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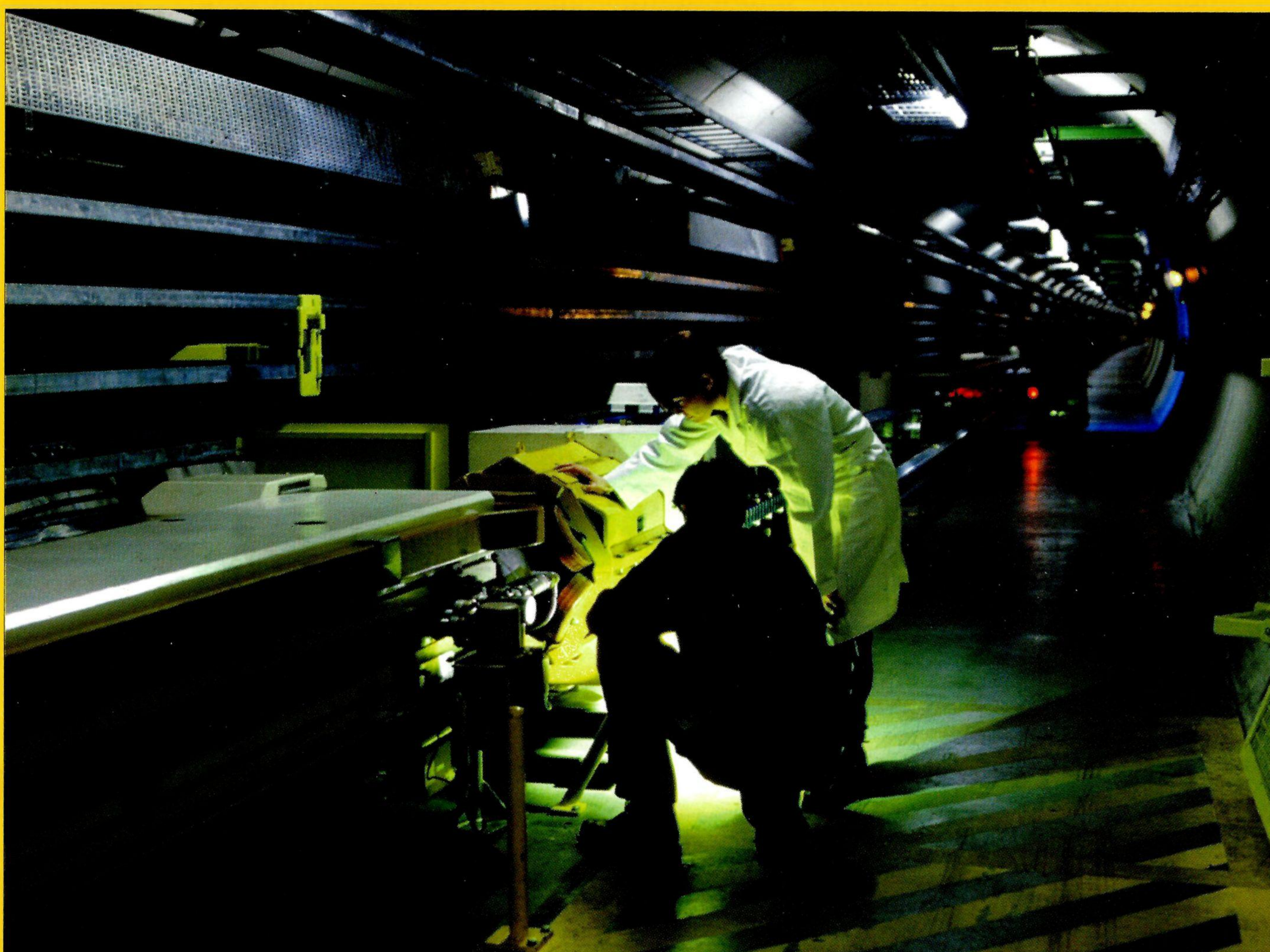

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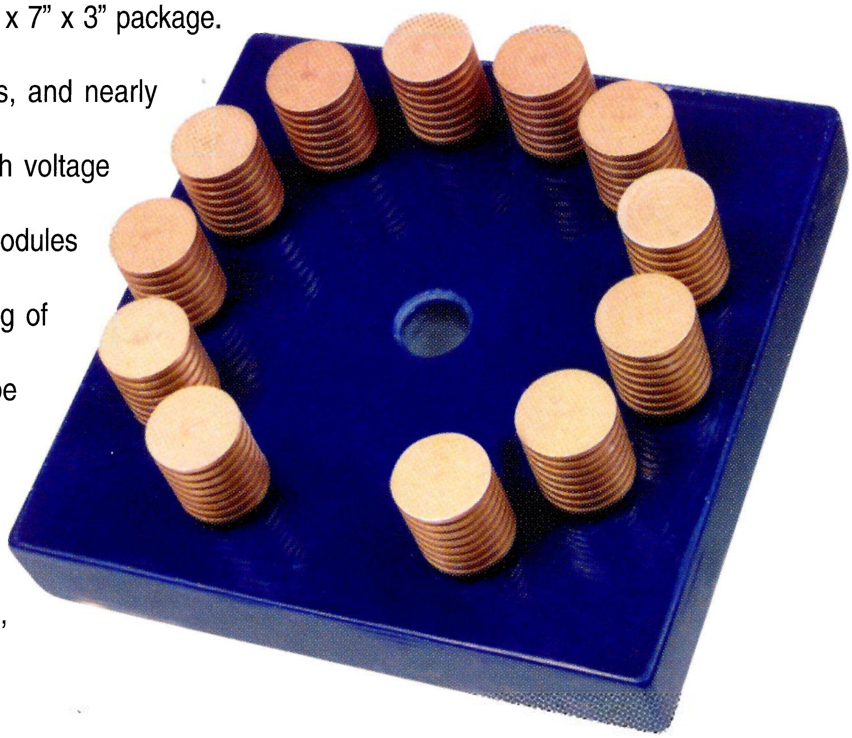

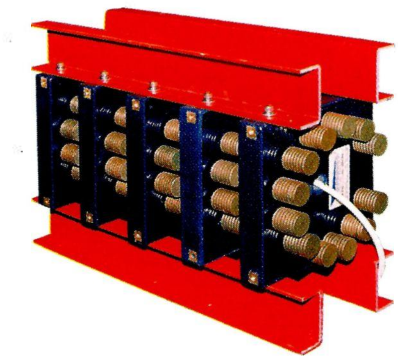

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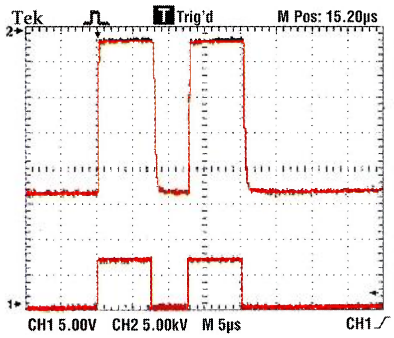

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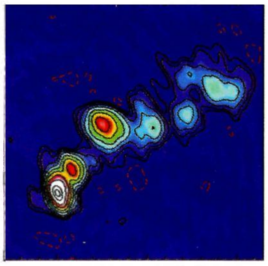

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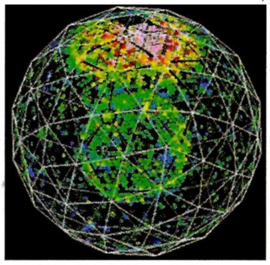

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Cover: In 10 years, CERN's 27 km LEP electron–positron ring has progressed from 45 to 100 GeV per beam, testifying to the foresight of the design team (p14).

First K2K events seen at KEK lab

During 22 days of stable data-taking in June, the K2K Long Baseline Neutrino Oscillation experiment, connecting the Japanese KEK Laboratory with the detectors in the Kamioka mine 250 km away, observed four neutrino interactions in the inner Super-Kamiokande detector. This is the first step towards the verification of the neutrino oscillation results given by the Super-Kamiokande last year.

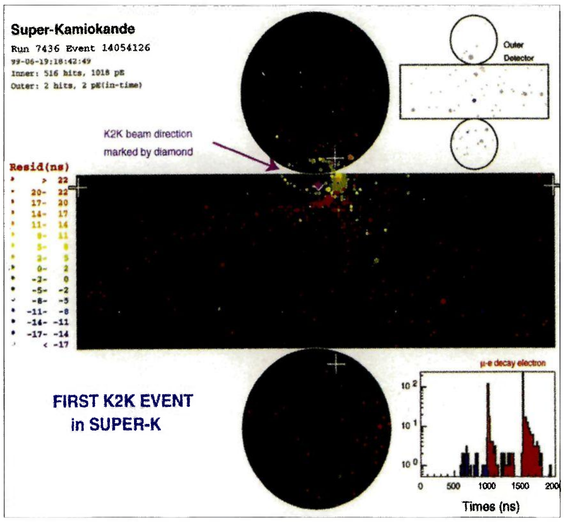
One event occurred inside the 22.5 kiloton "fiducial volume" (2 m from the inner photomultiplier tubes) and another three events occurred outside. The event characteristics are consistent with a neutrino interaction in water. More importantly, all four events happened within 1 μs of the time expected for neutrinos generated at KEK.

No further events were seen in the inner detector within 50 μs of the expected time. Before reaching the distant Super-Kamiokande detector, the neutrinos pass through a "near detector" on the KEK site. Both detectors have a clock synchronized by the Global Positioning System (GPS), which is accurate to 100 ns. The probability that each of the four events comes from an atmospheric neutrino interaction is estimated to be a few parts in 10 000.

The K2K experiment began tuning the beamline, beam monitors, magnetic horn system and the near detector on 5 March. All of the detector components worked as expected. During an engineering run from March to May, physicists ensured that neutrinos were being sent in the direction of Super-Kamiokande to an accuracy of 0.3 mrad and that the flux and the profile of the beam were as expected.

During the summer shutdown period, the KEK beamline group will be improving the transmission of the primary proton beamline and will increase the current of the magnetic horns. The KEK accelerator succeeded in circulating 6.5×10^{12} protons in nine bunches in the main ring in June and will look for a further improvement in intensity. Thus, K2K hopes to have more neutrinos in the coming run, which will be starting in late October.

The K2K experiment is an international collaboration of institutes from Japan, Korea and the US.



The first K2K event seen by Super-Kamiokande. The colour of the dots indicates the arrival time of the light detected by each photomultiplier and the size shows the amount of charge. The diamond shows the entrance point of the neutrino and the crosses give the coordinates of the interaction point. The direction of the incoming neutrino given by these two positions is consistent with it coming from the Japanese KEK Laboratory, 250 km away.

An aerial view of the K2K neutrino beamline at the Japanese KEK Laboratory. At the bottom left are the KEK 12 GeV Proton Synchrotron and its north counter hall. The extracted proton beam is bent around towards the near detector (small white building, top right) and exits towards Kamioka, 250 km away.

Shown here is the near detector of the K2K experiment. The silver tank in the back is a 1 kiloton water Cherenkov detector and at the front is the muon detector, consisting of iron plates and scintillation fibre planes.

MINOS to explore neutrino mass

Left to right: Earl Peterson, University of Minnesota; John O'Fallon, US Department of Energy; Michael Witherell, Fermilab director; Stan Wojcicki, Stanford University and MINOS spokesperson; Paul Maurer, Minnesota Department of Natural Resources (which owns the mine); Christine Maziar and Ed Wink, University of Minnesota.

Deep in a former Minnesota iron mine, scientists and government officials recently wielded pickaxes to chip away, at least symbolically, at the mysteries surrounding the subatomic particles known as neutrinos.

The miners-for-a-day in the Soudan mine took the first steps in carving out a huge cavern, half a mile underground, that will become home to a 5000 ton particle detector. Physicists of the 200-member Main Injector Neutrino Oscillation Search (MINOS) experiment will use the detector to explore the question of neutrino mass.

Physicists once believed that neutrinos were massless, zipping through matter at the speed of light. However, recent results (*CERN Courier* September 1998 p1) suggested that these elusive particles have a small mass. Even a tiny neutrino mass would have major consequences for our understanding of the nature and distribution of mass in the universe.

For the MINOS experiment, 120 GeV protons from Fermilab's newly commissioned Main Injector accelerator will be used to generate an intense beam of muon neutrinos directed towards the underground Soudan detector, 730 km away. Neutrinos are reluctant to interact with matter and can pass through the Earth without any effect. However, interaction is probability not zero, so an intense beam and/or a large detector will record some interactions.

From early 2003, MINOS collaborators will use the detector to determine whether some of the muon neutrinos in the beam have changed to another type, known as tau neutrinos. Such a change, or oscillation from one type to another, would constitute clear evidence of neutrino mass and would allow physicists to begin to calculate just how much mass the particles possess. Locating the detector far below ground screens out cosmic rays that would otherwise flood the detector with irrelevant signals.

Earlier neutrino experiments detected fewer naturally-occurring neutrinos than expected, so they concluded that one type of neutrino had oscillated into another and, hence, had "disappeared" from detection. In contrast, the MINOS experiment could detect not only the disappearance of muon neutrinos, but eventually their appearance as neutrinos of a different type – tau neutrinos (p19).

To monitor the evolution of the neutrino beam, MINOS will use two detectors – the "near detector" at Fermilab and the 5400 tonne "far detector" in the Soudan tunnel. The design initially proposed foresees fine-grained iron-scintillator sandwich calorimeters providing both tracking and energy deposition information.

On the other side of the Pacific Ocean is a similar study – K2K – using neutrinos provided by the accelerator at the Japanese KEK Laboratory in Tsukuba (p5). The particles are directed towards the Super-Kamiokande underground detector 250 km away. K2K is recording its first data.

At CERN, physicists are studying a proposal to direct a neutrino beam towards the Italian Gran Sasso underground laboratory. Curiously, like MINOS, it is 730 km from the accelerator neutrino source (*CERN Courier* November 1998 p13).

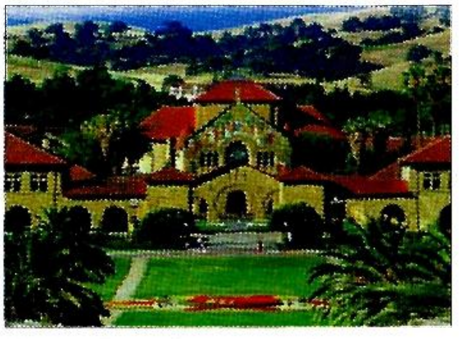
Lepton–photon symposium at Stanford

The major international focus of high-energy physics in odd-numbered years is the International Symposium on Lepton-Photon Interactions at High Energies, which took place this year on 9–14 August at Stanford University, California. Several reports from the meeting feature in this issue.

The lepton-photon symposia alternate with the International Conference on High-Energy Physics (ICHEP), often known as the "Rochester" series, after the founding venue.

Both of these interlocking biennial meetings are sponsored by the International Union of Pure and Applied Physics (IUPAP) and the venues follow a traditional pattern, rotating between Europe (Western and Eastern), North America and Asia.

Next year the ICHEP will be held in Osaka, Japan, from 27 July to 2 August. The 2001 Lepton-Photon Interaction Symposium will take place in Rome and the 2002 ICHEP in Amsterdam.



Stanford University, the venue for this year's International Symposium on Lepton–Photon Interactions at High Energies.

First beams of nuclei circulate rings at Brookhaven's RHIC

During August, work continued to establish circulating beams of nuclei in the two rings of Brookhaven's Relativistic Heavy Ion Collider (RHIC). Equipped with superconducting magnets, the machine operates at 4.6 K.

The beam was injected and stored in the first ("blue") ring. Lifetimes of up to 45 min and modest acceleration – about 1 GeV per nucleon – were achieved. A few apparent obstacles will be investigated when the ring is warmed up.

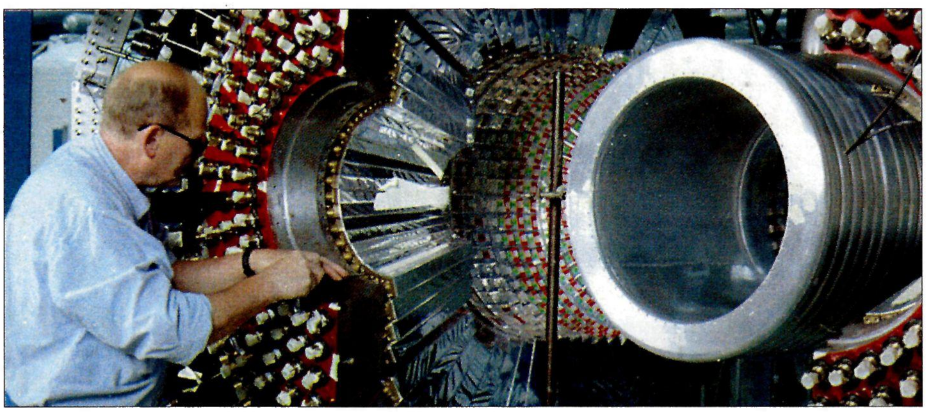
Thousands of turns of beams have been seen briefly in the second ("yellow") ring, with successful radiofrequency capture. Long lifetimes have not yet been established, nor has acceleration been performed. While no apparent obstacles have been found in this ring, steering and second turn closure in the injection region were found to be more difficult than in the first ring, as was steering through the dump area.

