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# CERN COURIER

VOLUME 38 NUMBER 8 NOVEMBER 1998



## HERA experiments get RICH

### GRAN SASSO

The Italian laboratory's MACRO muon detector is adding to the evidence for neutrino oscillations

### HIGH-ENERGY CULTURE

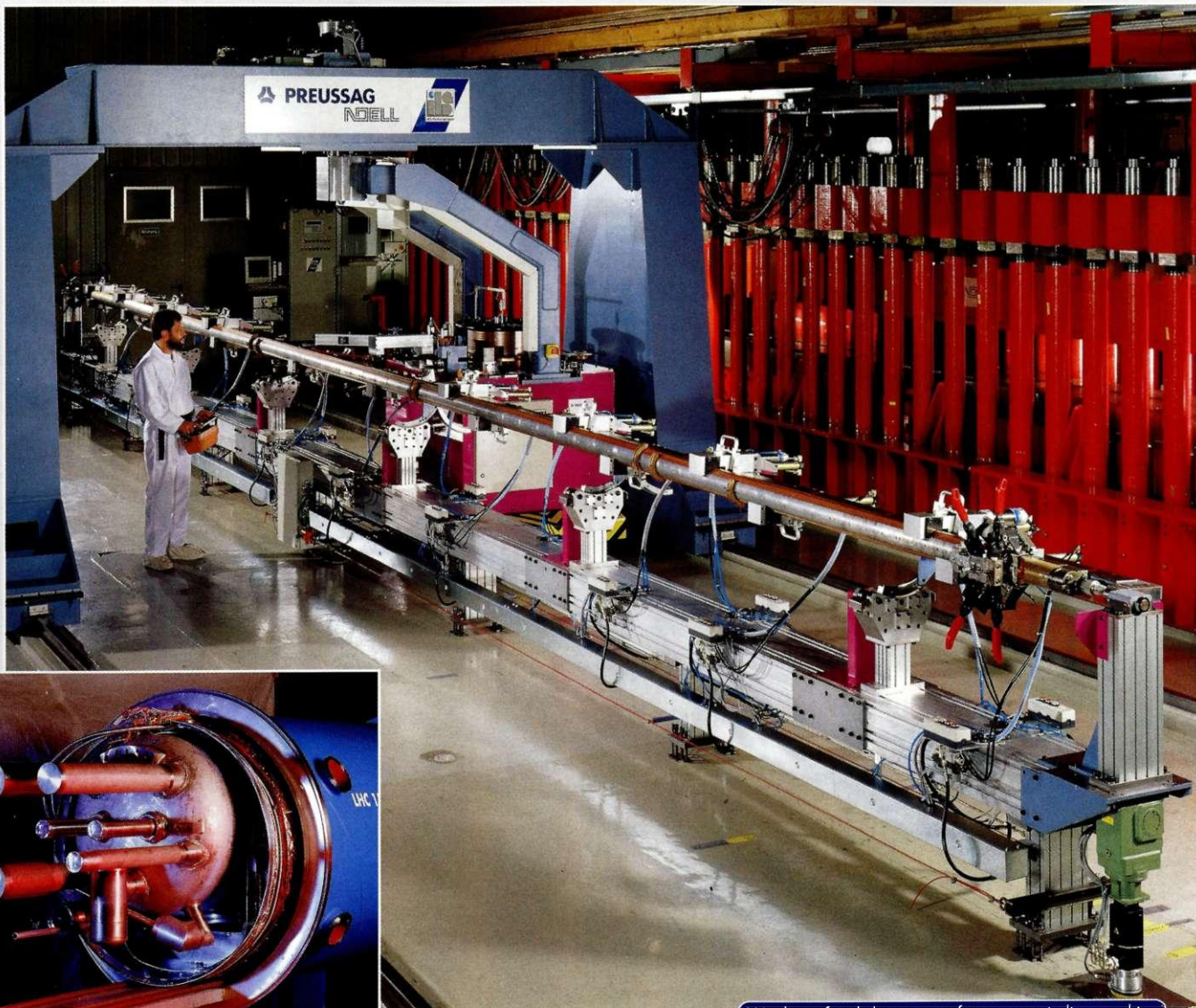
Why is it so difficult to convey the excitement of new developments in quantum physics to the layman?

### PARTICLES FOR EXPORT

In the quest to understand neutrinos, particle beams from CERN may be fired 730 kilometres to Italy

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Winding of coils by means of a gantry winding machine



Complete dipole prototype

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to prove its competence in the manufacture of complete dipole magnets. Presently Noell manufactures prototypes of the latest design that are precursors of series magnets. Parallel to the development of prototypes the production lines for series magnets are being prepared.

Noell itself is designing and manufacturing the tools required for production, e.g. a numerically controlled winding machine. With the winding machine shown especially trained staff is winding coils for the LHC.

In addition to completing dipoles for the LHC, Noell is also

developing magnetic components for nuclear fusion experiments, e.g. the Joint European Torus, Wendelstein 7X and ITER. This is just one more reason for you to contact us for a meeting. Give us a call.

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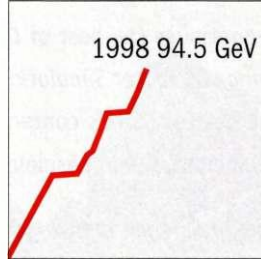
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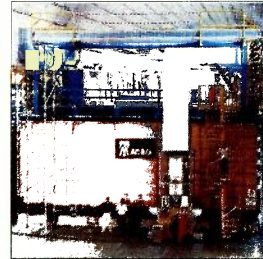


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**Cover:** Physics strikes it RICH - photomultiplier tubes for the Ring Imaging Cherenkov (RICH) detector of the HERMES experiment at the HERA electron-proton collider at the DESY Laboratory, Hamburg. (Photo: Manfred Schulze-Alex.)

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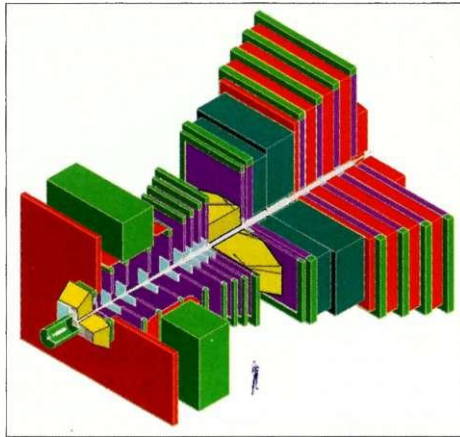
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# Beauty is in the eye of the LHC beholder

The LHCb experiment has been formally approved for CERN's LHC collider. Unlike the other major LHC detectors (ALICE, ATLAS and CMS) which will completely surround their respective collision points, LHCb will use a large (20 metre) single-arm spectrometer along the beam direction on one side of the collision point. The diagram shows LHCb in its underground area, surrounding the LHC beam pipe, with the collision point on the left. LHCb's goal is to look for new physics by studying in detail the physics of the Standard Model's third generation of particles, in particular the "beauty" or "b" quark (May, page 3).



## Final magnet installed at Fermilab

On 24 September, US Energy Secretary Bill Richardson put the finishing touches to the installation of the 366th and final 20-ton dipole magnet to steer the beams in Fermilab's new 150 GeV, 2.25 mile Main Injector Ring.

Construction work on the Main Injector began in 1993 and the new machine should begin operation next year, boosting performance of Fermilab's Tevatron by increasing its supply of protons and antiprotons. With higher collision rates, the Tevatron, already the world's highest-energy particle collider, will be able to attack new physics goals.

The Main Injector replaces Fermilab's original 400 GeV four-mile Main Ring, closed in September 1997 after 25 years of service as the hub of the laboratory's particle beam system. Many of the Main Ring's components, including quadrupole focusing magnets, have been taken over for the new Main Injector.

Built as Fermilab's front-line machine, the Main Ring took on a new role in 1983 as the injector for the superconducting 800–900 GeV Tevatron, which operated as a proton–antiproton collider and in fixed target mode using proton beams. For the future, the Tevatron is a dedicated proton–antiproton collider. As well as feeding the Tevatron collider, the Main Injector will be able to support its

own programme of fixed target experiments.

The Main Ring and the Superconducting Tevatron shared the same tunnel. The Main Injector is in a new tunnel which is tangential to the Tevatron.



US Energy Secretary Bill Richardson helps install the final magnet in Fermilab's Main Injector Ring. Making sure all is well is Fermilab Director John Peoples (behind) and Main Injector Project Manager Steve Holmes (right).

## Cosmic mystery

A recent paper by Glennys Farrar of Rutgers and Peter Biermann of the Max Planck Institute for Radio Astronomy in Bonn suggests interesting possibilities for the orbits of cosmic particles.

Cosmic rays, particles arriving from outer space, are generally believed to be the result of cosmic fireworks like supernovae. But this is not the whole story.

The energy spectrum of cosmic rays extends above  $10^{20}$  eV, more than a million times the energy of CERN's future LHC proton collider. Quite apart from the difficulty of imagining a mechanism which can produce such astronomical energies, the fact that such energies are seen at all is an enigma.

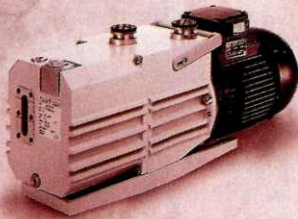
The universe is filled with cosmic background radiation, the faint echo of the Big Bang, discovered by Penzias and Wilson in 1965. Shortly after this discovery, it was pointed out that cosmic particles gradually lose energy by scattering off these photons. Theorists calculate that because of this continual attrition, no cosmic particle should be able to maintain an energy above about  $5 \times 10^{19}$  eV.

But some of them do. A handful of ultra-high-energy particles have been recorded which have somehow negotiated this brick wall. Perhaps some new kind of ultra-high-energy cosmic particle – "uhecron" – is able to shake off the interaction with the cosmic background radiation. Another possibility, put forward by Sidney Coleman and Sheldon Glashow, is that these extreme energies encounter relativistic effects which under ordinary conditions are too small to be noticeable.

The paper by Farrar and Biermann points out other interesting features of these extreme cosmic energies. Normally, galactic and intergalactic magnetic fields make charged particles loop around in tangled orbits so that it is impossible to tell from which direction they have come. However, the higher the energy, the "stiffer" these orbits become, so that the very high energy ones continue to move more or less in their original direction.

Farrar and Biermann point out that the handful of events above  $10^{20}$  eV appear to come from the direction of quasars, stellar beacons from the dawn of time. If the particles are indeed quasar generated, some additional explanation is still needed for why these signals from the early universe are not eroded by the cosmic background radiation.

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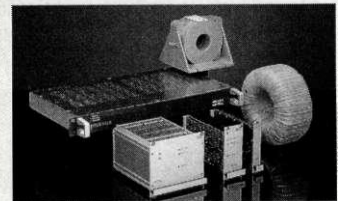
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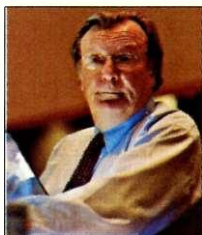
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# Marsters of science

Two recent talks at CERN focused on the problems of a voyage to Mars, where novel propulsion techniques are called for to overcome the logistical problems of otherwise having to construct huge space vehicles and for astronauts to spend over a year in space.

● On 27 August, 1984 Nobel Physics laureate and former CERN Director General Carlo Rubbia (right) described how his recently completed TARC experiment at CERN (April 1997, page 8)



suggests how it is possible to confine neutrons as "black body radiation". Rubbia's fertile mind sees how surrounding such an "n-Hohlraum" cavity by a micro-layer of americium could quickly go critical, the fission fragments acting as a very-high-energy exhaust, attaining temperatures much higher than those of chemical fuels. Such a motor would also have no moving parts. In this way, a few kilograms of nuclear fuel could be sufficient to power a substantial space vehicle.

The TARC experiment was a neutron study en route to Rubbia's proposed Energy Ampli-

fier, which would use beams from a particle accelerator to produce spallation neutrons and in turn feed a target-moderator assembly. The TARC study demonstrated how the neutrons could "scavenge" the target-moderator assembly, eating up nuclear waste.



● On 3 August NASA astronaut Franklin Chang-Diaz, mission specialist on the recent Space Shuttle flight carrying the Alpha Magnetic Spectrometer (September, page 28),

described the 236-hour voyage, which was also the final docking between a Space Shuttle and the Russian Mir space station. Chang-Diaz, an accomplished plasma physicist, is also Director of the Advanced Space Propulsion Laboratory at the Johnson Space Center. He concluded his talk by describing ongoing development work for rocket propulsion systems using magnetically confined high-temperature plasmas, the ultimate objective being to sustain flight to Mars. The picture shows him arriving at Kennedy Space Center for a Terminal Countdown Demonstration Test.

## CERN-Asia Fellows and Associates Programme

Within the framework of the CERN-Asia Fellows and Associates Programme, CERN offers three grants every year to young East, South-east and South Asia\* postgraduates under 33, to participate in its scientific programme in the areas of experimental and theoretical physics and of accelerator technologies. The appointment will be for one year, which might, exceptionally, be extended to two years.

Applications will be considered by the CERN Fellowship Selection Committee at its meeting on 26 January 1999. An application consists of a completed application form on which it should be stated "CERN-Asia Programme", three separate reference letters, a curriculum vitae including a list of scientific publications and any other information in favour of the quality of the candidate. Applications, reference letters and any other information must be provided in English only.

Application forms can be obtained from: Recruitment Service, CERN, Personnel Divi-

sion, 1211 Geneva 23, Switzerland. E-mail: "Recruitment.Service@cern.ch". Fax: +41 22-767 2750. Applications should reach the Recruitment Service at CERN before the deadline of 12 November 1998.

The CERN-Asia Fellows and Associates Programme also offers a few short term Associateship positions to scientists under 40 who wish to spend a fraction of the year at CERN or a Japanese laboratory and who are "on leave of absence" from their institute. Applications are accepted from scientists who are nationals of the East, South-east and South Asian\* countries and from members of the CERN personnel who are nationals of a CERN Member State.

\*Candidates are accepted from Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, China, India, Indonesia, Japan, Korea, the Laos Republic, Malaysia, the Maldives, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam.

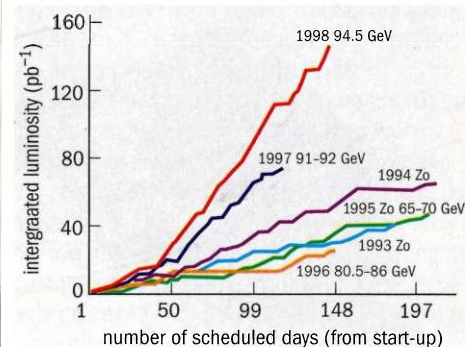
## Work on triangle anomaly wins Dirac Medal

The Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste has awarded its Dirac Medal this year to Stephen Adler of Princeton's Institute for Advanced Study and Roman Jackiw of MIT. This medal, widely viewed by theorists as highly prestigious, is given each year to scientists who have made outstanding contributions to theoretical physics and mathematics.

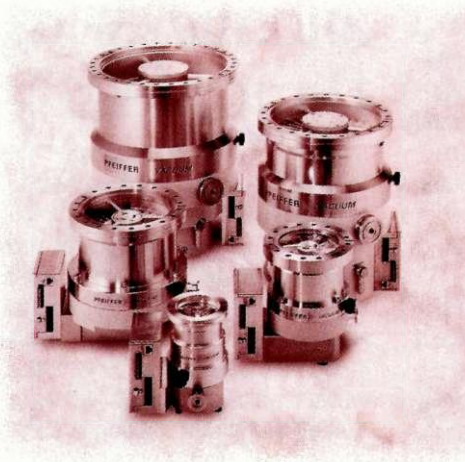
Adler and Jackiw are honoured for their work on the "triangle anomaly". CERN theoretician John Bell, who died in 1990, also played a major role in this work. It underlies the process by which a neutral pion transforms into two photons, the calculation of which was first carried out by Jack Steinberger in 1949. Such processes place severe strains on the underlying formalism - hence "anomaly". For the mathematics to work properly, several such anomalies should mutually cancel, placing important restrictions on modern grand unified theories.

## Long hot summer

Smooth running at CERN's LEP electron-positron collider, now at 189 GeV collision energy (94.5 GeV per beam), is reflected in a fast climbing, integrated luminosity curve. Integrated luminosity is a measure of the number of electron-positron collisions provided for physics, and the 1998 score is already well past that of previous years. LEP runs until early November. Recent performance has yielded luminosities of more than  $9 \times 10^{31}$  per  $\text{cm}^2$  per second and an integrated luminosity of 3 inverse picobarns in a 24-hour period.



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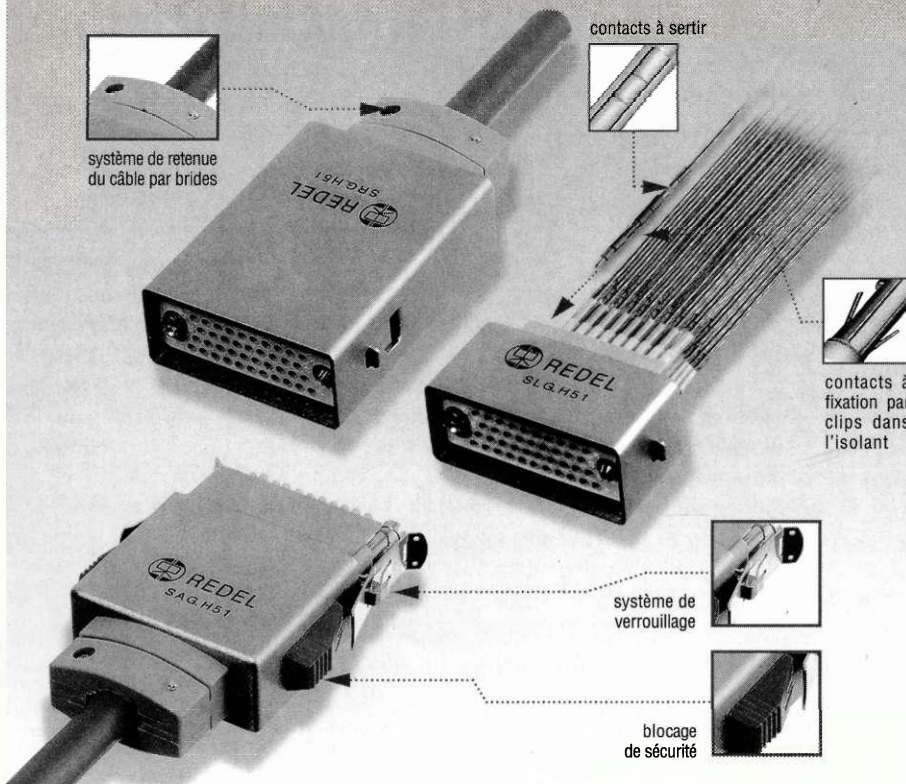
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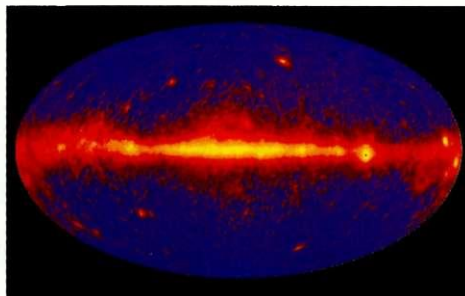


Edited by Emma Sanders

# New eye on the sky



*Integral, ESA's new gamma-ray satellite due for launch in April 2001.*



*The sky as seen by the EGRET detector on the Compton Gamma Ray Observatory.*

A new satellite is nearing completion that will give astronomers an unprecedented view of the violent activity around black holes, starquakes and other strange phenomena. The International Gamma Ray Astrophysics Laboratory (Integral) will have a resolution 10 times better than current facilities of its kind.

