrino problem. However, warned Bahcall, now that the solar standard model seems to work perfectly well, we should not stop testing it.

The elegance and completeness of the experiments at the Sudbury Neutrino Observatory (SNO) – with its outstanding feature of being sensitive to both charged and neutral current interactions on deuterium – emerged clearly from the talks by SNO project director Art McDonald of Queen's University, Ontario, and by Richard Hahn from the Brookhaven National Laboratory. The experiment now has evidence at the 5.3 $\sigma$ level for neutrino flavour oscillation to active neutrinos. Yoichiro Suzuki of Tokyo described the contribution that Kamiokande and Super-Kamiokande have made in this field, including the first directional observation of solar neutrinos, the first measurement of the $^8$B neutrinos from the Sun, and the most precise detection of high-energy solar neutrinos through neutrino–electron scattering, as well as the detection of neutrinos emitted by the explosion of the supernova SN1987A. Kamiokande and Super-Kamiokande also produced the first clear evidence of neutrino oscillations through the distortion of the zenith distribution of atmospheric muon neutrinos. Support for this result came from the MACRO detector at the Gran Sasso Laboratory and Soudan2 in the US. Takaaki Kajita of Tokyo presented an exciting series of measurements in this field, together with the first confirmation of muon neutrino oscillations with a long baseline neutrino beam, which has been made by the K2K experiment. This experimental programme will continue with the long baseline experiment at the Japan Proton Accelerator Research Complex (J-PARC, formerly the Japan Hadron Facility).

Moving to the low-energy region, Vladimir Gavrin of the Institute for Nuclear Research (INR) of the Russian Academy of Sciences (RAS) reminded us of the contributions made by the Baksan Neutrino Observatory. Its most outstanding result was provided by SAGE, the radio-chemical experiment with metallic gallium that has been taking data for 13 years. Thanks to the low threshold of the neutrino capture reaction in the metal, gallium experiments are the only ones that are sensitive to all the components of the solar neutrino flux, in particular the *pp* neutrinos. On the same topic, Till Kirsten of the Max Planck Institute, Heidelberg, described the evolution over the ▷

years of the Gran Sasso Laboratory's activities on solar neutrinos. The GALLEX experiment announced the first observation of solar *pp* neutrinos 10 years ago, and also made the first neutrino source calibration of any solar neutrino detector. Today, Gran Sasso's involvement in solar neutrino physics continues with the Gallium Neutrino Observatory, which began running in 1998; the BOREXINO real-time, low-threshold solar neutrino detector, which is almost ready; and the LUNA experiment that aims to measure the cross section of the fusion reactions at the energy of the solar Gamow peak (that is, the optimum energy for the reactions).



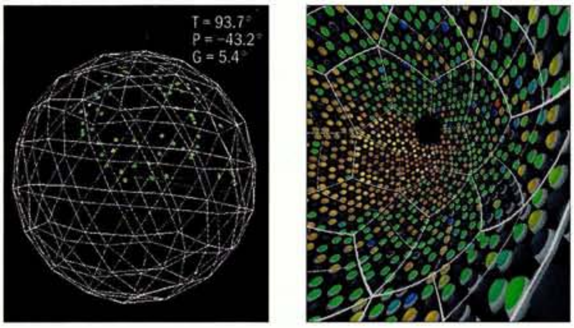
*Plots based on data from solar neutrinos (top) and solar plus KamLAND (bottom) show how the large mixing angle solution for neutrino oscillations allows two close but separate regions in parameter space. (Pedro de Holanda and Alexei Smirnov.)*

The final brush-stroke to this picture of solar neutrino oscillations – after a quest that has lasted for 50 years – has come from the KamLAND experiment, which has shown the first strong evidence for the disappearance of reactor antineutrinos (*CERN Courier* March 2003 p7). As Atsuto Suzuki from Tohoku pointed out, the present KamLAND result is completely consistent with large mixing angle (LMA) solar neutrino oscillations. In addition, the experiment has such a low background that it can observe the antineutrinos from the decay of uranium and thorium in the Earth, and could in the near future provide a measurement of the beryllium-generated solar neutrinos. In this context, Gianno Fiorentini of Ferrara stressed that it is now time to use such geo-neutrinos to determine the radiogenic contribution to the energetics of the Earth. More generally, Gianluigi Fogli of Bari pointed out that we are entering the era of precision tests for several neutrino parameters. In the solar sector, the large angle solution at present includes two close, but separate regions in parameter space (see figure above). Fogli showed that there is now statistical evidence for matter effects in the Sun, which were also nicely reviewed by Alexei Smirnov of INR/RAS and ICTP, one of the founding fathers of this field.

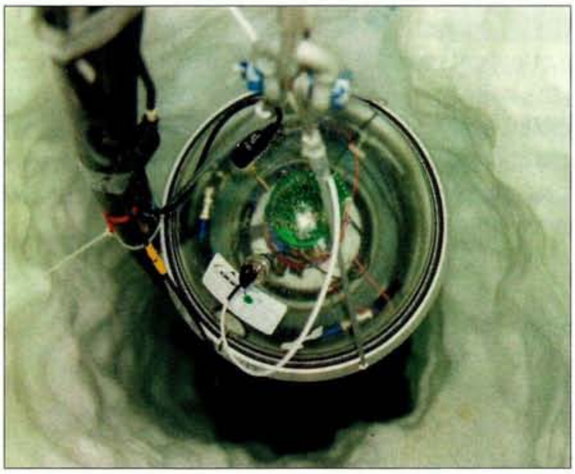
Artificial neutrino beams will continue to play a fundamental role in the precise determination of neutrino oscillation parameters. Bill Louis from Los Alamos presented the evidence for neutrino oscillation from the LSND experiment, through the appearance of electron antineutrinos in a muon antineutrino beam. He also described the status of MiniBooNe at Fermilab, which should unambiguously confirm or refute the LSND result, and which is now taking data with the results expected in early 2005. The final and complete mapping of the neutrino oscillation parameters will, however, require new facilities and new detectors. Deborah Harris from Fermilab presented future long baseline neutrino experiments, introducing new concepts in neutrino beams such as off-axis neutrino beams, "super beams" and "beta beams". Ken Peach from the Rutherford Appleton Laboratory illustrated the road towards what appears to be a final neutrino beam facility – the Neutrino Factory – where neutrino beams of unprecedented intensity and purity will be produced by the decays of muons in flight.

The general implications of the recent neutrino results on physics beyond the Standard Model were discussed by Guido Altarelli from CERN. He remarked that the neutrino properties fit nicely, and actually support the framework of grand unification in its supersymmetric version, where dark matter and baryogenesis can be included naturally. In such a context, the dominant source of neutrino masses could be the "see-saw" mechanism, which was reviewed by Steve King of Southampton, Rabindra Mohapatra of Maryland and Ferruccio Feruglio of Padova. Neutrino masses are also considered in models with extra dimensions, as summarized by Qaisar Shafi from the Bartol Research Institute. The challenging and fundamental direct determination of neutrino mass, both with integral spectrometers and cryogenic detectors, was discussed by Christian Weinheimer of Bonn and Angelo Nucciotti of Milano–Bicocca. The relevance of a positive signal in neutrinoless double beta decay for understanding the neutrino spectrum was emphasized by Serguey Petcov of SISSA/INFN and INRNE, Sofia, while Alessandro Strumia of Pisa reminded us about the existing unconfirmed neutrino "anomalies".

On the third day of the workshop, the discussion moved to neutrino astrophysics. Petr Vogel of Caltech explained that supernova neutrinos are essential for improving our knowledge about the emission models in gravitational collapses. Neutrinos with energies in the MeV



*Solar neutrinos detected by the Sudbury Neutrino Observatory (left) and reactor neutrinos detected in KamLAND (right) have brought us to an era of precision tests for neutrino oscillation parameters.*



*Pressure-resistant glass spheres house the phototubes in the AMANDA neutrino telescope – constructed in the ice at the South Pole – which has the best limit on a neutrino source above the TeV region. (DESY Zeuthen.)*

range could also shed light on other types of gravitational collapse, such as the one leading to a strange-quark star starting from a neutron star, as described by Arnon Dar of Technion and CERN.

The detection of high-energy cosmic neutrinos represents one of the most exciting future prospects in astrophysics – indeed, in 1988 the first Neutrino Telescope Workshop held in Venice promoted the birth of this new field. Dar, Daniele Fargion of Rome and Francis Halzen of Wisconsin reviewed the theoretical motivations for studying high-energy cosmic neutrinos. Such studies are expected to play an important role in unravelling the mysteries associated with major cosmic accelerators, such as active galactic nuclei and gamma-ray bursters. There are several existing models, and competition between them is fierce, as noted by Alvaro de Rujula of CERN, so observations will be crucial. Sandip Pakvasa of Hawaii pointed out that neutrino decay might affect the flavour composition of astrophysical neutrinos.

Impressive progress has been made in the construction of neutrino telescopes since the first workshop in 1988. As Stephan Hundertmark of Stockholm reported, AMANDA, the muon and neutrino detector array at the South Pole, is now a successfully operating telescope. It currently has the best limit on a neutrino source above the TeV region, with a sensitivity of about 0.1 event per km$^2$ per year. The future of AMANDA will be IceCube, a kilometre-scale neutrino observatory designed to detect neutrinos of all flavours at energies from $10^7$ eV to $10^{20}$ eV. The first of its 80 strings will be deployed in 2004, and the detector will be completed in 2009. Closer to Europe, Jürgen Brunner of Marseille reported on ANTARES, the neutrino telescope under construction off the Toulon coast, which will be ready to take data in less than three years (see p22). A strong programme has also already begun on the Neutrino Mediterranean Observatory (NEMO), a km$^3$ deep-sea neutrino telescope. The wish of all the participants is that the first "light" through this new window on the universe might be announced in Venice at a future Neutrino Telescope Workshop.

Neutrinos in cosmology were the subject of the fourth and last day of the workshop. Few things in recent years have had the same impact on our view of particle interactions as the recent impressive experimental achievements in cosmology. The data from WMAP, for example, confirm that we are now performing precision tests of cosmological models (*CERN Courier* April 2003 p11). Evidence for dark matter was reviewed in great detail by Marco Roncadelli of INFN Pavia, while Rita Bernabei of Rome reported the status of LIBRA. This is the upgraded version of DAMA, the experiment at Gran Sasso that is reporting a signal from dark-matter particles. We know that neutrinos can be, at most, a sub-dominant component of dark matter, and as Sergio Pastor of Valencia recalled, we can infer from the power spectrum of density fluctuations, an upper bound on the sum of neutrino masses of about 1 eV. The canonical dark-matter candidate remains the lightest particle – possibly a neutralino – in a supersymmetric extension of our world. Neutrinos could, however, provide an efficient way of revealing neutralinos captured by the Sun, after annihilation, as suggested by Antonio Masiero of Padova. On a related topic, the observed baryon density could have been produced by leptogenesis, through the CP-violating, non-equilibrium decay of a right-handed neutrino. Franco Buccella of Napoli showed how leptogenesis can be elegantly incorporated into grand unified theories such as SO(10). It is remarkable that the range of neutrino masses required for successful leptogenesis is essentially the same as the one obtained from neutrino oscillations, as was discussed by Wilfried Buchmüller of DESY.