Beams are next expected in RHIC in December.

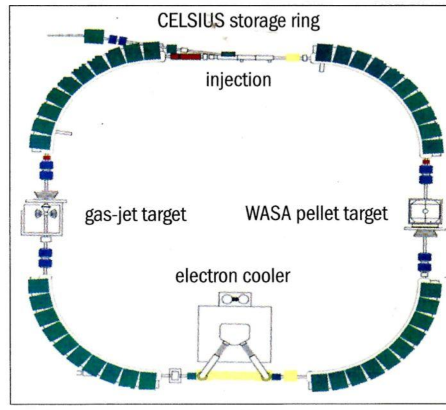
Work on the cryogenic system for Brookhaven's Relativistic Heavy Ion Collider. Equipped with superconducting magnets, the machine operates at 4.6 K. (R Stoutenburgh.)

Earlier this year a meeting took place between members of the directorates of Brookhaven National Laboratory and the Joint Institutes for Nuclear Research (JINR), Dubna, near Moscow. The timing of the meeting was chosen to allow visitors from JINR to tour the RHIC complex prior to the start of RHIC operations. The purpose was to discuss areas of mutual interest for scientific collaboration. Brookhaven director John Marburger (right) and JINR director Vladimir Kadyshevsky signed a protocol of understanding, regarding activities that will be accomplished in 1999 in areas of mutual interest. A key element of the agreement is to establish a PC farm at JINR to support JINR's ability to participate fully in the analysis of data and the production of scientific results from RHIC, Fermilab and CERN. The establishment of the farm has already been achieved since the meeting.

WASA meson detector inaugurated



The two halves of the WASA caesium iodide calorimeter barrel.



A schematic of the CELSIUS storage ring.

During the recent PANIC99 particle/nuclear physics conference (*CERN Courier* September p9), CELSIUS/WASA, a new detector facility for the CELSIUS cooler storage ring, was inaugurated. The inauguration talk was given by Erwin Gabathuler and the facility was shown to conference participants during tours of the the Svedberg Laboratory – a Swedish national facility for accelerator-based research.

The name of the laboratory is associated with Svedberg, the 1926 chemistry Nobel Laureate, who in 1945 took the initiative to build the Gustaf Werner 185 MeV synchrocyclotron that was, in the early 1950s, the highest-energy accelerator in Western Europe.

This accelerator, rebuilt into a sector-focusing synchrocyclotron, is used for research and also serves as an injector for CELSIUS (Cooling with Electrons and Storing Ions from the Uppsala Synchrocyclotron), which is an accelerator and storage ring intended for internal target experiments.

The magnets for the 82 m circumference CELSIUS ring – formerly used in the CERN g-2 experiment (to measure the muon's magnetism) and ICE (beam cooling) experiment – were brought from CERN to Uppsala in 1983. CELSIUS experiments began in 1990. There are two target stations. One is occupied by CELSIUS/WASA and makes use of protons with energies of up to 1.36 GeV.

The CELSIUS/WASA collaboration involves groups from Uppsala, Stockholm, Hamburg, Tübingen, Jülich, Warsaw, Moscow, Dubna, Novosibirsk, Osaka and Tsukuba. Studies will be made of decays and production of light mesons from inelastic proton–hydrogen collisions. CELSIUS/WASA consists of a forward part, primarily for measurements of the scattered protons, and a central part for measuring the mesons and their decay fragments. The targets are hydrogen pellets injected at high speed (60 m/s) through a tube that connects to the CELSIUS beam tube. They are produced from a liquid jet broken up into droplets by a piezoelectric crystal at the nozzle. The stream of 0.03 mm diameter pellets can be collimated so that the desired size and frequency are reached at the circulating proton beam.

One key component is the very thin superconducting solenoid coil, which is a further development of airborne magnets for Japanese space experiments. Copper of 3 mm thickness, corresponding to only 0.18 radiation lengths, is placed inside the caesium iodide calorimeter barrel, which has 1012 individual elements. Inside the solenoid are a plastic scintillator barrel with 146 elements and a mini drift chamber with 1738 individual straws. The trigger system has to cope with a total event rate of 10 MHz.

Already, several years of production experiments, with only the forward part of WASA, have provided interesting new information on meson production near the kinematical threshold. These measurements will continue, and studies of rare eta decays are being initiated. Of main interest are suppressed electromagnetic decays and strong decays. These will be used to measure limits of C and CP symmetries and their relations to the corresponding symmetries in the kaon system.

Understanding low-energy phenomena in terms of quarks is one of the great challenges of subatomic physics. The rare decay processes may also unravel surprises that are not easily explainable by the Standard Model.

ISAC achieves 10 μA

The new isotope separator and accelerator (ISAC) facility at the Canadian TRIUMF laboratory passed a milestone on 28 July when the proton current on target was raised to 10 μA, making it the highest intensity isotope separator on-line (ISOL) radioactive ion beam facility. Current experiments focus on the very short-lived isotope rubidium-74, for which measurements of the half-life (65 ms) and branching ratios are expected to provide fundamental tests of the weak interaction.

Nuclear shape measurements are also under way using the low-temperature nuclear orientation (LTNO) facility from Oak Ridge. Experiments at lower intensity have been carried out since late November 1998 (*CERN Courier* March p7), when ISAC was first commissioned with a 1 μA proton beam. An initial test at 100 μA is planned for December 1999. Meanwhile, progress is on schedule with the radiofrequency quadrupole and drift-tube linac sections for the acceleration of the ions to 1.5 MeV/nucleon for nuclear astrophysics experiments at the end of 2000.

Edited by Alison Wright

Except where otherwise stated, these news items are taken from the Institute of Physics Publishing's PhysicsWatch service, which is available at "http://PhysicsWeb.org".

Quantum modelling of the mind

Some of the best minds in biophysics have been divided on the question of how to model the workings of the human brain. Mainstream research has concentrated on developing complex neural networks to perform the cognitive processes that we call consciousness. However, others, including Roger Penrose at Oxford, have argued that consciousness is in fact a quantum effect and can only reasonably be simulated by a quantum computer.

The big issue in quantum consciousness is coherence time: how long can a superposition of quantum states in the brain persist? For the brain to be a true quantum mechanical system, the coherence time must be at least 1 s. Some say that it is, while others, including Stephen Hawking, say that it isn't. Now, Mark Tegmark of Princeton has weighed in with new calculations of coherence times for two cognitive models.

The first model describes the thought process as "neuron firing", where brain impulses are caused by neurons pumping out sodium ions and absorbing potassium ions. In the quantum picture, a neuron can exist in a superposition of firing and non-firing states.

In Penrose's alternative model, consciousness resides in microtubules – hollow cylinders of protein that act as "scaffolding" to maintain the shape of brain cells. Using techniques from string theory, thoughts can be modelled as the collapse of a quantum superposition of electrical excitations propagating in a microtubule.

Whether the model involves neuron firing of charged ions or propagating excitations in microtubules, Tegmark calculated that the influence of nearby ions, by collision or coulomb interaction, will destroy the coherence of the superposed states on very short timescales (10^{-20} s for neurons and 10^{-13} s for microtubules) – too short for a quantum system.

"There is nothing fundamentally quantum mechanical about the cognitive process in the brain", said Tegmark. For the neural network community "it's business as usual". *AIP*

Only 18 clicks of hyperlink separation

Two randomly selected Web pages are on average 18 hyperlinks (or clicks) apart. So says a group of US scientists who used a technique based on power law distributions, borrowed from statistical physics, to investigate the topology of the Internet. The team also predicted that, even if the number of pages on the Web grows by 1000%, any two pages will still be only 20 clicks apart.

Symptoms of supersymmetry

Some particle physicists were excited when they heard rumours that supersymmetry had been found. The rumours were true. However, the supersymmetry in question is not the duality that boldly predicts that every known half-integer spin ("fermion") particle should have an as-yet-unseen integer spin ("boson") partner and vice versa.

A Swiss–German team has analysed in depth the energy level spectrum of gold-196, which has an odd number of protons (79) and an odd number of neutrons (117). Adding this information to their existing knowledge of neighbouring even–even and even–odd nuclei, the experimenters were able to find correlations in the energy levels that showed that nuclear forces are fermion–boson symmetric – a property known in the physics world as supersymmetry.

This is good news for nuclear physicists, who now have an additional tool to help them to understand complex nuclear spectra. However, particle physicists are still waiting for their supersymmetric day to come.

Quantum non-demolition is demonstrated on a single photon

The first repeated measurement of a single photon has been reported at Ecole Normale Supérieure, Paris. Usually light detection is a destructive process, because photons are absorbed and converted into electrical signals. However, it doesn't have to be that way – the rules of quantum mechanics do actually allow repeated measurements of a quantum object without destroying it. This is called quantum non-demolition (QND) and has been demonstrated for large photon fluxes, but never before for a single photon.

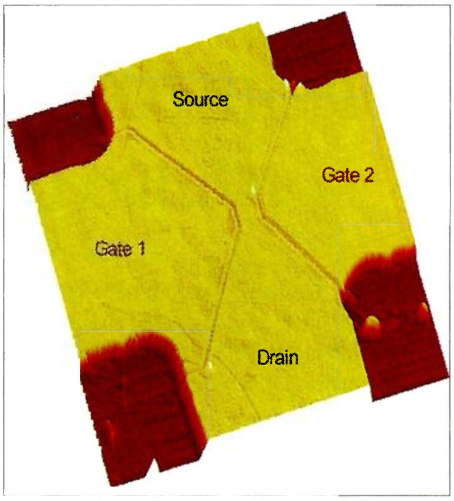
After many years of effort, the Parisian researchers have now mastered the tricky QND technique and have made repeated measurements of a single photon trapped in a niobium cavity. In the experiment, a rubidium atom is passed through the cavity and the photon causes a phase shift in the atom's wavefunction. The phase shift is detected by interferometry. Sending atoms through the cavity again and again repeats the measurement, because the photon remains undisturbed (although it does suffer a phase shift – Heisenberg's Uncertainty Principle won't let you have it every way).

This QND technique could become the basis of a quantum logic gate.

Correction

The e-mail address printed in the advertisement for VAT Vacuum Products on p12 of the July issue of *CERN Courier* was incorrect. The correct address is "uk@vatvalve.com".

Flat transistor



Scratches on the surface of a semiconductor, made using an AFM, can influence the conduction of electrons in the material. Shown here are grooves of 110 nm width, which form an in-plane-gate transistor in a GaAs/AlGaAs sample.

Scientists at Hannover and Stuttgart have demonstrated a new nanomachining technique to make tiny electronic components. An atomic force microscope (AFM) was used to etch the surface of a semiconductor and form a micrometre-sized in-plane-gate (IPG) transistor – a device in which the source, drain and gate of the transistor all lie in a single plane rather than the usual sandwich structure.

First the group formed the semiconductor from layers of GaAs and AlGaAs, finishing with a hard layer of GaAs on top. In the plane between these semiconductor layers, a reservoir of electrons collects. Then, by carefully scratching grooves into the surface of the GaAs with the AFM, conduction channels for the electrons are defined.

The experimenters were also able to monitor the resistance across the etched lines during fabrication, thereby allowing the characteristics of the electronic device to be tuned very accurately.

With a few more scratches (as tunnelling barriers across the conduction channel), the IPG transistor was transformed into a single-electron transistor that (as its name suggests) is capable of registering the movement of single electrons. *AIP*

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DEUTSCHE PHYSIKALISCHE GESELLSCHAFT

Edited by Emma Sanders

Millennium 'delayed' by space mission to Saturn

Hold the champagne! Millennium celebrations throughout the world will be delayed. The culprit is the Cassini–Huygens space mission, which flew by the Earth in August in order to pick up speed for its outward journey to Saturn. The energy gained by Cassini was lost by the Earth, thus slowing down its orbital motion. However, astronomers shouldn't be criticized as party poopers – celebrations will only have to wait an extra million millionth of a second.

Cosmology not constant

A simulation of the evolution of the universe suggests that it is expanding at an accelerating rate. This is more evidence for the existence of Einstein's cosmological constant – a kind of gravitational pressure in space that acts against the attraction due to mass.

Last year the Virgo consortium carried out the largest computer simulation ever, modelling the evolution of some 1 billion particles. The consortium groups astronomers from Canada, Germany, the UK and the US and it is led by Carlos Frenk at Durham University in the UK.

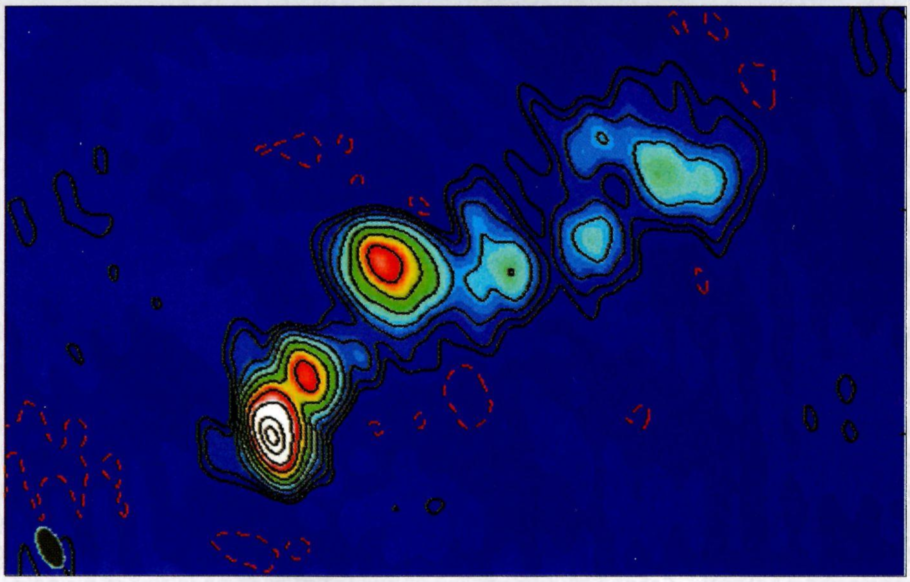
The Durham group has now used the Virgo simulation to explain observations of real galaxies. It used models of galaxy formation together with the distribution of matter predicted by the simulation.

"This is the first time that we have had a theory that matches the observed distribution of clustering", said Frenk. "Its amazing. I couldn't believe it when I first saw it!" However, to get a perfect match, they needed to use a non-zero cosmological constant.

This is not the first time that observations have implied the existence of a cosmological constant. Supernova studies (*CERN Courier* May p9) have also hinted at this and Frenk says that his results are "beautifully consistent". The group is trying to test its result by carrying out an additional simulation in parallel, this time including both dark matter and gas. First indications are in agreement, but there is a greater margin of error.

The Virgo supercomputer simulations were carried out at the Max-Planck centre in Garching, Germany, and the Edinburgh computer centre in the UK.

Picture of the month



This radio map shows the nucleus of the quasar 3C380 (left), with emission from a huge jet 240 light years across blasting out into space to the right. Quasars are galaxies with supermassive black holes at their centre. Radio emission is caused by synchrotron radiation from electrons moving close to the speed of light along the huge magnetic fields produced by the black hole. 3C380 is the first radio source processed with the new European Very Long Baseline Interferometry (VLBI) Network Processor which was commissioned this summer. VLBI observations use up to 16 radiotelescopes simultaneously at different sites around the world. The data are then combined to simulate one enormous telescope, giving the highest resolution available in astronomy. (JIVE.)

FUSE lift-off

A new satellite to explore the ultraviolet universe – the Far Ultraviolet Spectroscopic Explorer (FUSE) – was launched on 24 June. It will investigate the origin and evolution of the lightest elements – hydrogen and deuterium.

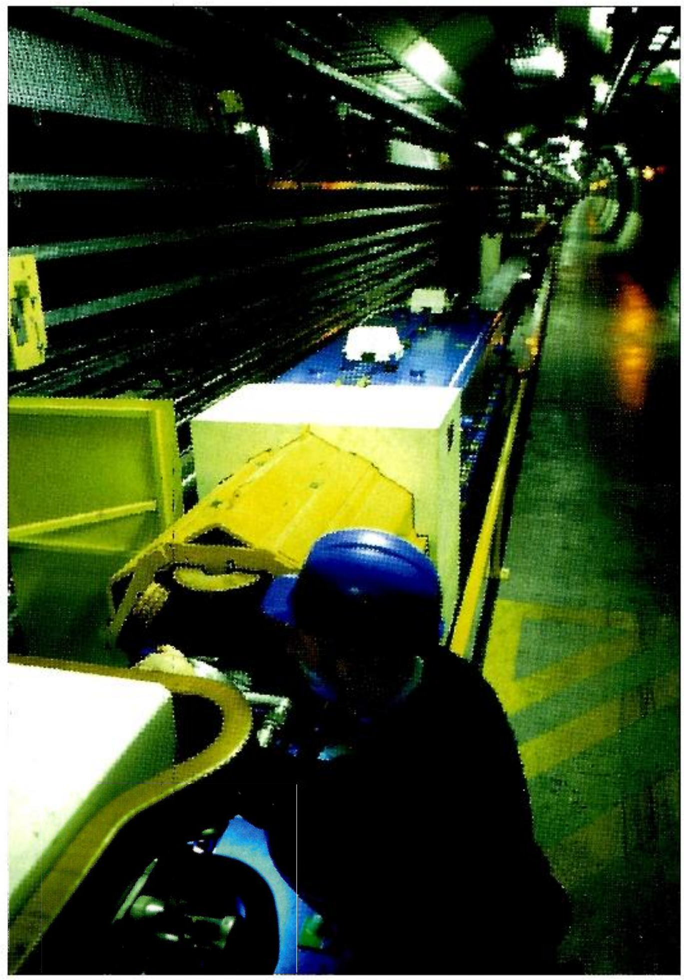
Deuterium is a valuable indicator of what happened in the early universe, because its formation depended on the temperature and density at that time. The amount of deuterium has been decreasing ever since because it is recycled by nuclear fission in stars. A measure of the relative abundance of hydrogen and deuterium can reveal valuable information about the conditions just a few seconds after the Big Bang.