The European Space Agency (ESA) plans to launch the satellite in April 2001 and use it to

study hard X-ray and gamma-ray sources in the energy range 15 keV to 10 MeV. A full-scale structural and thermal model of the telescope has just been completed ready for testing.

There will be two main instruments on board. A spectrometer made of high-purity germanium will measure gamma-ray energies extremely precisely whilst an imager will

record their position in the sky.

With a resolution of 12 arc-minutes it is the imager that excites astronomers the most. Current telescopes, such as NASA's Compton Gamma Ray Observatory, have difficulty pinpointing the source of gamma-ray emissions sufficiently to match them up with objects seen at other wavelengths.

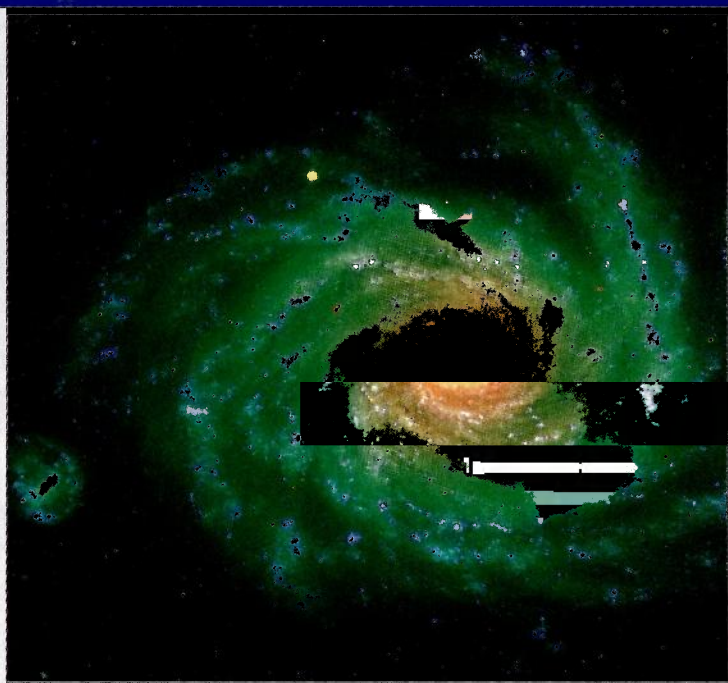
A breakthrough came last year when the Italian BeppoSax X-ray satellite identified the origin of a gamma ray burst. The observations showed the burst came from a galaxy towards the edge of the visible universe and must therefore be incredibly energetic – way over  $10^{50}$  ergs, more than the energy released by all the  $10^{11}$  stars in our Galaxy over several days! The mechanism fuelling gamma-ray bursts remains a mystery that astronomers hope Integral will help to solve.

Astronomers will also use Integral to study active galaxies and, nearer to home, to see close up to the accretion discs surrounding black holes.

Meanwhile, Integral's spectrometer will be used to measure the emission lines of heavy elements ejected into space by the supernova explosion at the end of a heavy star's lifetime.

## Picture of the month

An image of the spiral galaxy NGC 1232 taken using the new FORS (FOcal Reducer and Spectrograph) instrumentation installed on the European Southern Observatory's Very Large Telescope. FORS was designed and built by Heidelberg State Observatory and the universities of Göttingen and Munich. Capable of operating in a variety of imaging and spectroscopy



modes, it is sensitive to light in the range 330 nm to 1100 nm. The detector is a CCD with 24-micron pixels. FORS will be used to investigate the faintest and most remote objects in the universe. (Picture: European Southern Observatory.)

## Moon sheds light on Sun

Moon dust contains traces of rare solar gases, krypton and xenon. This discovery, made by researchers at ETH Zurich, promises a unique archive of the life of the Sun.

Buffeted by the solar wind for over four billion years, the dust on the surface of the Moon has absorbed traces of rare gases. Moreover, the proportion of the gases varies according to the age of the sample. This means researchers will be able to learn more about the formation and evolution of the solar system.

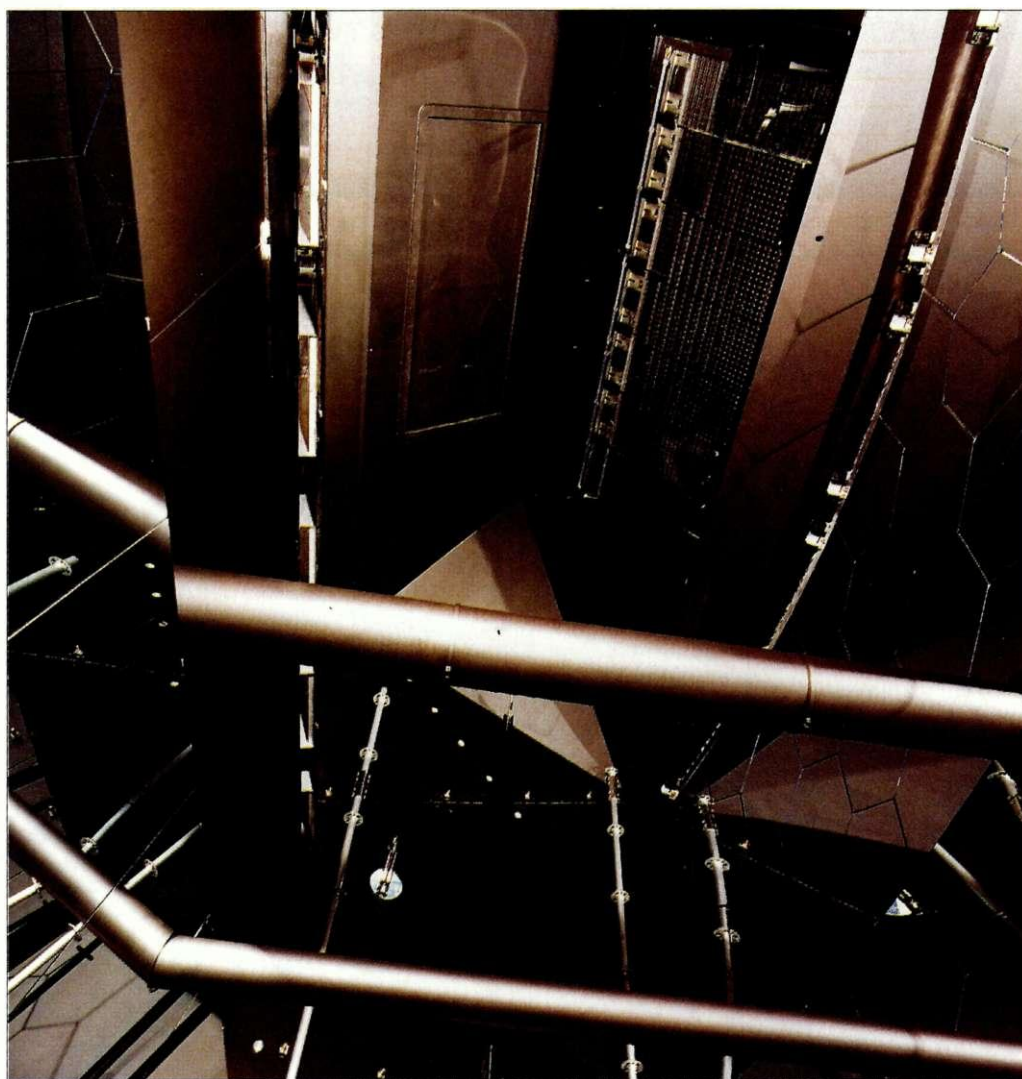
## Left-handed life

It's not just neutrinos that are left-handed, nearly all amino acids, vital for life, are left-handed as well. Now new observations using the Anglo-Australian telescope might explain the origin of life's left-handed bias.

Astronomers observed a region of the Orion nebula containing clouds of organic molecules. Most radiation, such as that from the Sun, is unpolarized, but in this case 17% of the radiation is circularly polarized. Astronomers believe this effect was caused by scattering of dust grains aligned in a magnetic field. Circularly polarized UV light could be responsible for the left-handedness of amino acids.

# HERA strikes it

At the German DESY laboratory in Hamburg, two major new experiments for the HERA electron-proton collider - HERA-B and HERMES - are being equipped with ambitious Ring Imaging Cherenkov (RICH) detectors for particle identification.



In the RICH technique, high-speed particles passing through a medium generate an optical shock wave - Cherenkov radiation - whose opening angle depends on particle velocity. If the momentum is known from the curvature in a magnetic field, then the particle's mass, and hence its identity is revealed. Over the years, this basic RICH idea has been improved and embellished by a series of technical innovations (June 1996, page 13).

## HERA-B

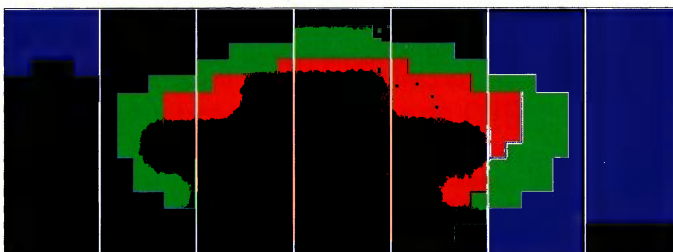
The newly installed RICH detector of the HERA-B experiment was recently tested successfully in the HERA proton beam with the experiment's wire target in place. There were several Cherenkov rings

*A wide-angle view of the interior of the Ring Imaging Cherenkov (RICH) for the HERA-B experiment at DESY. The mirror systems (planar on the left, spherical on the right) are intercepted by the proton and electron beam pipes. The upper half of the photon detector is visible. (Photo: Manfred Schulze-Alex.)*

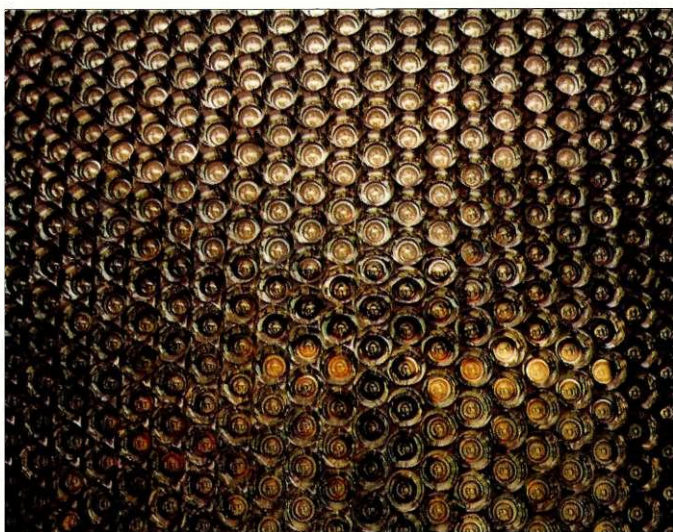
which perfectly matched the shapes that were expected.

In the HERA-B RICH 106 m<sup>3</sup> gas tank filled with C<sub>4</sub>F<sub>10</sub>, charged particles radiate a cone of Cherenkov light. This is focused by a system of 80 spherical mirrors and 36 planar mirrors, and a special lens system boosting the light collection efficiency to 65%. Light photons are detected by a total of 2250 multi-anode photo-

# RICH at DESY



On-line display of a "perfect" RICH ring from the HERA-B detector. The photomultiplier hits are represented as black squares. The inner region (red) is covered by 16-channel photomultipliers, with coarser 4-channel tubes outside.



Photomultiplier tubes for the Ring Imaging Cherenkov (RICH) detector of the HERMES experiment at the HERA electron-proton collider at the DESY Laboratory, Hamburg. (Photo Manfred Schulze-Alex.)

multipliers, with an inner region using 16-channel devices and coarser 4-channel tubes outside. Most parts of the detector were installed during last winter's HERA shutdown.

For the first test using 820 GeV protons, the radiator vessel was filled with air and the wire target tuned to a nominal interaction rate in the range of 10 to 30 MHz. An unbiased, random trigger initiated readout of the lower photon detector, the upper awaiting additional data acquisition electronics.

Under these conditions, most photons were expected to come from relatively soft electrons and positrons from electromagnetic showers, a picture consistent with the observed events: many were blank or had a few isolated hits; others had a diffuse pattern of hun-

dreds of hits. Some showed what appeared to be intersecting rings and a few had clear, isolated rings.

One particularly striking ring (see figure) was fitted to the expected shape, including optical corrections, yielding a Cherenkov angle of  $23.5 \pm 0.2$  mr, in perfect agreement with the expected value. Note that the number of Cherenkov photons is considerably larger than expected for a single track (7), indicating that the ring is probably due to an electron-positron pair from a high-energy photon.

HERA-B's goal is the investigation of CP violation in the B meson system. B mesons, plentifully produced when the halo of HERA's proton beam hits a wire target, will be detected in a large acceptance forward spectrometer.

HERA-B was approved in February 1995. After installation and test operation of various components, 1997 saw the installation of the electromagnetic calorimeter, the data acquisition system and the gas vessel for the RICH detector, which was completed during last winter's shutdown.

The HERA-B RICH group includes the University of Texas at Austin, Barcelona, IIP Coimbra, Northwestern, UT Houston, and University and J. Stefan Institute of Ljubljana. It is supported by the University of Hamburg and DESY.

See "<http://www-hera-b.desy.de/notes/98/98-142.pdf>".

## Dual-radiator RICH for HERMES

Installation was completed earlier this year of a dual-radiator RICH for the spectrometer of the HERMES experiment. (HERMES will use a polarized gas jet target in the HERA proton beam.) The HERMES RICH was designed and built in 12 months by a collaboration of Argonne, Bari, Caltech, Frascati, Gent, Rome, Tokyo and Zeuthen.

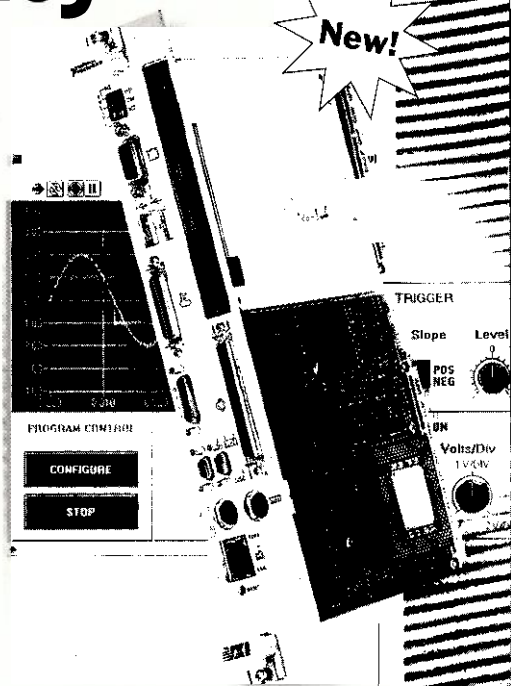
It will be the first to use the recently developed clear, hydrophobic gel as radiator. To identify almost all HERMES' pions, kaons and protons, the RICH is filled with a second radiator ( $C_4F_{10}$  gas) which, in combination with the aerogel, provides hadron identification from 2 to about 16 GeV. Rings from the aerogel (refractive index 1.03) provide identification up to about 9 GeV, while rings from the gas (1.0015) will be used for higher momenta.

The RICH consists of a pair of identical counters, one in the upper half and the other in the lower half of HERMES. Each photon detector is an array of 1934  $\frac{3}{4}$  inch photomultiplier tubes arranged in a planar array of honeycomb packing.

For a fully relativistic particle, a typical ring pattern will have a small inner ring generated by photons from the gas and a larger concentric ring of photons from the aerogel.

With so many produced particles unambiguously identified, HERMES will be able to make incisive studies of the enigmatic spin structure of the nucleon.

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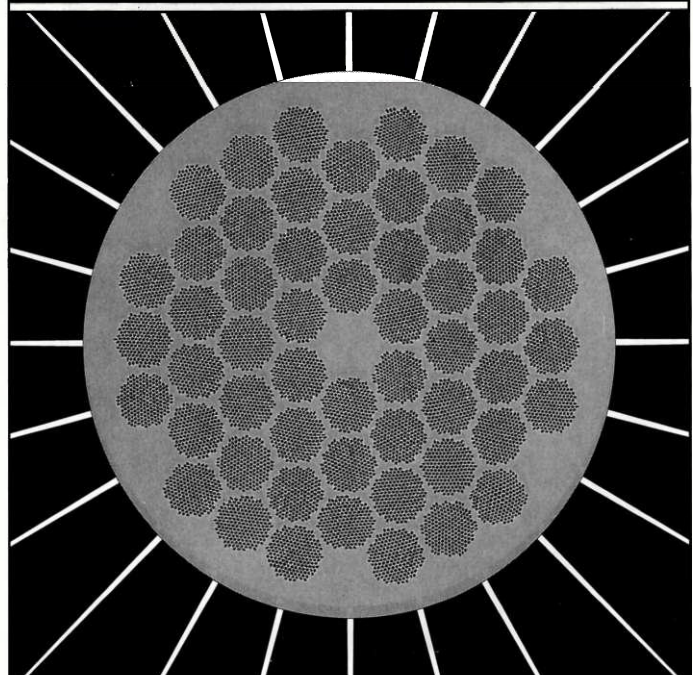
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# Particles for export

With CERN's site straddling the Franco-Swiss frontier near Geneva, exporting particle beams is an everyday occurrence. Now a new proposal foresees CERN particles also being exported to Italy, for use in the Gran Sasso underground laboratory, 730 kilometres away.

This summer's neutrino news underlined how little we really know about neutrinos. New data, notably from the SuperKamiokande detector, 1000 metres underground in a Japanese mine (September, page 1), show that the behaviour of neutrinos, the most inactive of known particles, is probably much more complex than originally supposed and poses many new physics questions

Neutrinos come in three varieties – electron, muon, or tau – according to which kind of weakly interacting particle (lepton) they escort. The new results suggest that this lepton allegiance can be temporary, changing as the neutrinos fly through matter. Neutrinos could be Nature's floating voters – a neutrino which sets out preferring the company of muons could arrive favouring taus instead.

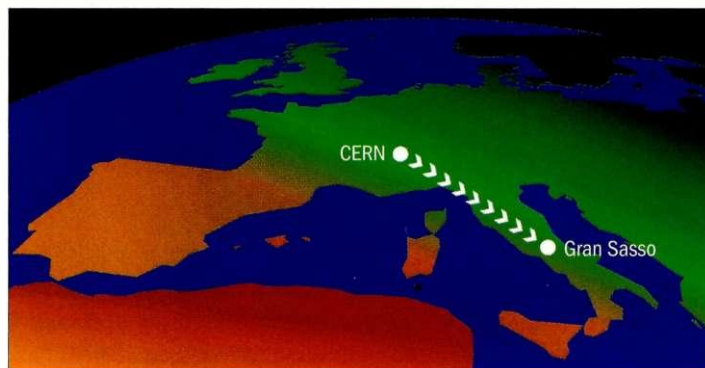
Some of the neutrinos picked up by SuperKamiokande and other underground detectors derive from cosmic rays crashing into the Earth's atmosphere. These collisions produce unstable particles such as pions and kaons, which subsequently decay, and whose decay products can in turn decay, producing neutrinos. At face value, there should be twice as many muon-type neutrinos as electron-type. However, for some time, such underground detectors have been seeing fewer muonic neutrinos than expected.