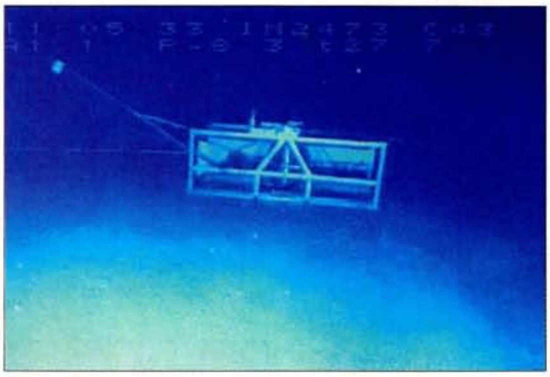
Dark energy is currently one of the most intriguing mysteries of our universe, and was described for the conference by Masiero and Sabino Matarrese of Padova. Dark matter and dark energy are also expected to affect the time variation of fundamental constants in specific frameworks such as string theory, as Thibault Damour of IHES, Bures-sur-Yvette, explained. Neutrinos are apparently not involved here – unless, as Guido Altarelli observed, the equality between the dark-energy scale and the scale of neutrino masses is not a numerical coincidence but is instead an indication of some deep and yet unidentified relationship.

Scrutinized at any length scale, from the microscopic to the cosmological, our world is fascinating. This workshop illustrated that neutrinos are capable of carrying information about our universe from the smallest scales to the largest distances, and this, in the words of Sheldon Glashow of Boston who closed the meeting, is the kind of unification that we should really be looking for.

**Carlo Broggini**, **Ferruccio Feruglio** *and* **Mauro Mezzetto**, *INFN and Padova University.*

# ANTARES succeeds with

A prototype ANTARES detection line is returning data after a two-day mission by the *Nautile* submersible to make the necessary connections on the sea-bed.



*The ANTARES junction box under* Nautile's *floodlights at a depth of 2400 m. On the left are the cable linking the junction box to the shore and the current return electrode on its support arm. (Underwater photos: IFREMER.)*

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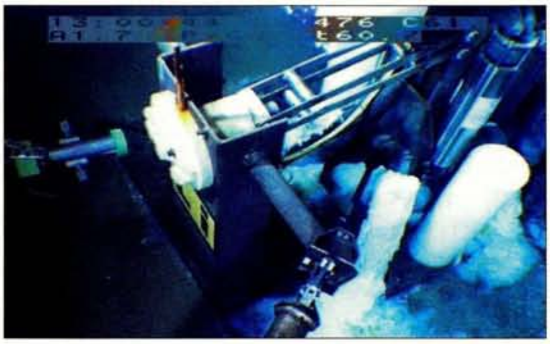

*Connecting the electro-optical interlink cable to the base of the instrumentation line. The connections at the sea anchors used deep-sea mateable plugs and sockets identical to those at the junction box. Behind the receptacle is the titanium cylinder of the coded acoustic release, which will allow recovery of the instrumentation package, leaving the steel anchor base plate and interlink cable on the sea-bed.*

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The ANTARES underwater neutrino telescope, located in the Mediterranean Sea south of l'Ile de Porquerolles near Toulon, has passed a major milestone on the way to implementation in late 2004. At around 1700 h on 17 March, 2003, the first data were received from a prototype detection line of optical modules containing photomultiplier tubes. Earlier in the mission, the *Nautile* manned submersible of the French IFREMER oceanographic research agency had made the vital connections from both the detection line and a second line carrying underwater environmental instrumentation to the underwater electro-optical junction box, which had been deployed in December 2002 (*CERN Courier* March 2003 p21).

After navigating by fixes from a network of sea-bed acoustic transponders deployed around the ANTARES site, and then staying in place with its GPS dynamical positioning system, the *Nautile*'s service ship *l'Atalante* had deployed a 350 m spool of electro-optical interlink cable. Around 30 minutes later, a position fix from an acoustic transponder attached to the spool confirmed that it had been accurately positioned to within 100 m of the junction box, more than 2400 m below. It was then the turn of *Nautile* to begin its two hour descent. On the sea floor, the submersible would use its own acoustic navigation system to triangulate within the ANTARES transponder network and recover the cable spool.

A buoy made from syntactic foam having constant buoyancy down to 2500 m depth was attached to the spool to give it a slightly negative buoyancy, allowing *Nautile* to carry the cable between its manipulator arms. Placing the spool within 25 m of the junction box, *Nautile* grasped the deep-sea "mateable" electro-optical connector containing two electrical and four fibre-optic pathways, which can be plugged and unplugged in seawater at pressures of 250 atmospheres. The cable was then unwound and plugged into one of the 16 outputs from the junction box. After shore-based measurements using optical time-domain reflectometry had verified that the light loss and reflection at the connection were within acceptable limits, *Nautile* recovered the cable spool and laid out the cable in the direction of the detection line's sea anchor. Waypoint markers on this interlink cable would allow future forays into the site of the detector to be made without acoustic navigation.

During the same mission, *Nautile* unfurled a second interlink cable to connect the junction box with an instrumentation line, which was deployed on 12 February. This line incorporates a sea-bed seismometer as well as monitors of the underwater environmental parameters that are necessary for the reconstruction of upgoing muons in the ANTARES detector. The monitors include a pulsed laser light calibration system, a deep-sea Doppler current meter, a sound velocity monitor and instruments for the measurement of salinity and water transparency. The laser flash system has been used to send calibration light pulses to the photomultipliers on the detection line and will aid in the synchronization of the optical readout modules for the reconstruction of muon tracks.

The mission was accomplished in two *Nautile* dives on successive days, with a total of 15 hours on the sea-bed. Four successful underwater connections were made. The validation of this connection technique gives the collaboration confidence in the viability of the configuration for the final ANTARES detector. This will consist of 12 detection lines with around 1000 photomultipliers arranged in triplets on "storeys" that lie at depths varying between −2300 m and

# underwater connections

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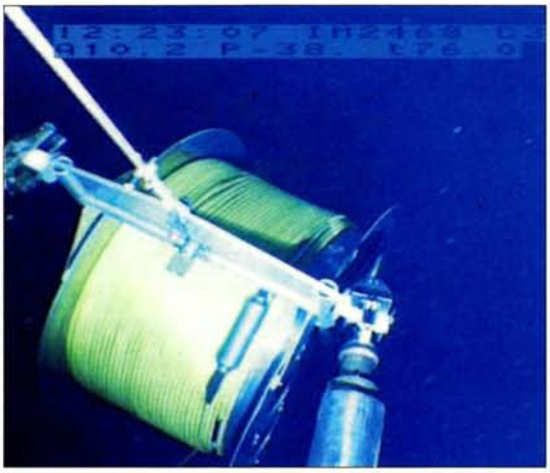
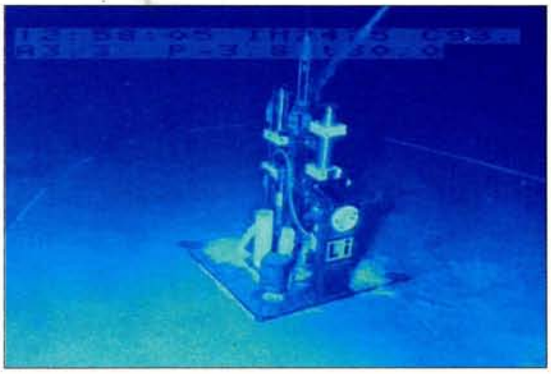


*Unwinding the spool of electro-optical interlink cable held between* Nautile's *manipulator arms.*



*Approaching the sea anchor of the underwater instrument line. The line is held taut by a buoy 300 m above the sea-bed. The snow-like deposits are corrosion debris from magnesium sacrificial anodes attached to the steel anchor base.*

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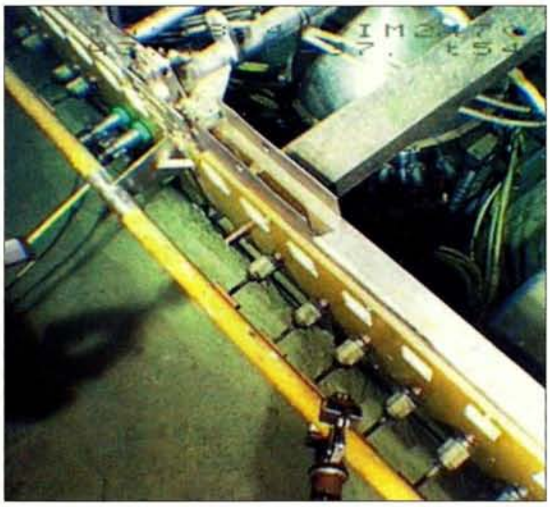
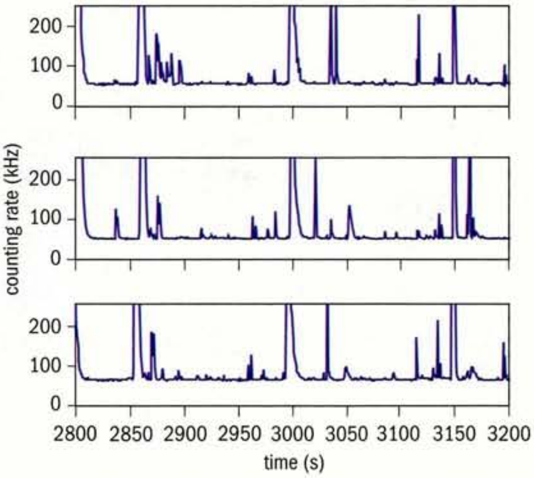


*The two completed connections of the prototype detection line and the instrumentation line at the junction box.*



*Plots showing the typical singles rates from the three photomultipliers of one storey of the prototype detection line.*

−1950 m, with inter-connections radiating from a central junction box.