FUSE will also be used to observe the composition of interstellar gas and the chemical evolution of galaxies. The satellite will observe the far-ultraviolet spectrum from 90 to 120 nm with more than 10 000 times the sensitivity previously attainable.

FUSE was built by collaborators in France, Canada and the US and is part of the NASA Origins programme. Future Origins telescopes include the successor to the Hubble – the Next Generation Space Telescope, currently programmed for launch in 2006.

200 GeV achieved for 2000

In the last 10 years electroweak, physics has been transformed from a subtle effect into big science. At the forefront of this effort has been CERN's LEP electron–positron collider, which is now celebrating its tenth birthday.



CERN's LEP electron–positron ring – operating between 45 and 100 GeV per beam.

The news broke in the September issue (p7) that CERN's LEP electron–positron collider was running at 100 GeV per beam (giving a total collision energy of 200 GeV) and giving very stable conditions.

Some 10 years ago, equipped with room temperature copper radiofrequency cavities, LEP began operating at 45 GeV per beam. From 1995, superconducting radiofrequency began to be added and the machine's energy increased initially to 65 GeV per beam, then to 80.5 GeV in 1996 and to 94.5 GeV in 1998.

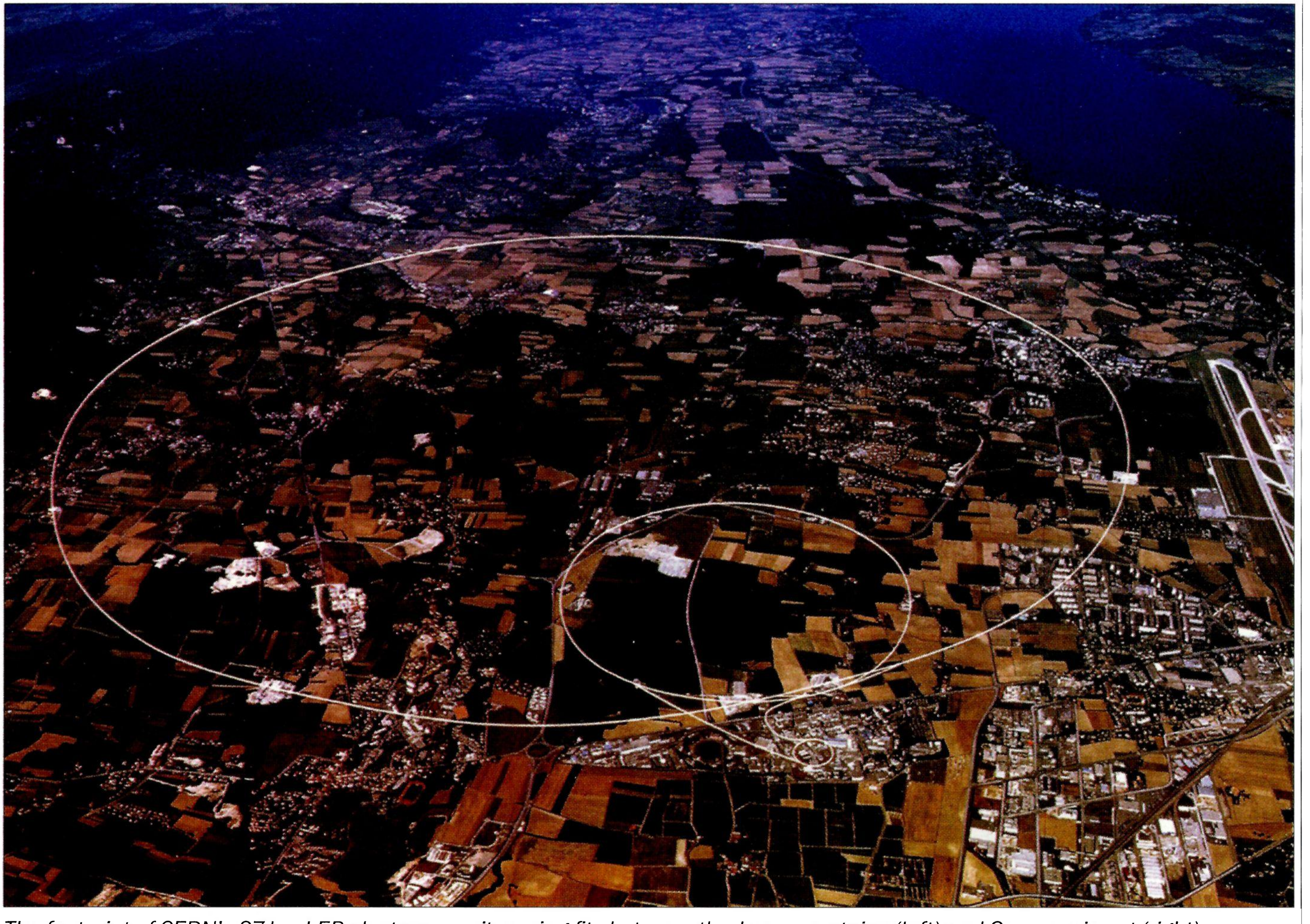
While this dramatic boost in collision energy via superconducting radiofrequency power looks like a latter-day accomplishment, from the very outset LEP was foreseen as being capable of attaining at least 100 GeV beams. The pioneer 1976 study group (which included Burt Richter, visiting CERN from SLAC in Stanford) addressed a machine that was designed to achieve a beam energy of 100 GeV and a luminosity (which is a measure of the particle collision rate) of 10^{32}/sq. cm/s. Electrons are very light particles, so electron rings have to combat losses owing to synchrotron radiation as the beams are bent. To minimize these losses, the LEP circumference was made as large as possible. Therefore the magnets do not have to be very powerful.

Protons, however, do not lose much energy via synchrotron radiation and proton rings can be compact, with powerful magnets to bend the beams. As a result, CERN has its 27 km LEP ring running with electrons and positrons at 100 GeV. However, the protons in the LHC machine, built in the same tunnel, go beyond 8 TeV.

The 1977 LEP study group looked at 100 GeV per beam or more in a 51 km circumference ring, but, because of technical difficulties and the cost, a study for a machine half the size of LEP-100 was prepared. In 1978 the study group produced a 22 km ring design aimed at 70 GeV, and the emerging 1979 design foresaw a 31 km ring with stored beams capable of being taken from an injection level of 22 GeV up to 130 GeV, with an initial operation of 86 GeV. The ring was subsequently trimmed to 27 km and, as approved by CERN Council in 1981, LEP was optimized for a beam energy of 80–100 GeV but with an initial operation phase of up to 55 GeV. The initial LEP study group at CERN was led by Eberhard Keil, Wolfgang Schnell and Kees Zilverschoon. Emilio Picasso became project director in 1981.

LEP's initial physics goal was to find and make precision measurements of the Z, which is the neutral carrier of the weak interaction. Using the freshly minted electroweak model, other experiments in the late 1970s and early 1980s began to hint that the mass of the Z and its electrically charged W companion were around 100 GeV.

Synthesizing the Z in electron–positron annihilations would need only 50 GeV per beam, but the W, which has to be produced in


The footprint of CERN's 27 km LEP electron–positron ring fits between the Jura mountains (left) and Geneva airport (right).

oppositely charged pairs, would need twice as much beam energy. Thus LEP had to be capable of producing W pairs.

However, by the time the final LEP design report had been formulated in 1984, the W and the Z had been discovered at CERN's proton–antiproton collider with masses of around 80 and 90 GeV respectively. The lattice of magnets, which hold LEP's electrons and positrons on track, was optimized for the 80–100 GeV beam energy range.

Although the Z had been found, LEP still had the formidable task of making precision measurements of this particle. An electron ring that is optimized for running at around 80 GeV per beam is not unduly taxed when running at 45 GeV per beam to produce Z particles. From 1989 to 1995 the four LEP experiments amassed between them some 20 million Zs.

Meanwhile, work had been under way to ensure that the superconducting radiofrequency power would be available for the higher-energy LEP beams – the R&D programme had begun even before LEP had been formally approved. With sufficient superconducting accelerating power on board, the four LEP experiments began logging the production of W pairs in 1996, and this physics too became the subject of precision study.

As these electroweak data began to pile up, another physics horizon beckoned. At the heart of the electroweak model is the mysterious Higgs mechanism, which endows the vacuum with a preferred direction. Higgs particles have to be present to make the electroweak theory tick, but the theory can predict very little about them.

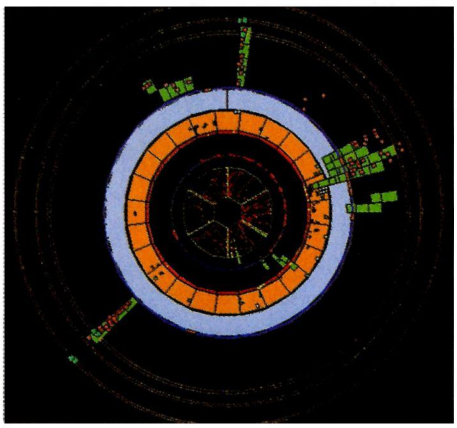
No explicit sign of Higgs particles had turned up by the time the W pair threshold had been reached at 80.5 GeV per beam. However, physicists had another lever to prise open the Higgs door. The inter-consistency of the accumulated electroweak data limits where the Higgs particles can be, even if the particles are as yet invisible. In the same way that parallax measurements from two telescopes give a better fix on a distant star than can be achieved by a single sighting, electroweak measurements from different sectors give a sharper picture with less room for the Higgs to maneouvre.

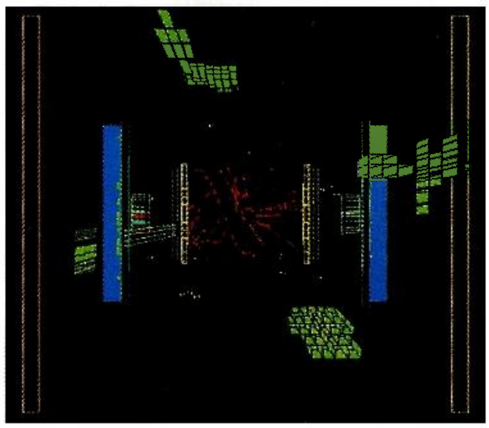
With the electroweak prize at stake, LEP's beam energy was pushed beyond the W pair threshold from 1998. When the beam energy is increased from 80 to 100 GeV, the electrons and positrons lose 2.44 times as much energy via synchrotron radiation and these losses have to be compensated for by superconducting power.

That this can be achieved is the ultimate success of LEP's superconducting radiofrequency programme and its attendant cryogenics. The continually increasing collision rate (luminosity) at these higher energies reflects the foresight of the LEP machine designers, who ensured that the ring had all of the necessary beam-handling power right from the beginning. The trick was to allow for flexible phase advance, which focused the beams more tightly as the energy increased, to combat their natural tendency to increase in size. □

From Z to ZZ – a decade of electroweak precision

After having carefully amassed some 18 million Z particles one by one over 10 years, the experiments at CERN's LEP electron-positron collider are now producing Zs in pairs.





Exactly 10 years ago, experiments at CERN's LEP electron–positron collider saw their first Z particles. Now, with its energy increased from 45 to 100 GeV per beam, LEP can produce pairs of Zs. In the event shown here from the DELPHI detector, the first picture shows energetic muons (the green squares are muon signals) and the second shows the showers (jets) produced by a quark pair.

The Z pairs are the latest addition to a physics gallery that was opened 21 years ago when an experiment using a polarized electron beam at SLAC, Stanford, provided the first firm evidence that nature included a synthesis of weak and electromagnetic interactions.

This landmark experiment succeeded in measuring the delicate interference effects between processes mediated by electromagnetic photons and those mediated by the Z (the electrically neutral carrier of the weak force). Soon after, Abdus Salam, one of the architects of the unified picture, coined the term "electroweak".

Five years on, at CERN's proton-antiproton collider, the Z came out into the open. In 1989, CERN's new LEP electron-positron collider and the SLC linear collider at SLAC were being commissioned and the stage was set for a new kind of physics - precision studies of the electroweak interaction using Z particles.

At the 1989 Lepton-Photon Symposium at Stanford, SLC physicists reported finding 233 Zs. LEP reported 10 000 Zs in October.

A decade later, this year's lepton-photon meeting returned to Stanford (p6). Morris Swartz of Johns Hopkins, who reported on precision electroweak physics with Z particles, had 18 million Zs to draw on, amassed, mainly, by the four LEP experiments from 1989 to 1995, before LEP's energy was increased. The SLC went out in a blaze of glory last year (*CERN Courier* October 1998 p29) and, with LEP exploring pastures new, these 18 million events will probably remain the bulk of the world's Z physics archive for some time.

From the Z discovery in 1983 until the advent of LEP and the SLC in 1989, colliders at CERN and Fermilab enjoyed a monopoly on Z physics. This monopoly continued for the W, the electrically charged counterpart of the Z, until 1996, when LEP's energy was increased sufficiently for experiments to record their first W pairs.

At Stanford this year, David Charlton of Birmingham reported on electroweak physics from LEP2 (LEP operating at or beyond the threshold for producing W pairs). The W mass fix from LEP is 80.35 ± 0.056 GeV, which is now more accurate than the Fermilab Tevatron fix and reflects the shifting focus of W physics. Even greater accuracy is obtained via indirect measurements from the latest round of neutrino experiments at Fermilab.

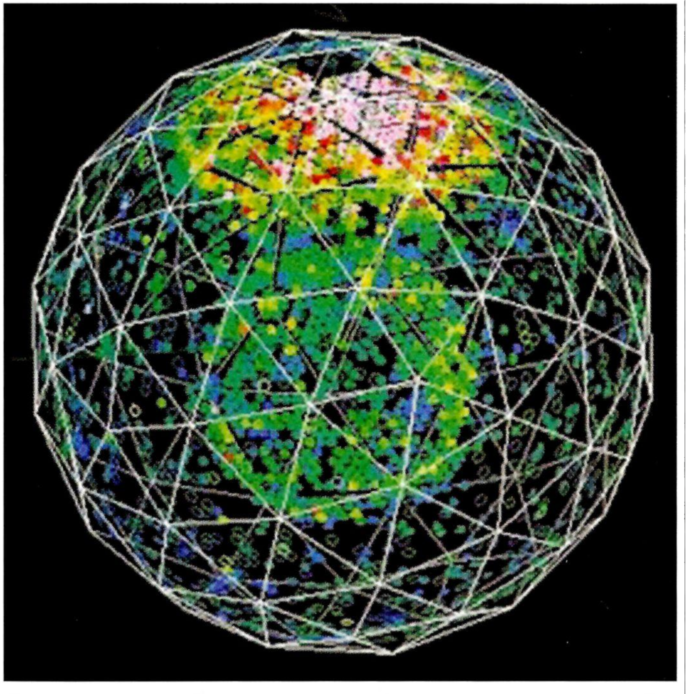
Using this and other input, electroweak consistency arguments strongly hint that the mass of the Higgs particle, which is responsible for the subtle symmetry-breaking mechanism at the heart of the electroweak mechanism, is lighter than 300 GeV.

At its new energies, LEP is able to probe the interaction of electroweak carriers among themselves, for example via WWZ and WW-photon mechanisms. (A fuller report of LEP2 physics achievements will be published shortly.)

Fermilab's Tevatron proton-antiproton collider still enjoys exclusive coverage of the sixth top quark, which was discovered in 1995. The latest mass fix, reported at Stanford by Mark Lancaster of Berkeley, is centred at 174.3 GeV. Electron-positron machines cannot see the top quark directly, but can infer its presence indirectly. The LEP electroweak consistency fit gives a compatible top quark mass.

After 10 years of precision electroweak physics, the Higgs particle now looms large. However, with LEP's radiofrequency powerhouse working at full stretch, there is still a chance that LEP could deliver the Higgs before the machine is finally switched off next autumn. □

Neutrino physics gains weight



The Sudbury Neutrino Observatory in Canada has produced its first images of neutrino interactions in its 1000 tonnes of heavy water. The data from this new type of neutrino detector could help to pin down the properties of solar neutrinos.