## Drilling through Earth

With their contempt for matter, neutrinos can easily drill through the 13 000 kilometres of the Earth and fly out into space on the far side. Just as a champion motor-racing driver is not immune to being run over when crossing the road, even after surviving transit through the Earth there is always a probability that neutrinos will interact in the next obstacle they reach. Thus a few neutrinos coming up through the Earth are finally absorbed in the SuperKamiokande detector.

Even more intriguing than the deficit of muon neutrinos coming down from the sky is the marked difference between the signals due to downward neutrinos reaching detectors from the atmosphere, and upward neutrinos having passed through the Earth.

The interpretation is that the neutrinos "oscillate". Although they slip right through the Earth, they do not emerge entirely unscathed, and have their electron, muon, or tau allegiance changed en route.



Scientists meet in November to discuss how they could use neutrinos sent 730 kilometres from CERN to Italy.

Results from other neutrino experiments under very different conditions (January, page 5) appear to rule out electron-to-muon oscillations, leaving muon-tau as the most likely oscillation culprit – neutrinos entering the Earth as muon-type leave it as tau-type.

To pin down the details of this effect needs continued systematic study of tau neutrinos. At 1777 MeV, the tau particle is much heavier than the muon (105 MeV) and the electron (0.5 MeV). So investigating tau neutrinos and tau particles is helped by having a neutrino beam from a particle accelerator with enough energy for its particles to interact and produce taus.

Neutrinos have traditionally been considered to be massless, spinning left-handedly (anticlockwise around their direction of motion) through the cosmos at the speed of light. However, the possibility of neutrino oscillations suggests this might not be 100% accurate. To oscillate, neutrinos must have some mass.

The oscillation probability of neutrinos depends on the quantity  $\Delta m^2 L/E$ , where  $\Delta m^2$  is the squared mass difference between the oscillating neutrinos,  $L$  is the "baseline" (the distance between the site of neutrino production and detection), and  $E$  is the energy.  $\Delta m^2$  can be very small – the new results suggest in the region of  $10^{-3} \text{ eV}^2$ , corresponding to mass differences of a few hundredths of an electronvolt.

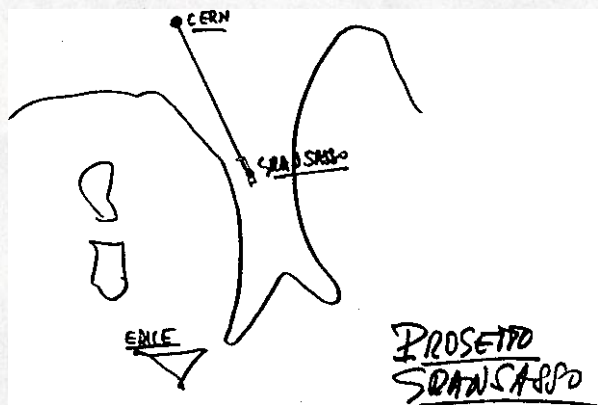
For each type of oscillation, a large range of oscillation probabilities has to be explored. For the muon-tau channel, the pioneer Chorus and Nomad tau neutrino experiments at CERN, with a baseline of about 1 kilometre, see no evidence for oscillation. Taking the new results from SuperKamiokande and other detectors at face value, this is hardly surprising – to reveal such small mass differences needs long baselines.

The high-energy neutrino beams from CERN and from Fermilab can explore this unexplored oscillation territory. Both, strangely enough, have underground neutrino detectors 730 kilometres away: for Fermilab the Soudan mine in Minnesota, for CERN the Italian Gran Sasso laboratory.

In Japan, the K2K project to fire a 1.4 GeV neutrino beam from the

## CERN-Gran Sasso link?

CONDIZIONE LA DORA PUBBLICI DEL SENATO



Sketch from Antonino Zichichi's original 1979 proposal for an Italian underground laboratory, pointing out the possibility of a neutrino beam linking CERN and Gran Sasso.

KEK laboratory towards the SuperKamiokande underground detector 250 kilometres is nearing completion. This could produce indirect evidence for oscillations via the disappearance of muon neutrinos.

Fermilab and Soudan are the scenes of a major effort for the MINOS (Main Injector Neutrino Oscillation Search - September

1996, page 20) using 10 GeV range neutrinos, while CERN, whose neutrinos currently point north-west, is putting the finishing touches to a plan to point 20 GeV range neutrinos in roughly the reverse direction and shoot them towards Gran Sasso. (In his original 1979 Gran Sasso proposal, Antonino Zichichi had already pointed out such a possibility, and the experimental halls are deliberately oriented towards CERN.)

For the detailed project plan now drawn up, a proton beam from the SPS synchrotron with an energy of up to 450 GeV would be focused on a target to produce pions and kaons, which would then be magnetically focused using a horn and reflector to point the pions and kaons in the required direction - once produced, the electrically neutral neutrinos cannot be steered. After about 1000 metres, many of these pions and kaons will have decayed, producing the required neutrinos, and the remaining hadrons absorbed by a beam stop (which the neutrinos easily penetrate).

Gran Sasso is already the home of the ICARUS detector using a liquid-argon time projection chamber and originally foreseen as a solar neutrino detector.

To investigate a detector scenario at Gran Sasso for CERN neutrinos, a joint meeting of CERN's SPS Experiments Committee and the Gran Sasso Scientific Committee was organized for early November at CERN (October, page 5).

**Gordon Fraser, CERN.**

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# MACRO- scope

The Monopole, Astrophysics and Cosmic Ray Observatory (MACRO) is an underground muon detector at Gran Sasso, which is now adding to the evidence for neutrino oscillations.

Fully operational since 1994–95, MACRO's bread-and-butter physics is the detection of cosmic-ray muons, but its ultimate objective is to search for new phenomena and to pick up particles from cosmic sources such as supernovae. In its search for cosmic signals, MACRO is assisted by the EAS-TOP array on the mountain 1400 metres above.

MACRO intercepts particles which pierce the overhead rock shield. 77 metres long, 12 metres across and 9 metres high, the detector is divided lengthways into six modules. The bottom half of the detector is composed of seven layers of crushed rock absorber interspersed with streamer tubes, together with an outer cladding of scintillator and streamer tube detectors and a box-like top layer with scintillator and streamer chamber walls and roof running the length of the detector.

While magnetic monopoles continue to be elusive, a bonanza for MACRO is the study of muons produced by neutrino interactions inside the detector, confirming an intriguing effect seen in other detectors (September, page 1). These studies show a marked difference between the signals due to upward- and downward-moving neutrinos.

## Multistage decays

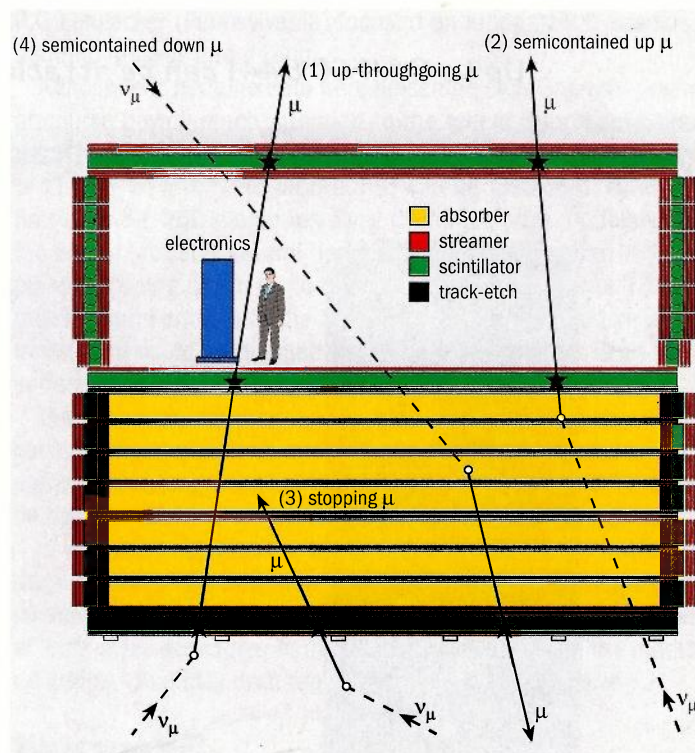
On the Earth's surface, muon-like neutrinos (as distinct to electron-like) mainly result from the decay of particles produced by high-energy cosmic rays hitting nuclei high up in the atmosphere. These reactions produce kaons and pions, which themselves decay to produce muons, which in their turn decay. In these multistage decays, the end result should be that there are twice as many neutrinos producing muons as producing electrons.

However, the detectors see fewer such muons than expected. MACRO, showered by other cosmic muons from above, cannot isolate those downward muons that are due to neutrinos, but does see a clean signal due to muon neutrinos arriving from below, which have passed right through the Earth before hitting the detector.

There are considerably fewer of these upward muons than expected, underlining the suggestion that muon neutrinos "oscillate" on their way through the Earth, changing into other neutrino types which do not produce muons.



The MACRO detector in the Italian Gran Sasso underground laboratory. The lower, absorbing, half of the detector is interspersed with streamer tubes and is covered with scintillator and streamer chamber detectors (orange-coloured) to pick up muons emerging from reactions in the inner absorber. Additional information comes from the box-like "roof" of detectors above.



Different types of neutrino interactions in MACRO: (1) An upward throughgoing muon hits three layers of scintillator and 14 streamer tube planes. (2) A "semicontained" upward muon – an upward muon neutrino (which has passed right through the Earth) interacts in the detector, producing an upward muon. (3) An upward "stopping" muon – an upward neutrino produces a muon which is absorbed inside the detector. (4) A downward neutrino produces a muon which emerges from the bottom of the detector. As far as MACRO is concerned, interaction types 3 and 4 are indistinguishable.

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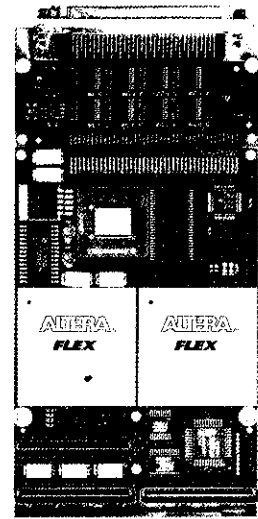
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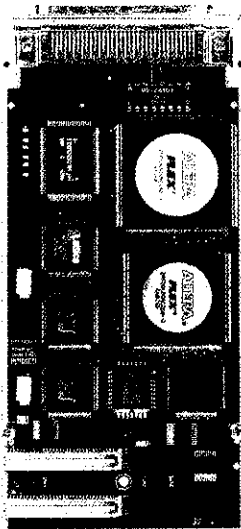
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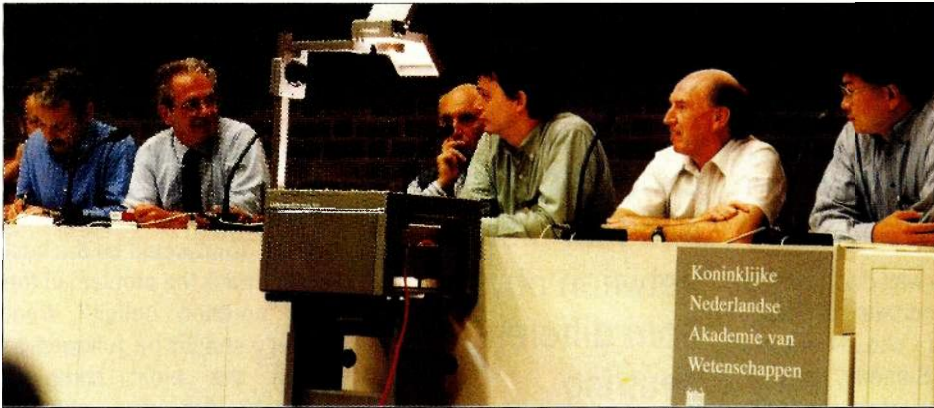


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Discussions oscillate at NOW'98 in Amsterdam. Left to right: Y Declais (hidden), V Palladino, E Bellotti, S Bilenky, P Zucchelli, P J Litchfield, H T Wong.



Chairman Jaap Panman of CERN (left) with summary speaker Michel Spiro of Saclay.

# Neutrino oscillations NOW

Neutrinos are never far from the physics headlines. Neutrino oscillations – when different types of neutrinos transform among themselves – has emerged as the big talking point of 1998. A topical workshop in Amsterdam surveyed the latest results and looked to the implications.

Neutrino oscillations – continuous changes of neutrino type or “flavour” – might not only explain the observed lack of neutrinos from the Sun and the atmosphere, but may also provide a very sensitive probe for tiny mass differences between neutrinos of different flavour. These possibilities were on the agenda on 6 September when 130 physicists from all over the world gathered in an Amsterdam brewery for the Neutrino Oscillation Workshop NOW'98.

Recently the SuperKamiokande underground experiment in Japan presented evidence for neutrino oscillations and thereby neutrino mass (September, page 1). Although these masses are believed to be much smaller than that of any other particle, neutrinos are so abundant that they would – even with such a tiny mass – contribute significantly to the mass of the universe and to its gravitational fate.

At NOW'98, recent results presented in morning sessions provided ground for discussions on the future directions of neutrino oscillation physics during the afternoons.

The workshop opened with a talk by M Nakagawa (Meijo), a godfather of neutrino oscillations, who covered the underlying theory from a historical perspective. Currently available data and their phenomenological implications were reviewed by G L Fogli (Bari), while

P G Langacker (Pennsylvania) focused on fundamental aspects of neutrino masses and mixing.

Atmospheric neutrino data were presented by W Gajewski (Irvine), of course paying much attention to the recent SuperKamiokande result. K Nishikawa (KEK) explained how from next year, neutrinos produced at the KEK laboratory will be detected by Super-Kamiokande, 250 kilometres away (Summer, page 7). This will be the first of probably several “long baseline” experiments; in the US plans are being drawn up to direct a neutrino beam over 730 kilometres from Fermilab to the Soudan mine, while in Europe a neutrino beam could be directed from CERN to the Italian Gran Sasso underground laboratory at a similar distance (see page 13).

The afternoon sessions concentrated on the theory of neutrino oscillations, on solar and atmospheric neutrino experiments, short, medium and long-baseline experiments, reactor experiments and on neutrino beams.

In one morning session, S Sarkar (Oxford) brought cosmology down to earth, showing how measurements of the cosmological microwave background radiation and scenarios for the development of large-scale structures in the universe can constrain the mass of neutrinos – and may even require neutrinos to be massive.

## Sterile neutrino?

J Kleinfeller (Karlsruhe) presented options for future short and medium-baseline experiments, which should shed more light on the oscillation signal of electron to muon-neutrinos reported by LSND experiment at Los Alamos. This result implies either the existence of an additional, sterile neutrino or – in a three-flavour oscillation scenario – a reinterpretation of the solar and atmospheric neutrino data.

The updated KARMEN experiment at the UK Rutherford Appleton Laboratory, sensitive to the same type of oscillations, does not see a signal but cannot rule it completely out either. A definite answer might be given by new projects being proposed at Fermilab (Mini-

Boone) and perhaps at the CERN PS proton synchrotron.

A Suzuki (Sendei) showed that the research on reactor neutrinos enters a new phase with the ongoing Palo Verde project and plans for KamLAND, both aiming to detect neutrinos from different reactors simultaneously.

The deficit of solar neutrinos detected on Earth was discussed by G Ewan (Queen's, Ontario) who pointed out the importance of detecting neutral current interactions of these neutrinos – one of the goals of the new SNO Sudbury Neutrino Observatory (Summer, page 1). Such measurements could provide the crucial information needed to nail down the origin of the solar neutrino deficit. The energy spectrum of solar neutrinos as being measured by the SuperKamiokande, SNO and Borexino experiments may help us to understand what happens to neutrinos on their way from the Sun to the Earth.

For the final day of the workshop, delegates left the now familiar brewery and went across the canal to the "Trippenhuys", the seat of the Royal Academy of Arts and Sciences. Here the convenors presented the highlights of the topical sessions while kinematical and quantum mechanical aspects of oscillations were covered by H J Lipkin (Weizmann).

In his summary M Spiro (Saclay) stimulated further discussion by raising such provocative questions as "Do we fully understand the production of atmospheric neutrinos?" and "Is there need for a long-baseline enterprise both in the US and in Europe?" These ques-

**One important conclusion was the need for discussion between physicists from different neutrino experiments.**

tions were addressed in the final plenary discussion together with other key issues – how can we verify the LSND and Kamiokande results? What would be the best way to attack the problem of the solar neutrino deficit? What strategy should be followed to obtain the most complete answers? Are we ambitious enough in designing new beams? One important conclu-

sion can already be drawn: the NOW'98 workshop saw the need for discussion between physicists from different neutrino experiments and it seems appropriate to organize a similar workshop in 1999. Meanwhile, discussions continue via the Internet, where the proceedings of the workshop can also be found (<http://www.nikhef.nl/pub/conferences/now98>).

The workshop was supported by the City of Amsterdam, the European Physical Society and Dutch scientific and industrial institutions, and was organized by the local NIKHEF laboratory.

**Margriet van der Heijden and Maarten de Jong, NIKHEF, Amsterdam.**

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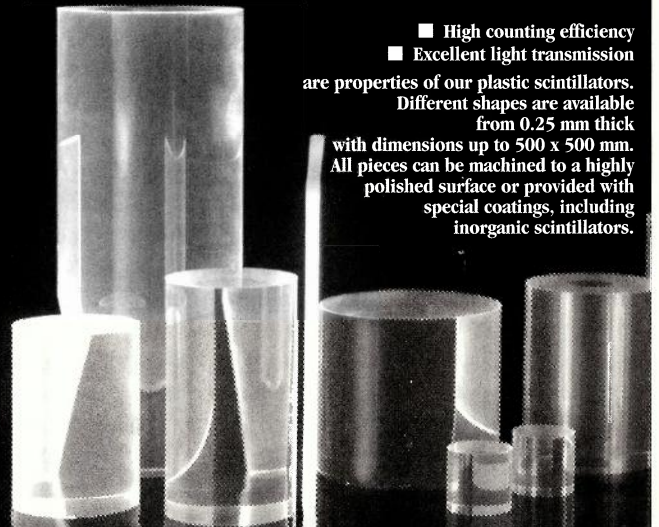
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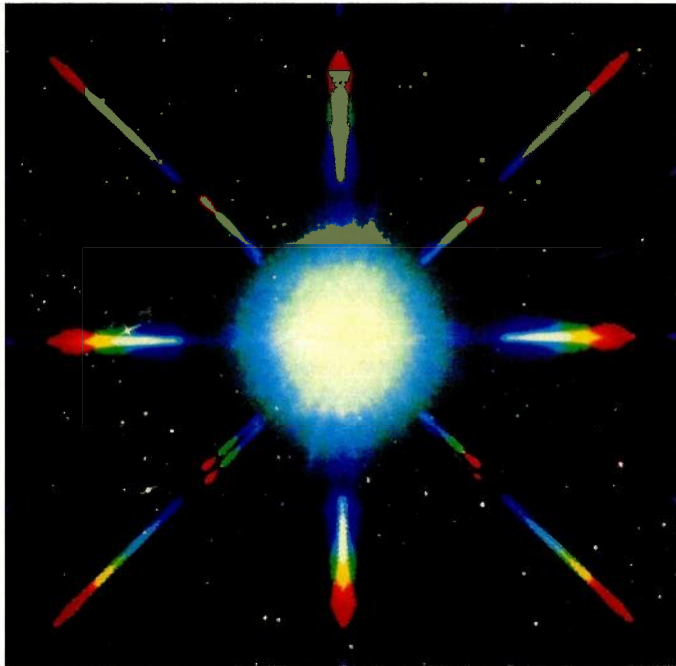
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# Applied superconductivity in Russia

A school on applied superconductivity held near the Russian proton accelerator at the Protvino Institute for High Energy Physics (IHEP), near Moscow, provided a valuable snapshot of this important field and highlighted a long tradition of Russian expertise in this area.