The detection lines will be held taut between sea anchors and flotation buoys, so they will be subject to curvature and rotation due to the effects of deep-sea currents. Each triplet will be equipped with a tiltmeter and compass to log its movement in real time, and a series of hydrophones along the line will be used to measure the line shape by triangulation with the acoustic transponder network on the sea-bed. On-line measurement of the position of individual photomultipliers to a precision of better than 20 cm (better than 1 ns timing resolution) is needed for the reconstruction of up-going muons from the conversion of high-energy cosmic neutrinos in the deep-sea water and sea-bed.

Data are being acquired from the photomultipliers, tilt meters and compasses of the detection line, and from the instrumentation line monitors. The baseline singles counting rates of around 50 kHz, observed in the triplets of 25 cm diameter photomultipliers, is consistent with the expected background due to disintegrations of $^{40}$K present in sea salt. Peak background rates in excess of 250 kHz with time correlations between the three photomultipliers are consistent with the expected rates previously measured around the site from sea fauna. A few months of data taking and evaluation with the prototype detection line are now planned before it is recovered during the summer.

## Further reading

For more on the ANTARES collaboration (France, Germany, Italy, the Netherlands, Russia, Spain and the UK), see http://antares.in2p3.fr.

**Greg Hallewell**, *Centre de Physique des Particules de Marseille.*

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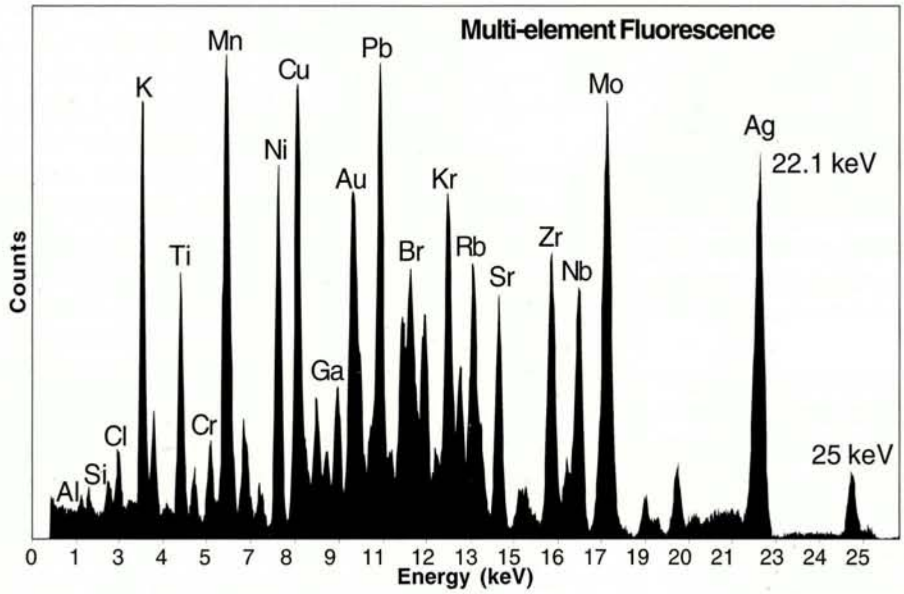

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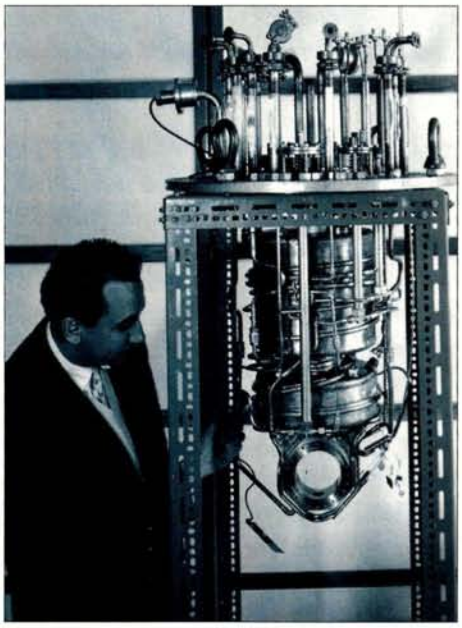
# Charles Peyrou and his impact on physics

**Lucien Montanet**, one of the closest colleagues of Charles Peyrou, who died on 6 April, recalls Peyrou's major contributions to physics and to research at CERN.

In 1938 the "mesotron" (now known as the muon, $\mu$) was discovered in cosmic rays. After a few years of uncertainty, a justly famous experiment showed that the mesotron was not Hideki Yukawa's meson (the pion, $\pi$), and soon after, in 1947, the $\pi$ meson was itself discovered in cosmic-ray showers. That same year, the discovery of strange particles, again in cosmic rays, caused great excitement among physicists. It was in this particularly stimulating context that Charles Peyrou began his brilliant career as a physicist.

With strong support from Louis Leprince-Ringuet, Charles took part in the building of the first Wilson chamber at the Ecole Polytechnique and in its installation at an altitude of 1000 m at Largentière, near Briançon. In 1947 Charles used this chamber, which was equipped with a magnetic field, to measure the mass of the $\mu$ ($m_\mu = (212 \pm 5)\, m_e$). However, he did not observe any mass close to 1000 $m_e$, as had been detected at Largentière in 1943 and which was no doubt the first observation of the $K^+$ in the history of physics.



Charles Peyrou in 1958 with the first liquid-hydrogen bubble chamber built at CERN, which had a diameter of 10 cm.

Charles also studied the kinematic properties of the showers (due to the multiple production of $\pi$ mesons) observed in cosmic rays, but he understood as early as 1949 that the study of pions had become a matter for accelerators. By contrast, cosmic rays were still an excellent source of muons, and in 1951, together with André Lagarrigue at the Ecole Polytechnique, Charles used them to measure the electron spectrum from $\mu$ decay and to provide the first estimate of the Michel parameter, $\rho$, different from zero. The following year, using the same apparatus, he obtained a first indication of the hypothesis that electrons and muons have different lepton numbers, because no electrons were observed in the capture of the $\mu$ by the nuclei (upper limit of 5%).

Reflecting on the possible causes of the absence of $K^+$ in the data taken at Largentière in 1947, 1948 and 1949, Charles realized that this failure could be due either to too short a lifetime of the $K^+$ compared with the muons, or to the fact that the energy of the primary cosmic-ray particles selected for the experiment was too low.

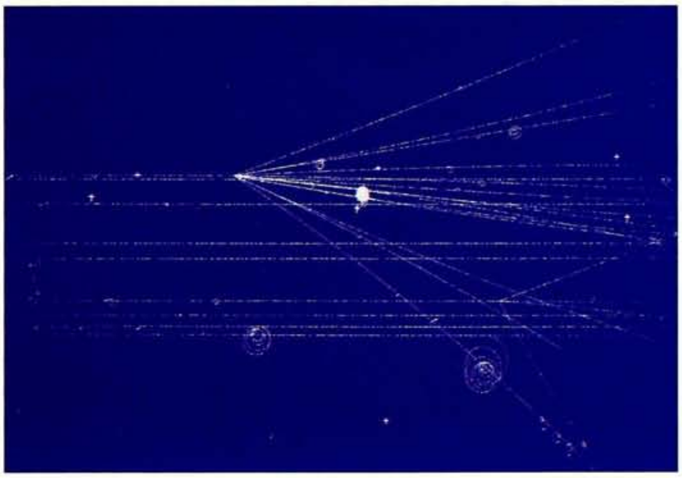
With the agreement of Bernard Gregory, Charles persuaded Leprince-Ringuet to set up an experiment at 2800 m on the Pic du Midi in the Pyrenees with two large superimposed Wilson chambers – a large magnetic chamber placed on top of a chamber fitted with copper plates. Nuclear reactions of cosmic rays occurred in a lead absorber placed immediately above the magnetic chamber, allowing short-lived secondary particles to be detected. It was hoped that the high altitude of the Pic du Midi would mean that a non-negligible fraction of the nuclear interactions would be of high energy. In 1953, after the experiment had been running for a few months, the first two examples of K mesons passing through the first chamber and stopping in the second were observed.

Following a series of results that gave credence to the existence of a whole spectrum of heavy mesons, the Pic du Midi experiment showed that the $K^\pm$ had a unique mass. In addition, the close similarity in range of the muons from $K^+$ decay made it possible to affirm that the majority of K particles emitting a $\mu$ suffered a two-body decay, contrary to the view generally held at the time.

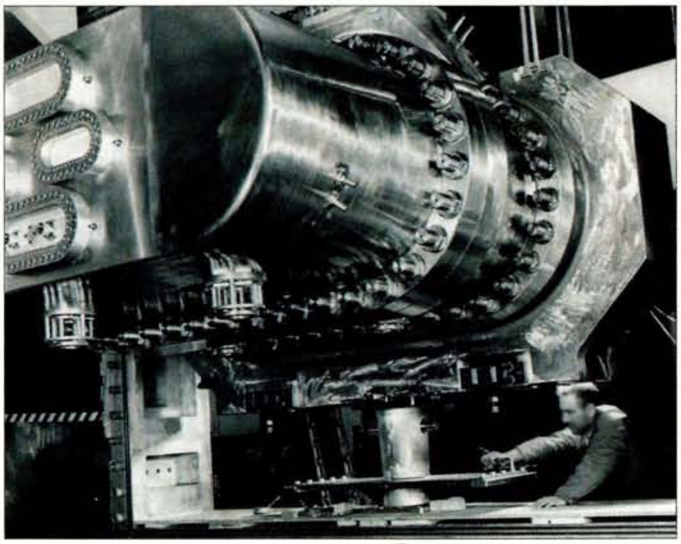
The Pic du Midi experiment produced many other interesting results until 1955, but in 1956 cosmic rays were overtaken by accelerators, at least for the study of elementary particles, and the Wilson chambers were replaced by bubble chambers.

### The first hydrogen bubble chambers at CERN

On his arrival at CERN in 1957, four years before the commissioning of the PS, Charles embarked on the difficult but very promising task of building liquid-hydrogen bubble chambers. A first prototype hydrogen bubble chamber, the 10 cm chamber, was built at CERN in 1957 under Charles's direction. It was first used in 1958 in an experiment in a 270 MeV $\pi^-$ beam from the SC, making it possible to analyse the elastic scattering $\pi^- + p \rightarrow \pi^- + p$. The results were of no particular interest to Charles who was, however, very proud ▷



*The spatial resolution of the 30 cm hydrogen bubble chamber, which began operation at the PS in 1960, is clearly seen in this image of multiparticle production by 24 GeV/c negative pions.*



*Assembly work on the 2 m bubble chamber during May 1964.*

of the quality of the tracks obtained in the first prototype.