Neutrinos are always compelling physics. The neutrino sessions at this year's International Lepton–Photon Symposium at Stanford gave an up-to-date snapshot.

Neutrinos, which interact only via the weak force, may be the purest form of lepton and deserved to be in the spotlight at the International Lepton–Photon Symposium at Stanford (p6). Neutrino physics questions are frequently unresolved and are even controversial, like Pauli's prediction of a particle that hardly interacts at all. Neutrino physics has lived up to this reputation ever since.

Last year, data on neutrinos generated by cosmic-ray collisions in the atmosphere ushered out the old orthodox view that neutrinos are massless particles. Endowed with mass, the three kinds of neutrinos – electron, muon and tau – are not immutable and can "oscillate" from one kind of neutrino to another. This year the neutrino results presented at the International Lepton–Photon Symposium showed that this view has now firmly taken root.

The 1998 paradigm shift was the outcome of the release of initial data from the 50 000 tonne Super-Kamiokande underground neutrino detector in Japan. The effect – a deficit of muon neutrinos – measured by the Super-Kamiokande detector had been known since the early 1980s from smaller experiments. However, the Super-K signal inspired physicists with new 50 000-tonne confidence. One year down the line this confidence seems complete.

Atmospheric neutrinos are not alone in oscillating. The dearth of neutrinos from the Sun – an effect known for 30 years – was initially attributed to the innate difficulties of neutrino experiments and of estimating the radiative neutrino power of the Sun rather than the neutrinos themselves.

In his presentation, Yoichiro Suzuki of Tokyo asked why solar neutrino experiments, which were the first to detect neutrino deficits, had not claimed the discovery of neutrino oscillations. The reasons, observed Suzuki, were the uncertainty of gauging the solar neutrino flux and the difficulty in providing a unique oscillation solution.

Flux-independent indicators, such as a systematic difference between the daytime and night-time signal and a spectrum revealing the way that neutrino behaviour changes with energy, would provide a more reliable indication. However, these were not forthcoming from the pioneer experiments.

Super-K has amassed 825 days of logged solar neutrino data, and the day–night rates differ by 6.5% (albeit with an error of almost 50%) – a possible indication of solar neutrino effects owing to neutrino transitions occurring while they pass through the Earth. The energy spectrum does not look flat.

The Sudbury Neutrino Observatory in Canada will soon provide valuable new data on additional reactions of solar neutrinos via the neutral as well as the charged current of weak interactions.

At Stanford, Tony Mann of Tufts covered the atmospheric neutrino sector – centre stage since the Super-K results of 1998. As well as the Super-K water Cherenkov detector, the Soudan II sampling calorimeter in the US and the Macro muon detector in the Italian Gran Sasso laboratory are also adding their weight.

The angular distribution of Super-K signals, originally displayed in only five angular bins – now extended to ten – clearly show the sharp deficit of muon neutrinos travelling upwards, after having passed through the Earth before hitting the detector.

Neutrino oscillation looks likes it's here to stay, but the nature and parameters of the oscillations have yet to be determined. Studies using neutrinos from reactors and from accelerators are playing a key role. At Stanford, Luigi Di Lella of CERN was the reviewer.

The Chooz (pronounced "Shaw") reactor experiment in France provided key results that limited the possibilities for the disappearance of electron-type neutrinos over a 1 km flight path from the reactor to the detector. The Chooz experiment has now completed its mission but another, at Palo Verde in the US, continues to take data.

As for neutrino experiments at accelerators, a long-standing feature has been results from the LSND study at Los Alamos and the Karmen detector at the UK Rutherford Appleton Laboratory on the appearance, or otherwise, of (anti)electrons from a beam of muon (anti)neutrinos. The former "sees" a signal, the latter does not, but the two results are not entirely incompatible – the regions accessed by the two experiments (and others) do not coincide totally. Thus, the oscillation signal suggested by LSND cannot be ruled out. Making this effect consistent with the rest of the neutrino data is highly constraining, according to Hamish Robertson of Washington in his subsequent review of neutrino mass and oscillations.

A feature of current neutrino dogma is that the bizarre "sterile" neutrinos, which do not react, could sap the power of other neutrino beams as their non-sterile particles oscillate out of sight. Some physicists are openly sceptical of the LSND result. Di Lella dutifully surveyed the experiment's track record but found no cracks.

Chorus and Nomad at CERN had set out to see the production of tau neutrinos from an accelerator-produced beam mainly composed of muon neutrinos. Both studies have completed data taking, although Chorus has not yet analysed all of the interaction triggers in its emulsion target. With no tau production yet seen, the contours showing the limits on neutrino mass difference and mixing parameters can be extended substantially.

A major new player on the neutrino scene will be the MiniBoone experiment, which uses a beam derived from the Fermilab booster. This should definitively confirm or refute the LSND result.

To explore the remaining allowed oscillation territory, the emphasis also turns to "long baseline" experiments in which neutrino beams from accelerators travel over several hundred kilometres before reaching the main neutrino target.

The K2K experiment using beams from the Japanese KEK laboratory and the Super-K detector has now started (p5), while the MINOS study (p6) will cover a longer baseline and use higher-energy particles. The KAMLAND experiment in Japan (*CERN Courier* April p22) will look for interactions from neutrinos emitted by nuclear reactors more than 100 km away.

With questions unanswered and several projects under way, with more at proposal stage, and the fact that the implications of the results are of importance for our understanding of the universe, neutrino physics will maintain interest well into the next century. □

A good BaBar gain

The dedication of the BaBar detector for the recently commissioned PEP-II B factory at SLAC, Stanford, showed the increased international aspect of US particle physics.

The BaBar experiment represents "a new mode of US experimentation", said Stanford Linear Accelerator Center (SLAC) director Burt Richter at the experiment's formal dedication on 13 August. BaBar is the detector at the heart of the recently commissioned PEP-II B factory at SLAC, Stanford. Some 50% of the physicist participation and 40% of the hardware value come from outside the US.

Physicists habitually use an overstrike to denote an antiparticle. They talk about "p-bars" instead of antiprotons, and "B-bar" as the antiparticle of a B meson – hence BaBar, better known in certain circles as the friendly elephant in the stories by Jean de Brunhoff.

SLAC research director David Leith explained that BaBar is highly "non-SLACentric", with a spokesman (David Hitlin of Caltech) who is elected rather than appointed. "We went to school at CERN to learn how to manage large international projects," explained Leith.

SLAC, which was established to exploit the 2 mile linear electron accelerator, is no stranger to major projects. However, the more than 600 strong BaBar collaboration is the largest research group that SLAC has ever seen, with physicists from Canada, China, France, Germany, Italy, Norway, Russia and the UK, as well as the US.

The keynote speaker was director of the US Department of Energy's Office of Research, Martha Krebs, who underlined the role of PEP-II and BaBar in current US particle physics research. After the demise of the superconducting supercollider in 1993, a "future visions" panel, chaired by Sid Drell of SLAC, foresaw a US programme with significant US participation in the LHC collider at CERN. Also included was the SLAC B factory, initially green-lighted in the same wave of legislation that swamped the SSC.

Krebs went on to point out that no fewer than 8 of the 10 DOE labs in her portfolio had appointed new directors. She called for leadership during a difficult transition period.

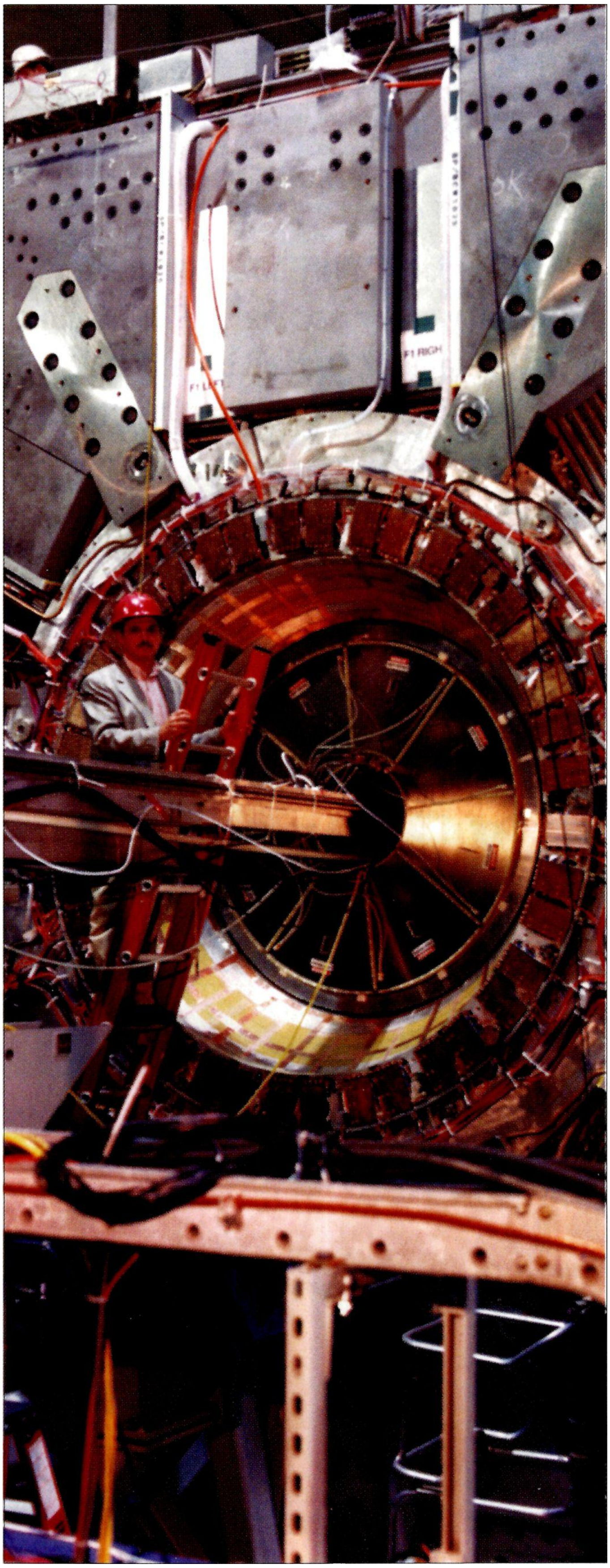
In a recent hiccup, a US Senate subcommittee explicitly recommended a reduction in research and development spending for the Next Linear Collider (NLC), an electron–positron machine being touted around the Pacific Rim to attack the next energy frontier. While physicists are gung-ho about the need for such electron–positron machines to explore fully the immediate energy frontier, the move is redolent of the early 1990s disfavour in certain political quarters that eventually torpedoed the SSC. "In staying at the energy frontier," said Krebs, "we cannot count on an orderly progression."

"They are not as ready to proceed with the NLC as we are," commented Richter, who stepped down as SLAC director at the end of August. He is succeeded by Jonathan Dorfan, formerly SLAC associate director and head of the PEP-II B factory project. Richter becomes chairman of the International Union of Pure and Applied Physics. Krebs paid tribute to Richter's exemplary role as a leader, both at SLAC and for the community.

The BaBar dedication fitted nicely into the programme for the International Lepton–Photon Symposium at Stanford (p6). □

The keynote speaker at the formal dedication of the BaBar experiment at the recently commissioned PEP-II B factory at SLAC, Stanford, on 13 August was director of the US Department of Energy's Office of Research, Martha Krebs. (Diana Rogers, SLAC.)

The podium at the BaBar dedication ceremony, with experiment spokesman David Hitlin at the microphone. At the event, everyone sported a BaBar baseball cap.



The BaBar detector at the heart of the PEP-II B factory at SLAC, Stanford.

Physicists focus on quest for Bs

The physics of B particles is a major new focus of world particle physics research. A session at the recent lepton-photon symposium provided a useful overview.

Both SLAC in Stanford and the Japanese KEK Laboratory are beginning physics research with new B factories. The electron-positron annihilations in these colliders are a copious source of B particles, so called because they contain the fifth "beauty", "bottom" or simply "b" quark. The decays of these B particles are expected to reveal new information about CP violation – the subtle symmetry breaking widely thought to be responsible for a Big Bang that was matter-antimatter symmetric, which eventually produced a visible universe composed entirely of matter.

The factories – PEP-II at SLAC and KEKB at KEK – use the BaBar and BELLE detectors respectively to study the decays of B particles.

This new effort for B physics was an overture for the International Lepton-Photon Symposium in Stanford (p6). Jonathan Dorfan, then SLAC director designate, described the PEP-II and BaBar programme. Fumihiko Takasaki of KEK described KEKB and BELLE.

However, there are other B physics players. Klaus Honscheid of Ohio State covered the programme at Cornell's CESR electron-positron collider equipped with the CLEO detector. CESR – whose collision rate has continually been boosted – and CLEO – now undergoing its third major facelift – have been working in tandem for some 20 years and have made pioneer contributions to B physics.

Warming up on the B touchline is the HERA-B experiment at DESY using the proton ring of the HERA collider. Michael Medinnis of DESY-Zeuthen outlined the detector effort under way en route to scheduled completion next year.

Manfred Paulini of Berkeley sketched the B physics potential of the big CDF and D0 detectors at Fermilab's Tevatron proton-antiproton collider, now fed by the new Main Injector. Also from next year, detector upgrades and collision rate improvements are set to ensure that the Tevatron remains a focus of B physics.

Major contributions also come from LEP at CERN. Not described in the Lepton-Photon Symposium presentations but gearing up for longer-term contributions are the LHCb experiment at CERN's LHC collider and the BTeV project at Fermilab. □

Hands off

The International Committee for Future Accelerators (ICFA) is a platform for the world particle physics community, particularly where international collaboration on major machine projects is concerned. In the aftermath of a recent US Senate recommendation (p21) to reduce funding on the Next Linear Collider (NLC) – an electron–positron machine to attack the next energy frontier – the ICFA issued the following statement after its meeting during the International Lepton–Photon Symposium at Stanford (p6):

"Scientific panels charged with studying future directions for particle physics in Europe, Japan and the US have concluded that there would be compelling and unique scientific possibilities at a linear electron–positron collider in the TeV energy range. Such a facility is a necessary complement to the LHC hadron collider, now under construction at CERN. Experimental results over the last decade from the LEP and SLC electron–positron colliders, combined with those from the Tevatron – a hadron collider – have led to this worldwide consensus.

"The latest experimental results point ever more clearly to the conclusion that there is fundamentally new physics in the energy range just out of reach of existing colliders. At the very least we will find one or more Higgs scalar bosons or other structure that has the same effect as a Higgs boson. To explore and characterize fully the new physics that must exist will require the LHC plus an electron–positron collider with energy in the TeV range. Just as our present understanding of physics at the highest energy depends critically on combining results from LEP, the SLC and the Tevatron, a full understanding of new physics seen in the future will require both types of high-energy probes.

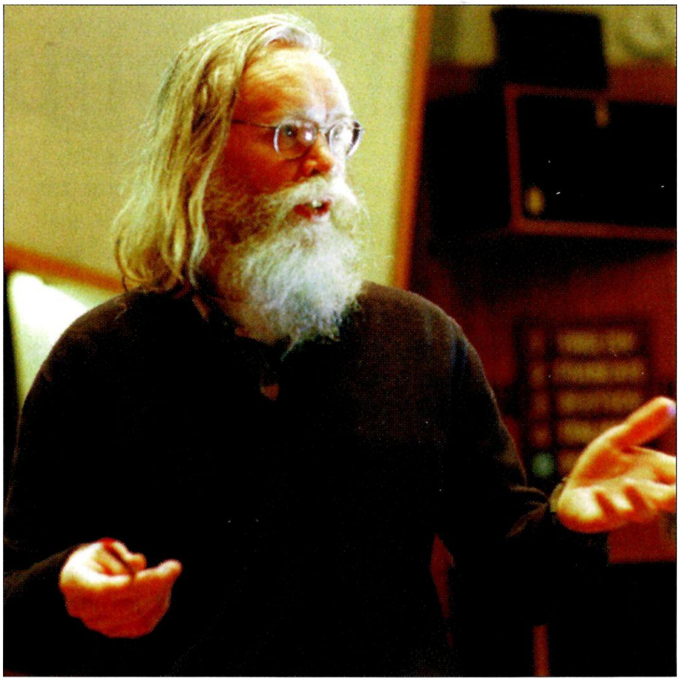
"Major laboratories around the world are presently conducting accelerator research and development that will lead to detailed designs of a linear electron collider capable of reaching this energy range. The technology being developed for this purpose will also have applications in other areas of science and technology through new generations of intense light sources. A worldwide group is studying the physics at an electron–positron collider and the detectors needed to observe that physics.

"ICFA recommends continued vigorous pursuit of the accelerator research and development on a linear collider in the TeV range, with the goal of having designs complete, with the most reliable cost estimates, in a few years. We believe that an electron collider optimized for the new physics should be built in a timely way with international participation."

ICFA is a working subcommittee of the International Union of Pure and Applied Physics.

Why does CP violation

The seemingly obscure phenomenon of CP violation is increasingly being viewed as the key to a deeper understanding of both the behaviour of elementary particles and the Big Bang origin of the universe. Here, *John Ellis* of CERN explains how far and how deep the implications of CP violation extend.