Ever since the pioneering work by P L Kapitza in 1924 (for which he shared the 1978 Nobel Prize), there has been a continual interest in Russia in producing high magnetic fields and putting them to work. Much of this effort has been focused at Moscow's Kurchatov Institute which also organizes an annual school on applied superconductivity for young engineers and scientists. At this year's event, Evgeny Krasnoperov reviewed the devices for generating high magnetic fields developed at the Kurchatov Institute.

In 1939 F Bitter built high-field solenoid-type magnets which could generate stationary fields of 10 T. As early as 1972 the Kurchatov Institute exceeded 25 T by nesting a resistive magnet inside a large superconducting solenoid. Currently under construction is a new hybrid magnet to attain up to 30 T with superconducting coils based on niobium-titanium and niobium-tin superconductor.

Russia is involved in the International Laboratory for High Magnetic Fields and Low Temperatures in Wroclaw, Poland. Lev Luganskij (Kapitza Institute) described the 30-year history of this laboratory, established by an agreement of the Academies of Sciences of the Soviet Union, German Democratic Republic, Bulgaria, and Poland.

## Wroclaw

The Wroclaw laboratory is open to guests for experimental investigations of extreme magnetic fields and low temperatures. At present there are several magnets for stationary fields and one for pulsed fields up to 47 T. Several Bitter-type magnets and superconducting magnets produce a range of stationary fields. The largest Bitter-type magnet generates magnetic fields up to 20 T, its total power exceeding 6 MW. Bitter-type magnets are cooled by a two-circuit water cooling system.

Another important Russian magnetic contribution is tokamaks. In 1950, A D Sakharov and I E Tamm put forward the idea of magnetic confinement of high-temperature plasma and proposed the thermonuclear reactor tokamak concept. Sergey Egorov of the Efremov Institute (St Petersburg) covered the history and progress of these devices. The ultimate outcome is the International Thermonuclear Experimental Reactor (ITER), a fusion device to demonstrate ignition.

The ITER tokamak is currently being developed jointly by Euroatom, Russia, the USA, and Japan. The superconducting components are toroidal and poloidal field coils and a central solenoid,



*The Kurchatov Institute's superconducting-magnet test facility.*

the latter producing a magnetic field up to 13 T at its inner radius. The superconducting coils for the system will require more than 1600 tons of niobium-tin.

In the Bochvar All-Russia Scientific Research Institute of Inorganic Materials (Moscow), niobium-tin wires for ITER have been developed and studied. Production of the first ton of ITER wire was completed in April 1998. Critical current density (non-copper cross-section) exceeds 550 A per sq. mm at 12 T.

A review of fabrication methods of niobium-titanium and niobium-tin wire was presented by Victor Pantisirnyi. Victor Sytnikov (Cable Institute, Moscow) reported on ITER conductor development. The conductor is of cable-in conduit niobium-tin type with an incoloy alloy 908 external jacket, carrying 46 kA up to 13 T magnetic field. This international collaboration comprises 12 companies in Europe, Russia, Japan and the USA.

Subrata Pradhan (IPR, India) reported on the superconducting magnets for Tokamak SST-1. The superconducting cable for this project was produced in Japan and part of the cable was transported to Moscow in May. Superconducting model coils for the conductor testing will be fabricated and tested by the Kurchatov Institute.

Alexey Dudarev of the Kurchatov Institute reported on a 6 T superconducting wiggler. This three-pole wiggler was built at the Kurchatov Institute and successfully tested in the Chinese National Synchrotron Radiation Laboratory (800 MeV Hefei storage ring) in March. Its magnetic field is generated by three pairs of racetrack niobium-titanium windings. The wiggler, with a short magnetic field period of 187 mm, enables an electron storage ring to provide a wider spectrum of synchrotron radiation.

Nikolai Chernoplekov, the Director of the Institute for Solid State Physics and Superconductivity, concluded the school with a review of several problems vital to the future of this field. The advent of warm superconductors has inspired new interest, with the promise of new (and as yet unknown) applications, or even a revolution in the traditional applications of superconductors.

**Leonid Shirshov**, *Institute of High Energy Physics, Protvino, Russia.*

# Twenty-five years of

In the summer of 1973, an experiment at the Gargamelle bubble chamber at CERN discovered a new physics effect. *Gordon Fraser* looks back at how confirmation of the existence of neutral currents ushered in a new understanding of physics.

A quarter of a century ago, after raging controversy and nailbiting doubt, an experiment at CERN discovered “neutral currents” in neutrino interactions. For the first time, the weak force had been seen to act without shuffling electric charges.

The saga has been covered many times, notably by Don Perkins of the Gargamelle collaboration speaking at the 1992 “Rise of the Standard Model” historical seminar held at the Stanford Linear Accelerator Center (SLAC). Five years ago, for the 20th anniversary of the discovery, several *CERN Courier* articles recalled those momentous times, when two complementary experiments – Gargamelle at CERN and the E1A electronic experiment at Fermilab – had to resolve difficult problems chasing a will-o’-the-wisp physics effect, while in the wings many physicists steadfastly refused to believe in neutral currents.

In 1973 CERN had yet to reach full scientific maturity. European physicists were not used to making major discoveries at their accelerators and were sometimes hesitant to swim against powerful currents of opinion. The discovery enabled CERN to attain research maturity.

It was not the first time in modern physics history that dogma had to be revised virtually overnight. For a quarter of a century, physicists had believed that quantum mechanisms are unaffected by space reflection (parity) and particle–antiparticle charge conjugation. The dramatic overthrow of these principles in 1956–57, following a bold hypothesis by T D Lee and C N Yang, underlined how much weak interaction physics could be ignored by so many for so long.

The weak interaction scene had been set in the early 1930s when Enrico Fermi formulated his classic theory of beta decay, in which a neutron spontaneously decays into a proton, an electron and an antineutrino – four particles meeting at a single space-time point. In this process, electric charge gets shuffled around, an initial neutral particle producing two oppositely charged particles.

Rearranging the four legs of the Fermi interaction gave other reactions, such as a neutrino interacting with a neutron to produce a proton and an electron. But electric charge was always rearranged – the interaction was always a “charged current”.

In principle, other reactions could be imagined – for example a



*Neutral current – in 1973 the Gargamelle bubble chamber at CERN captured this historic photo showing how an invisible neutrino has jogged an electron.*

neutrino or an electron bouncing off a proton – in which electric charge was not rearranged: a “neutral current”. But no such reactions with neutrinos had been seen, while the corresponding effect with electrons was in any case blanketed by electromagnetic scattering.

In the 1960s, with no experiment ever having seen a weak neutral current effect, some physicists spoke of a “no neutral current selection rule”. Occasionally a new search for such effects was mounted, but nothing was found and the disbelief in weak neutral currents grew.

With the emergence of modern quantum electrodynamics in the 1940s following the work of Feynman, Schwinger and Tomonaga, and of Dyson, physicists realized the importance of “renormalization”, the process of carefully constructing a theory so that it did not throw up nonsensical infinite probabilities for things that were

# neutral currents



This 1967 aerial view of CERN shows (top left) the mound over the 28 GeV PS proton synchrotron with, pointing downwards and to the right, the beamline feeding the Gargamelle heavy-liquid bubble chamber, where neutral currents were discovered in 1973. In 1976 Gargamelle was laboriously reinstalled further away to work with the neutrino beams from CERN's new 450 GeV SPS proton synchrotron.

clearly finite. In quantum electrodynamics, for example, the mass and electric charge of the participating particles (which have to be put in by hand anyway) can be redefined to sidestep these infinities. Quantum electrodynamics is “renormalizable”.

However, the Fermi theory of weak interactions as it stood could not be made renormalizable. While some theorists took this warning lightly, others declared “there is no theory of weak interactions”.

## Theoretical foundation

With far-sighted physicists such as Julian Schwinger convinced that deeper mechanisms were at work, a continual effort tried to reconcile the weak force with electromagnetism. After many major contributions by a host of theoreticians, this ultimately led to the 1967 prescription by Weinberg and Salam to unify the two forces. This provided a theoretical foundation for a neutral current, a weak force analogue of electromagnetism. But few people took any notice of the theory. Nobody had ever seen a weak neutral current, and anyway people believed the theory was not renormalizable. The



In 1983 construction began near the former Gargamelle site for the injection system to supply particles destined for CERN's LEP electron-positron collider. LEP's initial objective was to mass produce the Z particle, the carrier of the neutral current discovered by Gargamelle. In a six-year programme, LEP provided some 12 million Zs before moving on to explore higher energies. This photo, taken from a different angle, shows the injector (centre) feeding the PS ring (right), which gives the LEP particles their next boost in energy. Just above the injector, the Gargamelle hall is still visible, but the beamline has disappeared.

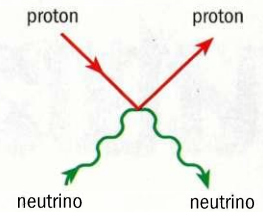
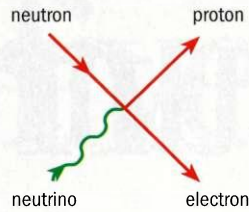
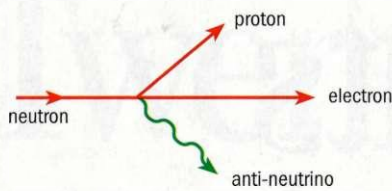
Weinberg-Salam seed fell on infertile ground.

This changed dramatically in 1971, when Gerard 't Hooft, Martin Veltman's student at Utrecht, showed that the new theory, with its neutral current, was indeed renormalizable. People sat up and took notice, and began calculating its consequences. Weinberg said it had “become urgent to settle the question of the existence of neutral currents”, and urged experimentalists to start looking afresh.

Pioneer neutrino experiments at CERN in the 1960s using a 1.2 metre heavy-liquid chamber had looked for neutral currents and unfortunately claimed that the ratio of neutral to charged currents was less than 3% (a value which is several times smaller than the presently accepted ratio!).

The result of a bookkeeping error, this overstatement was eventually discovered and corrected, but the new limit of 12%, augmented by additional data, was not published until 1970. Such a false limit

## CERN: Gargamelle



In Enrico Fermi's classic theory of beta decay (left), a neutron spontaneously decays into a proton, an electron and an anti-neutrino – four particles meeting at a single space-time point. In this process, electric charge gets shuffled around, an initial neutral particle producing two oppositely charged particles. Rearranging the four legs of the Fermi interaction gave other reactions, such as (middle) a neutrino interacting with a neutron to produce a proton and an electron. But electric charge was always rearranged – the interaction was always a “charged current”. In principle, other reactions (right) could be imagined, for example a neutrino bouncing off a proton, in which electric charge was not rearranged – a “neutral current”.

could have deterred imaginative theorists from proposing new ideas, although it clearly had not deterred Weinberg and Salam.

Motivated by the news that the theory was renormalizable and that the limits were not as severe as had been supposed, in 1971 experimenters on both sides of the Atlantic set off on a new hunt in possible neutral current territory. The rest is history.

The 1973 European particle physics conference took place in Aix-en-Provence. In his 1979 Nobel lecture, Salam related: “I still remember Paul Matthews and I getting off the train... and foolishly deciding to walk with our rather heavy luggage to the student hostel where we were billeted. A car drove from behind us, stopped, and the driver leaned out. This was [Paul] Musset [of the Gargamelle col-

laboration] whom I did not know well personally then. ‘Are you Salam?... Get into the car. I have news for you. We have found neutral currents.’ At the Aix-en-Provence meeting, that great and modest man Lagarrigue was also present [André Lagarrigue, who led the French effort to build the Gargamelle bubble chamber, died in 1975] and the atmosphere was that of a carnival.”

### References

D Perkins 1997 “Gargamelle and the Discovery of Neutral Currents” in *The Rise of the Standard Model* edited by L Hoddeson, L Brown, M Riordan and M Dresden, Cambridge University Press.  
P Galison 1987 *How Experiments End* University of Chicago Press.

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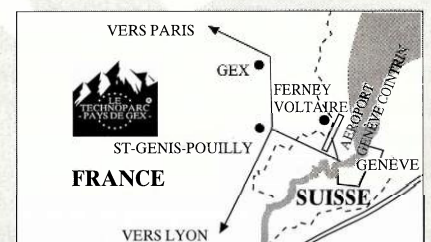
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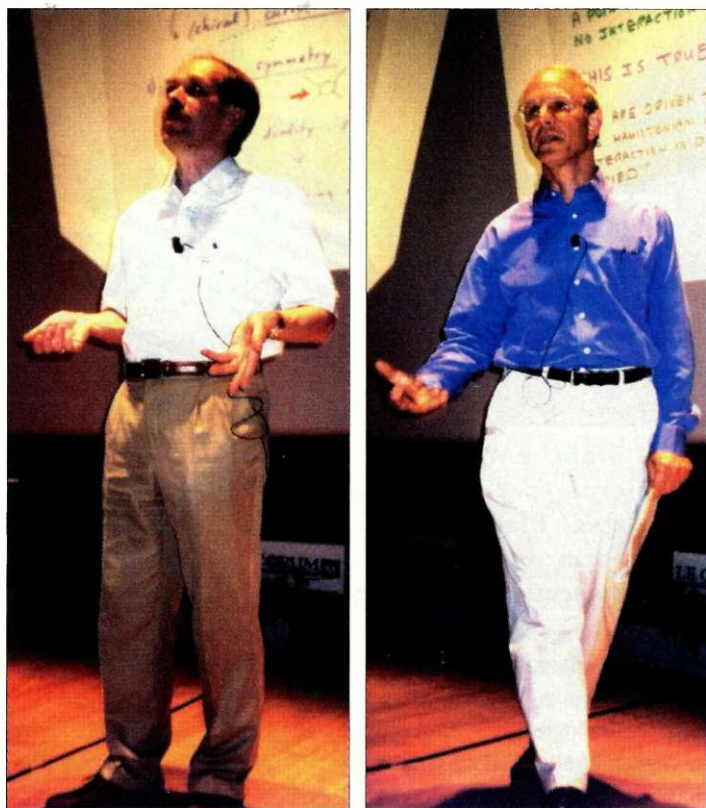
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# 25 years of asymptotic freedom

A quarter of a century ago, several theorists published an unexpected result which opened the door to quantum chromodynamics (QCD), the unusual field theory that describes quarks and gluons. This year's international QCD conference was able to look back as well as forward.



Like members of a close-knit family, quarks and gluons behave like free particles when they are very close together, but feel much stronger forces if they are separated. This result, paradoxical at first sight and embodied in the term "asymptotic freedom", is basically why quarks and gluons cannot be isolated as free particles. They can only be studied in their native habitat, using high-energy particle beams to spy on them deep inside protons and neutrons and other strongly interacting particles.

The idea was pointed out in two landmark papers by David Gross and Frank Wilczek at Princeton and by David Politzer at Harvard, published in the June 1973 issue of *Physical Review Letters*. In his presentation at the 1992 history seminar at Stanford, now published in *The Rise of the Standard Model* (edited by Lillian Hoddeson, Laurie Brown, Michael Riordan and Max Dresden, Cambridge University Press, 1997), David Gross described this breakthrough: "For me, the discovery of asymptotic freedom was totally unexpected. Like an atheist who has just received a message from a burning bush, I became an immediate true believer."

But the idea had been noticed elsewhere. In his book *In Search of the Ultimate Building Blocks* (Cambridge University Press, 1997), Gerard 't Hooft relates: "In 1972 a small conference took place in Marseille. On arriving at Marseille airport, I discovered that (prominent field theorist) Kurt Symanzik and I had shared the same plane... He had been trying to understand Bjorken scaling [the behaviour seen in high-energy scattering when the incoming projectile particle transfers a lot of momentum to the target - Ed.] in a quantum field theory, but had limited himself to what he considered to be the prototype of all field theories, a simple spin zero model. Unfortunately it had the wrong scaling behaviour.

"'If only I could turn this scaling behaviour round,' Symanzik said, 'then you would get a theory where particles at close distance behave almost as free particles, but when they separate to larger distances they would feel much stronger forces.'

"'Well,' I ['t Hooft] cried, 'that is exactly what you get in a Yang-Mills (spin one) gauge theory!'

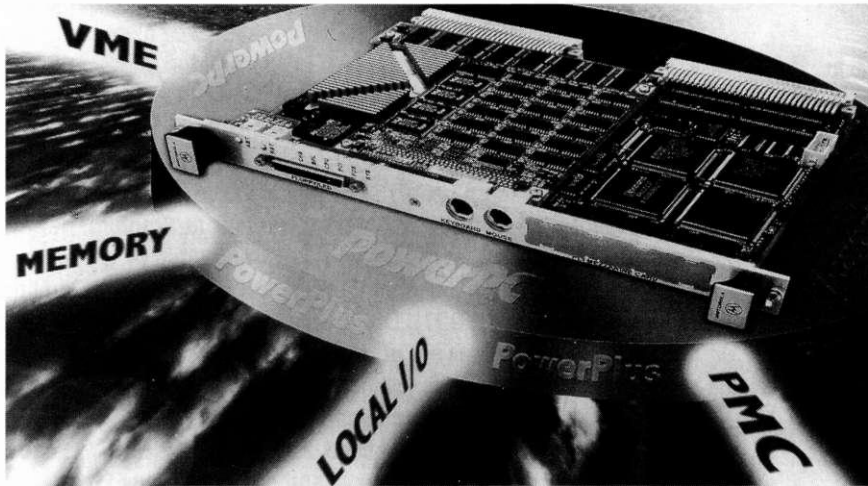
"Symanzik replied: 'You should publish this quickly, because this would be very important.'"

"Much to my later regret, I did not follow this sensible advice," says 't Hooft, whose 1971 work on the renormalizability of Yang-Mills theories had underlined the importance of gauge fields for understanding particle behaviour. However, 't Hooft did air his idea for spin one fields following Symanzik's talk at the Marseille meeting.

This idea was the key to quantum chromodynamics (QCD), the field theory of quarks and gluons. A host of theoreticians contributed to the subsequent development of the theory, many of whom, including Gross (now at Santa Barbara) and 't Hooft (Utrecht), attended the 6th international QCD conference (QCD 98) held in Montpellier from 2-8 July. The QCD series, now an established event in the particle physics calendar, is run by Stephan Narison of Montpellier.