The experience acquired with the 10 cm prototype made it possible in 1958 to start constructing a 30 cm chamber, this time with a 1.5 T magnetic field. This chamber was used for a few experiments at the SC in 1959 ($\pi^+ + p \rightarrow \pi^+ + \pi^+ + n$, $\pi^+ + p \rightarrow \pi^+ + \pi^0 + p$). With these data it proved possible to demonstrate the exceptional qualities of the chamber, such as efficiency, spatial precision with a "maximum detectable momentum" of 90 GeV/c, and ionization measurements. These characteristics made it a very useful detector, despite its small dimensions, when the PS first started up in 1960. The 30 cm chamber allowed successful exploration of the multi-GeV physics supplied by the first PS beams (16 GeV/c $\pi^-$ and 24 GeV/c protons), and Charles was to make an active contribution to the analysis and interpretation of these data.

Ever since his first research into multi-pion production in the hadronic interactions of cosmic rays, Charles had been particularly interested in these interactions. Now "his" 30 cm bubble chamber and the PS provided him with the opportunity to give free vent to his imagination, allowing him to develop methods of analysing these complex interactions, such as the "Peyrou plot" and the "principal axis". Naturally, in these experiments he was also interested in the production of strange particles, including the first indications of the leading particle effect, angular correlations, etc.

### An engineer and a physicist

The next step in the construction of hydrogen bubble chambers was an ambitious extrapolation as it entailed building a 2 m chamber rather than a 30 cm one, with all the new associated problems relating to cryogenics, the very important issue of safety, optics, etc. Charles approached all these technical problems with the same enthusiasm as he did for physics, and he succeeded in surrounding himself with an excellent team of engineers and technicians. An engineer himself, Charles was never the type to be condescending about technology. His all-embracing curiosity led him to take part in discussions on the austenitic transformations of steel at low temperature as readily as on the spin of the $\Lambda$. That was why his technical team respected him and was as devoted to him as his group of physicists.

In 1961 the PS started to deliver good-quality separated beams, and as several years more work were needed to complete the 2 m chamber, Charles, John Adams and Bernard Gregory had proposed in 1960 that Saclay's 81 cm hydrogen bubble chamber should be installed at the PS. In 1961, a series of experiments using this chamber began that would provide essential data on the spectrum and properties of hadronic resonances: low-energy antiproton annihilation; 3, 3.6 and 5.7 GeV/c antiproton annihilation; 4 and 6 GeV/c $\pi^+$ scattering; 3 and 3.5 GeV/c $K^+$ scattering; experiments on the formation of baryonic resonances of strangeness −1 with $K^-$ from 400 to 1200 MeV/c, and so on.

Special mention must be given to the original experiment carried out in 1962 with $K^-$ at rest, to study the relative $\Sigma - \Lambda$ parity. This parity, long debated between the proponents – of whom Charles was one – and opponents of the eight-fold way, had been exercising physicists' minds for several years. Benefiting from the good performance of the Saclay 81 cm chamber, the new experiment accumulated 150 events of the type $K^- + p \rightarrow \Sigma^0 + \pi^0$, where the $\Sigma^0$ undergoes the three-body decay $\Sigma^0 \rightarrow \Lambda + e^+ + e^-$. This unambiguously showed that the relative $\Sigma - \Lambda$ parity is positive. In addition, this experiment made it possible to study the leptonic decays of the $\Sigma^+$ and the $\Sigma^-$. The absence of $\Sigma^+ \rightarrow \mu^+ + \nu + n$ and $\Sigma^+ \rightarrow e^+ + \nu + n$ decays confirmed the validity of the then highly controversial $\Delta Q/\Delta S = +1$ rule.

The motivation for performing a wide range of experiments was naturally founded on scientific interest, but there was also an intent to meet the demands of many European universities. Charles attached considerable importance to this latter issue, for his interest in physics was equalled only by his interest in CERN and its users. Beneath an exterior that was sometimes regarded as imperial, lay a fundamentally liberal temperament, convinced as he was that research depended on the unfettered initiative of the physicists. He applied this liberalism equally to both his group and outside the laboratory. This method of directing, with the dispersed effort that it entailed, might sometimes have had a negative impact on the efficiency with which the PS and the bubble chambers were run, but it did great service to European physicists, who at the time were not as accustomed to collaborative efforts as they are now.

*In the control room of the 2 m bubble chamber during its first tests in December 1964. From left to right: Pierre Lazeyras, Charles Peyrou, Albert Burger and Hans Schultes.*

*Peyrou shows how large future bubble chambers should be, during a visit of the French science minister, Gaston Palewski (right), in April 1963. To the left, CERN's director-general at the time, Victor Weisskopf, can be seen looking over Peyrou's shoulder, while to Peyrou's right stands Louis Leprince-Ringuet.*

Charles Peyrou did CERN a considerable service in establishing international collaborations. It was at his initiative that the Track Chamber Committee (TCC) was set up. Its purpose was to receive all the experimental proposals from physicists throughout the world, and then to filter these proposals because then, like now, demand outweighed the available resources. Charles often played a crucial role in this selection process, with his sound judgement of the merits of a given physics issue and certainly with his knowledge of the PS's potential, the available beams and the detector performances. In this respect, it can be said that the fine results obtained using the 81 cm chamber often bore Charles's stamp.

The year 1965 was marked by the commissioning of the 2 m chamber and the creation of the 10 GeV/c $K^-$ beam with RF separators. This beam was essential for producing the $\Omega^-$, which had been suggested by Murray Gell-Mann at the CERN conference in 1962, and which was to be the jewel in the crown of his SU(3) theory. The production of the $\Omega^-$ required the construction of a $K^-$ beam of at least 3.2 GeV/c. Some months prior to the commissioning of the 2 m chamber, the first two $\Omega^-$ were discovered at Brookhaven using a 200 cm (80 inch) chamber and a 5 GeV/c separated $K^-$ beam. In the period before the 2 m chamber started up, the 10 GeV/c $K^-$ beam was used at CERN in conjunction with the 1.5 m British bubble chamber in early 1965, and three $\Omega^-$ were observed, corresponding to the decay $\Omega^- \rightarrow \Lambda + K^-$. (Analysis of the photos obtained in the 2 m chamber exposed to the 10 GeV/c $K^-$ beam was to provide 15 $\Omega^-$).

In 1970, Charles maintained the view, contrary to general opinion, that the 2 m chamber could be effectively used in certain instances to study weak interactions. (It was accepted at the time that weak interactions were the preserve of heavy-liquid chambers). He therefore encouraged data-taking, with the 2 m chamber, on the reaction $K^+ + p \rightarrow K^0 + p + \pi^+$ with 1.2 GeV/c incident $K^+$. The aim was to study $K^0$ decays. The quality of the kinematical measurements in the 2 m chamber made it possible to define accurately the $K^0$ trajectory independently of its possible decay over a distance corresponding to several $K^0_S$ lifetimes. This experiment was to produce original results on the ratio between the amplitude for $K^0_S \rightarrow \pi^+\pi^-\pi^0$, and that corresponding to CP conservation, $K^0_L \rightarrow \pi^+\pi^-\pi^0$, as well as on the $\Delta Q = \Delta S$ rule for $K_{e3}$ and $K_{\mu3}$.

Charles also played an important role in the saga of neutral currents. The search for neutral currents called for the rapid installation of Gargamelle, the heavy-liquid bubble chamber whose components were built at Saclay, in a neutrino beam at CERN. The bubble chamber was installed in record time despite some unforeseen accidents such as the fire that damaged the beam in 1969. Gargamelle's first exposures to the neutrino beam were made in March 1971.

## The discovery of neutral currents

It is interesting to note that, in his report of activities for 1972, Charles gave priority for the first time to the results obtained on weak interactions with the heavy-liquid chambers, which demonstrated the proportionality with energy of the cross-sections. He also noted that the theory of weak interactions predicted the existence of neutral currents that would be able to generate events of the type $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$ (leptonic neutral currents).

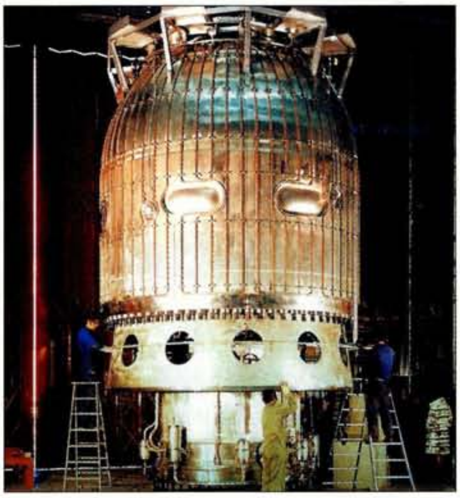
No event of this kind was observed, but the sensitivity of this first phase of the experiment was still too weak for precise conclusions to be drawn. This limitation was eliminated the following year with a detailed analysis of the events corresponding to "hadronic" neutral-current candidates of the type $\nu_\mu$ + nucleon $\rightarrow \nu_\mu$ + hadrons, whose cross-section is much larger than that of leptonic neutral currents but for which the background (due to uncontrolled incident neutrons) is much greater. The Gargamelle collaboration nevertheless concluded in July 1973 that neutral currents existed. This result was confirmed in spectacular fashion by the observation of two leptonic events several months later. The experiment made it possible to determine, for the first time, the mixing parameter in the Weinberg–Salam theory, $\sin^2\theta = 0.39 \pm 0.05$.

The discovery of the existence of neutral currents was initially received with a great deal of scepticism by several eminent scientists and, after an in-depth and unbiased study of the arguments put forward by Paul Musset and colleagues in the Gargamelle collaboration, Charles became one of the most eloquent defenders of this important discovery.

In the 1970s, convinced that future research at the SPS re- ▷

quired the use of giant bubble chambers, Charles launched the construction of BEBC, a 4 m diameter hydrogen bubble chamber equipped with a superconducting magnet. This bubble chamber arrived at just the right time to supplement Gargamelle's neutrino physics results. Exposed to 70 and 110 GeV/c $K^\pm$, $\pi^\pm$, $p^\pm$ beams, it also provided the opportunity for studying hadronic interactions at SPS energies.

However, BEBC could not reach the spatial resolution at the vertex required to observe short-lived particles such as the $D^0$, $D^+$ and $D_S$. In addition, the identification of these particles required good identification of the secondary particles. Charles therefore encouraged members of his group to propose the construction of a detector assembly (the European Hybrid Spectrometer, EHS) which, in conjunction with a small rapid-cycling hydrogen chamber and electronic detectors, made it possible to detect and accurately measure the properties of these new particles. The EHS in fact supplied the first lifetime measurements, branching ratios and cross-sections for the production of charmed particles.