Exploring the untracked expanses of the cosmos and the microworld – eminent CERN theorist John Ellis.

The visible universe is composed of matter particles – protons, neutrons and electrons – rather than their antimatter partners – antiprotons, antineutrons and positrons. If the Moon were composed of antimatter, then lunar probes and astronauts would have vanished in a fireball of energy as soon as they touched the lunar surface. The solar wind and cosmic rays do not destroy us, implying that the Sun and the Milky Way are also made of matter.

If there were any region of antimatter within our local cluster of galaxies, we would be able to see radiation from matter-antimatter annihilations at the boundaries. Moreover, the cosmic microwave background radiation shows no signs of disturbance by subsequent annihilation radiation, suggesting that there are no large regions of antimatter within at least 10 billion light years – and perhaps the whole visible universe.

The Big Bang should have created equal amounts of matter and antimatter. Why is there now so much of one and so little of the other? CP violation – an obscure effect seen only with certain kinds of elementary particles – could provide the answer.

Enter CP violation

A recent article by Gerry Bauer ("In hot pursuit of CP violation" *CERN Courier* June p22) set the CP violation scene. In 1964, James Cronin, Val Fitch and collaborators discovered that the decays of neutral kaons did not respect the symmetry known as CP – the combination of particle-antiparticle (charge conjugation – C) and mirror (parity – P) symmetry.

It had been known since 1957 that weak interactions violate both the C and P symmetries – neutrinos spin left-handedly, whereas their antiparticles (antineutrinos) exist only in right-handed form. Despite this maximal violation of C and P, it had been thought that they were always violated together so as to respect the combination CP.

However, the Cronin-Fitch experiment showed that this could not be exactly true. What is the connection between this abtruse property of elementary particles and the matter dominance of the universe? A possible answer was provided by Andrei Sakharov in 1967. He laid out three conditions that would enable a universe containing initially equal amounts of matter and antimatter to evolve into a matter-dominated universe, which we see today.

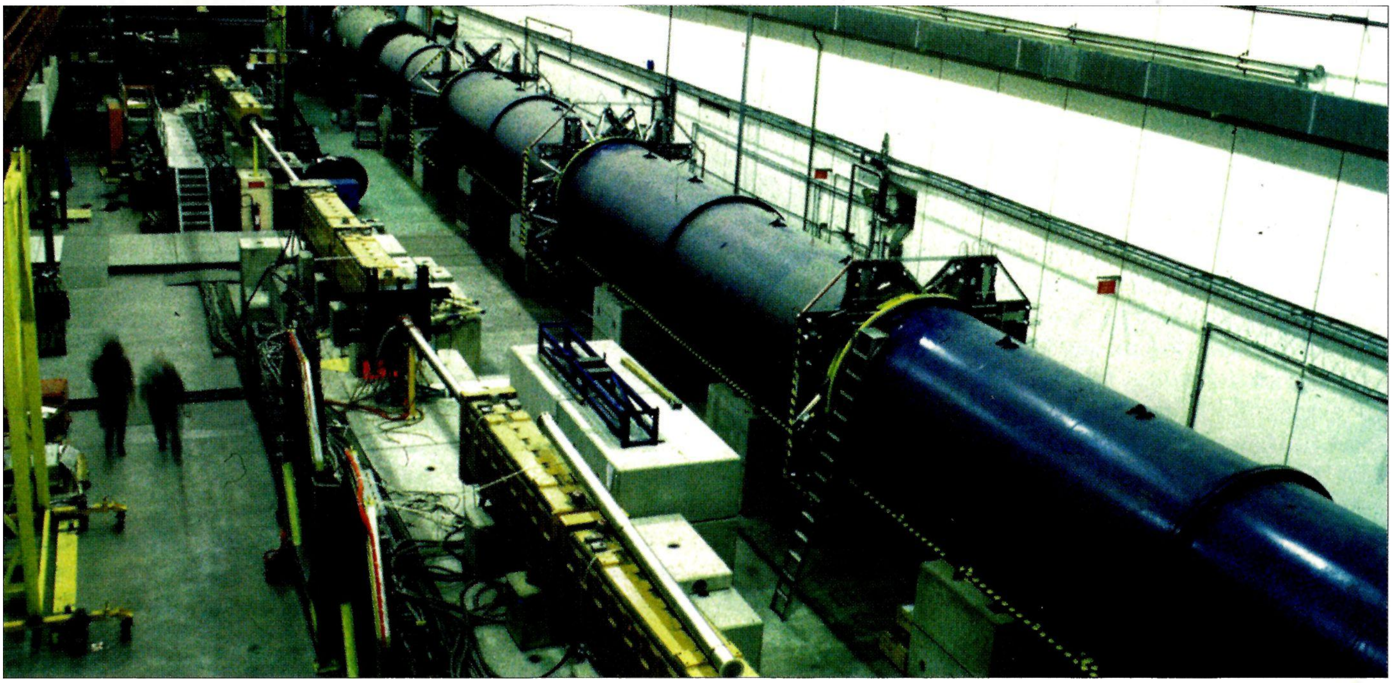
The first requirement was that the proton – the bedrock particle of nuclear matter – should be unstable. The second was that there would be interactions violating C and CP, as shown by Cronin and Fitch, that would open up the possibility that the universe's initial exact matter-antimatter symmetry could be upset. The third condition was that the universe would undergo a phase of extremely rapid expansion: otherwise, matter and antimatter particles, having equal masses, would be fated to pair up with equal densities.

If a cosmological matter-antimatter asymmetry could be built up in this way, all of the remaining antimatter particles would annihilate later in the history of the universe, leaving behind matter particles and radiation, as observed today.

Sakharov's landmark paper provided the conceptual framework for generating a matter universe, but it has fallen to subsequent generations of physicists to explore specific mechanisms realizing his ideas, opening up some possibilities and excluding others. Key roles in this exploration are being played by recent experimental results from CERN and Fermilab, and new data from SLAC, KEK, Cornell, DESY and Frascati may soon be making important contributions.

The favoured theoretical framework for CP violation was provided

matter to the universe?



The kaon decay channel of the NA48 experiment at CERN – the latest study to provide a precision measurement of CP violation.

in 1973 by Kobayashi and Maskawa, who pointed out that CP violation would follow automatically if there were at least six quark flavours. Measurements in the neutral-kaon system and elsewhere are all consistent with this being the only source of CP violation, although they leave room for other sources, which inventive theorists continually propose.

GUT feeling

Also in 1973, Pati and Salam, and Georgi and Glashow, proposed grand unified theories (GUTs) containing new interactions that allowed for proton decay. Such decay would violate the conservation of baryon number – the total number of strongly interacting particles minus the number of antiparticles. So far, dedicated searches in such large underground detectors as Super-Kamiokande have not seen any evidence for this. However, the evidence that they have found for neutrino masses suggests that interactions that violate lepton number (the total number of weakly interacting particles minus the number of antiparticles) do exist. This is another key prediction of many GUTs, and may even play a role in generating the matter in the universe, as discussed later.

In 1978, CP violation and GUTs were combined by Yoshimura in a proposal for generating the matter asymmetry of the universe via the decays of massive particles. His idea was that, if they produced a CP-violating excess of quarks in their decays, this would evolve into the matter that we see in the universe today. Unfortunately, it was soon realized that the minimal GUTs originally proposed would yield too small an excess of quarks, so the GUT would need to be expanded to produce the amount of matter particles that are observed in the universe today: 10^{-9} of the number of photons.

It was suggested that the extra CP violation required might also generate a neutron electric dipole moment large enough to be detected. (Although a neutral particle, the neutron could contain an asymmetric distribution of equal and opposite positive and negative charge.) However, a long experimental campaign currently led by an experiment at ILL Grenoble limits this to less than 6×10^{-26} e cm, analogous to the Earth's surface being smooth and symmetric to less than 1 μm.

By then, theorists had developed new ideas. One idea was that the strong interactions might also violate CP. The fact that this has not been seen led to the postulation of the axion, which might be a component of the universe's dark matter.

Weak washout

The other surprise was that electroweak interactions could also change baryon number. This does not happen via the exchange of a specific particle. Instead it arises from coherent fields with non-trivial topological properties. These non-perturbative electroweak interactions provide both a challenge and an opportunity. The challenge is that they might "wash out" any matter density that is built up by GUT particles. The opportunity is that they might enable the matter density to be built up by the electroweak interactions alone.

One way to avoid the weak washout is to have the GUTs generate a net density of leptons, which the additional weak interactions would then recycle into baryons. One such scenario, proposed by Fukugita and Yanagida, relies on the decays of heavy right-handed neutrinos in the early universe. Some indirect support for this scenario comes from recent experimental hints that the known light neutrinos can mix (oscillate) and have masses, which could be due to mixing with such heavy neutrinos. At least some neutrino models that fit the neutrino data are also able to generate the matter in the universe. Another weighty implication of the new neutrino data?

As a GUTless alternative, perhaps the matter in the universe was generated when the cooling of the universe triggered a phase transition enabling quarks and the W and Z carriers of the weak force to acquire their masses from the Higgs boson? This electroweak mechanism would require the phase transition from a hot universe with massless particles to the present state with massive particles to have been abrupt, so as to meet Sakharov's third requirement.

Unfortunately, the Higgs boson has not yet shown up at CERN's LEP electron–positron collider, implying that it weighs more than about 100 GeV and that the electroweak phase transition was too weak to allow the matter of the universe to be generated this way.

However, the door is not yet closed. For example, a supersymmetric scenario, with new "sparticles" partnering the known particles, might provide a suitable abrupt transition, and also contain additional CP-violating effects that could generate a suitable matter density. These supersymmetric options suggest that LEP, which is now operating at higher energy, might produce a Higgs boson this year or the next. If LEP is lucky, this could also have weighty implications for the universe.

CP in the laboratory

One of the great attractions of such GUTless models is the possibility that they could be tested in laboratory experiments on CP violation. This exciting prospect has been underlined by the recent confirmation, by the KTeV experiment at Fermilab and by NA48 at CERN, of direct CP violation – the decay of neutral kaons into two pions – first measured by the NA31 experiment at CERN . The magnitude of the effect is surprisingly large.

Another possible observation of CP violation has recently been reported by the CDF collaboration at Fermilab in the decays of neutral B particles, each giving a J/psi and a neutral kaon. A large effect is expected in the Standard Model, and this is the most likely interpretation of the CDF data, although a null result cannot yet be excluded completely.

CP violation in the decays of B mesons is the primary objective of the experiments BaBar and BELLE at the B factories, which are starting to take data at SLAC in Stanford and KEK in Japan. Their first task will be to seek confirmation of CP violation in the reaction probed by CDF and to search for CP violation in the decays of neutral Bs into pion pairs.

Also in the hunt will be HERA-B at DESY, the revamped CLEO detector at Cornell and experiments at Fermilab's Tevatron collider. Even if these experiments turn out to agree with the orthodoxy of the Standard Model, there is scope for follow-on experiments that might be sensitive to subtle effects indicating new physics that might be related to a mechanism for generating the matter in the universe.

One such experiment is LHCb, which is scheduled to start taking data at CERN's LHC collider in 2005. BTeV, another next-generation B experiment, is under consideration for the Tevatron. There are plenty of other opportunities for future experiments to probe CP violation and cast light on the origin of the matter in the universe. One is provided by rare neutral kaon decays, for example, producing a neutral pion together with a neutrino and an antineutrino or an electron–positron pair. The measurements of direct CP violation in decays into two pions leave room for large supersymmetric contributions to CP violation, which could cast light on supersymmetric scenarios for the origin of matter.

CP violation provides a uniquely subtle link between inner space, as explored by experiments in the laboratory, and outer space, as explored by telescopes measuring the density of matter in the universe.

Another opportunity is the continued search for the neutron electric dipole moment, which might be able to reach the sensitivity required to test GUT models for the origin of matter.

Future violations

In the longer term, there are enticing opportunities to search for CP violation in neutrino oscillations, which could explore aspects of the models based on the decays of heavy neutrinos. Studies are under way on "neutrino factories" based on the decays of muons in storage rings (*CERN Courier* July p22). These provide well defined neutrino and antineutrino beams with both electron and muon flavours, which provide opportunities to search for CP-violating effects in the oscillations of neutrinos and antineutrinos. Looking further ahead, if the problems of controlling the muon beams can be solved, muon colliders could study Higgs bosons in unparalleled detail.

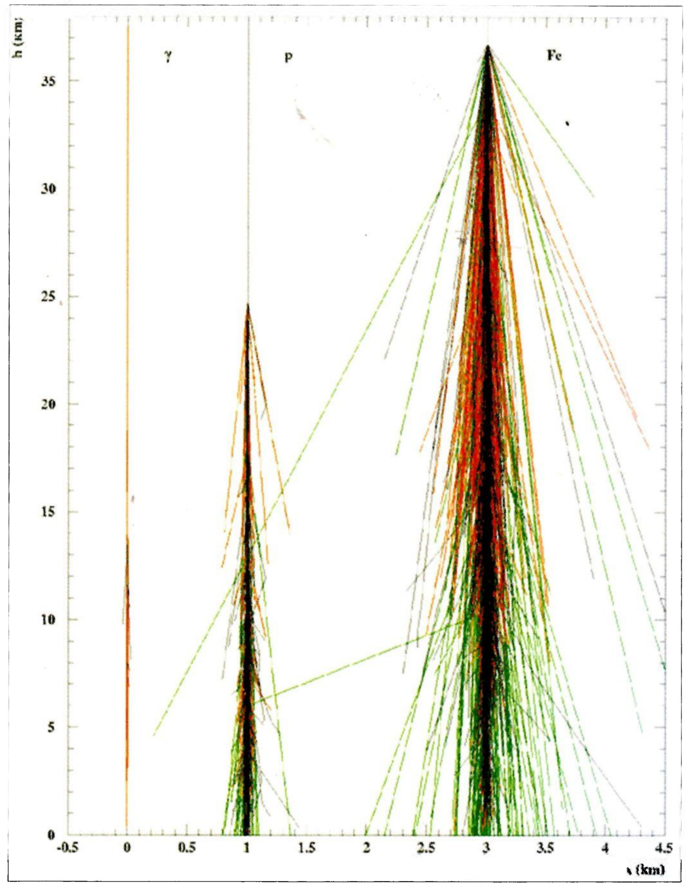
Supersymmetric models capable of generating matter in the universe raise the possibility that the decays of Higgs bosons might reveal novel violations of CP symmetry.

CP violation provides a uniquely subtle link between inner space, as explored by experiments in the laboratory, and outer space, as explored by telescopes measuring the density of matter in the universe.

I am sure that this dialogue between theory, experiment and cosmology will culminate in a theory of the origin of the matter in the universe, based on the far-reaching ideas proposed by Sakharov in 1967. This would be an achievement comparable in significance to the emerging theory of the formation of structure in the universe, based on inflation and dark matter. Microphysics and macrophysics are now yoked together, pulling scientific explorers across the untracked expanses of the cosmos.

John Ellis, *CERN.*

Looking at cosmic rays with accelerator detectors



Simulation of the atmospheric showers produced by a 100 TeV cosmic iron nucleus (right), a proton (centre) and a gamma ray (left). Red denotes electromagnetic particles above 10 GeV, green denotes muons above 10 GeV and black denotes hadrons above 10 GeV.

Large detectors constructed at accelerator labs can also be used in parallel for cosmic-ray studies. Effects measured in distant detectors could be correlated to provide a broader view of particles from the cosmos.

When CERN came into being in the early 1950s, a sea change was taking place in particle physics research. Until then, cosmic rays had provided most of the basic particle physics discoveries. Accelerators made their first contributions at Berkeley in 1949, with the Chicago and Carnegie synchrocyclotrons not far behind. In 1953, the Cosmotron, so named because it was the first accelerator to attain cosmic-ray energies, began operation at Brookhaven and provided physicists with the first laboratory-made strange particles.

At the Bagnères conference in 1953, leading cosmic-ray physicist Cecil Powell, who had been awarded the 1950 Nobel Prize for his 1947 discovery of the pion, said: "We have been invaded. The accelerators are here."

Although many of CERN's first-generation physicists cut their research teeth on cosmic rays, for more than 40 years CERN went about building and exploiting its large accelerators, and cosmic-ray physics took a back seat.

With cosmic rays reporting particles beyond 10^{20} eV – thousands of times as high as the highest laboratory energies now available – particle physicists are rediscovering the attractions of natural sources of high-energy particles. While these natural sources provide energies far beyond those that will be opened up by the next generation of particle colliders, the event rates are puny in comparison.

Cosmic-ray revival

There are two primary motivations for this cosmic-ray revival. First, dramatic results from the Super-Kamiokande underground experiment in Japan, studying neutrinos produced by cosmic-ray collisions in the atmosphere, strongly suggest that the different kinds of neutrinos transform into each other – or "oscillate". To exploit these neutrino possibilities fully requires accurate knowledge of the cosmic-ray muon spectrum. With existing data samples mutually disagreeing by 20–30%, more accurate data are called for.