*The at-first curious idea of asymptotic freedom, first published in 1973, provided the key to quantum chromodynamics (QCD), the field theory of quarks and gluons. Asymptotic freedom pioneers 't Hooft (left - Utrecht) and David Gross (right - now at Santa Barbara), attended the 6th international QCD conference (QCD 98) held in Montpellier from 2-8 July.*

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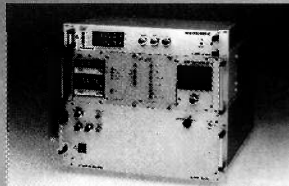
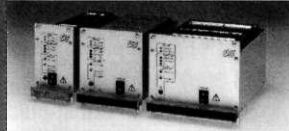
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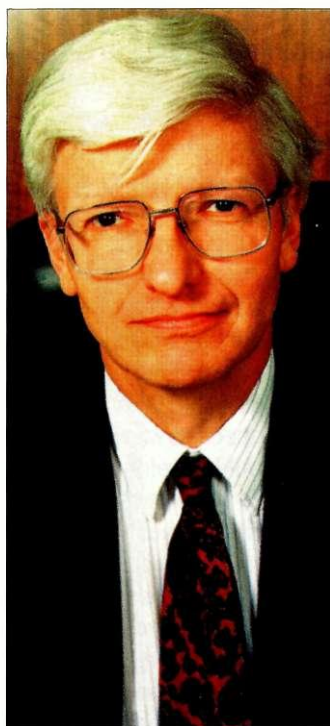
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# The prospects for particle physics

The second of two articles, in which as his five-year mandate as Director-General of CERN nears its end, *Chris Llewellyn Smith* reflects on what particle physics has achieved, and where it may be going. The focus is on conceptual advances building on the Standard Model.



The very successful Standard Model summarizes our present understanding of the constituents of matter and the forces that control their behaviour. Descriptions of this model usually emphasize its content – quarks, leptons, W and Z bosons, and gluons – and do not stress that it embodies three very important conceptual advances.

First, according to the Standard Model all forces are generated by the exchange of particles. For example, when an electron scatters from a proton, energy and momentum are carried from one to the other by a particle of light, called a photon. Thus, *force is not a separate concept – given the existence of particles, and of interactions that allow particles to be emitted and absorbed, forces follow!*

Second, *Nature elegantly allows all conventions to be fixed locally, and this determines the form of all the known forces.* For example, quarks (the constituents of nuclear particles such as the proton) are distinguished by different labels, but their properties are unchanged when the labels are switched in certain ways. The assignment of these labels is therefore a matter of convention (such independence of the choice of a convention is known generally as a symmetry). Remark-

ably, this convention does not have to be fixed once and for all, but can be chosen differently at different times and places. The possibility of choosing conventions locally *requires* the existence of the observed force carrying particles and fixes their interactions.

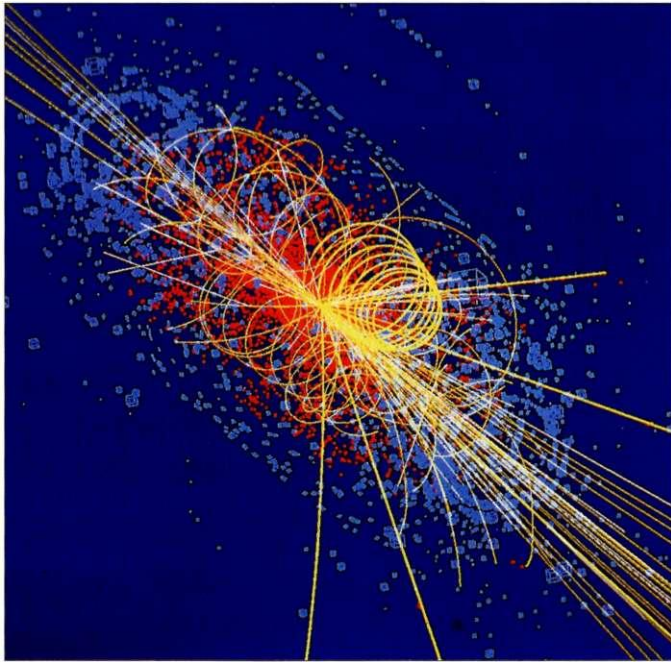
Third, the Standard Model contains “hidden symmetries”, symmetries in the underlying mathematical description that do not show up in Nature. In particular, there is excellent evidence for a symmetry that relates the electromagnetic and the weak forces. But it must be hidden – otherwise the choice of the labels “W”, “Z” and “photon” would be a matter of convention, and the massive W and Z particles, that carry the weak force, would be massless like the photon, which carries the electromagnetic force. The exciting discovery that Nature hides symmetries *opens the possibility that they are hidden links between other phenomena.*

## Key evidence

These concepts were established by a monumental series of painstaking experiments at the world’s leading particle physics laboratories. CERN’s major contribution was to provide the key evidence for the existence of a (hidden) symmetry that “unifies” the electromagnetic and weak forces – the discovery of neutral currents in 1973 (see page 28), the discovery of the W and Z with their predicted masses in 1983, and the demonstration by experiments at the Large Electron-Positron Collider (LEP) that the unified description works in exquisite detail.

However, while the Standard Model is economical in concepts, their realization in practice is baroque, and the model contains many arbitrary and ugly features. Furthermore, although the data show clearly that there is a hidden symmetry between the electromagnetic and weak interactions, we do not know how it is hidden. Luckily the different possible mechanisms for hiding the symmetry all require the existence of a new particle or particles (including the hypothetical Higgs boson) which, according to theoretical arguments, should be discovered by studying proton-proton collisions at the Large Hadron Collider (LHC) now under construction at CERN. The LHC is therefore expected to discover how Nature hides symmetries, or equivalently – since the symmetries of the Standard Model otherwise require all particles to be massless – how constituent particles acquired their masses.

The Standard Model, together with attempts to explain its seemingly arbitrary features, raises many other questions. I single out four as being particularly interesting, both intrinsically and because



CERN's LHC collider, now under construction, is expected to discover how Nature hides symmetries. This simulation from the CMS experiment shows how this might be revealed.

they are amenable to experimental investigation:

- *Are neutrinos massless?* The “hot news” of 1998 is that the answer may be yes (see page 17), as theorists have long suspected.
- *How is the so-called CP symmetry, that relates the properties of matter and antimatter, broken or hidden?* Our universe seems to be composed entirely of matter. If CP symmetry were not broken or hidden, the universe would instead be a “soup” of matter and anti-matter in which mankind could never have evolved. The Standard Model can accommodate the violation of CP symmetry that is observed in laboratory experiments, but the paucity of experimental information leaves plenty of room for additional sources of CP violation, which are probably needed to explain the dominance of matter in the universe as a whole. Future studies of B particles (containing the fifth “b” quark), especially at DESY in Germany and the “B-factories” currently being commissioned at KEK in Japan and SLAC in the USA, as well as at Fermilab and Cornell, and eventually at the LHC at CERN, should cast light on this very important question.
- *Could the strong interquark force be unified with the electroweak force?* Yes: theorists can construct so-called “grand unified” theories, which work in principle and successfully explain one feature of the unified electroweak theory. But more evidence is needed to know whether grand unified theories are really correct. They make one clear prediction – that protons should decay, but present experimental limits on the proton’s lifetime, of more than  $10^{33}$  years, do not exclude these theories.
- *Could a (super)symmetry connect the force-carrying particles and the constituents?* Particles normally described as constituents and those normally described as force carriers have very different properties (constituents are “fermions” – carrying half integer quanta

of spin angular momentum, while force-carrying particles are “bosons” with integral spin, which allows them to be emitted and absorbed singly). It was discovered in the early 1970s that there could be a symmetry that connects fermions and bosons, in which case every fermion would be twinned with a boson with related properties, and vice versa. Such a “supersymmetry” (SUSY) would, in a sense, unify matter and force. Moreover, if the choice of the labels fermion or boson can be made locally, this would *require* the existence of the gravitational force! This is strong motivation to search for SUSY experimentally, encouraged by arguments that “supersymmetric partners” of known particles should be found by the LHC, or possibly by LEP in 1999–2000.

### Surprises

These questions, together with that of how the electroweak symmetry is hidden, provide an exciting menu of possible discoveries for experiments in the coming decade. Of course, these experiments may also produce surprises, particularly at the LHC which will increase tenfold in energy (or equivalently decrease tenfold in size) the region explored so far.

The stakes are high, with the possibility of establishing a unified description of matter and the strong and electroweak forces, in a framework that would bring in gravity, albeit not in a form that is fully consistent with the laws of quantum mechanics. The search for a consistent quantum theory of gravity has become the holy grail for many particle theorists who suspect that there may only be one such theory, which could therefore be a “theory of everything”. Such a theory may need new concepts, the most fashionable being that the fundamental entities are not point particles but extended objects (strings).

What about experimental prospects, beyond those currently opening up? First, there are good arguments for complementing the LHC with a linear electron-positron collider which would allow more precise studies in very different conditions. Proposals to construct linear colliders that could eventually match the exploratory range of the LHC are being prepared in the USA, Japan and Europe, and I hope that at least one of them will be successful.

It is certainly possible to build a proton collider with energy greater than that of the LHC, but the physics potential increases with the energy much more slowly than the expected cost. Second generation linear colliders (possibly based on interesting ideas developed in the CLIC – Compact Linear Collider – studies at CERN: September, page 18), that could extend the physics “reach” of the LHC, are under study. A muon collider could be another route. It is important to continue research and development on how to build higher

**The most fashionable new concept is that the fundamental entities are not point particles but extended objects (strings).**

energy machines, although the case for construction will obviously depend on what is found at the LHC and elsewhere.

In any case, whatever the very long term future may hold, the prospects for particle physics in the dawn of the 21st century are excellent, especially at CERN where the LHC will be the world’s front-line facility for exploring the fundamental properties of matter.

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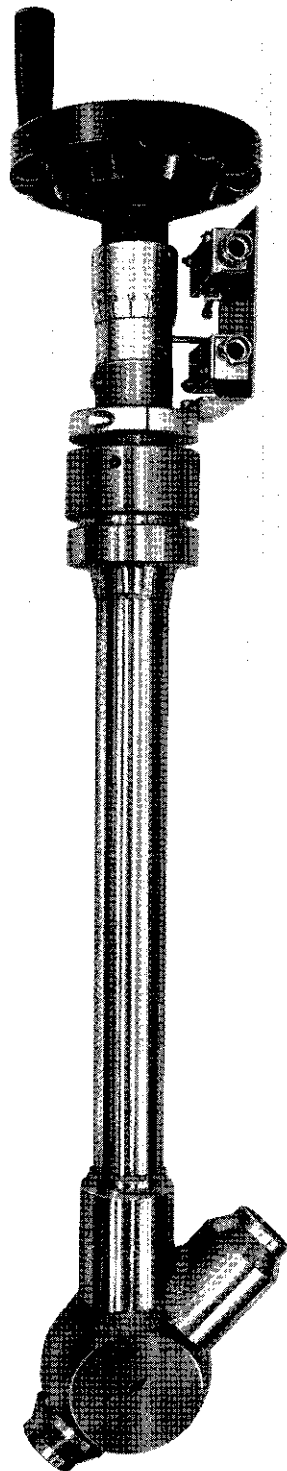
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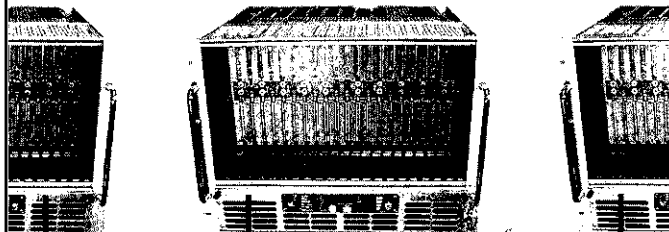
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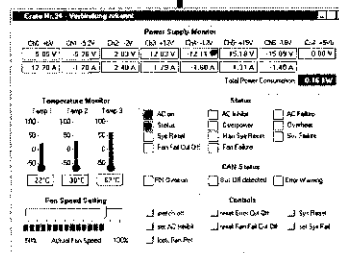
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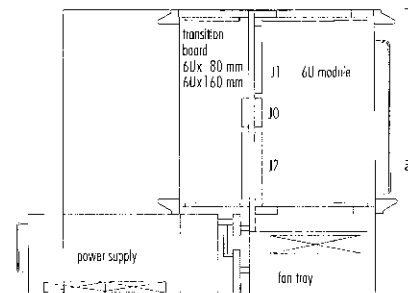


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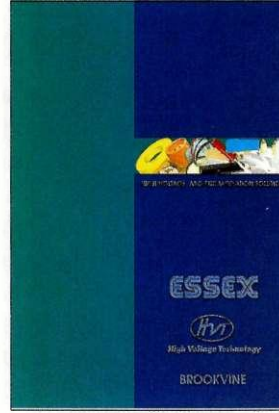


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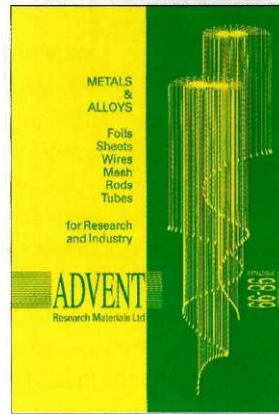


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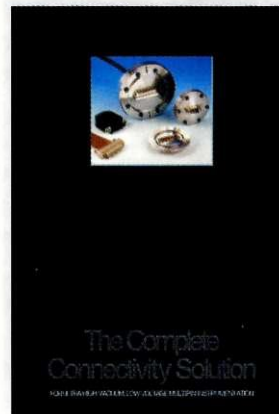
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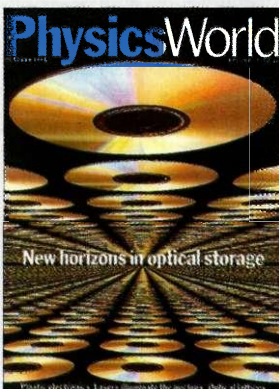


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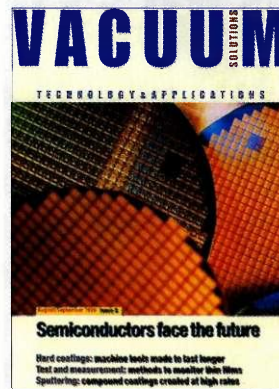


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# Making a song and dance about physics

Who needs the Spice Girls? What physicists want (what they really, really want) is science entertainment from Les Horribles Cernettes and the physics chanteuse Lynda Williams.

Thé Cernettes have been pulling in the crowds at CERN since 1990 with their unique blend of '60s pop and physics lyrics from the pen of computer scientist Silvano de Gennaro. Singer-songwriter Lynda Williams is a relative newcomer, but ever since she hit the road in 1996 at the 44th Midwest Solid State Conference her feet have hardly touched the ground.

Les Horribles Cernettes are the original physics entertainers. Their name is a play on the title of CERN's next major particle accelerator, the Large Hadron Collider, and the song *Collider* was their first hit. It was an anthem to unrequited love in the time of coloured quarks, and it was also a plea from the heart.

Back in 1990 a CERN employee was dating a particle physicist but she hardly ever saw her Romeo because he was always too pre-occupied with his experiment. In desperation she asked CERN's de-facto songwriter in residence, Silvano de Gennaro, to put her tragic tale to music.

Soon after, the Cernettes came together. Michelle Muller, the only original Cernette still in the band, teamed up with Catherine Decosse, Caroline Good and Ruth Rubio Marin. That summer they were on stage for the first time at the CERN Music Club's annual "Hardronic Festival". (Mix "hadron" with "hard rock" and that's what you get.) As they belted out for the first time *Collider's* unforgettable refrain, "You don't go out with other girls either, You only love your collider", there was more than one amorous physicist blushing with shame. Particle-physics partners the world over must have heaved a collective sigh of recognition at that sad story.

Since their first gig in 1990 the band has never looked back. Over the years Michelle has been joined by Angela Byrne, Angela Higney, Anne MacNabb, Patty McBride, Colette Reilly, Sue Swannel, Linda Timms, and Lynn Veronneau. The Cernettes played to thousands at the World Expo in Seville in 1992. They thrilled them to bits at the Computing in High Energy Physics conference, CHEP'92. They've recorded a CD, starred on the Franco-German TV channel ARTE, and they still top the bill at the CERN Hardronic Festival. But the final seal of their success came this year with a copy-cat band. All the top groups have them. The Beatles had the Monkeys, Oasis have No-



Les Horribles Cernettes sing songs of physics at Expo'92 in Seville. Left to right: Lynn Veronneau, Michele Muller, Angela Higney, and Colette Reilly.

Way-Sis, and at the latest Hardronic festival, the Cernettes had the Canettes ("large beers" in the Geneva dialect). Show me a CERN physicist, male or female, who hasn't felt their attraction (it's a strong interaction) and I'll show you a pig that can fly.

There are many bands out there claiming to be first on the Web, but that honour belongs to the Cernettes whose site includes pictures, sound clips, and even a fan club set up by some ardent admirers in Norway. True, the Cernettes had a head start, being based at the lab where the Web was invented, but they haven't rested on their cyber-laurels. With their latest number, *Surfing on the Web*, they've made another breakthrough with the world's first interactive pop video. You'll need to be equipped with a VRML (Virtual Reality Markup Language) browser to get the full benefit, but once you've got it you can sail off into cyberspace with your favourite Cernette (but only for as long as the song lasts).

## The Physics Chanteuse

Like the Cernettes, Lynda Williams is out to entertain, but she also has a more serious agenda. "I didn't know what science was until I was an adult," she says, and urges other young people not to fall into the same trap. She chose philosophy at college where her professor gently guided her towards physics. "Particle physics was my first true love!" Lynda exclaims, and like all first loves it demanded to be shouted from the rooftops. With a passion for music and dance, Lynda was better equipped than most to do the shouting. And so with a Masters in physics, she created the Physics Chanteuse, a well polished one-woman show doing the rounds of conferences in the Western US and Canada.

Each conference is different, and each show is tailored to fit. At her first gig, the 44th Midwest Solid State Conference in October 1996 she was Marilyn Monroe, tickling delegates' diodes with *Carbon is a*

## Physics Spice!

*Girl's Best Friend.* At the IEEE conference on Compound Semiconductors she was in a *Solid State of Mind*. And for the 1997 Particle Accelerator Conference, she brought the Kit-Kat Club to Vancouver with her rendition of Sally Bowles' *Cabaret*.

"Lynda established a new standard with her unique vernacular," said Herb Gronokin of her performance at The 24th International Symposium on Compound Semiconductors. And as Gary Prinz remarked, she gets the physics right: "At one point, she made a very esoteric reference to some solid-state work, and I thought, there must be 12 people in the world who know about that."

Lynda's day job is teaching physics at the San Francisco State University where she encourages her charges to "Get your mind muscles in shape while you are young and you will get much more work and pleasure out of them in the long run". She tells them that science is for everyone, not just for experts, and that it is their "duty to be scientifically literate so that you can participate in the high-tech world we live in". But as well as teaching them, she's learning from them too. "I am learning a lot more about physics as a teacher than I ever



*Coollest star of them all Lynda Williams was radiant at the 10th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun held in Cambridge, Massachusetts in July.*

learned as a student," she says, and she feeds it all back in to the Physics Chanteuse. Physics teachers were never like that in my day.

A Lynda Williams gig is pure entertainment, but if you listen closely enough, you'll hear a message coming through loud and clear. Science is good for you, and what's more, it can be fun. It's a message for everyone, but girls in particular, and it is encapsulated in the song *High-Tech Girl* which goes to the tune of Madonna's *Material Girl*: "Some boys kiss me, some boys hug me

I think they're passé  
if they can't talk about quantum theory  
I just walk away.  
I like geeks and I like nerds  
at least they see the light.  
Science is my first true love  
Cuz it excites my mind."