*The body of BEBC, seen here in 1971, was 3.7 m long with a volume of 35 cubic metres. A superconducting coil supplied a 3.5 T magnetic field.*

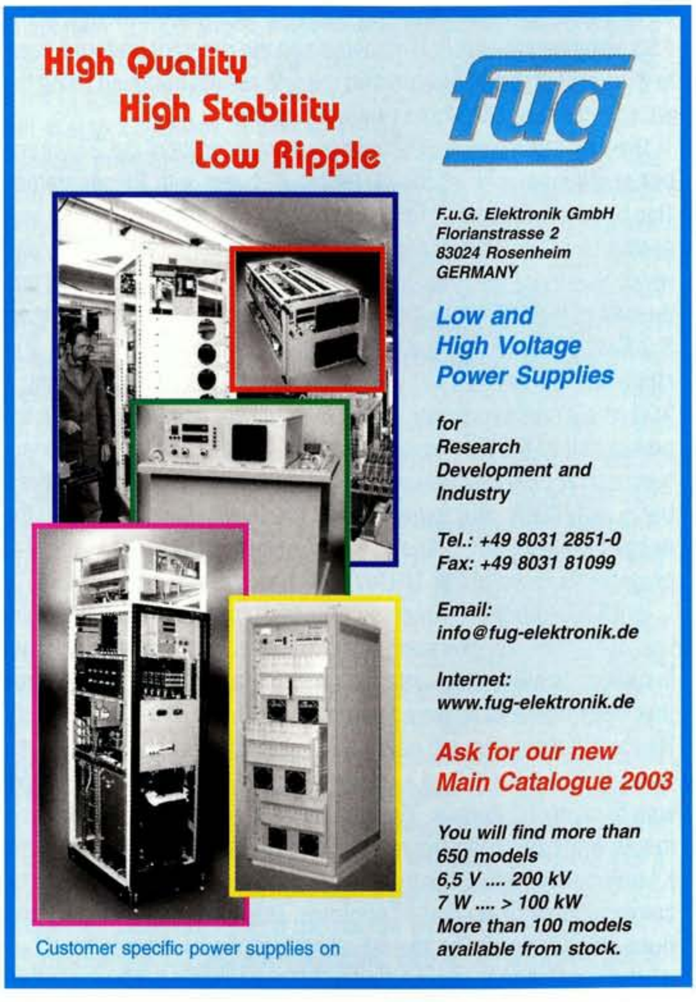
After the EHS, bubble chambers were replaced by other experiments that were equipped with high-precision vertex detectors and allowed the accumulation of information with the statistics required for particle physics in the 1980s. Charles always made himself available to give advice, make suggestions and give a critical response to new projects, bringing his curiosity and passion to the fore in equal measures.

All those who knew Charles Peyrou well will recognize his brilliant intelligence, his incisive and enquiring mind, his unusual, colourful and extrovert personality, his generosity and humanity, and his capacity to be passionately interested in science, history, music, the theatre, and in everything that made life fascinating.

**Further reading**

An obituary for Charles Peyrou can be found on p33.

**Lucien Montanet**, *CERN*.



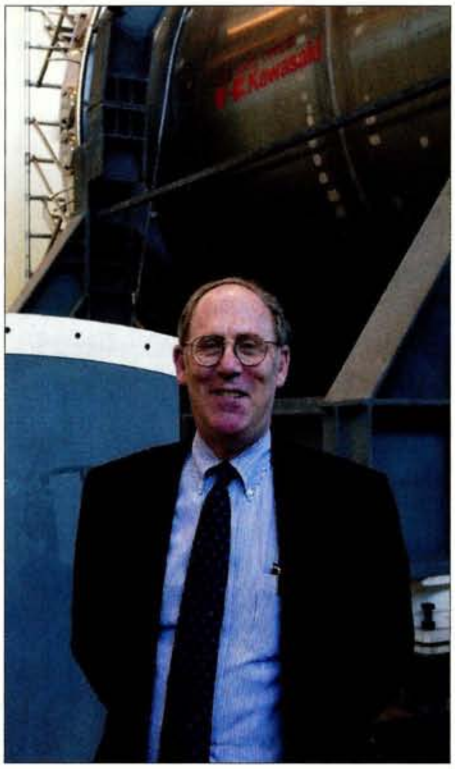
**APPOINTMENTS**

# Robert Eisenstein to head Santa Fe Institute

Robert Eisenstein, who until recently was assistant director for mathematical and physical sciences at the US National Science Foundation (NSF), is to become president of the Santa Fe Institute from 1 June 2003. This appointment follows a year at CERN, where he worked with the ATLAS collaboration.

Founded in 1984, the Santa Fe Institute is a private, not-for-profit centre for research and education. Although rooted in mathematics, physics and computer science, over the past few years the Institute has broadened its agenda to include research in the life sciences, economics and, more recently, social sciences. It operates as a visiting institution to catalyse new collaborative, multidisciplinary research; to break down the barriers between the traditional disciplines; to spread its ideas and methodologies to other institutions; and to encourage the practical application of its results. Since 1984 it has grown from a small group of dedicated scientists to an affiliated network of scientists and researchers from the best academic and research institutions around the world.

"I have followed the progress of the Santa Fe Institute for a long time and I think its reputation for excellence in scientific research is very well deserved," Eisenstein said on the announcement of his appointment. "We will not rest on our laurels, but will continue to press on in terms of involving the very best and brightest scientists currently working in the field of complexity science. What was once a nascent thought of a few academics bold enough to begin this experiment called the Santa Fe Institute, has become an important part of the academic tableau in universities and research institutions around the world."



*Robert Eisenstein, seen here in front of the ATLAS electromagnetic calorimeter cryostat at CERN, is now bound for New Mexico as president of the Santa Fe Institute.*

**INTERNATIONAL COLLABORATION**

# Egypt seeks ways to stem the brain drain

A workshop on high-energy particle physics was recently held in Cairo at the initiative of the high-energy particle-physics community in Egypt. Its aim was to seek ways to reverse the current brain drain towards more developed nations, by developing attractive international collaborations, for example via CEA/Saclay, the National Centre of Physics in Pakistan, and CERN. Egyptian participants presented their work on emulsion experiments, nuclear and theoretical physics, while the external participants presented the physics of the LHC, the CMS experiment and experience in developing high-energy physics in Pakistan.

The picture shows, from left to right, John Ellis (CERN), Mohamed M Sherif (Cairo University), Hafeez Hoorani (National Centre of Physics, Islamabad) and Diether Blechschmidt (CERN). Daniel Denegri from CEA/Saclay (who took the photo) also participated in the workshop.

PRIZES & AWARDS

# The 2002 Pontecorvo and Bogoliubov prizes

Samoil Bilenky of the Joint Institute for Nuclear Research (JINR), Dubna, has been awarded the Institute's prestigious Bruno Pontecorvo Prize for 2002, for his theoretical research in the field of neutrino oscillations. Bilenky is seen here with his award (right), together with the director of JINR, Vladimir Kadyshevsky (centre), and Nicolai Russakovich, the jury chairman for the prize and director of the JINR Dzhelepov Laboratory of Nuclear Problems.

The Nikolai Nikolaevich Bogoliubov Prize for 2001–2002 has been awarded to Albert Tavkhelidze (the Institute of High Energy Physics, Tbilisi, Georgia and the Institute of Nuclear Research, RAS, Moscow) and Yoichiro Nambu (Chicago University), for their fundamental contribution to the theory of quarks with colour. They were the first to suggest a hypothesis for a new quantum number – the colour charge. In 1965, while studying composite hadron models, Tavkhelidze, together with Bogoliubov and B Struminsky, and independently Nambu and Moo-Young Han, suggested a new quantum number for quarks, later called "colour". A particular feature of the dynamical approach they used is that quarks with colour are regarded as physical fundamental particles – fermions that stay in hadrons in a quasi-free state.

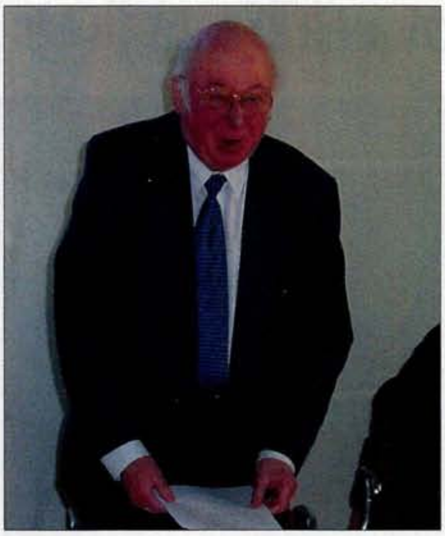
The dynamical quark model of hadrons became the foundation of the relativistic generalization of the SU(6) symmetry of elementary particles, and led to the relativistically co-variant equations for particle bound systems in quantum field theory. The concept of colour quarks became the keystone in the theory of quantum chromodynamics.

**Earlier this year Bryan Pattison was at Buckingham Palace, London, to receive an OBE for services to British interests in Switzerland, awarded in the 2003 New Year's Honours List. Pattison moved to Switzerland in 1966 when he joined CERN as a physicist working on the interactions of neutrinos in heavy-liquid bubble chambers. More recently he has become well known at CERN as head of the Users' Office and president of the CERN Cricket Club. He is seen here with his medal – which was presented by Prince Charles – along with his son Andrew and daughter Maxine.**

**Guillaume Unal, from LAL Orsay, has been awarded the 2003 Joliot-Curie Prize of the SFP (French Physical Society), which is given to a particle physicist or nuclear physicist in alternate years. After his thesis on the UA2 experiment on the W mass measurement in 1991, Unal went to CDF at FNAL where he was one of the most active participants in the discovery of the top quark. In 1995 he joined NA48 at CERN, where he was heavily involved in the measurement of direct CP violation in $K_L$ decays.**

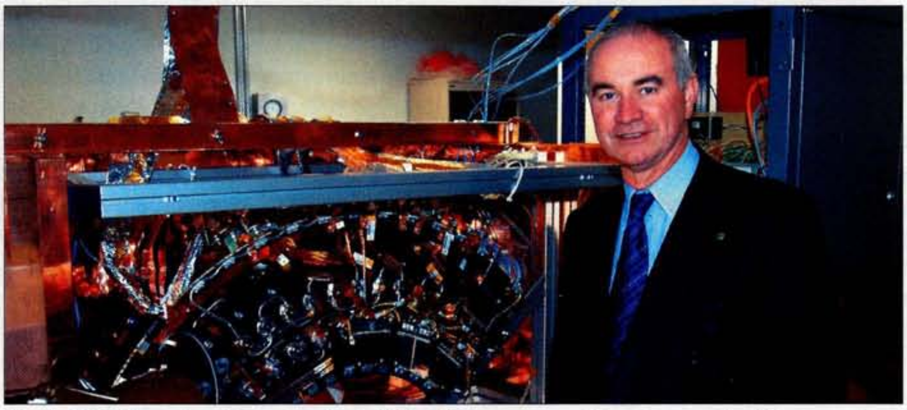
## AWARDS

At the occasion of the 13th Meeting of the BMBF JINR Association Committee, **Horst Rollnik**, emeritus professor for theoretical physics at the Physics Institute at Bonn University, received an honorary doctorate of the Joint Institute for Nuclear Research (JINR), in recognition of his long-lasting engagement in the Heisenberg–Landau Programme. This programme was set up to support scientific exchange in various fields of theoretical physics by financing schools, workshops and mutual working visits, and it was originated by Rollnik in 1991 in close collaboration with Vladimir Kadyshevsky, who is the current director of JINR.