Second, direct measurements of primary cosmic rays of energies of greater than 10^{14} eV (100 TeV) are impractical. For example, above 10^{16} eV there is only one particle per square metre per steradian per year. However, the primary cosmic-energy spectrum extends beyond 10^{20} eV and there is great interest in the composition, the energy spectrum and the interaction of the primary cosmic rays with nuclei in the upper atmosphere. Knowledge of the cosmic-particle composition above the "knee" (a few times 10^{15} eV) could shed light on how particles are accelerated to such high energies.

From ground-based observations of different particles (in extensive air showers) and from studies of atmospheric scintillation and Cherenkov light, the cosmic-ray community has learned a lot, but many mysteries and uncertainties remain. Even with good data, it is difficult to determine simultaneously a unique primary composition and interaction model.

The cosmic-ray community has learned a lot, but many mysteries and uncertainties remain

Data collected by large detectors at accelerator laboratories would be a valuable contribution. With a relatively modest investment, these detectors can be exploited for cosmic-ray physics in parallel with, and with no loss in efficiency for, the primary mission.

At CERN's LEP collider, a subgroup of the L3 collaboration has formed the L3+Cosmics group, using new electronics to enable the muon spectrometer drift chambers to be read out independently of LEP data collection. A blanket of about 200 sq. m of scintillator has been installed over the top three octants of the magnet to provide a reference time signal for cosmic-ray data collection. Under 30 m of rock, the cosmic-ray muon threshold for L3 is about 15 GeV.

Elsewhere in the LEP ring, members of the ALEPH collaboration are running a pilot CosmoALEPH experiment to look for coincident muons over long distances. This group has examined, together with the newly established CosmoLEP group, the cosmic-ray data collected during the ALEPH runs.

Data archives have revealed a substantial collection of cosmic-ray muon events. Although the detector is live for only 10% of the time for cosmic-ray particles, this nevertheless adds up over several years to more than a million seconds (about 12 days).

Muon multiplicities, etc, have been analysed using sophisticated cosmic-ray simulation programs developed by the Karlsruhe group. Intriguing events, producing unprecedented numbers of muons, have sparked a proposal to study these phenomena in more detail.

Topical workshop

A topical workshop in Sodankyla, about 100 km north of the Arctic Circle in Finland, on 24–29 April and organized by Karsten Eggert of CERN, highlighted the resurgence of interest in cosmic-ray muons.

The Karlsruhe group with its KASCADE detector array has, perhaps, the most comprehensive data so far on ground-level air showers, which can be interpreted in terms of the primary cosmic-ray spectrum and its composition.

C Taylor (Case Western Reserve) and R Engel (Bartol) looked at the primary cosmic-ray nuclear interaction, noting the uncertainty in the final state particle production at very small forward angles that dominates cosmic-ray muon production.

Even though Fermilab's Tevatron Collider energy corresponds to a cosmic ray, of about 2×10^{15} eV, interacting with an air nucleon at rest, there are almost no data on forward particle production at energies above the older fixed-target experiments at a few hundred giga electron-volts.

ALEPH and L3 surveyed their respective cosmic-ray muon observations. H Wilkens (Nijmegen) gave an update on the additions to the L3 detector and electronics and the muon programme in progress. S Tonwar (Tata Institute) described the planned addition of a surface air shower array above L3, which will enable the observation of energetic muons together with the related air shower. J Strom (Arcada), A Bruhl (Siegen) and M Schmelling (Max-Planck Institute) presented the current status of the ALEPH cosmic-ray programme. More than 300 000 cosmic-ray muon events have been analysed, and good agreement with the KASCADE Monte Carlo simulations obtained for multimuon events observed in the 16 sq. m time-projection chamber for multiplicities (total number of produced particles) between 2 and 40. However, there are five events with unexpectedly large multiplicities: up to 150 (in some cases with additional muons observed in the hadron calorimeter).

Other ALEPH studies look at the "decoherence" curve – the coincidence rate between two muon detectors as a function of their separation, extending beyond 1 km.

Horst Wachsmuth (CERN) proposed looking for muon coincidences between the four LEP detectors, a phenomenon that should not occur for any "ordinary" cosmic-ray interaction in the Earth's upper atmosphere. Such a coincidence, suggested by some earlier cosmic-ray experiments, would certainly require explanation.

Other major particle physics detector groups are also interested. A De Roeck (DESY) discussed the potential involvement of the big H1 and ZEUS detectors at DESY's HERA electron–proton collider for studies of coincident cosmic-ray muons. With these detectors only 3 m below ground they could study cosmic-ray muons down to energies of 2 or 3 GeV, which is of great interest to the atmospheric muon neutrino groups.

It is also possible, using satellite (GPS) time recording, to look for time correlations between cosmic-ray muons at DESY and CERN.

Future study

M Vallinkoski (Oulu) described a possible new cosmic-ray muon experiment in a mine in Phyhasalmi, Finland. The Centre for Underground Physics in Phyhasalmi (CUPP) would deploy a seven-detector array at several vertically aligned depths to study the multiplicity, lateral distribution and energy spectrum of cosmic-ray muons.

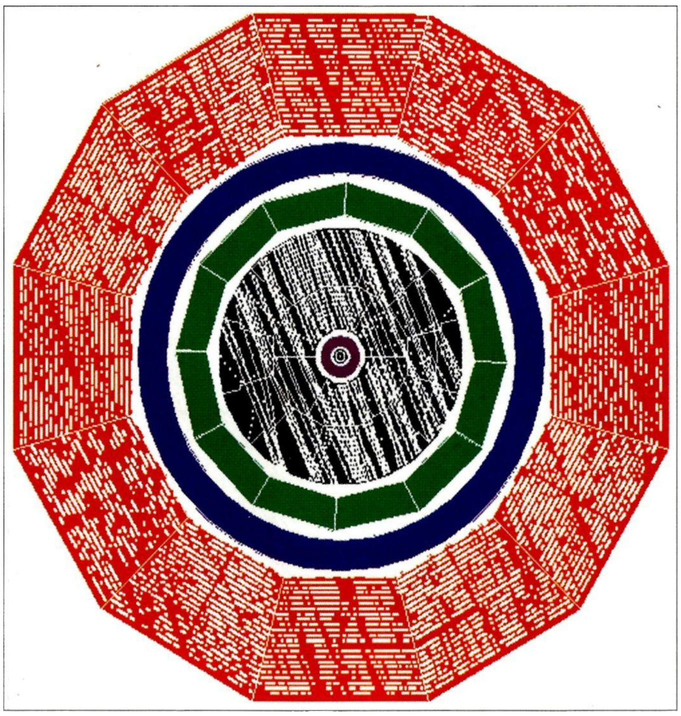
It was noted that major detectors could also be sensitive to point sources of cosmic-ray muons and, using the Moon as a cheap and efficient absorber and the Earth's magnetic field as a spectrometer, might set a limit on the relative flux of high-energy primary antimatter nuclei.

The Chinese IHEP group is particularly interested in seeking evidence for possible cosmic-ray associated weakly interacting massive particles (WIMPS) in L3.

Workshop organizer Karsten Eggert discussed other areas of future study, including working with larger and upgraded detectors. As noted by Lawrence Jones (Michigan) in his opening discussion, muon studies with LEP detectors contain both elements of an ideal experimental programme: practical and useful results, such as the absolute inclusive muon spectrum, while at the same time there is sensitivity to new and potentially exciting discoveries, such as unexpected muon multiplicities, cosmic-ray point sources, WIMP discoveries and statistically significant coincidences. Paolo Liperi of Rome summarized the attractions of the proposed new programme. □

ALEPH experiments go cosmic

Designed to study man-made electron–positron collisions in CERN's LEP ring, the ALEPH detector is also ideal for observing complicated natural cosmic-ray events.



Manifold muons: one of the intriguing cosmic events seen in the ALEPH detector.

High-energy primary cosmic-ray particles crashing into the atmosphere 20 km above our heads initiate large air showers with hadrons, electrons, muons and neutrinos. By the time they reach ALEPH, 125 m underground, all of these particles are absorbed except for neutrinos and muons above 70 GeV.

ALEPH provides high resolution tracking in its central Time Projection Chamber (TPC) in a solenoidal magnetic field and the large hadron calorimeter surrounding the TPC provides further information about cosmic muons.

After analysing cosmic muon events, five were found with the highest muon density ever seen.

Precision study of these muons, in particular of muon bundles, gives vital information about the primary cosmic rays and the way in which shower particles are produced in the very forward (downward) direction. The primary cosmic particle composition around the "knee" of the energy spectrum (4×10^{15} eV) is fundamental input for understanding the cosmic acceleration mechanism that pushes particles to these energies.

After analysing cosmic muon events captured by ALEPH in parallel with LEP data-taking and during a special one-week cosmic run, five events were found with the highest muon density ever seen. Some 100 muons hit the sensitive area (16 m^2) of the ALEPH TPC. The most crowded event showed about 160 muons in half of the TPC, the other half suffering data overflow.

Extensive simulations using the Corsika program, which was developed by the Karlsruhe group, reproduce the lower muon multiplicities, assuming a primary cosmic particle composition ranging from protons up to nuclei like iron. However, the five spectacular events are an order of magnitude above the simulation prediction. They could come from either unusually large air showers, above 10^{17} eV, or fluctuations from lower-energy showers, which could hint at new mechanisms for forward particle production.

Charge and momentum determination of the muons in these events, as well as the study of their structure over larger areas, may shed light on their origin. A special cosmic run of ALEPH using the tracking hadron calorimeter extended muon measurements to cover 50 m^2. The largest event from this run produced more than 100 muons.

High-multiplicity events

To study these intriguing events the CosmoLEP group proposes placing a 200 m^2 array of drift chambers beside the ALEPH experiment. With this large array, the rate of high multiplicity events would be increased by a factor of more than a hundred and the muon patterns would give a window on the energy and composition of the primary cosmic particles. The larger samples could also reveal point sources of cosmic particles in the depths of the universe.

The underground muon showers that have been seen so far extend over, at most, a few hundred metres. The CosmoALEPH effort covers the barrel of ALEPH's central hadron calorimeter together with several scintillator counter stations installed around the LEP ring near ALEPH, which are up to about 1 km distant. This pilot experiment saw coincident muons in counters that were several hundred metres apart and triggered an idea for a still wider muon search.

The four LEP experiments, equally spaced around the 27 km tunnel, could look for muon correlations over much larger distances. The same approach is being followed at the H1 and ZEUS detectors at the HERA collider at DESY in Hamburg, which are approximately 2 km apart. □

L3+C = new tool set to study cosmic-ray muons

Also under way at CERN is the L3 experiment at LEP, which has installed a 200 sq. m screen of scintillator to intercept comic rays arriving from the atmosphere.

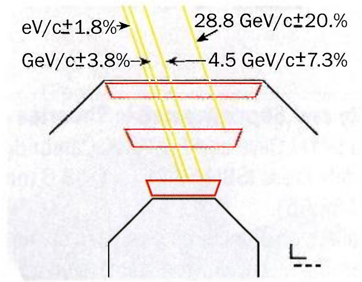
At CERN's LEP collider the L3 experiment has installed a blanket of about 200 sq. m of scintillator over the top of the magnet to provide a reference time signal for cosmic-ray data collection.

L3+C, an offshoot of the L3 experiment at CERN's LEP electron–positron collider, has been a "recognized" experiment at CERN since April 1998. It takes advantage of the unique properties of the big L3 muon spectrometer (low energy threshold compared to other underground detectors and unrivalled momentum resolution over a wide momentum range) for accurate measurements of cosmic-ray muons penetrating 30 m underground.

A new muon trigger, readout and data acquisition system have been installed, as well as a 204 sq. m scintillator matrix covering the L3 magnet to time the passage of particles. Data are collected independently, in parallel with L3 running at LEP.

New results for a variety of fundamental topics in cosmic rays, astrophysics and particle physics are expected. The cosmic-ray muon momentum spectrum, zenith angular dependence and charge ratio are being measured to 1% between 10 and 2000 GeV, thanks to L3's muon drift chambers and large magnetic volume.

The results will provide new information on the primary composition of cosmic rays, shower development in the atmosphere, and pion and kaon levels at high energies. These data will also help us to understand the "atmospheric neutrino puzzle", where an anomalous muon neutrino signal seen by underground neutrino detectors is heralded as an indication of neutrino oscillations. In particular, the precision measurements will allow a prediction of the absolute number of upward-moving, through-going muons above 10 GeV observed by Super-Kamiokande and MACRO underground.



L3+C picture of a family of four muons.

L3+C started gathering data in 1998. Then in early 1999 it increased its acceptance considerably, achieving an event rate of 550 Hz. In addition to providing more reliable data, this extends both the momentum measurement and the angular range.

The detector could reveal bursts of point source signals, and eventually gamma-ray bursts, and analyse their associated muons. The absence of high energy, upward-moving muons (above a few hundred giga electron-volts) will allow a limit to be set on the neutrino flux from active galactic nuclei. Studies of the primary composition of cosmic rays in the "knee" region (near 10^{15} eV) will be boosted in a unique way by recording muon "families" and measuring all of their momenta. With exotic events recorded by many different experiments, particle momentum spectra should reveal clues to the processes involved.

The detector will also intercept some upward muons (due to particles that have traversed the Earth). Time variations could reveal meteorological or sidereal effects. Correlations with events seen by other detectors are also among L3+C's experimental objectives.

Observing the Moon's muon shadow may give a flux limit of primary antiprotons near 1 TeV – the Earth's magnetic field acting as a convenient momentum analyser and the Moon as an absorber of cosmic particles.

Independent apparatus

The collaboration is preparing to install 50 scintillators below the roof of the L3 access hall (above ground). This air shower array will help to estimate the primary energy of some showers associated with the muons measured underneath. This apparatus is completely independent and runs by itself. Events are correlated via the GPS satellite clock and a signal in the data acquisition system.

The L3+C experiment already has collected some 900 million events and is expected to run up to the end of the LEP operation period next year. The first data were presented at August's International Cosmic-Ray Conference in Salt Lake City. □

BOOKSHELF/NEW PRODUCTS

BOOKSHELF

High Field Superconducting Magnets by Fred M Asner, Oxford University Press, ISBN 0 19 851764 5 (£55).

Fred Asner traces the discovery and understanding of superconductivity. This includes the development and manufacture of semiconducting materials, the cooling of superconducting magnets and their control. Asner looks at beam dynamics and winding configurations specific to accelerator magnets and discusses their design principles using examples from recent major projects. All of these magnets have to work under extreme conditions. It is stressed that the design criteria are not to be taken lightly. One chapter is dedicated to particle physics detectors and superconducting magnets for medical applications. Both are major growth areas.

Pulsars as Astrophysical Laboratories for Nuclear and Particle Physics by Fridolin Weber, Institute of Physics Publishing ISBN 0 7503 03328 (hbk £99/$180, 682 pages).

Pulsars were discovered by J Bell and A Hewish in 1967 and were identified as rapidly rotating neutron stars. The physics of neutron stars – of which there are estimated to be about one billion in the Milky Way alone – is covered, along with Strange quark matter – when additional quarks come into play beyond the "up" and "down" varieties constituting normal nuclear matter. This physics is also receiving a terrestrial boost with the start of the programme at Brookhaven's RHIC.

The Symbolic Universe: Geometry and Physics 1890–1930 edited by Jeremy J Gray, Oxford University Press ISBN 0 19 850088 2.

At the Second International Congress of Mathematicians, held in Paris in 1900, David Hilbert presented a list of 23 outstanding problems in mathematics that, in his opinion, needed to be addressed. The sixth congress prophetically called for a greater interplay between geometry and physics.

The bridge from 19th to 20th-century physics has characterized new physics insights. Relativity, with its multidimensional spaces, ushered in new developments. Some of the greatest minds in physics and mathematics focused on these new goals. This is a fascinating collection of papers presented at a 1996 conference at the UK Open University.

Duality and Supersymmetric Theories edited by D I Olive and P C West, Cambridge University Press ISBN 0 521 641158 6 (hbk £45/$69.95).

A collection of lectures given in a six-month programme at the Newton Institute in Cambridge, with an introduction and guide by the editors. The contributors are M K Gaillard, B Zumino, J Gauntlett, T Eguchi, G W Gibbons, A Sen, C Bachas, D I Olive and P C West.

CP Violation by G Castelo Branco, L Lavoura and J P Silva, Oxford University Press, International Series of Monographs on Physics ISBN 0 19 850399 7 (£60).

A complete theoretical and phenomenological study of CP violation and the CKM matrix, including the implications for heavy quarks. This is a good reference for physicists at B factories, but little mention is made of the enormous efforts that are going into measuring the phenomenon of CP violation.

FORTRAN 90/95 explained (2nd edn) by Michael Metcalf and John Reid, Oxford University Press ISBN0 19 850558 2 (pbk).

Despite the continual appearance of new programming languages Fortran, now well into middle age, soldiers on. This new edition summarizes the latest standards. Michael Metcalf, now retired, was a longtime member of CERN's Information Technology Division.

Cyclotrons and their Applications 1998 – Proceedings of the 15th International Conference on Cyclotrons and their Applications, Caen, France, 14–19 June 1998 edited by E Baron and M Lieuvin, GANIL, France, Institute of Physics Publishing ISBN 0 7503 0663 7 (hbk £220.00/$400).