Perhaps if that CERN person had talked to Lynda back in 1990, she would have thrown her lot in with her Romeo and his collider. But then we'd never have had the Cernettes, and the world of physics would be a poorer place for it.

**James Gillies, CERN.**

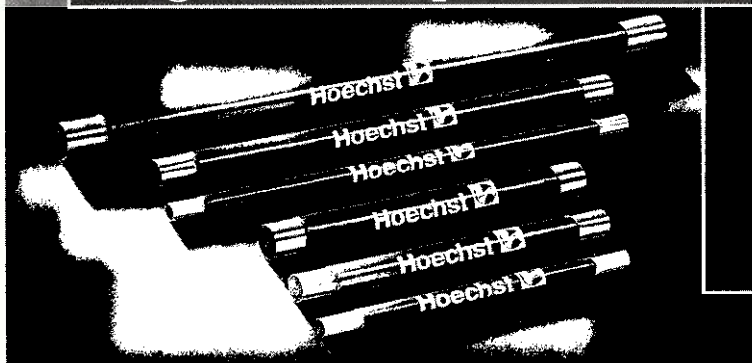
### Further reading (and listening)

Les Horribles Cernettes Web page: "<http://sgvenus.cern.ch/musicclub/cernettes>".

Lynda Williams' Net Node: "<http://www.physics.sfsu.edu/~william>".

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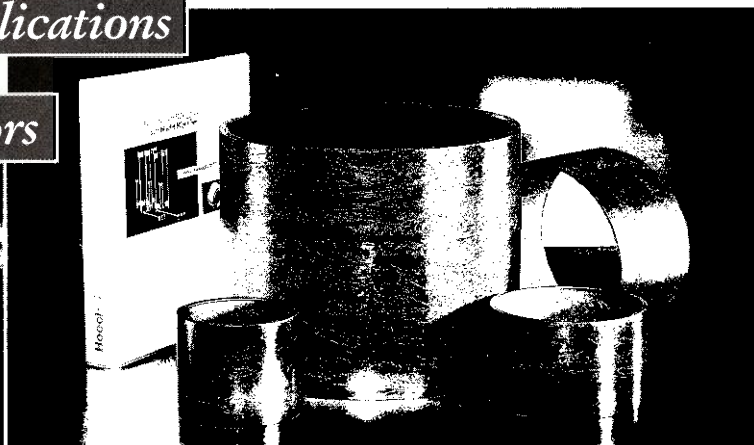


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# Spreading high-energy physics culture

In our society, the implications of science share one characteristic with cosmic neutrinos: people are totally immersed in them but their detection and recognition are very difficult.

But while neutrinos don't care if they remain undetected, science in general, and particle physics in particular, is facing growing problems because of this invisibility. While proud to be at the vanguard of discovery, scientists are becoming increasingly aware of an ambivalent place in society. The SSC cancellation was a major signal, but similar difficulties are found everywhere.

The 20th century began as "the century of science", with great enthusiasm for scientific and technological progress, but this euphoria is now tempered by doubts and real fear. What will scientists do next... where are they taking us? Has science gone too far? The reasons for this change in attitude are not yet fully understood: surely it is related to the development of weapons of mass destruction and by industrial and ecological disasters, real or perceived. In part it also reflects a natural reaction by laymen to an unfortunate attitude of superiority and detachment shown by some scientists. There are also unfulfilled expectations, the disappointment following over-optimistic claims, and in some cases deliberate propaganda.

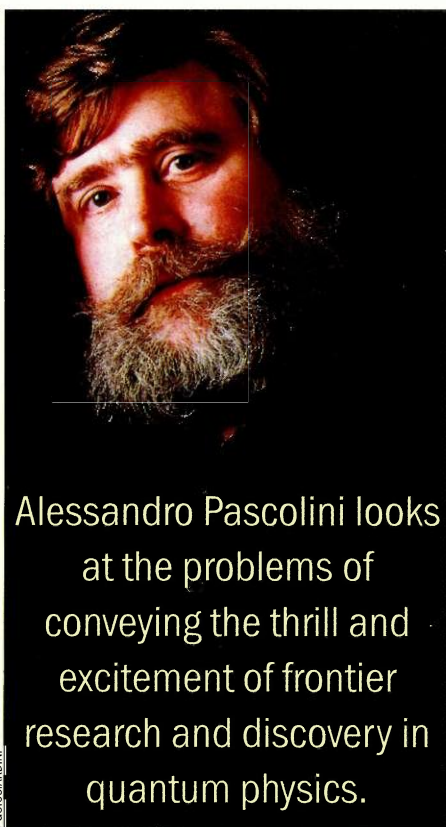
But a major reason is the scientific illiteracy and ignorance of the majority of otherwise educated people. This is due to science being excluded from specialized education, to irrational fears and to a dangerous revival of the occult. Such ignorance is one of the reasons behind the often exaggerated perceptions of health risks, one of the driving forces behind decisions on science and new technology.

## Specific problems

Particle physics is a far from everyday experience, and research continually explores frontiers which are even more remote. Starting from commonsense notions, science observes and explores the world around us. In doing so it discovers apparent paradoxes and then reflects on how commonsense must be reappraised to explain these paradoxes. In turn these fresh ideas suggest new observations and more refined experiments. Thus scientific evidence and everyday experience move further apart. Particle physicists use concepts totally foreign to a layman: or for that matter even to chemists or biologists.

The paradox is that a branch of knowledge which in principle sets out to explore the most basic questions of all has become almost a closed field. We can be proud of the intellectual achievements of particle physics and the technological skills and ingenuity it demands, but from the point of view of the public and most intellectuals, these efforts are hidden behind an impenetrable curtain.

The American anthropologist Margaret Mead noted: "Scientists at



Alessandro Pascolini looks at the problems of conveying the thrill and excitement of frontier research and discovery in quantum physics.

the frontier, where the terminology and imagery are developed, speak mostly to other scientists at or near their own level of understanding... scientific language has escaped from the realm of 'natural language'."

Since Galileo, the language of physics has been mathematics, even less familiar than physics itself! Many "intellectuals" are not ashamed of their mathematical ignorance, which is not considered to be an educational deficiency or a handicap in understanding the surrounding world. Richard Feynman's suggestion to learn some mathematics and to use logic and reasoning to understand physics becomes instead an open invitation to many to give up trying to understand it.

## Risky metaphors

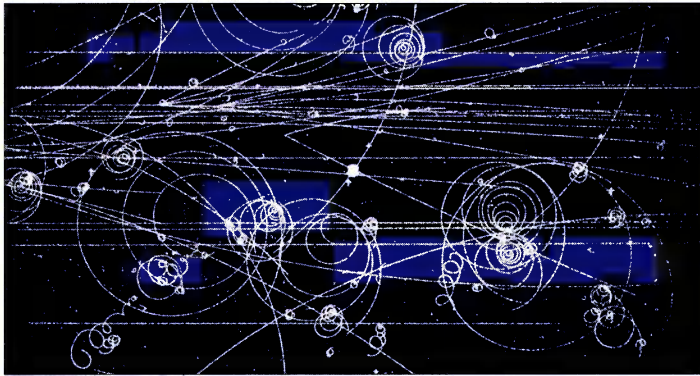
Deep knowledge and understanding is not easy, but associating concepts with images - if only symbolic - can be a powerful way of learning, boosting confidence in the concepts and allowing elaboration and increased understanding. In various fields, such collective imagery is a cultural inheritance, facilitating the transmission of ideas and giving a valuable vision of reality.

However, such iconography becomes more and more difficult and risky for fundamental physics. There are no conventional images for microsystems and moreover we have no authority to invent them. In addition, these representations are usually not self-explanatory but require their own interpretation using other metaphors. Consider the representation of the "constituent" quarks of a proton as small "coloured" spheres, suggesting an image of "particles" building a "particle" - all the words in quotes are dubious metaphors.

Human imagination and scientific creativity work by evoking sensory impressions. For the microworld, our intuition rests on formulating the visual imagery of the underlying mathematical structure of a physical theory. Bubble chamber pictures can be held up as visualizations of particle interactions, but because of the complexity of the experimental setup, such pictures are many layers removed from the "raw" mechanisms of particle collisions. The pictures show the result of particles interacting, but not how they interact.

On the other hand, Feynman diagrams provide a valuable glimpse of an otherwise highly intangible world. However, a lot of work is needed to formulate such enlightenment: but we can use them as a starting point for metaphors which are more correct than those based on classical concepts.

The main problem with metaphors, useful though they are, is that they do not give any clear indication of their areas of applicability. Using them out of context can lead to misunderstandings. They may be effective tools for informed scientists, but a straw in the wind otherwise. Metaphors can help bridge an intellectual gap, but there



Bubble chamber pictures show particles interacting, but not how they interact.

is no substitute for understanding. Ultimately we have to exploit logic, not facile pictures.

The role of science is to explain, to communicate. There are communication difficulties, but the more conspicuous they are, the more effort should go into overcoming them.

Another paradox is that the popularization of science is not always popular among scientists. Many see it as a lowering of standards, a loss of rigour. Whilst remembering Einstein's advice that "everything should be made as simple as possible but not simpler", scientists must nevertheless be tolerant of efforts to communicate difficult

ideas and help to bridge the gap between scientists and the public.

Happily, there is now an increased interest in such "outreach" activities in particle physics by individuals and institutions. In France, where most scientists are civil servants, this duty has recently been written into their contracts of employment. In the UK, research groups are allowed to devote up to 1% of their research resources in education and communication activities.

In the USA, major experiments are engaged in a broad spectrum of outreach initiatives, and in particular the ATLAS and CMS groups for CERN's LHC collider are highly productive. In Europe, an overall "European Particle Physics Outreach Group" has recently been set up, coordinated at CERN by Frank Close.

For all these initiatives, the goal is to convey emotion – the thrill and excitement of frontier research and discovery. We are fortunate that our business is to investigate some of the most interesting and fundamental issues in the history of science and of civilization itself. What better subject matter could there be?

**Alessandro Pascolini**, born in 1944, is Associate Professor of Mathematical Methods of Physics at the University of Padua. For the past 10 years he has been responsible for the outreach activities of the Istituto Nazionale de Fisica Nucleare, producing several exhibitions in Italy and abroad, and audiovisual materials. His research interests are in the fields of theoretical nuclear physics and nonlinear phenomena.



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## Portrait of a Nobel Prize winner

*Spectroscopy with Coherent Radiation, Selected Papers of Norman F Ramsey, with commentary*, World Scientific, Singapore, ISBN 9810232500.

Norman Ramsey, who shared the 1989 Nobel Prize, has made many major contributions to physics. This volume, in World Scientific's Series in 20th Century Physics, includes *Methods for Spectroscopy with Coherent Radiation and Atomic Clocks; Radiofrequency and Microwave Spectroscopy Experiments; Parity, Time Reversal Symmetry and Electric Dipole Moments; Theories of Nuclear Mag-*

*netic Shielding and NMR Chemical Shifts; Theories of Nuclear Interaction in Molecules; General Principles and Theories.*

Ramsey's early career, at Columbia and the MIT Radiation Laboratory, was very much involved with Isidor Rabi, and the two played vital roles in pioneering the magnetic resonance technique and in the establishment of Brookhaven National Laboratory.

This book provides a complete picture of a distinguished scientific career. Its autobiographical introduction, full of anecdotes, is especially valuable.

## Some recent publications of interest

● *Foundations of Quantum Chromodynamics, An Introduction to Perturbative Methods in Gauge Theories*, by T Muta, World Scientific, Singapore, ISBN 9810226748.

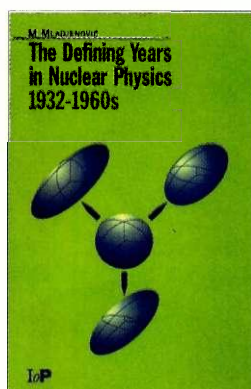
In the World Scientific series of Lecture Notes in Physics, this includes new QCD developments since the first edition of this book appeared in 1986.

● *Nuclear and Particle Astrophysics*, edited by J G Hirsch and D Page, Cambridge University Press, ISBN 0 521 63010 X (hbk £45/US\$69.95).

The proceedings of the 1997 Mexican School on Nuclear Astrophysics.

● *Lie groups, Lie algebras, cohomology and some applications in physics*, by José A De Azcàrraga and José M Izquierdo, Cambridge University Press, ISBN 0 521 59700 5 (pbk £29.95/US\$105).

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£25/US\$150).

This traces the evolution of nuclear physics from the discovery of the neutron and the first accelerators to its becoming one of the most important sectors of physical science. As well as science, it includes much historical background.

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● *The Defining Years in Nuclear Physics 1932-60s*, by M Mladenovic, Institute of Physics Publishing, ISBN 0750304723 (hbk

## Perseus Books takes over Advanced Book Classics

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## Feynman anniversary increases demand

1998 marks the 10-year anniversary of the death of Richard P Feynman, whose books are increasingly in demand.

● In *Quantum Electrodynamics*, Feynman presents the main results and calculational procedures of quantum electrodynamics in a simple and straightforward way. ©1961 ISBN 0-201-36075-6 \$35.00.

● Physics, not mathematics, is Feynman's focus in *Statistical Mechanics*, providing a concise introduction to basic concepts and a clear presentation of difficult topics.

©1972 ISBN 0-201-36076-4 \$35.00.

● In *The Theory of Fundamental Processes*, Feynman considers the basic ideas of quantum mechanics, discusses relativity and the idea of antiparticles, then gives considerable attention to quantum electrodynamics. ©1961 ISBN 0-201-36077-2 \$35.00.

● Theoretical questions related to electron and photon interactions at high energies are analysed by Feynman in *Photon-Hadron Interactions*. ©1972 ISBN 0-201-36074-8 \$35.00.

## German dictionary

Dedicated science writer and former DESY physicist Pedro Waloschek continues his endowments to physics literature with *Wörterbuch Physik*, published by Deutscher Taschenbuch Verlag, a collection of concise definitions of some 5500 physics terms. Designed to allow non-specialists to decode physics messages in German, it also contains an English-German glossary to help them decode physics messages in English.

## Alan Wetherell 1932–1998

CERN senior research physicist Alan Wetherell died on 13 September. After studies at Liverpool and a period at Caltech, he came to CERN in 1959, going on to participate in a series of experiments at the then new Proton Synchrotron.

After work at Serpukhov in the late 60s and at CERN's Intersecting Storage Rings in the early 70s, he became head of this group when Giuseppe Cocconi became a CERN Director. The group shifted to weak interactions and joined with Klaus Winter for the CHARM (CERN/Hamburg/Amsterdam/Rome/

Moscow) experiment.

He was appointed Leader of CERN's Experimental Physics Division in 1981, and served for three-and-a-half years. Subsequently he joined Ugo Amaldi and Jim Allaby in the Delphi collaboration at LEP, eventually taking responsibility for the hadron calorimeter which was built under his guidance by a Russian team.

In 1971 he was elected a Fellow of the Royal Society (FRS). He was also a visiting professor at Liverpool. He formally retired from CERN in December 1997.

## Alexei Andreevich Anselm 1934–1998

Theoretical physicist Alexei Andreevich Anselm, former Director of the Petersburg Nuclear Physics Institute, died on 23 August.

Born in Leningrad into a family of scientists, Alexei Anselm studied physics at Leningrad, then joined the Theory Group of the Ioffe Physical-Technical Institute.

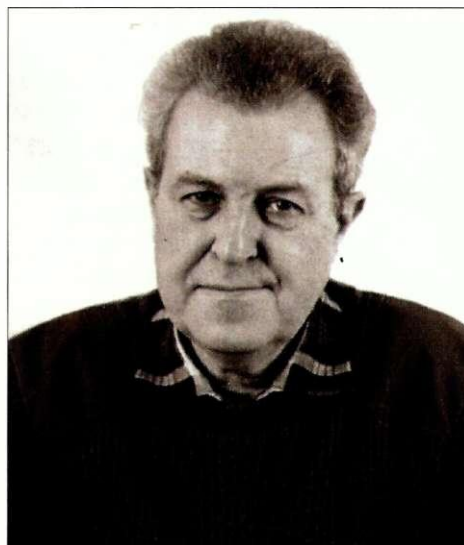
In 1971 he moved with the nuclear and particle physics branch of the Ioffe Institute which became the Leningrad Nuclear Physics Institute, the considerably enlarged Theory Group becoming the Theory Division of the LNPI. Alexei Anselm was its Head from 1983 until 1997, when illness forced him to retire.

During the troubled years from 1992 until September 1994 he was also Director of the Petersburg Nuclear Physics Institute (PNPI), as it became known.

Alexei Andreevich, or Alyosha, as he was fondly known to his many friends worldwide, published his first paper at the age of 23. During a 40-year career, he published over 130 papers, mostly on fundamental problems of particle physics and field theory.

In 1958 he was the first to discover that the Landau pole is not a universal phenomenon in quantum field theory: it is absent for a 2-D model with a four-fermion interaction, a result of which he was always proud.

During the 1960s he was best known for his contribution to the theory of complex angular momenta, in which the Theory Group under V N Gribov played a leading role. There followed work on the quark model, on spontaneous symmetry breaking, on mechanisms of CP violation and on modifications of the



Standard Model. During the early 1990s his work extended both to cosmology and to the development of a simple model for the proton "spin crisis".

In spring 1995 he underwent his first operation for cancer and moved to Boston in the hope of getting better treatment. In spite of his illness he continued to work and publish, lecturing at the 1996 CERN Summer School in Marseille.

In January 1998 Alyosha came to the PNPI Winter School dedicated to the memory of Vladimir Gribov. When we listened to his warm, thoughtful words of appreciation for Gribov, we did not know that they were to be his farewell to the Institute and to his friends. *His colleagues.*

## Frederick Reines 1918–1998



Frederick Reines, who shared the Nobel Physics Prize in 1956 for his historic 1956 experiment with Clyde Cowan which discovered the neutrino, died in August.

After graduate studies at New York University, Reines was recruited into the wartime Theory Division at Los Alamos, eventually working at the laboratory for 15 years. In 1951 he was side-tracked into an ambitious project, with Clyde Cowan, to search for Pauli's elusive neutrino, first at the Hanford nuclear reactor, then at the more powerful Savannah River facility. As well as discovering the neutrino, this work also led to important advances in detectors to monitor radioactive tracers for medicine.

In 1959 Reines moved to the Case Institute of Technology, Cleveland, where he continued to promote neutrino experiments at reactors and pioneer studies deep underground to search for atmospheric and cosmic particles.

In 1966 he went to the University of California, Irvine, whose neutrino group still plays a leading role in major neutrino experiments, including the famous "IMB" (Irvine/Michigan/Brookhaven) underground detector.

He was showered with honours, including the J Robert Oppenheimer Memorial Prize, the US National Medal of Science, the Bruno Rossi Prize, the Michelson-Morley Award, the W K H Panofsky Prize, and the Franklin Medal as well as the Nobel.

As well as being a distinguished physicist, Fred Reines also had a fine singing voice, with which he would occasionally entertain close friends with Gilbert and Sullivan lyrics. He claimed the peak of his musical career was when he performed with the chorus of the Cleveland Symphony Orchestra.