**Klaus Winter** (right), who is well known for his contributions to neutrino physics at CERN, together with **Masatoshi Koshiba** from the University of Tokyo, in Stockholm on the occasion of the award of the 2002 Nobel Prize to Koshiba for his pioneering work in detecting cosmic neutrinos (*CERN Courier* November 2002 p6).

## VISITS



The ATLAS silicon test laboratory in Building 161 was one of the stops on the itinerary of **Gary Nairn MP**, chair of the Standing Committee on Science and Innovation, Australia, when he visited CERN on 17 April. In the test lab he saw work on silicon detectors for ATLAS, to which Australian universities are contributing. Nairn also toured the ATLAS assembly area and the cavern where the experiment is due to be installed.

The ALICE experiment, with its future emphasis on heavy-ion collisions in the LHC, was a key part of the visit to CERN of **Walter Henning**, director of the German heavy-ion research centre, GSI (Gesellschaft für Schwerionenforschung mbH), Darmstadt, on 14 April. Here Henning (second right) listens intently together with, from left to right, **Jurgen Schukraft** (ALICE spokesperson), **Hans Gutbrod** and **Norbert Anger** (both from GSI), while **Lars Leistam** (ALICE deputy technical coordinator) describes the challenges in the construction of ALICE.

In the ATLAS assembly area, in front of one of the two vacuum vessels for the ATLAS end-cap toroid magnets, **Horst Wenniger** (left) of CERN describes the construction of the ATLAS detector to **Manfred Popp**, chairman of the executive board of the Forschungszentrum Karlsruhe GmbH, when he visited CERN on 2–3 April. Popp not only toured the ATLAS assembly area, but also visited the CMS construction site, the LHC magnet test area, and met with representatives of the LHC Computing Grid and European DataGrid projects.

## CELEBRATIONS

# Sessler and Chirikov celebrate their 75th birthdays

On 15 March the Lawrence Berkeley National Laboratory held an event to celebrate Andy Sessler's 75th birthday, and his many scientific achievements and humanitarian contributions. Sessler, who joined the laboratory in 1961 to work on plasma and accelerator physics, is a former director (1973–1980) and founded both the Earth Sciences and what is now the Environmental Energy Technologies Division. He continues to be very active and will soon be visiting Japan and Russia to talk on particle-beam cooling, quantum interference and stochastic phenomena in particle accelerators.

The celebration consisted of an afternoon symposium followed by a dinner in the LBNL cafeteria overlooking San Francisco bay. The symposium speakers, who covered a subset of Sessler's broad range of interests, were Larry Jones (University of Michigan), Kwang-Je Kim (ANL), Simon Yu (LBNL), Bob Palmer (BNL), George Trilling (LBNL), Art Rosenfeld (CA Energy Commission) and Irving Lerch (APS). There were more than 100 guests at the dinner, some of whom came from as far away as Japan for the event. Electronic proceedings of the symposium will be available at http://mafurman.lbl.gov/sesslerevent.

As a lasting tribute to Sessler's accomplishments, the Accelerator and Fusion Research Division at LBNL has established a new, on-going, postdoctoral fellowship. Announcements inviting applications will soon appear in *Physics Today* and *CERN Courier*.

*Andy Sessler (left) chats with Moishe Pripstein of LBNL's Physics Division at the symposium held on 15 March in Sessler's honour.*

*Boris Chirikov in the 1980s.*

A friend and colleague of Sessler's from the 1960s, Boris Chirikov, from the Budker Institute of Nuclear Physics at Novosibirsk in Russia, and full member of the Russian Academy of Science, is also celebrating his 75th birthday this year, on 6 June. Chirikov started his career in experimental physics, but soon became interested in the theoretical aspects of the stability of motion of charged particles in accelerators and magnetic traps. His seminal paper of 1959 revealed unexpected chaotic oscillations that occur in Hamiltonian systems as a result of the interaction between nonlinear resonances. Based on these studies, Chirikov suggested his "criterion of overlapping resonances", which turned out to be very efficient in finding the conditions under which "deterministic chaos" arises in classical Hamiltonian mechanics. This universal phenomenon has now been found to occur in very different fields, such as geophysics, meteorology, astronomy, biology, economics and social sciences.

The analytical approach that Chirikov developed allowed him to solve many physical problems and predict new effects that were later confirmed experimentally. His review paper of 1979, published in *Physics Reports*, has been cited in more than 2400 research papers, and remains a "bible of chaos" for many researchers. In the mid 1970s investigations by Chirikov and his group provided a basis for the creation of a new field of theoretical physics, "quantum chaos", which has attracted the interest of a wide circle of researchers.

A special conference on dynamical chaos, which is devoted to Chirikov's 75th birthday, will be held in Novosibirsk on 4–9 August, 2003. For further information, see the conference website at www.inp.nsk.su/events/confs/dc2003/.

## NEW PRODUCTS

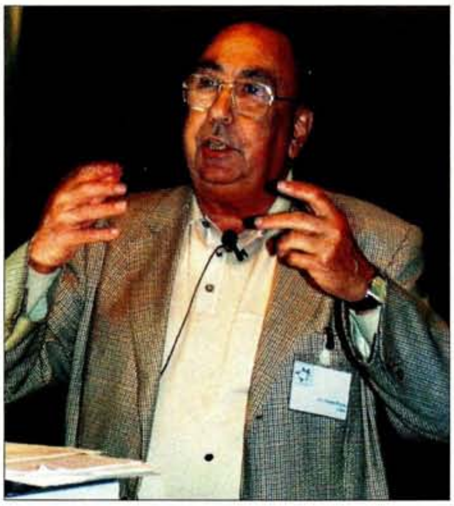
**Final** is offering high-temperature ceramic filters for gases, liquids and particles at 1400 C. Made from Mullite ($Al_6Si_2O_{13}$), the filters are suitable for applications under pressure or vacuum in aggressive chemical environments. For further information, tel: +33 3 88 54 26 00, or e-mail: info@final.fr.

**International Light Inc** has announced a new research-grade scanning spectroradiometer for characterizing a large variety of light sources over a wide spectral range. The IL RGS-2 UV-VIS-NIR features two gratings for an optimal coverage from 200–1100 nm, a resolution better than 2 nm, and a stray light rejection of better than $10^{-5}$. Features include an integrated internal optical filter wheel, a 250 micron entrance slit and optional fibre-optic input assemblies, complete software and a USB interface. For further information, contact Roy E Grayzel, tel: +1 978 465 5923, fax: +1 978 462 0759, e-mail: ilsales@intl-light.com, or see www.intl-light.com.

**CEDIP Infrared Systems** is showing two IR cameras at trade exhibitions this summer. Designed to meet the demanding infrared analysis requirements of spectroscopic test equipment for telecoms and process-monitoring applications, the JADE SWIR is sensitive from 0.8–2.5 microns. Also on show is the EMERALD, a new high-performance, large-format (640 × 512 pixel) IR camera, which can operate up to 100 frames per second at full image size. For further information, tel: +33 1 60 37 0100, e-mail: cedip@cedip-infrared.com, or see www.cedip-infrared.com.

**OBITUARIES**

# Charles Peyrou 1918–2003



Charles Peyrou, who was one of the outstanding personalities at CERN for more than 30 years, passed away on 6 April 2003.

Born in Oloron-Sainte-Marie, France, on 18 May 1918, Peyrou studied at the Ecole Polytechnique, where he attended the first class given by Louis Leprince-Ringuet in 1936. Here, he was part of the small group of enthusiastic physicists who took part in the first cosmic-ray experiments. In 1938 the group built its first chamber, a large Wilson chamber in a magnetic field, operating with Geiger counters. After the Second World War, following his appointment as chief engineer of one of the large national technical institutes known as the Corps de l'Etat, he was detached to his old laboratory to resume research on cosmic rays, and a system of two superimposed cloud chambers was set up at the Pic du Midi in the Pyrenees. This device proved very effective in the study of the strange particles that were starting to be detected at the time. Here, for example, the disintegration of the K meson into a muon and a neutrino was identified for the first time.

Physicists were satisfied with about 50 "good" events a year in those days, but progress was being made in the accelerator field. In Europe, the construction of CERN was underway. Peyrou, who was already a senior lecturer at the Ecole Polytechnique (1946–1954), became a professor at the University of Bern (1954–1958), where he continued to give a course until 1974. Flying in the face of a certain degree of scepticism, he dedicated himself entirely to the European cause.

Having joined CERN in 1957, he championed the laboratory's conversion to bubble chambers as head of the Bubble Chamber Group and subsequently of the Track Chamber Division in 1961, finally becoming director of the latter's mother department, the Physics II Department, in 1966, a post he held for 10 years. His deep understanding of both physics and engineering enabled him to talk to physicists and engineers with equal authority. Thanks to his generous, strong, realistic temperament, his exceptional physics intuition, his tenacity and imagination, track physics experienced remarkable progress.

He directed the construction of successive hydrogen bubble chambers, starting with an initial 10 cm chamber and moving on to a 30 cm chamber in 1959, a 200 cm chamber in 1965 and finally BEBC, a bubble chamber with a superconducting magnet, which collected more than 6 million photographs. The technological impact was important, especially for cryogenics and superconductivity. In parallel, Peyrou offered valuable support to the European bubble-chamber user community, helping physicists to conduct their research in the institutes of CERN's various member states.

When the time of the bubble chambers was over, he maintained an active interest in the life of CERN. He enjoyed discussing the latest physics results with young physicists, and his energy, enthusiasm for mathematics, astounding memory and articulacy made every encounter with him a memorable one. His organizational abilities and great experience continued to benefit the whole laboratory even after his retirement.

Goodbye Charles, and thank you.