Cyclotrons 1998 was the fifteenth in a series of international conferences initiated in 1959. Cyclotrons are used in basic and applied research, radiotherapy and nuclear medicine. Included is a complete list of existing cyclotrons and their characteristics.

Effective Medium Theory – Principles and Applications by Tuck C Choy, Oxford University Press, International Series of Monographs on Physics ISBN 0 19 851892 7.

While not at the cutting edge of fundamental physics, effective medium theory is a fruitful way of describing and handling microstructure at the mesoscopic scale. The introduction is by Marshall Stoneham.

NEW PRODUCTS

HDF plug-in for Adobe Photoshop

Fortner Software, experts on the Hierarchical Data Format (HDF) data model, announced the availability of the Power Macintosh HDF import plug-in v1.1 for Adobe Photoshop.

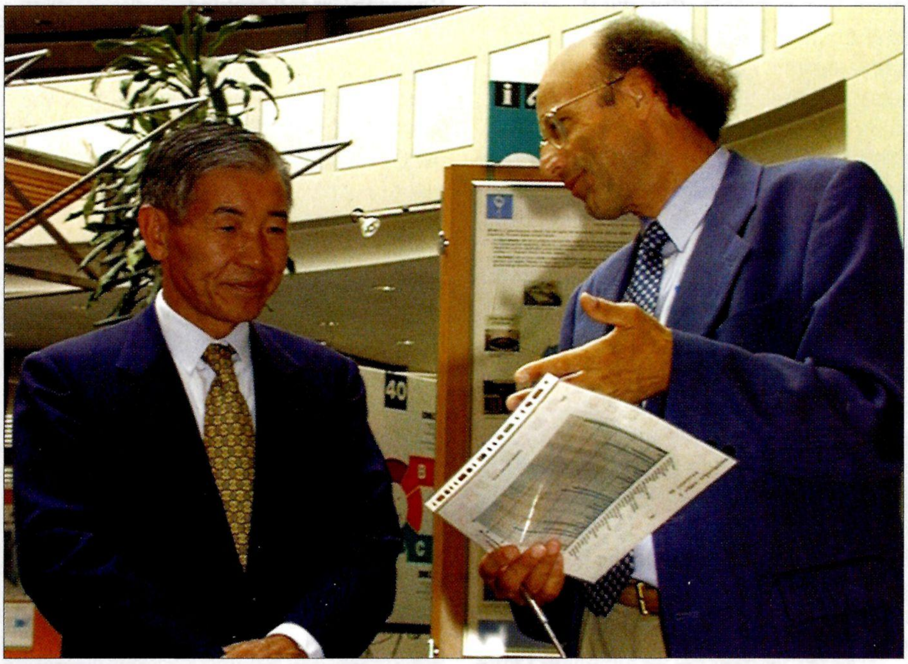
With this plug-in, Photoshop owners can access and raster image and data objects stored in HDF files. Photoshop's advanced annotations, colour manipulation, additional imaging and Web publication features compliment the image and data manipulation functionality of Fortner Software's data access and visualization applications: Noesys, Transform, T3D and Plot. For example, Noesys and Transform can import many data formats, including text, binary, SDTS, DTED, GeoTIFF and FITS, and convert them to HDF, thus providing Photoshop users with access to data from sources that were previously inaccessible.

The HDF import plug-in v1.1 runs on the Power Macintosh, Mac OS 8+ and requires 1 MB of hard disk space. It is compatible with Adobe Photoshop versions 3.x, 4.x and 5.0, 5.1, 5.2. The plug-in can be purchased on line ($49) and downloaded via the Website at "http://www.fortner.com". For full details, contact Hilary Lewis, tel. (+1) 703 478 0181 (103) or e-mail "hilary@fortner.com".

Model 218 Temperature Monitor

The eight-channel Model 218 temperature monitor, Lake Shore's most versatile to date, reads up to eight diode or resistance temperature sensors twice each second and displays all of the channels continuously. The Model 218 supports diodes, Platinum RTDs and negative temperature coefficient (NTC) resistor sensors. Diode sensors are easily interchangeable and provide a wide measurement range (1.4–475 K). Platinum RTDs are recommended for high temperatures up to 800 K. NTC resistor sensors are measured with constant current excitations for less demanding applications that require their specialized temperature response.

Contact Lake Shore Cryotronics, Inc, Steve Hoenig, Sales and Marketing, 575 McCorkle Boulevard, Westerville, Ohio 43082; tel. (+1) 614 891-2244; fax 614 818-1600; e-mail "sales@lakeshore.com"; Internet "www.lakeshore.com".



Japanese ambassador to Switzerland, **Mitsuhei Murata** (left), at CERN with **Peter Jenni**, spokesman of the ATLAS experiment for CERN's LHC collider.

CERN–Asia Fellows and Associates Programme

Within the framework of the CERN–Asia Fellows and Associates Programme, CERN offers three grants every year to East, South-East and South Asian* postgraduates under the age of 33, enabling them to participate in its scientific programme in the areas of experimental and theoretical physics and accelerator technologies. The appointments 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 25 January 2000. An application must consist of a completed application form, on which it should be written "CERN–Asia Programme"; three separate letters of reference; and a curriculum vitae that includes a list of scientific publications and any other information regarding the quality of the candidate. Applications, references and any other information must be provided in English.

Application forms can be obtained from the Recruitment Service, CERN, Personnel Division, 1211 Geneva 23, Switzerland; e-mail "Recruitment.Service@cern.ch"; fax +41 22 767 2750. Applications should reach the Recruitment Service at CERN before 15 November 1999.

The CERN–Asia Fellows and Associates Programme also offers a few short-term associateship positions to scientists under 40 who wish to spend part 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.

MEETINGS

The 6th International Conference on Materials and Mechanisms of Superconductivity and High Temperature Superconductors (M2S-HTSC-VI) will take place in the George R Brown Convention Center, Houston, Texas, on 20–25 February 2000. Contact Centennial Conferences, 4800 Baseline Road, A-112, Boulder, Colorado 80303 USA; tel. 303 499 2299; fax 303 499 2599; e-mail "m2s@centennialconferences.com"; "http://m2sconf.uh.edu".

The 11th biennial **NATO Advanced Study Institutes on Techniques and Concepts of High-Energy Physics** will be held on 15–26 June 2000 in St Croix, Virgin Islands. It is sponsored by the Division of Scientific Affairs of NATO, the High-Energy Physics Programme of the US Department of Energy, the Elementary Particle Physics Programme of the US National Science Foundation, Fermilab, Florida State University, ITEP in Moscow and the University of Rochester. Attendence is limited to 60 participants. There are no special application forms. Any advanced graduate student or recent postgraduate in experimental high-energy physics interested in attending should submit a letter of application containing a CV and a list of publications. In addition, a letter from a senior scientist (advisor), in support of the application, should also be sent to the address below. Although the deadline for application is 1 February 2000, it is advisable to apply as early as possible. For further information contact Ms C Jones, Department of Physics, University of Rochester, Rochester, New York 14627-0171, "http://www.pas.rochester.edu/ASIinfo.html", e-mail "connie@pas.rochester.edu".

Bottled up

The operations crews are the unsung heroes of high-energy physics, ensuring the delivery of the particle goods. A letter of appreciation from the NA48 experiment measuring direct CP violation, *CERN Courier* September p6, thanked all who participated in the provision of their beams at the SPS synchrotron. While pleased to receive thanks, the operations specialists said that "the LEP experimenters traditionally use another channel to express their gratitude (champagne), which is much appreciated in the control room".

AWARDS

Shiju-Ho-Sho

The Japanese KEK Laboratory director-general, Hirotaka Sugawara, has received the prestigious Shiju-Ho-Sho (medal with purple ribbon) from the Emperor of Japan as one who has made an outstanding contribution to cultural activity in Japan. His achievements have been widely recognized, both in theoretical physics and in his management of KEK, where he has been director-general since 1989. Under his directorship, KEK has become one of the major world high-energy physics laboratories, with two forefront projects: the KEKB B factory and the K2K Long Baseline Neutrino Oscillation experiment. This award is not only a personal honour but also a recognition of high-energy physics achievement by a Japanese citizen, and it will help to further particle physics research in Japan.

1999 Dirac Medal

The Dirac Medal of The Abdus Salam International Centre for Theoretical Physics in Trieste, Italy, is awarded this year to Giorgio Parisi of Rome I "La Sapienza". Parisi, who graduated from Rome in 1970, has made outstanding contributions in many areas of theoretical physics, including elementary particle physics, phase transitions, statistical mechanics, mathematical physics, string theory, neural networks and disordered systems. He has worked at the National Laboratories in Frascati (Italy), Rome University, and University of Rome II and I ("La Sapienza"). In addition, he has had one-year appointments at Columbia and at the Institute des Hautes Etudes Scientifiques and Ecole Normale Superieure in France. He is the author/co-author of two books and 200 scientific articles and he received the Feltrinelli Prize for Physics in 1986, the Boltzman Medal in 1992 and the Italgas Prize in 1993.

Money for string

Two string theorists – Juan Maldacena of Harvard and Eva Silverstein of SLAC – were among the 32 recipients of 1999 MacArthur Fellowships.

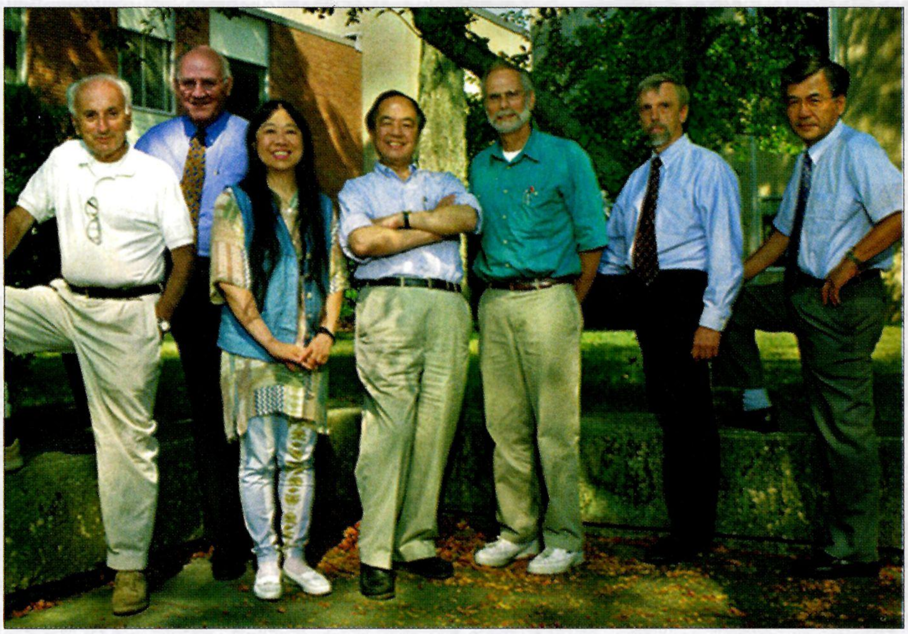
Guggenheim fellowships

Among those awarded prestigious Guggenheim fellowships in 1999 was Michael Riordan, physics author and assistant to the director at SLAC, Stanford. Riordan is also the SLAC correspondent of *CERN Courier*. He plans to use the award to research and write a book on the history of the US Superconducting Supercollider, the construction of which was abruptly terminated in 1993.

Also awarded a Guggenheim fellowship was Bruce Winstein of Chicago, who will be working at Princeton for the year on an experiment led by Suzanne Staggs to detect polarization in cosmic-microwave background radiation.

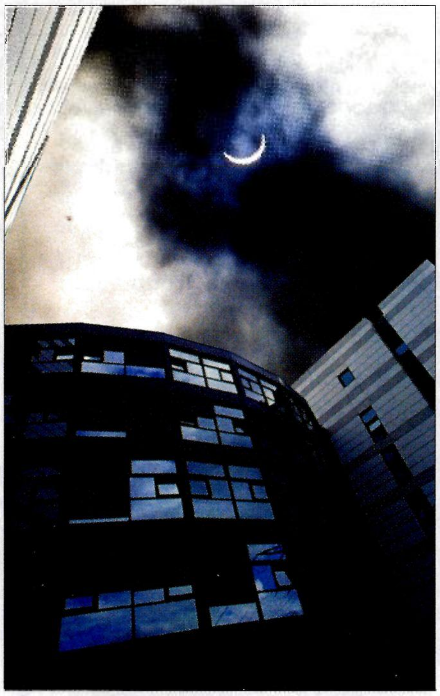
Gravity Research Foundation Awards for Essays

First prize in this year's Gravity Research Foundation Awards for Essays went to John Ellis of CERN, Nikolaos Mavromatos of Oxford and Dimitri Nanopoulos of Texas A&M for their paper "Search for quantum gravity" (e-print archive gr-qc/9905048), to be published in the journal *General Relativity and Gravitation*.

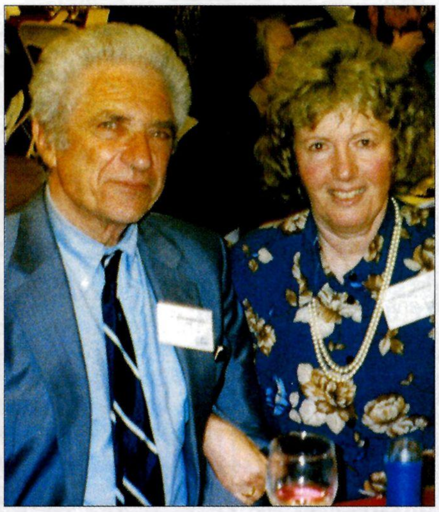


A line-up of speakers at a recent users' meeting at Brookhaven for a review, "The AGS Alternating Gradient Synchrotron: Past, Present and Future", chaired by Bill Wallenmeyer, former director of the US Department of Energy's Division of High-Energy Physics. Left to right: **Mel Schwartz** (Nobel 1988) – "The Early Years"; **Bill Wallenmeyer**; **Sau Lan Wu** (Wisconsin) – "J/psi and the Middle Years"; **T D Lee** (Nobel 1957) – "Theory in the Future; **Mike Zeller** (Yale) – "The Rare K-decay Era"; **Bill Mozon** (UC Irvine) – "The Future Era"; and **Shoji Nagamiya** (KEK) – "Heavy Ions".

Bernd Surrow (left) of Schwäbisch Hall, now working on the Opal experiment at CERN, receives the annual PhD thesis prize awarded by the Verein der Freunde and Förderer des DESY (Association of the Friends and Sponsors of DESY) for his thesis on proton structure measurements at the ZEUS experiment at DESY. Presenting the prize was former DESY and CERN director **Erich Lohrmann**, head of the association, which, by supporting social and cultural activities, aims to make DESY more than just a centre of scientific excellence.



The solar eclipse at CERN on 11 August.



Among the participants from CERN at the C N Yang retirement meeting were 1988 Nobel Prizewinner **Jack Steinberger** and **Cecilia Jarlskog**. (Cecilia chairs the Nobel Prize Committee for Physics, but not for chemistry, as wrongly indicated in the June issue on p40. Apologies for the error.)

Quantum choreodynamics – physics chanteuse **Lynda Williams** upstage at CERN.

RECRUITMENT

For advertising enquiries contact *CERN Courier* recruitment/classified, IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
Tel: +44 (0)117 930 1026 Fax +44 (0)117 930 1178
Rates per single column cm: Mono £30, Single colour £34, Full colour £36. Please contact us for more information on publication dates and deadlines.

DESY is a physics research laboratory with 1.400 employees and more than 3.000 guest scientists from Germany and abroad. The scientific programme includes research in particle physics and synchrotron radiation.

DESY invites applications for the position of a

Postdoctoral Fellowship
in Experimental Accelerator Physics

for R&D work associated with the superconducting linear electron-positron collider project TESLA and free electron lasers in the VUV and X ray regime.

At the TESLA Test Facility in Hamburg superconducting cavities of highest performance are developed, and a linear test accelerator is under construction whose present energy of 250 MeV will be gradually increased beyond 1 GeV. The test accelerator will serve also as a drive linac for a VUV free electron laser (FEL) of unprecedented performance.

The candidate is expected to join the R&D programs aiming at the development of superconducting rf cavities of ultimate performance, and/or the development of high power rf couplers and other auxiliary components. In addition, an active participation in the commissioning of the test linac and the VUV FEL facility is expected.

Applicants should have a Ph.D. in physics and be under 32 years of age. Special knowledge in accelerator physics, superconductivity and/or microwave technology is highly welcome.

The appointment will be at DESY Hamburg and be initially limited to 3 years with a salary according to federal tariffs (BAT IIa).

Letters of application including curriculum vitae, copies of university degrees, list of publications and the names of three referees should be sent to:

DESY, Personalabteilung, Notkestraße 85, D-22607 Hamburg, closing date: November 30th, 1999 Code-No. 56/99

Applications are particulary welcomed from qualified women and handicapped persons as they are currently underrepresented within the workforce.

DESY is a physics research laboratory with 1.400 employees and more than 3.000 guest scientists from Germany and abroad. The scientific programme includes research in particle physics and synchrotron radiation.