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## Faculty and Postdoctoral Positions Institute for Theoretical Physics

State University of New York Stony Brook, N.Y. 11794-3840

The Institute for Theoretical Physics at the State University of New York at Stony Brook seeks candidates for postdoctoral positions, and continues to seek candidates for tenure-track faculty and tenured faculty, currently with anticipated appointment date 1 September 1999.

Research fields at the Institute include, but are not limited to, gauge field theory, elementary particle theory, statistical mechanics, supersymmetry, and superstrings.

For application instructions please see :  
(<http://www.physics.sunysb.edu/itp.jobs>).

If your computer manager cannot provide web access, there is a slower alternative - - please E-mail for instructions by auto-reply:

([jobforms@insti.physics.sunysb.edu](mailto:jobforms@insti.physics.sunysb.edu)). If you cannot connect electronically, and are prepared for significant processing delays, please write to:

### ITP Search

State University of New York  
Stony Brook, NY 11794 - 3840

Review of applications will resume this fall and continue until the positions are filled.

*The University at Stony Brook is an Equal Opportunity/Affirmative Action Employer. Applications from, women, people of color, disabled persons, and veterans are especially welcome.*



CENTRAL LABORATORY OF THE  
RESEARCH COUNCILS



UNIVERSITY OF  
SUSSEX

## RUTHERFORD APPLETON LABORATORY & THE UNIVERSITY OF SUSSEX

### TWO POSTS IN EXPERIMENTAL PARTICLE PHYSICS

Applications are invited for two posts in experimental particle physics. The posts are to be jointly funded by the Central Laboratory of the Research Councils and the University of Sussex for the first five years, and during this period the persons appointed will be based at the Rutherford Appleton Laboratory (RAL) for two thirds of the year and spend one term per year teaching at the University. Thereafter the persons appointed will be full time employees of the University.

The research interests of the group are currently in the areas of neutrino masses and precision measurements on the properties and interactions of free neutrons. Work is at present devoted to a measurement of the electric dipole moment of the neutron using stored neutrons at the Institut Laue Langevin, Grenoble and on preparations for the neutrino oscillation experiment (MINOS) to run in the USA. It is expected that the persons appointed will participate in this programme at RAL in Oxfordshire and at the University of Sussex.

**Post 1** (Reader / Band 3, Salary £26,700 - £41,180; 1998 pay award pending) is available from 1st October 1999. **Post 2** (Lecturer / Band 4/5, Salary £15,180 - £24,820; 1998 pay award pending) is available immediately. The person appointed would work initially on the EDM experiment.

**Candidates should send a CV with a list of publications and statement of research interests, and arrange for two letters of reference to be sent directly, to Dr R C Smith, Chair, Physics & Astronomy Subject Group, University of Sussex, Brighton BN1 9QJ by 30th November 1998.**

**Further particulars may be obtained from Prof. K Green (RAL; 01235-445381 and e-mail [k.green@rl.ac.uk](mailto:k.green@rl.ac.uk)) and Prof. JM Pendlebury (University of Sussex; 01273-678114 and e-mail [m.pendlebury@sussex.ac.uk](mailto:m.pendlebury@sussex.ac.uk)).**

*The CLRC and the University of Sussex are committed to Equal Opportunities; the CLRC is committed to achieving the Investors in People standard.*

## The Department of Physics University of Wisconsin-Madison

anticipates a tenure track position at the assistant professor level in the interdisciplinary field of astroparticle physics, with the appointment to begin fall, 1999. The appointment may be at higher rank if qualifications and experience warrant. We seek an experimentalist with a strong track record. Preference will be given to candidates interested in the operation of the recently completed Antarctic Muon and Neutrino Detector Array and the research and development for its extension to a neutrino detector of kilometer-scale dimensions.

Applicants should submit a letter of application outlining their qualifications and interests with a resume and publications list, and arrange to have at least three letters of reference sent to Lee G. Pondrom, Chair, Department of Physics, UW-Madison, 1150 University Avenue, Madison, WI 53706 by December 1 1998. The material submitted should provide evidence of teaching skills and abilities to carry out an independent research program.

*The University of Wisconsin is an equal opportunity/affirmative action employer and especially encourages women and minorities to apply. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality.*



UNIVERSITY OF  
CAMBRIDGE

Department of Physics  
Cavendish Laboratory

### Fixed-Term Lectureship in Experimental Particle Physics

Applications are invited for a three-year fixed-term Lectureship in Experimental Particle Physics at the Cavendish Laboratory. The successful candidate will carry out research within the Cambridge group's experimental programme; OPAL, NA48, ATLAS and LHCb at CERN, with new initiatives also under discussion. Teaching duties, including lecturing, allow time for active research.

Applicants must have a PhD in experimental particle physics. Starting salary is in a range up to £24,591 per annum. The post is pensionable. The position is open from 1st January 1999. Applications, including a *curriculum vitae*, a list of publications and the names and addresses of three referees, should be sent by Friday 20th November 1998 to: Professor M.S. Longair, Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, UK. Further information can be obtained from Dr.J.R. Carter at the Cavendish Laboratory, e-mail [JRC1@hep.phy.cam.ac.uk](mailto:JRC1@hep.phy.cam.ac.uk), telephone +44(0) 1223 337235.

The University follows an equal opportunities policy and has a policy on arrangements for part-time work.



**SENIOR MECHANICAL ENGINEER**  
(Position #AR3223)

The Accelerator Division of Thomas Jefferson National Accelerator Facility (TJNAF) is seeking a senior level mechanical engineer to work as a project engineer on a variety of tasks including injector design, magnets, superconducting radio frequency cavities and cryostat design. These activities will support a continuing effort to further develop high gradient super conducting accelerator technology and high current, high polarization injectors for application in TJNAF's program of upgrades. The candidate must be able to work independently, applying their expertise in one or more of the following areas: injectors, ultra high vacuum, materials, welding, superconducting radio frequency and cryostats to solve complex problems where there are limited precedents. The incumbent will work with one or two designers or lead a group of several engineers and designers to turn concepts from physicists and other engineers into working designs.

A BS or MS in Mechanical Engineering or closely related field with a minimum of fifteen years of design experience related to particle accelerators is required. Some supervisory and/or project management experience along with good communication skills and the ability to interact with a staff of varying backgrounds and education are required. Requests for information should be addressed to Mark Wiseman, (wiseman@jlab.org) while applicants should submit a CV with at least three references to:

**JEFFERSON LAB**  
Attn: Employment Manager  
Mail Stop 28D  
12000 Jefferson Ave.  
Newport News, VA 23606, USA

Please specify position number and job title when applying.

*Jefferson Lab is an Affirmative Action/Equal Opportunity Employer.*



**LANCASTER UNIVERSITY**

Department of Physics

**UNIVERSITY LECTURESHIP  
IN EXPERIMENTAL PARTICLE PHYSICS**

Lancaster University invites applications for the above post which is available from 1st April 1999.

Lancaster University has a diverse research programme in experimental particle physics and a growing involvement in particle theory and cosmology. The experimental particle physics group is heavily involved in preparations for the ATLAS experiment at the LHC, while continuing strong participation in the ALEPH experiment at LEP and the H1 experiment at DESY. We are also active in the development of radiation hard semiconductor particle detectors. The appointee would be expected to participate in the future development of, and possible additions to this programme.

The salary is according to age and experience on the University Lecturer scale.

**Further particulars of the duties associated with this post and application forms may be obtained from Personnel Services, Lancaster University, Bailrigg, Lancaster, LA1 4YW, UK (email [personnel@lancaster.ac.uk](mailto:personnel@lancaster.ac.uk)), quoting reference number A71. The head of the group, Professor T Sloan, is happy to receive informal enquiries from potential applicants by telephone (+44 1524 593615) or email ([t.sloan@lancaster.ac.uk](mailto:t.sloan@lancaster.ac.uk)).**

Applications including a statement of research interests, any teaching experience, curriculum vitae, list of publications and the names of three referees should be mailed to Personnel Services, at the above address to arrive no later than 14 December 1998. The referees should be asked to send letters of reference directly to Prof T Sloan at the Department of Physics, Lancaster University, Lancaster, LA1 4YW, UK to arrive by the closing date. It is expected that short-listed candidates will be interviewed in Lancaster in early January 1999. Applicants are asked to provide an email address, fax or telephone number where they can be contacted.

*The University is an Equal Opportunities Employer*

**MIT**

**TENURE TRACK POSITION**

**ASSISTANT PROFESSOR LEVEL  
EXPERIMENTAL RELATIVISTIC  
HEAVY ION PHYSICS**

The Physics Department of the Massachusetts Institute of Technology invites applications for a physicist with a strong interest in Heavy Ion Physics at the high energy frontier. The MIT Relativistic Heavy Ion Group has a major involvement in the Phobos Experiment at RHIC. Phobos is expected to start taking data in the fall of 1999. The appointed candidate will have an opportunity to play a major role in the physics of Phobos and will be expected to play a leading role in the formulation and implementation of the group's research program in the light of the first RHIC results. The candidate is also expected to supervise graduate students and to participate in the department's undergraduate and graduate instructional program.

Applicants should submit, before January 15, 1999, a curriculum vitae, publication list and a list of four references to: **Professor B. Wyslouch, Chairman, Search Committee, 24-518, Massachusetts Institute Of Technology, 77 Massachusetts Ave., Cambridge, MA 02139-4307.** MIT is an Affirmative Action/Equal Opportunity employer and especially solicits applications from qualified women and minorities.



**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

An Equal Opportunity/Affirmative Action Employer  
Non-Smoking Environment



**ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE**

The Swiss Federal Institute of Technology Lausanne (EPFL)  
invites applications for the post of

**Professor of Electromagnetism  
in the Department of Electrical Engineering**

The successful candidate will develop high level research in the field of radiation and free or guided propagation of electromagnetic waves, in the microwave bands. He/she should possess a degree (Msc/PhD) in engineering. Open-mindedness to multidisciplinary collaboration with industries and within the Department of Electrical Engineering of the EPFL is essential, as well as experience in project management. He/she should preferably have several years of experience in industry. Education and teaching will constitute an important part of his/her responsibilities. His/her aptitude for research should be confirmed by scientific publications in international journals and/or patents. He/she will assume the direction of the Laboratory of Electromagnetism and Acoustics of the Department of Electrical Engineering of the EPFL.

**Closing date for receiving applications: January 31st 1999. Starting date : to be discussed. Application forms and further information may be obtained by writing to the Presidency of the Swiss Federal Institute of Technology Lausanne, CE-Ecublens, CH-1015 Lausanne, Switzerland, or faxing +41 21 693 70 84. Further details are also available on the web: <http://www.epfl.ch>, <http://dcwww.epfl.ch/> or <http://admwww.epfl.ch/pres/profs.html>**

# MIT

## TENURE TRACK FACULTY POSITION

### EXPERIMENTAL GRAVITATIONAL PHYSICS

The Physics Department of the Massachusetts Institute of Technology invites applications for a Tenure Track Faculty Position in Experimental Gravitational Physics. As the construction of the Caltech - MIT Laser Interferometer Gravitational Wave Observatory (LIGO) nears completion, the Department of Physics at MIT seeks candidates for a faculty position in experimental gravitational physics. This NSF-funded national facility for the detection of gravitational waves from astrophysical sources will provide unique research opportunities in physics and astrophysics. The successful candidate will be expected to play a leadership role in either the analysis of data from LIGO or in the continued development of the facility, and to teach at the undergraduate and graduate level. Candidates should have demonstrated accomplishments in experimental physics or astrophysics, including data analysis, and promise for future growth. Because of the developing nature of this field, candidates with various experimental backgrounds (e.g., astrophysics, high-energy physics, nuclear physics, atomic physics, precision metrology, etc.) will be considered. Preference will be given to candidates applying at the level of tenure track assistant professor, but in exceptional cases more senior, well-established, physicists may be considered for a tenured appointment.

Applications including a curriculum vitae, a brief description of current research, and three letters of recommendation should be sent before December 31, 1998 to: Professor June L. Matthews, Chair, Search Committee, Department of Physics, Rm. 26-433, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139-4307. MIT is an Affirmative Action/Equal Opportunity Employer and especially solicits applications from qualified women and minorities.



**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

An Equal Opportunity/Affirmative Action Employer  
Non-Smoking Environment

## Max-Planck-Institut für Physik, Munich, Germany

invites applications for two postdoctoral positions, one in the HERA-B experiment and one in the ALEPH- (data analyses) and ATLAS- (hardware preparation) experiments.

The HERA-B experiment at the HERA proton-ring in DESY is designed to study CP-violation in the B-System. The detector is being commissioned, and the MPI is responsible for the silicon vertex detector. A successful candidate is expected to contribute to all phases of detector work and physics analysis.

ALEPH will be taking  $e^+e^-$  data at the LEP collider in CERN at centre-of-mass energies up to 200 GeV through the year 2000 and data analysis will continue for a few years. The MPI Munich group is engaged in analysis of beauty physics with LEP1 data at the  $Z^0$ -peak and of QCD and the search for new particles with LEP2 data.

Participation in the ALEPH data taking and in the development work for the institute's engagement in ATLAS is expected.

The appointments will initially be for 2 years with the possibility of an extension of up to 5 years, but not beyond the age of 35. Candidates should hold a PhD or equivalent in particle physics.

Applications should include a statement of research interests, curriculum vitae and list of publications and be sent to Prof. Volker Soergel, Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München.

Applicants should arrange for three letters of recommendation to be sent to the same address. Further information can be obtained from Dr. Ronald Settles for ALEPH (settles@mppmu.mpg.de) and Dr. Iris Abt for HERA-B (isa@mppmu.mpg.de).

*Disabled applicants with equal qualification will be preferred.  
The Max Planck Society encourages especially women to apply for these kind of positions.*

## PROGRAM DIRECTOR

### SLOAN DIGITAL SKY SURVEY

The Sloan Digital Sky Survey (SDSS) invites applications for the position of Program Director. The Program Director will hold a permanent appointment and base of operations as a member of the scientific staff of the Fermi National Accelerator Laboratory.

The Program Director will supervise the operational phase of the survey at Apache Point Observatory and at Fermilab, with a primary goal of creating a survey quality photometric and spectroscopic database of the northern extragalactic sky. Intermediate milestones will include completion of science commissioning and achievement of stable science operations. It is also expected that the candidate will pursue a vigorous scientific program based on the SDSS data archive, and assume a leadership role in present and future directions of the Fermilab astrophysics effort. We intend to make this appointment at a senior level.

The SDSS achieved first light in May 1998, and will initiate survey operations in 1999. The project includes a dedicated 2.5-m wide-field telescope at Apache Point Observatory in New Mexico, a camera with an array including thirty 2048 X 2048 CCDs, and twin spectrographs capable of simultaneous measurement of over 600 spectra. The survey will construct a precision photometric catalog of some 100 million galaxies and 1 million quasars, from which approximately 1 million galaxies and 100,000 quasars will be selected for spectroscopy.

Data processing and archiving will be at Fermilab, where the astrophysics effort includes both a Theoretical Group and an Experimental Group, consisting of twelve staff scientists and eight postdocs, and has close ties to the Astronomy and Astrophysics Department of the University of Chicago. Fermilab is also involved in the Cryogenic Dark Matter Search and the Pierre Auger Cosmic Ray Project.

Qualifications include: a Ph. D. in astronomy, physics, or a related field; an international reputation for scientific leadership; and project management skills necessary to direct survey operations, to meet agreed-upon scientific requirements and schedule, and to exercise budget authority.

Applications, including a curriculum vita and a list of references, should be sent by December 15, 1998 to Edward W. Kolb [(630) 840-4695; rocky@fnal.gov]

#### Program Director Search Committee

c/o Edward W. Kolb

MS209

Fermilab

Box 500

Batavia, Illinois 60510

The SDSS is a collaboration of the University of Chicago, the Fermi National Accelerator Laboratory, the Institute for Advanced Study, the Japanese Participation Group, Johns Hopkins University, Princeton University, the United States Naval Observatory, and the University of Washington. Fermilab is operated by Universities Research Association, Inc. under contract with the Department of Energy.

EOE/M/F/D/V

## **ASSOCIATE DIRECTOR - ACCELERATOR DEVELOPMENT**

**SYNCHROTRON RADIATION CENTER (SRC)**

**UNIVERSITY OF WISCONSIN - MADISON**

• The University of Wisconsin-Madison seeks an innovative and creative Accelerator Scientist to lead the accelerator activities of the Synchrotron Radiation Center (SRC). This position carries responsibility as a Senior Scientist for directing all activities relating to the ongoing development of the "Aladdin" storage ring, which operates at energies of 800 MEV and 1 GEV, and for its operation and maintenance. The Associate Director will report to the Executive Director of the Synchrotron Radiation Center and will be expected to coordinate and supervise the activities of four functional organizational groups (Accelerator Technology, Engineering, Controls, and Operations) through their respective Group Leaders. These groups are responsible for developing new initiatives in synchrotron technology for Aladdin, managing the 24-hour operation of the facility, and for maintaining and upgrading the injector, the storage ring, and supporting equipment.

• The Associate Director will be expected to: conduct accelerator research to improve the characteristics of the synchrotron radiation utilized by several state-of-the-art beamlines and experimental systems; consult and collaborate with other synchrotron facilities regarding improvements to the stability, lifetime, and brightness of the synchrotron source; participate in the development of new initiatives and grant proposals for funding by the National Science Foundation and other federal and industrial institutions; and work with the Director of Research to provide state-of-the-art research facilities that will satisfy scientific needs at the Center. In addition, the Associate Director will play a leading role in Aladdin development programs including: participating in the planning for a fourth insertion device to enhance the spectrum for particular research applications (currently there are three such devices), initiating and supervising studies to increase the beam current, increasing the stability of the beam in position and size, and to improve the lifetime of the beam while maintaining or reducing the beam emittance.

• Madison, Wisconsin, (<http://www.ci.madison.wi.us/>), ranked as the number one mid-size city in the nation, offers a small town yet progressive life style with an abundance of cultural, and recreational resources. Educational opportunities are among the best in the nation with a school district ranking in the top ten, the UW-Madison, and a quality private liberal arts college and technical college located in the city.

• For prompt consideration for this position, send curriculum vitae and reference list immediately to Mr. Clay Vinje, UW-Madison, Synchrotron Radiation Center, 3731 Schneider Drive, Stoughton, WI 53589, email: [cvinje@psl.wisc.edu](mailto:cvinje@psl.wisc.edu). Unless confidentiality is requested in writing, information regarding applicants must be released upon request. Finalists cannot be guaranteed confidentiality.

## **NFR Naturvetenskapliga forskningsrådet**

**Swedish Natural Science Research Council**

invites applications for  
**A SENIOR RESEARCH POSITION in**

**Experimental Astroparticle Physics related to the AMANDA experiment (Ref: 702-236/98)**

The Council's intention in creating these positions is to contribute to the recruitment of researchers and to the renewal of research in Sweden. The programme is aimed primarily at scientists with a doctorate and several years of post-graduate research. The positions are held for three plus three years and are placed at appropriate university departments in Sweden to be chosen in consultation between the candidates, NFR and the universities. The applicant is kindly requested to state where he wants the position to be placed. The universities decide on tenure. Duties can commence from July 1, 1999. The salary range will correspond to that of an assistant/associate professor (SEK 300 000-390 000 per year, i.e. USD 39 000-50 000 per year).

A curriculum vitae including a list of publications, a short research plan plus a description of scientific achievements (max 5 pages), and a maximum of 10 reprints of scientific papers should be appended. Other documents which the applicant wants to refer to could also be included. Four copies of the application and all appendices and reprints should be submitted.