# Igor Nikolaevich Ivanov 1938–2003

On 1 March Igor Nikolaevich Ivanov, deputy director of the Laboratory of Particle Physics of the Joint Institute for Nuclear Research (JINR), died. Since 1959, when he first arrived in Dubna as a student of theoretical physics at Voronezh University, his life had been intimately connected with JINR.

From 1969, Ivanov worked with a group on the theoretical basis for a new collective method of acceleration, which had been suggested by Vladimir Veksler. Ivanov obtained important theoretical results on the stability and focussing of the electron ring, and on relativistic effects in the screened high-current beams.

In his last decade, he contributed much to the LHC, TESLA and CLIC projects, and to the development of an ecological accelerator. Under his guidance, and in close contact with specialists from CERN, activities were started on the development of the LHC transverse oscillation damping system, with a tremendous amount of work put in, from design to the industrial prototype. At present, the construction of the system is in its final stage.

Ivanov also devoted much time and effort to training young scientists. He lectured on accelerator subjects to students, and was the initiator and organizer of seminars and schools for young scientists.

**CORRECTION**

The caption to the picture on page 15 of the April issue should in fact say "Jerzy Pniewski (left) and Marian Danysz, who first observed a hypernucleus."

## LETTERS

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

### In memory of George Marx

I read with great sorrow about the demise of George Marx (*CERN Courier* April 2003 p33). I first met him in 1969 when, as a UNESCO adviser, he visited the Punjab University in Lahore, Pakistan, for about three weeks and delivered a series of lectures on CP violation in the Physics Department. He was an excellent speaker and knew the art of communicating his ideas to the audience. His deep understanding of the subject was commendable and he would answer questions to the entire satisfaction of the listeners. He was a witty person, we always enjoyed his comments during conversation, and he was also very keen to visit historical places in Pakistan.

During his stay he also prepared a detailed proposal for the establishment of a centre of excellence in the Punjab University. The centre was ultimately established a few years later but, owing to the local situation, in the field of solid-state physics.

We will always remember George as a sincere friend, an excellent teacher and a great scholar. Without doubt he was one of those physicists by whose names Hungary is recognized in the international physics community.

*Mohammad Saleem, c/o Physics Department, Punjab University, Lahore, Pakistan.*

### The universe as cellular automaton

In his book *A New Kind of Science*, reviewed by Luis-Alvarez Gaume (*CERN Courier* January/February 2003 p55), Stephen Wolfram presents certain ideas as if they were his own, without giving proper credit.

Konrad Zuse was the first to suggest that the physical universe is running on a cellular automaton (CA). His first paper on this topic dates back to 1967 (K Zuse 1967 Rechnender Raum *Elektronische Datenverarbeitung* **8** 336–344). Zuse's book on CA-based universes came out two years later (*Rechnender Raum, Schriften zur Datenverarbeitung, Band 1*, Friedrich Vieweg & Sohn, Braunschweig, 1969; translated into English in *Calculating Space*, MIT Technical Translation AZT-70-164-GEMIT, 1970). Ed Fredkin, who initiated the translation of Zuse's book, later also published related ideas.

Wolfram misrepresents Zuse's work, mentioning him in a single sentence claiming that Zuse said the universe "could be a continuous CA", as if something essential was missing in Zuse's work. Zuse in fact suggested that the universe is computed by a discrete computer or CA. Wolfram's book does not add anything substantial to Zuse's ideas, and does not make any predictions that go beyond Zuse's.

On page 486 of his book, Wolfram tries to distance himself from Zuse by writing that "the universe might not work like a CA...but instead like a mobile automaton or Turing machine". The first paper to suggest this was in fact by J Schmidhuber, "A Computer Scientist's View of Life, the Universe, and Everything" (in *Lecture Notes in Computer Science*, pp201–208, Springer, 1997). This essay also described what is probably the simplest algorithm for our universe, namely the one that computes all possible universe histories with all possible computable laws. This approach is echoed in Wolfram's chapter 9 section on multiway systems, without reference.

(I am trying to convince myself that this embarrassing kind of self-promotion is at least weakly justified as a reaction to Wolfram's own self-congratulatory style.)

For Zuse's 1967 book see www.idsia.ch/~juergen/digitalphysics.html, for the 1997 paper see www.idsia.ch/~juergen/computeruniverse.html.

*Juergen Schmidhuber, IDSIA, Lugano, Switzerland.*

## MEETINGS

An **EPS Technology Foresight Seminar on Synchrotron Radiation and Free Electron Lasers** will be held on 24 June in Munich, Germany. At the seminar, leading experts from academia and industry will give an overview of synchroton radiation and FEL technologies, and the potential benefits for industry, biology and medicine. For further information see www.eps.org/divisions/techgroup.html.

**The 2003 CERN School of Computing**, organized by CERN in collaboration with the Institut für Hochenergiephysik (HEPHY), Österreichische Akademie der Wissenschaften, Vienna and the Donau Universität, Krems an der Donau, will be held on 24 August – 6 September in Krems an der Donau, Austria. It is aimed at postgraduate students and researchers with a few years' experience in particle physics, computing or related fields. Special themes this year are algorithms, grid technologies and software technologies. More information is available at www.cern.ch/CSC/.

The 10th **Euro Summer School on Exotic Beams** will be held in Valencia on 4–12 September. It is intended for PhD students and young postdocs who are interested in the field of nuclear physics with radioactive beams. Theoretical talks will cover symmetries in N~Z nuclei and shell-model applications in nuclear physics and astrophysics, while experimental talks will review studies of the most exotic species. A special topic will be the transmutation of nuclear waste. For more information see http://ific.uv.es/~euschool/index.htm.

**The 5th Workshop on Small-x and Diffractive Physics** will be held at Fermilab on 17–20 September. The workshop will review theoretical and experimental progress in the physics of diffraction and rapidity gaps, and the small-x properties of the proton. New data are expected from the Tevatron, HERA, RHIC, etc and LHC and other plans will be reviewed. Progress in theory and phenomenology will be presented. For further details see http://conferences.fnal.gov/smallx/index.html.

# RECRUITMENT

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

## Research Assistant post in Particle Physics

The Department of Physics at RHUL invites applications for a PPARC-funded postdoctoral position, to work on the ATLAS project. The principal role of the successful applicant will be to carry out a research programme in preparation for the start of the LHC, with a view to broaden and strengthen our efforts in the area of physics analysis of ATLAS data. Some travel to CERN will be required. Previous experience with the C++ language and with objected-oriented programming would be an advantage.

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Applicants should have a PhD (or be about to submit a thesis) in particle physics.

Informal enquiries about the post can be made to Dr Pedro Teixeira-Dias at ***pedro.teixeira-dias@rhul.ac.uk.***

Further details and an application form can be obtained from The Personnel Department, Royal Holloway, University of London, Egham, Surrey TW20 0EX; fax: **01784 473527**; tel: **01784 414241**; email ***Sue.Clarke@rhul.ac.uk***

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Closing date for the receipt of applications is 1 July 2003. Interviews will be held as soon as possible after that date.

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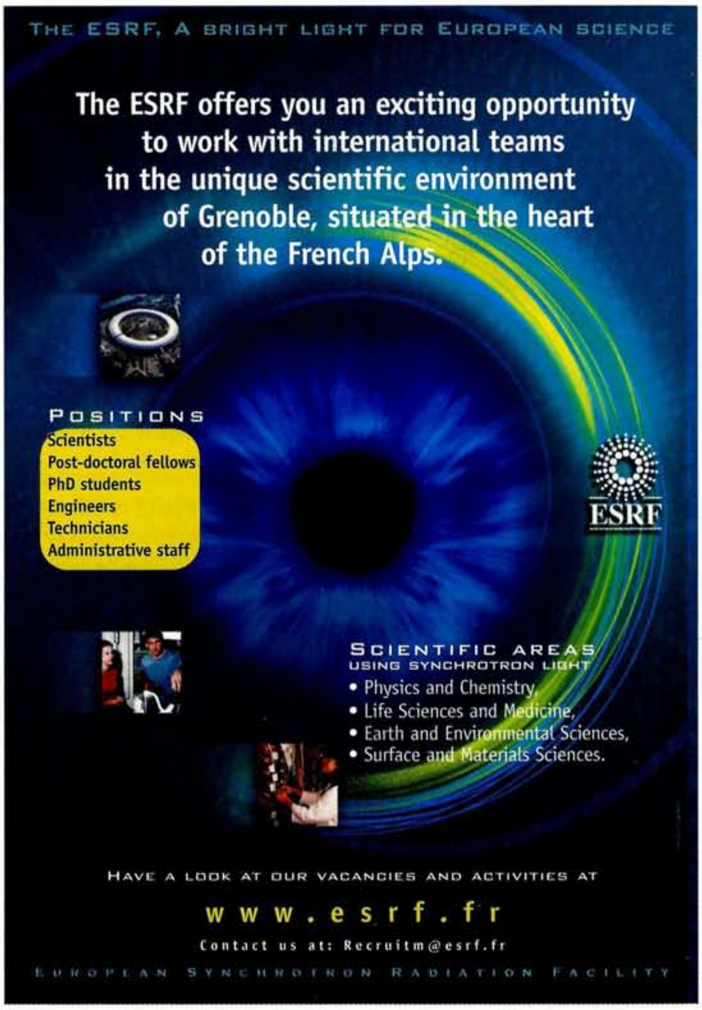

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**Prof. H. H. Williams,**
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**University of Pennsylvania,**
**209 S. 33rd St, Philadelphia,**
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We encourage candidates with experimental backgrounds 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.
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Please contact Andreas Peters (A.Peters@gsi.de) or Peter Forck (P.Forck@gsi.de) for further information.

Applications should be sent within 14 days after publication to

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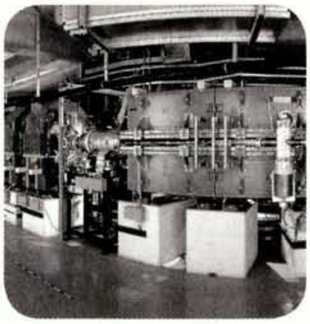

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The resources of the Center are currently being applied to laser-driven advanced accelerator-based research and radiation sources, the major accelerator-based High Energy Physics initiatives–LHC, NLC and muon storage rings–and a new concept for a synchrotron light source (LUX) producing femtosecond pulses for ultra fast x-ray science.

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**Further details about these positions are available from either of the undersigned:**
**Denjoe O'Connor, Werner Nahm, or Brian Dolan**
**School of Theoretical Physics,**
**Dublin Institute for Advanced Studies,**
**10 Burlington Road, Dublin 4, Ireland,**
**tel. ++353-1-6140126**
**Email enquiries to:** ***denjoe@stp.dias.ie***

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Send CV, pub. list, and names of three references to:
Buford Price (*bprice@uclink4.berkeley.edu*),
Physics Dept., U. of California, Berkeley, CA 94720, by 15 July 2003. AAE/EOE.