DESY invites applications for the position of an

Experimental Physicist
for the Radiation Protection Group

The position entails two main activities:

- verification of all aspects of radiation protection measures in the existing accelerator systems;
- planning and realisation of such measures for the new TESLA linear collider and FEL-laboratory projects.

The applicant will be expected to convincingly represent the importance of radiation protection both within DESY and in public. The chosen candidate will, after an appropriate period, assume the post of radiation protection group leader with responsibility not only for lab employees but also for liaison with the relevant authorities.

Applicants should have a Ph.D. preferably in nuclear or particle physics; several years of experience in the field of radiation protection; experience with extensive program systems in particular with data concerned with radiation protection matters; leadership qualities and the ability to interact with colleagues; good knowledge of English.

The appointment is to a permanent position with a salary according to federal tariffs (BAT Ib). Letters of application including a curriculum vitae, list of publications and the names of three referees should be sent to:

DESY, Personalabteilung, Notkestraße 85, D-22607 Hamburg, closing date: November 30th, 1999 Code-No. 87/99

Applications are particulary welcomed from qualified women and handicapped persons as they are currently underrepresented within the workforce.

FACULTY POSITIONS in EXPERIMENTAL and THEORETICAL HIGH ENERGY PHYSICS
UNIVERSITY OF OKLAHOMA

The Department of Physics and Astronomy at the University of Oklahoma invites applications for two tenure-track faculty positions to begin in Fall 2000. The positions are intended to be at the Assistant professor level, although in exceptional circumstances a more senior appointment may be possible. Applicants must hold a Ph.D. degree in physics, and must have the ability to teach effectively at both undergraduate and graduate levels. The potential to contribute strongly to the existing research program is essential. The applicants should have postdoctoral experience and research objectives that will enhance the external funding of the High Energy Physics (OU-HEP) group. For the experimental position preference will be given to applicants whose background and interests overlap those of the experimentalists in the existing OU-HEP group, whose current research focuses on colliding beam physics as members of the D0, ATLAS, and CLEO collaborations. The group has recently made contributions to the D0 and CLEO silicon microstrip vertex detectors and to development of the ATLAS pixel detector. Major experimental facilities include a VLSI design and testing laboratory, a machine shop, an electronics shop, and excellent computing facilities supported by a full-time staff physicist.

For the theoretical applicant the potential to initiate a strong theoretical research program is essential. The successful candidate will be able to interact fruitfully with members of both our theoretical and our experimental high energy groups. We are seeking a physicist with a strong background in phenomenology, by which we mean the ability to apply theories in particle physics, such as QCD, to the experimental situation which will unfold in the next century. Current research interests of our theoretical group include nonpeturbative quantum field theory, quantum chromodynamics, vacuum fluctuation phenomena, quantum gravity, and the physics of magnetic charge. Physics interests of the experimental group include electroweak phenomenology (Higgs bosons, bottom- and top-quark physics,...) and phenomenology of QCD.

For further information about our department see http://www.nhn.ou.edu.
To apply for the experimental position, please write to: **Dr. Patrick Skubic, HEPEX Search Committee Chair, Department of Physics and Astronomy, The University of Oklahoma, Norman, OK 73019-0225 (e-mail: pskubic@ou.edu).**

To apply for the theoretical position, please write to: **Dr. Kimball A. Milton, HEPTH Search Committee Chair, Department of Physics and Astronomy, The University of Oklahoma, Norman OK 73019-0225 (e-mail: hepthsearch@mail.nhn.ou.edu).** Initial screening of applicants will begin January 10, 2000 and will continue until the position is filled. Complete applications will consist of a vita, publication list, a brief description of research and teaching interests, and at least three confidential letters of recommendation sent directly to the appropriate search committee chair.

The University of Oklahoma is an Equal-Opportunity Affirmative-Action Employer and has a policy of being responsive to the needs of dual-career couples. Women and minorities are encouraged to apply.

RIKEN BNL Research Center
Brookhaven National Laboratory

SCIENTIFIC STAFF POSITIONS

A research center focusing on the physics program of the Relativistic Heavy Ion Collider (RHIC), hard QCD/spin physics, lattice QCD and relativistic heavy ion physics has been established by the Institute of Physical and Chemical Research Japan (RIKEN) at Brookhaven National Laboratory. The members of the center will be Research Associates (two-year appointments) and RIKEN BNL Fellows (five-year appointments). The Center will play a major role in shaping the spin and heavy ion physics research at RHIC. Frequent workshops are planned. Several positions for theorists in the above categories are expected to be offered for the fall of 2000. Members of the Center will work closely with the existing high energy and nuclear physics groups at BNL.

Theorists with appropriate backgrounds who are interested in applying for Research Associate and RIKEN BNL Fellow positions should send a *curriculum vitae,* publication list, and arrange for three letters of reference to be sent to Professor T.D. Lee, Director, RIKEN BNL Research Center, Building 510A, Brookhaven National Laboratory, P.O. Box 5000, Upton, Long Island, NY 11973-5000, before January 1, 2000. BNL is an equal opportunity employer committed to workforce diversity.

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www.bnl.gov

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

The Swiss Federal Institute of Technology Lausanne (EPFL) invites applications for three posts of

Professor of Applied Mathematics
in the Department of Mathematics

The future professors will be mathematicians with an international reputation, proven by published work at the forefront of their fields. Candidates from all areas of applied mathematics are welcome. Specialists in the fields of probability or statistics, differential geometry, and discrete mathematics or optimization are particularly encouraged to apply. A taste and talent for multidisciplinary collaboration would be an asset. Teaching will be an important responsibility; the positions demand strong interest and skills in teaching and the ability to direct PhD/advanced research in mathematics.

The EPFL is an internationally-oriented technical university which offers competitive salaries, substantial start-up packages and excellent research and teaching facilities.

Applications are sought for appointments at the associate or full professor levels. The EPFL strongly encourages women to apply.

Starting date: upon mutual agreement. Please ask for the application form by writing or faxing to:
Présidence de l'Ecole polytechnique fédérale de Lausanne, CE-Ecublens, CH-1015 Lausanne, Suisse, fax nr. +41 21 693 70 84.

For further information, please consult also URL: http://www.epfl.ch, http://dmawww.epfl.ch/, http://admwww.epfl.ch/pres/profs.html or http://research.epfl.ch/

RIKEN BNL Research Center
Brookhaven National Laboratory

TENURE TRACK -
STRONG INTERACTION THEORY

RHIC Physics Fellow Positions

The RIKEN BNL Research Center (RBRC) at Brookhaven National Laboratory, together with university partners, invites applications for a program of cooperative fellowships in strong interactions theoretical physics motivated by the experimental program of the Relativistic Heavy Ion Collider to be operating at BNL. Each RHIC Physics Fellow will be jointly selected and supported for five years, beginning September 2000, by the Center and one of the cooperating universities and will hold a tenure track faculty appointment (or equivalent) in that university's Physics Department. Each fellow will spend about half time at RBRC and the remaining time at the university. Candidates should have a Ph.D. degree in theoretical nuclear or particle physics and be interested in pursuing theoretical research within a broad range of hadron physics, such as high energy nuclear theory, RHIC physics, QCD (perturbative and lattice), hadronic spin physics, hadronic spectra and their transition matrix elements.

Scientists with appropriate backgrounds who are interested in applying should send a *curriculum vitae,* publication list, a brief description of their research interests, and arrange for three letters of reference to be sent to Professor T.D. Lee, Director, RIKEN BNL Research Center, Building 510A, Brookhaven National Laboratory, P.O. Box 5000, Upton, Long Island, NY11973 before January 1, 2000. Additional information, including a list of this coming year's participating universities, is available by sending an e-mail request to rhic_fellows@bnl.gov or by writing to the above address. BNL is an equal opportunity employer committed to workforce diversity.

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University of California, Riverside
Open Faculty Position in Experimental High Energy Physics

The Department of Physics at the University of California, Riverside invites highly qualified applicants to apply for a new faculty position in *experimental high energy physics.* This is an "open level" position and may be filled at any academic level including the senior level. The appointment will be effective July 1, 2000. The Department is seeking outstanding candidates with exceptional research records and demonstrated excellence in teaching. The successful candidate is expected to establish a leading edge research program involving graduate students and contribute to department teaching at all levels. In high energy physics the current research programs include OPAL at LEP, D-Zero at the Tevatron and CMS at the LHC. In neutrino physics, faculty are working on the LSND experiment at Los Alamos and BooNE at Fermilab. Candidates for this position are required to have a Ph.D. or equivalent degree in physics. Salary will be competitive and commensurate with qualifications and level of appointment. Candidates should submit a letter of application, a curriculum vitae, evidence of teachng skills and evidence of an outstanding research program. They should also arrange to have three letters of reference sent to the Department and be willing to submit additional references on request. Letters should be sent to:

Chair, Search Committee
Experimental High Energy Physics
Department of Physics
University of California
Riverside, CA 92521

Full review of applications will begin January 17, 2000. Applications received after this date will be considered on a case-by case basis until the position is filled.

The University of California is an Equal Opportunity/Affirmative Action Employer.

Deputy Computing Facility Directors

Brookhaven National Laboratory (BNL) is seeking to fill two positions, Deputy Computing Facility Director for the Relativistic Heavy Ion Collider (RHIC) and Deputy Computing Facility Director for US ATLAS. These deputy facility directors will hold scientific staff positions in the Physics Department and will share, with the facility director, primary responsibility for developing and operating major High Energy and Nuclear Physics computing facilities at BNL. These facilities, targeting the experiments of the RHIC project at BNL and the ATLAS experiment at CERN's Large Hadron Collider project, will operate at the Tera-scale of computation and the Peta-scale of data storage.

The **Deputy Computing Facility Director for US ATLAS** – Position #MK8726 – will play a principal role in developing and implementing the plan required to meet the computing needs of US ATLAS in the field of large-scale high energy physics. This plan will involve the cooperative use of facilities at CERN, at the US Tier 1 center at BNL, and at Tier 2 and institutional centers distributed across the US.

The **Deputy Computing Facility Director for RHIC** – Position #MK8725 – will play a principal role in evolving and implementing the plan required to meet the ongoing computing needs of RHIC in the field of large-scale nuclear physics. This plan spans the various RHIC experiments, their regional centers and collaborating institutions.

Requirements include a Ph.D. in Physics, at least five years postdoctoral experience in large-scale high energy physics (ATLAS) and nuclear physics (RHIC) projects and associated computing activities, and demonstrated leadership, planning and management skills. Substantial expertise in areas such as UNIX system administration, modern programming techniques, tools and languages and large-scale data processing and storage systems are also required.

For consideration, please forward your CV and three letters of reference, indicating position #, to: M. Kipperman, Brookhaven National Laboratory, Bldg. 185, PO Box 5000, Upton, NY 11973-5000. For more information about BNL, please visit our website. BNL is an equal opportunity employer committed to workforce diversity.

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PAUL SCHERRER INSTITUT

PSI

The Experimental Particle Physics Group of the Paul Scherrer Institute (PSI) is active in rare decay and exotic atom experiments at PSI using the world's most powerful proton accelerator, and participates in high-energy physics experiments at CERN and DESY. Applications are invited for a

Research Associate
in Experimental Particle Physics

The successful candidate will assume a major role in an international, medium size collaboration planning a new search for the decay of a muon into a positron and photon ($\mu \rightarrow e + \gamma$), forbidden in the Standard Model. Preferably, the applicant has several years of post-doctoral experience and some background in project coordination. Knowledge in high resolution, medium energy electron and photon spectroscopy would be beneficial.

For any further information please contact Kurt Gabathuler (tel.+41 56 310 32 51, e-mail Kurt.Gabathuler@psi.ch).

Applications should be sent to:
PAUL SCHERRER INSTITUTE, Personnel Division, ref.code 1400, CH-5232 Villigen PSI, Switzerland.
More openings: www.psi.ch

UNIVERSITY OF TORONTO
Tenure Track Faculty Position
Department of Physics
Experimental Nonlinear or Biological Physics

The Department of Physics will make a tenure track appointment at the rank of Assistant Professor with an expected starting date of **1 July 2000**. An appointment at a higher rank may also be considered.

We seek candidates with a Ph.D. in Physics, with proven or potential excellence in both research and teaching. Our goal is to find a candidate with a strong experimental background and an innovative, interdisciplinary outlook. We are interested in the general area of physics far from equilibrium: nonlinear physics (e.g. pattern formation, granular media, fracture) or biological physics (e.g. DNA dynamics, chemotaxis). We also invite outstanding candidates working in related areas of experimental soft condensed matter physics to apply. Salary will be commensurate with qualifications and experience.

Applications, including a curriculum vitae, a summary of proposed research and three letters of reference should be sent to:

Professor Pekka Sinervo
Chair
Department of Physics
University of Toronto
60 St. George Street
Toronto, Ontario, M5S 1A7, Canada

The deadline for the receipt of applications and letters of recommendation is 30 November 1999. We urge prospective candidates to visit our home page at http://www.physics.utoronto.ca/.

The University of Toronto is committed to employment equity and encourages applications from all qualified individuals including women, members of visible minorities, aboriginal persons, and persons with disabilities.

CERN COURIER RECRUITMENT BOOKING DEADLINES

November: 15 October

December: 12 November

Contact
Chris Thomas:

Tel:
+44 (0)117 9301031

Fax:
+44 (0)117 9301178

E-mail:
chris.thomas@ioppublishing.co.uk

EMBL

Hamburg Outstation

The European Molecular Biology Laboratory (EMBL), an international research organisation with its Headquarters Laboratory in Heidelberg (Germany), Outstations situated in Grenoble (France), Hamburg (Germany) and Hinxton (UK), and a Research Programme at Monterotondo (Italy) has the following vacancy **at the Hamburg Outstation:**

STAFF SCIENTIST (ref. no. 99/53) INSTRUMENTATION

The EMBL Hamburg Outstation carries out research in structural biology, making use of the special properties of synchrotron radiation. Currently, it operates seven beam lines at the DORIS storage ring at DESY. These beam line facilities are used by the International scientific community and for in-house research activities. Presently about 500 projects are carried out annually. The EMBL instrumentation group designs, builds and maintains these beam lines. In addition, the group develops and builds instruments for specialised and user friendly applications at these beam lines, in cooperation with the local research groups in X-ray crystallography, small angle scattering and X-ray absorption spectroscopy. The advertised position will be in the instrumentation group.

Applicants should have a Ph.D. or equivalent. Experience in the operation of Synchrotron Radiation beamlines, a background in X-ray optical instrumentation and basic electronic and programming skills are requested. The capability to integrate into a multi-disciplinary environment and the willingness to cooperate and provide support are essential. A working knowledge of English is required and the ability to communicate in German is important.

Commencing date: January 2000. Closing date for applications: 1 November 1999

Further information can be obtained from Dr. Christoph Hermes, fax: ++49 89902 149;
email: hermes@embl-hamburg.de; www: http://www.embl-hamburg.de.

EMBL is an inclusive, equal opportunity organisation.

Applicants should submit a CV, including a description of current professional activities, and names and addresses of three referees, quoting ref. no. 99/53, to:

The Personnel Section, EMBL, Postfach 10.2209, D-69012 Heidelberg, Germany
Fax: +49 6221 387555, email: jobs@EMBL-Heidelberg.de

TRIUMF

CANADA'S NATIONAL LABORATORY FOR PARTICLE AND NUCLEAR PHYSICS

Director

Canada's national laboratory for particle and nuclear physics is now seeking a Director.

Located on the University of British Columbia campus, TRIUMF houses research facilities which include a 520 MeV H^- cyclotron, and the new radioactive beam facility, ISAC. TRIUMF is Canada's main link to international laboratories engaged in subatomic physics research, and is providing for Canada's contribution to the LHC project at CERN. In addition, TRIUMF supports important programs in Life Sciences, Condensed Matter and other cross disciplinary applications.

The position of Director has a preferred starting date of September 1, 2000, and is subject to a five year initial term of appointment. Additional information about TRIUMF, and a description of the Director's position are available at *www.triumf.ca/director.html*

The search committee will be meeting to begin its selection process in November 1999, and is now inviting suggestions for suitable individuals, as well as expressions of interest from potential candidates.

TRIUMF is an equal opportunity employer, and asks that all applications and nominations be directed to:

W. John McDonald, Chair of the Search Committee
c/o Department of Physics
University of Alberta
Edmonton, Alberta T6G 2J1

FACULTY POSITIONS IN PHYSICS

University of California Berkeley

The Physics Department of the University of California, Berkeley intends to make one or more faculty appointments effective July 1, 2000. Candidates from all fields of physics are invited to apply; however applications in the fields of theoretical astrophysics and experimental atomic physics are particularly encouraged. Appointments at both tenure-track assistant professor and tenured levels will be considered.

Please send a curriculum vitae, bibliography, statement of research interests, and a list of references to:

Professor Roger W. Falcone, Chair, Department of Physics, University of California, 366 LeConte Hall #7300, Berkeley, CA 94720-7300, postmarked by Tuesday, November 23, 1999. E-mail applications will not be accepted. Applications submitted after the deadline will not be considered.

The University of California is an Equal Opportunity, Affirmative Action Employer.