Applications, quoting Ref. should reach the Swedish Natural Science Research Council, Box 7142, S-103 87 Stockholm, Sweden, by December 15, 1998.

Further information can be obtained from

**Ms Natalie Lunin at the Secretariat of NFR, phone no. +46 8 454 42 32, e-mail-address [Natalie.Lunin@nfr.se](mailto:Natalie.Lunin@nfr.se), fax no +46 8 454 42 50.**

## **UNIVERSITY OF COPENHAGEN**

*Niels Bohr Institute for Astronomy, Physics and Geophysics*

### **POST DOC IN EXPERIMENTAL PARTICLE PHYSICS**

A position as post doc in experimental particle physics at NBIfAFG will be open from April 1, 1999.

The particle physics group is located at the Niels Bohr Institute, a department of the NBIfAFG, and the experiments are performed at CERN, Geneva, Switzerland, and at DESY, Hamburg, Germany. The group at NBI is involved in the LEP experiments ALEPH and DELPHI and in the ATLAS experiment planned for LHC all at CERN and in HERA-B at DESY.

The chosen candidate will be based in Copenhagen but is expected to participate in the building up of ATLAS and to contribute to the preparation of the physics analysis.

The position allows participation in the University teaching programs at all levels. The chosen candidate must be able to teach undergraduate physics courses in one of the Scandinavian languages or English.

The position is a renewable fixed term contract for two years. Terms of appointment and payment according to the agreement between the Ministry of Finance and AC. The annual salary depends on seniority, and the scale ends at a yearly salary of DKK 281 931. Possibly an annual non-pensionable increment of DKK 38.386 as an assistant research professor can be granted. The graduation date for an assistant professor should not exceed 8 years by appointment.

Deadline for applications is December 14, 1998, at noon. An expert assessment committee will evaluate the applications.

The application should be send to:-

**Professor Jørn Dines Hansen, Niels Bohr Institute,  
Blegdamsvej 17, DK-2100 Copenhagen Ø,  
Denmark (E-mail: [dines@nbi.dk](mailto:dines@nbi.dk))**

U.S. DEPARTMENT OF ENERGY  
PHYSICIST, GS-1310-14/15  
OFFICE OF ENERGY RESEARCH  
OFFICE OF HIGH ENERGY AND NUCLEAR PHYSICS  
HIGH ENERGY PHYSICS DIVISION

GS-14: \$66,138 - \$85,978 per annum  
GS-15: \$77,798 - \$101,142 per annum  
PN-98-ER-76-22-220

The U.S. Department of Energy is seeking applicants for the position of Physicist within the High Energy Physics Division, Office of High Energy and Nuclear Physics, in the Office of Energy Research. The incumbent will serve as the Program Manager for experimental high energy physics activities relative to the oversight of large high energy physics accelerator research facilities conducting colliding beam experiments and utilizing large comprehensive particle detector facilities. The incumbent will be responsible for establishing goals and objectives as well as providing leadership and direction for this program with national and international scope and impact. Develops, recommends, and implements strategies, milestones, policies and near- and long-range plans for the operation of high energy physics laboratories and their accelerator and experimental facilities, both existing and under construction. Makes recommendations on the suitability performance, and utilization of high energy physics accelerator and experimental facilities, and assesses the capabilities and priorities of proposed new ones. A thorough knowledge and understanding of high energy physics, as well as extensive background and experience based on training and substantial research experience in the field are necessary.

Please refer to Vacancy Announcement PN-98-ER-76-22-220 (reference <http://www.hep.net/doehp/home.html>) for specific instructions on how to apply for this position. Applicants must comply with the instructions that are in the vacancy announcement in order to be eligible for consideration. Announcements can be faxed to you by calling 202-586-1705 or mailed to you by calling 301-903-1577.

Applications must be postmarked no later than December 28, 1998, and should be sent to the U.S. Department of Energy, HR-352, Room F-125, 19901 Germantown Road, Germantown, MD 20874-1290.

*The Department is an equal opportunity employer.*

## Postdoctoral position in experimental high-energy physics

*The experimental high energy physics group at the University of Hawaii invites outstanding applicants for a postdoctoral research associate position.*

The successful candidate will participate in the BELLE experiment at KEKB the asymmetric e+e B-factory that is currently under construction at the KEK laboratory in Japan. The primary goal of the experiment, which will begin recording data in early 1999, is to investigate CP violation in the decays of B mesons and conduct precision tests of the standard model. In addition to extraction of physics results from BELLE, he/she is expected to play a major role in the Hawaii group's R&D program on high resolution semiconductor vertex detectors which includes the development of pixel detector as well as the upgrade of the Belle silicon strip detector. A PhD in experimental high-energy physics is required and experience with modern electronics and computing techniques is desirable. The salary range is \$34,000 - \$50,000.

Applicants should submit a curriculum vitae and arrange for three letters or recommendation to be sent to **Professor Hitoshi Yamamoto, Department of Physics and Astronomy, The University of Hawaii, 2505 Correa Road, Honolulu, HI 96822.**

E-mail contact, [hitoshi@uhheph.phys.hawaii.edu](mailto:hitoshi@uhheph.phys.hawaii.edu).

*The University of Hawaii is an affirmative action/equal opportunity employer.*

## URGENT RECRUITMENT NEEDS?

Reach a global audience immediately with *CERN Courier's* Internet options. Recruitment advertisements are on the Web within 24 hours of booking and then also sent to e-mail subscribers.

**Call +44 (0)117 930 1031 for more details**



DESY announces several

## "DESY-Fellowships"

for young scientists in experimental particle physics to participate in the research mainly with the HERA collider experiments H1 and ZEUS or with the fixed target experiments HERA-B and HERMES. New fellows are selected twice a year in April and October.

DESY Fellowships in experimental particle physics are awarded for a duration of two years with the possibility for prolongation by one additional year.

The salary for the fellowship is determined according to tariffs applicable for public service work (IIa MTV Ang.).

interested persons, who have recently completed their Ph.D. and who should be younger than 32 years are invited to send their application including a résumé and the usual documents (curriculum vitae, list of publications, copies of university degrees) until 31 of March 1998 to **DESY, Personalabteilung - V2 -, Notkestraße 85, D-22607 Hamburg**. They should also arrange for three letters of reference to be sent until the same date to the address given above.

Handicapped applicants with equal qualifications will be preferred.

DESY encourages especially women to apply.

As DESY has laboratories at two sites, in Hamburg and Zeuthen near Berlin, applicants may indicate at which location they would prefer to work. The salary in Zeuthen is determined according to II a, BAT-O.

## Faculty Position: Experimental Particle Physics/Astrophysics Case Western Reserve University

The Department of Physics at Case Western Reserve University is launching a search for an experimentalist in particle physics/astrophysics. This will be a tenure track or tenured position which may be made at any level commensurate with qualifications. While significant start up funds are expected, we are likely to focus on candidates who already have some outside support for their research program. The successful candidate will join a growing effort in particle physics/astrophysics in the newly renovated research facilities of the physics department. Current experimental efforts include underground dark matter detection, and an experimental programme at the Fermilab, Tevatron, RHIC, and the LHC. The expected start date is Summer 1999, but an earlier start date may be possible.

Interested candidates should apply to Particle Physics/Astrophysics Search Committee, Department of Physics, Case Western Reserve University, 10900 Euclid Ave., Cleveland, OH 44 106-7079. Questions can be directed by email to [cct@po.cwru.edu](mailto:cct@po.cwru.edu).

*CWRU is an affirmative action/equal opportunity employer.*

## POSTDOCTORAL RESEARCH POSITION THEORETICAL ASTROPHYSICS/COSMOLOGY THE OHIO STATE UNIVERSITY

Applications are invited for a postdoctoral research position in Theoretical Astrophysics/Cosmology to begin autumn, 1999.

The appointment is for two years with the second year dependent on available funding. Preference will be given to those applicants having research experience in cosmology and/or the interface between particle physics and astrophysics. Faculty members with interests in this area include Gary Steigman, Robert Scherrer, Terry Walker, Barbara Ryden, David Weinberg, Andy Gould, Richard Boyd, Marc Pinsonneault, and Stuart Raby.

Applications, including a vita and 3 letters of recommendation, should be sent to Professor Robert Scherrer, Department of Physics, The Ohio State University, 174 West 18th Avenue, Columbus, OH 43210. All application materials should arrive by January 1, 1999.

*The Ohio State University is an affirmative action/equal opportunity employer.*

# NATIONAL INSTITUTE FOR NUCLEAR PHYSICS

## I.N.F.N.

POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS IN THE FOLLOWING RESEARCH AREAS:

### THEORETICAL PHYSICS (N. 10) EXPERIMENTAL PHYSICS (N. 20)

The I.N.F.N. Fellowship Programme 1998-99 offers thirty positions for non Italian citizens for research activity in theoretical or experimental physics.

Fellowships are intended for young post-graduates not more than 35 years of age at the time of deadline.

Each fellowship is granted for one year (which may start during the period from September to November 1999), and may be extended for a second year.

The annual gross salary is 36,000,000 Italian Lire, plus travel expenses for round trip transportation from the home fellows to the I.N.F.N. Section or Laboratory. Lunch tickets are provided for work days.

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

Applications should be sent to I.N.F.N. not later than *October 15, 1998*.

Candidates will be informed by the end of March 1999 about the decisions taken by I.N.F.N.'S committee.

The successful applicants may carry out their research activity in Italy, at any of the following Laboratories and Sections of I.N.F.N.:

National Laboratories of Frascati (Rome), National Laboratories of Legnaro (Padua), National Laboratories of Gran Sasso (L'Aquila) and Southern National Laboratory (Catania).

I.N.F.N. Sections in the Universities of:

Turin, Milan, Padua, Genoa, Bologna, Pisa, Rome 'La Sapienza', Rome 'Tor Vergata', Naples, Catania, Trieste, Florence, Bari, Pavia, Perugia, Ferrara, Cagliari, Lecce and Rome 'Tre'.

Information, requests for application forms, and applications should be addressed to Personnel Office - Fellowship Service, National Institute of Nuclear Physics (I.N.F.N.) - Post Box 56 - 00044 Frascati (Rome) Italy.

**NATIONAL INSTITUTE FOR NUCLEAR PHYSICS  
THE PRESIDENT**

*(Prof. Luciano Maiani)*

### Tenure Track Assistant Professorship in Experimental High/Medium Energy Physics

#### Northwestern University

The Department of Physics and Astronomy is seeking outstanding candidates for a tenure track Assistant Professor position in experimental high or medium energy physics. We are currently involved in research at Fermilab, DESY, CERN, Thomas Jefferson Lab, Brookhaven National Lab, and developing research programs in physics at Northwestern (for more information, see <http://www.physics.nwu.edu/>). The appointment would start September 1999. The successful candidate will be expected to teach effectively at all levels. Applicants should submit a curriculum vitae, statement of research interests, and the names of four references to:

Prof. David A. Buchholz, Chair, Department of Physics and Astronomy, Northwestern University, Evanston, IL 60208-3112

Applications should be received by December 15, 1998 to receive full consideration. Members of minority groups and women are especially encouraged to apply.

### POSITIONS AT THE NSCL MICHIGAN STATE UNIVERSITY

The National Superconducting Cyclotron Laboratory at Michigan State University has openings for top quality candidates to be post-doctoral fellows and assistant research professors. The appointments are typically renewable up to three years and are for research in nuclear or accelerator physics, both experimental and theoretical. The experimental nuclear physics program includes studies approaching the driplines with radioactive beams, nuclear astrophysics, and nucleus-nucleus reaction dynamics using the K1200 cyclotron system that can produce heavy ion beams in the 10 - 200 MeV/nucleon range.

Further descriptions of the research opportunities can be found on our web-site <http://www.nsl.msu.edu/> Please send a CV with a list of publications and arrange for three letters of reference to be sent directly by post to Prof. D.J. Morrissey, NSCL, Michigan State University, East Lansing, MI, 48824, or e-mail to [morrissey@nsl.msu.edu](mailto:morrissey@nsl.msu.edu)

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The Institut Laue-Langevin is an international research institute which operates a high-flux neutron research reactor, which is used to conduct experiments on the structure and dynamics of condensed matter (with applications in physics, chemistry, biology and materials science), as well as in the fields of nuclear and elementary-particle physics.

## RESEARCH SCIENTIST

### Time of Flight and High Resolution Group

The Science Division currently has an opening for a scientist to work, on the multichopper time-of-flight instrument IN5.

The position is best suited for a young postdoctoral scientist having an interest in dynamical studies either in condensed matter systems or in biological systems. The successful candidate will be assigned the task of assisting ILL's visiting scientists in conducting their experiments and taking charge of the operation and improvement of the instrument.

More experienced scientists on secondment may also be considered.

**Further information can be obtained by contacting the Group leader Dr. A.J. DIANOUX Tel +33 4 76 20 72 06 or e-mail dianoux@ill.fr**

Applications (with curriculum vitae, list of publications and the names of two academic referees) should be sent no later than 30 November 1998 to: **The Associate Director (Science Division) quoting reference C-98/17,**

## NETWORK TECHNICIAN

### The Projects and Techniques Division is looking for a HND/HNC Network Technician for its Computing Service.

Duties will include supervising the ILL internal and external networks, as well as maintaining network equipment, troubleshooting and repairs.

You will also be involved with user support for the installation of equipment on the network and the installation and development of network monitoring tools.

Experience of programming in C. Basic knowledge of Windows NT and UNIX

**For further information please contact Mr Alain Barthélemy, Tel.: +33 4 76 20 70 25 or e-mail: barthelemy@ill.fr**

Applications, with curriculum vitae, list of publications and the names of two academic referees should be sent no later than 30 November 1998 to:

**The Head of Personnel quoting reference C98/16.**

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Even archivists retire. On 30 September, CERN's diligent archivist **Roswitha Rahmy** left the laboratory after a long career. One of the objectives of the extensive archives is to preserve as much as possible of CERN's "living memory" on which the spirit of the laboratory draws. Roswitha has also played an important role in administering CERN's Pauli Collection, the comprehensive collection of Wolfgang Pauli papers entrusted to CERN, and on which CERN holds the copyright. CERN oversees the publication of Pauli's extensive scientific correspondence (October 1996, page 14).

**Maldacena macarena**

Theorists are excited about the conjecture put forward recently by Juan Maldacena of Harvard which greatly extends the application of multidimensional string theories to physical field theories.

The annual festival of the string community is the summer Santa Barbara meeting, for which theorist Jeff Harvey of Chicago composed a macarena-like song:

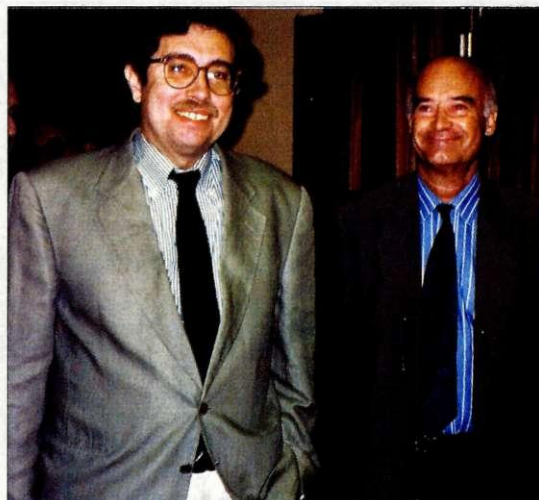
*You start with the brane  
and the brane is BPS  
Then you go near the brane  
and the space is AdS  
Who knows what it means  
I don't I confess  
Ehhhh! Maldacena!*

*Super Yang Mills  
With very large N*

*Gravity on a sphere  
flux without end  
Who says they're the same  
holographic he contends  
Ehhhh! Maldacena!*

*Black holes used to be  
a great mystery  
Now we use D-brane  
to compute D-entropy  
And when D-brane is hot  
D-free energy  
Ehhhh! Maldacena!*

*M-theory is finished  
Juan has great repute  
The black hole we have mastered  
QCD we can compute  
Too bad the glueball spectrum  
is still in some dispute  
Ehhhh! Maldacena!*



Opening a recent international conference for physics students in Coimbra, Portugal, was Portuguese Science Minister and high-energy physicist **Jose Gago** (left). On the right is Rui Nogueira Lobo de Alarcão e Silva, rector of Coimbra University. The current president of the International Association of Physics Students, Nigel Harris, is moving from Cambridge to the UK Rutherford Appleton laboratory to join work on the Atlas experiment for CERN's LHC collider.

**Fractional charges win Nobel Prize**

The 1998 Nobel Physics Prize goes to three researchers for their discovery and subsequent explanation of how quantum conditions can generate quasiparticles carrying fractional electric charge.

The quantum Hall effect, discovered by Klaus von Klitzing in 1980 and for which he earned the 1985 Nobel Prize, gives a stepwise behaviour of the apparent electrical resistance at liquid-helium temperatures. These steps are independent of the material, being combinations of basic physical parameters divided by an integer. Horst L Störmer of Columbia and Daniel C Tsui of Princeton discovered in 1982 that powerful magnetic fields could induce additional structure in the quantum Hall effect, beyond those found by Klitzing, with fractional, as well as an integer dependence.

Robert Laughlin of Stanford was able to explain this as quasiparticles generated in a quantum fluid. As some of these quasiparticles can carry one-third of the normal electronic charge, there was talk of quarks. But quasiparticles are nothing to do with quarks (November 1997, page 24).

**Bruno Touschek and the birth of electron-positron physics**

On 16 November 1998 a special meeting at the Italian INFN's Frascati national laboratory will mark the 20th anniversary of the death of Bruno Touschek, recalling his life and his great contribution to physics, at the same time reviewing progress and perspectives of particle physics.

For more information see "<http://www.lnf.infn.it/conference/touschek.html>" or contact the Secretariat: M R Ferrazza - L Sirugo. Tel: +39 6-9403 2573/2418. Fax: +39 6-94032582. E-mail: "Dirlnf@lnf.infn.it".

**Legion of Honour**

Senior CERN physicist Pierre Darrulat has become "Chevalier" of the French Legion of Honour.

**Fermilab conferences**

From 26-29 May 1999 at Fermilab there will be a memorial symposium "Inner Space/Outer Space II" for astrophysicist and cosmologist David Schramm who died in an airplane accident in December 1997.

From 5-8 October next year, Fermilab will host the traditional seminar on "Future Perspectives in High Energy Physics" organized by the International Committee for Future Accelerators, ICFA. Attendance is by invitation only.

See "<http://www-ppd.fnal.gov/conferences/icfasem99/announce.html>" or e-mail "icfasem99@fnal.gov".

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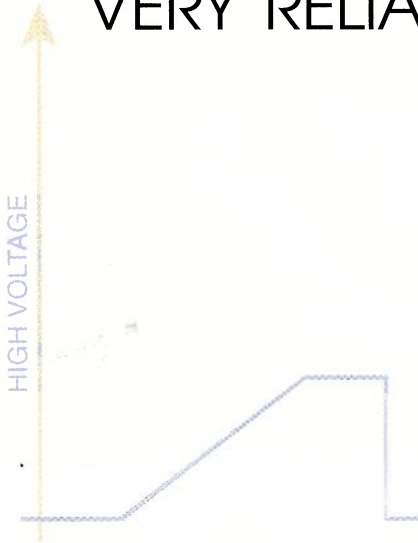
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