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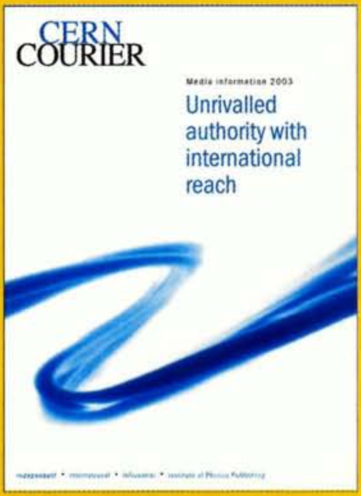

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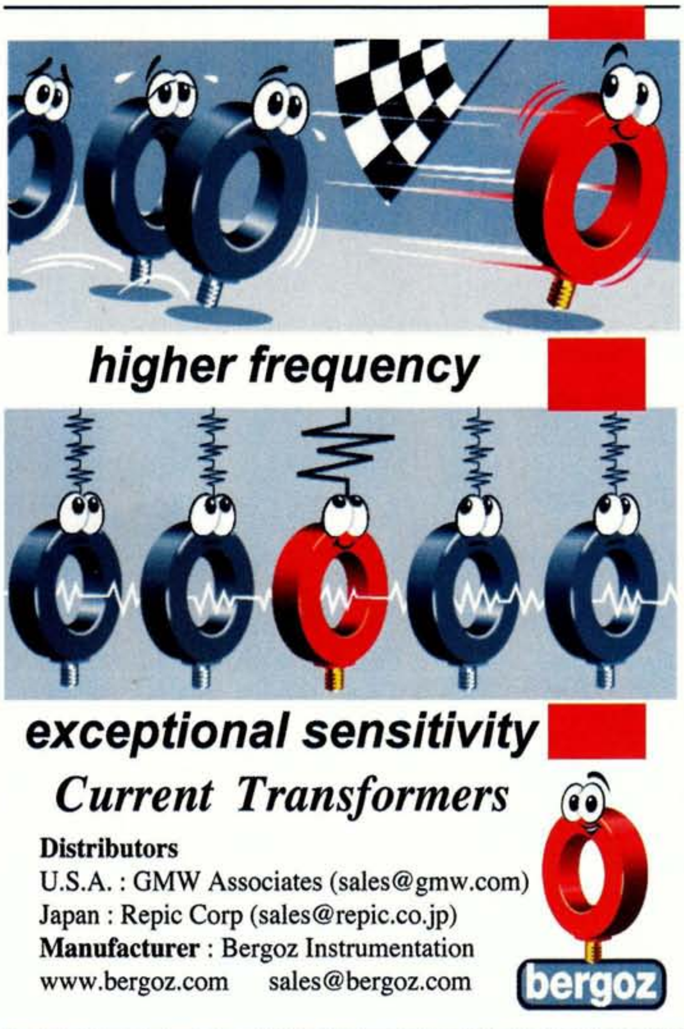

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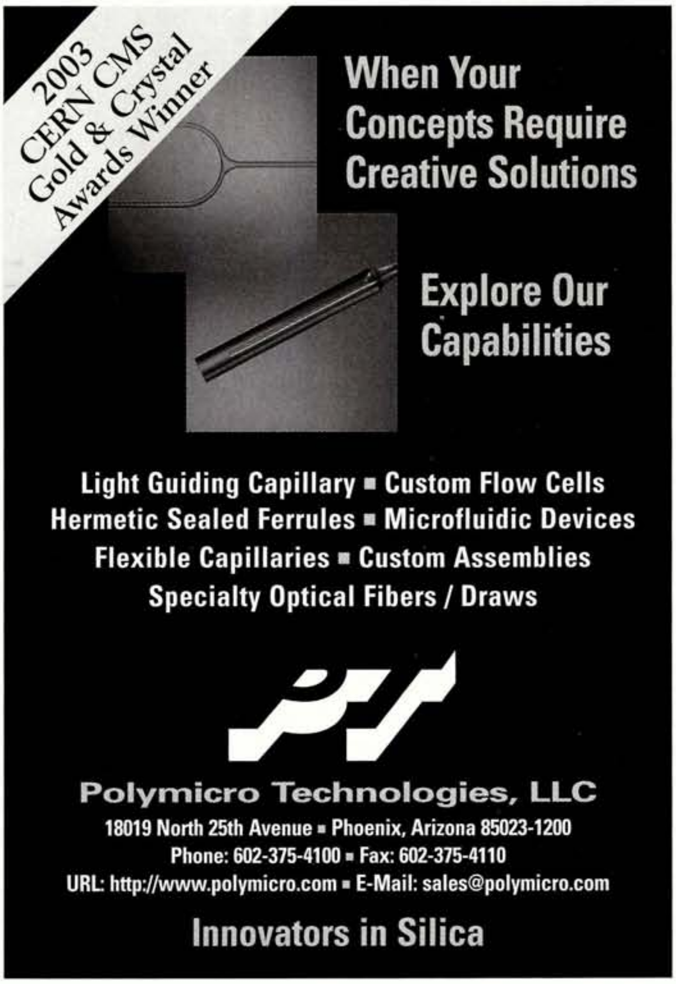

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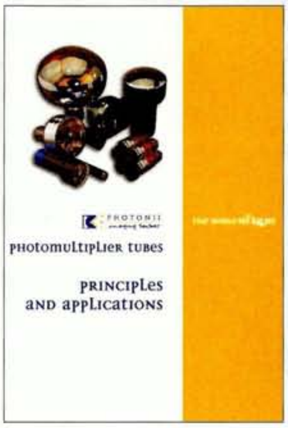

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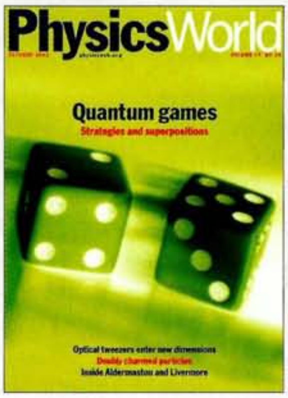

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# Physics in a knowledge-based economy

**Maurice Jacob**, a former president of the European Physical Society, argues that a future dynamic economy will depend on a strong physics base.

Last year, at the first ever joint symposium organized by ESO, CERN and ESA, in Garching, Germany, David Southwood, science director at ESA, quoted a statement from the EU Commission saying that: "Europe should become the most competitive and dynamic knowledge-based economy in the world." The EU statement is full of sense and summarizes a legitimate ambition. The question is how to achieve such a goal and how physics can help in achieving it.

The structure and pace of change of modern economies is such that wealth and power are no longer found in the abundance of available minerals, fossil fuels and raw materials, but lie instead with the ability and know-how to process these commodities into high-technology products that bring a high added value. A competitive economy thrives on innovations, displacing older products with better and more efficient new ones. It is clear that important innovations no longer come from well-targeted inventions, but result from new knowledge and know-how. For example, while it was possible for the invention of the incandescent lamp to result from ingenious trials based on known facts and existing technology, the invention of the transistor would not have been possible without the new ways of thinking brought by quantum mechanics, and therefore without a long, open development of basic research – research that was curiosity-driven and essentially conducted for its academic interest. This change of style in the process of innovation is here to stay and is an important element in developing a knowledge-based economy.

The succession of discovery and innovation phases seen over the past two centuries in the world economy is a well-documented fact. Nevertheless, if one is to base future success on innovations to come, it is worth preparing for them through a healthy research effort in which physics should provide its share of acquired new knowledge. However, one cannot use knowledge as a mere commodity, called upon when needed. We should instead consider it as a constantly developing entity, bringing new insight, new facts and, sometimes, providing new ways of thinking, as nature is much richer than our imagination. One may safely assume that in future the most innovative pieces of new knowledge will come from open research driven basically by human curiosity and yielding unexpected results.

A few years ago, when young French hospital doctors were on strike, they marched with the slogan "At Christmas no scanner, at Easter the churchyard" (which rhymes in French). The scanner had quickly become a key instrument for them, but would there be any scanners without basic research in physics a few decades ago? The answer is no! There are many similar examples. Today many topical questions are associated with the genome, which will play a key role in understanding the mechanisms of life and pave the way to new biotechnologies. Here we see many physicists taking an important role in genome analysis. It is not surprising that Paolo Zanella, who first directed the European Bioinformatics Unit (the EMBL's outstation in Cambridge that manages databases related to research on the genome), was a former head of CERN's computer division. Genome research depends on methods and computational means recently developed in particle physics, and for which the physicist's culture – that is the physicist's ways of thinking and acting – is instrumental.

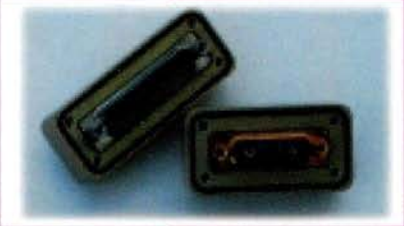
What relative priority should we then attach to domains like particle physics, whose research objectives seem to be very remote from standard human conditions? It is tempting to say that further knowledge about quark dynamics or CP violation is unlikely to bring any useful application, and the same can also be said of many astrophysics questions associated with the structure and evolution of the universe. Yet this research, because it takes us far away from the natural conditions met in everyday life, has acquired a special style of its own, which turns out to be highly conducive to new conceptual and technical developments. Even though its objectives may look very academic, such research should be considered as an asset in the building of a sustainable knowledge-based economy. As Victor Weisskopf said: "The problems at the frontier of science are exactly those that cannot be solved with established methods." This is where the new methods originate.

Consider information technology, a clear priority for a knowledge-based economy. Key developments, such as the Web in the recent past and the Grid today, originated from particle physics and again rely heavily on the physicist's culture. Further progress in many sciences, in particular life sciences and environmental sciences, will depend on efficient handling of very large amounts of information. The large LHC collaborations have become efficient think-tanks for that purpose. The fact that each LHC detector will have to deal with petabytes ($10^{15}$) of information per year – a million times that contained in the human genome – is a strong selling point when trying to convince hard-nosed people that the LHC is worth the effort and money put into it, notwithstanding its great physics potential.

Physics research is already worth supporting as part of human culture: man does not live by bread alone. A successful economy should allow us to put questions about the deep nature of the world around us, but even on very practical grounds, supporting physics research is also a key element when searching for a dynamic knowledge-based economy.

● Extracted from the closing talk at a special workshop of Marie Curie Fellows on Research and Training in Physics and Technology, held at CERN in 2002.

*Maurice Jacob, CERN.*

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