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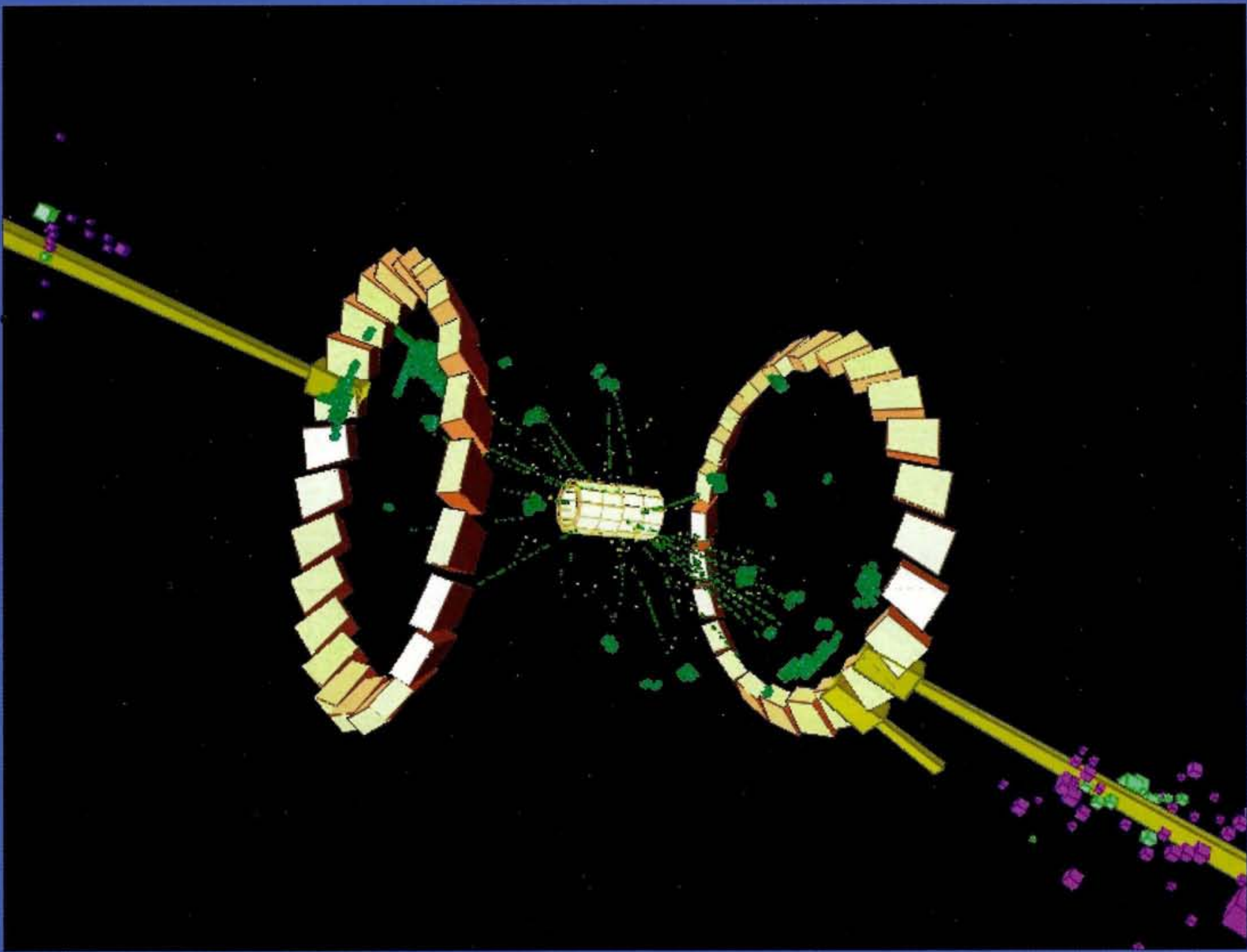

LEP leaves a legacy

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Innovative detector techniques give improved performance p14

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Second Announcement

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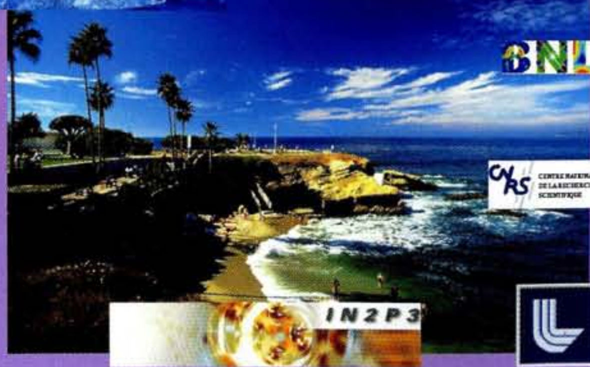

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Covering current developments in high-energy physics and related fields worldwide

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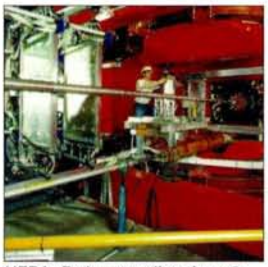
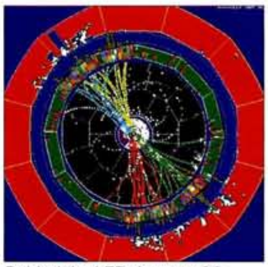


HERA–B changes direction p8



Behind the LEP closure p26

Leprince-Ringuet tribute p36

Cover: Higgstogram – a candidate Higgs event seen by the L3 detector at CERN's LEP electron–positron collider. For the history of LEP's final year of operation, see p25.

Rack clearance

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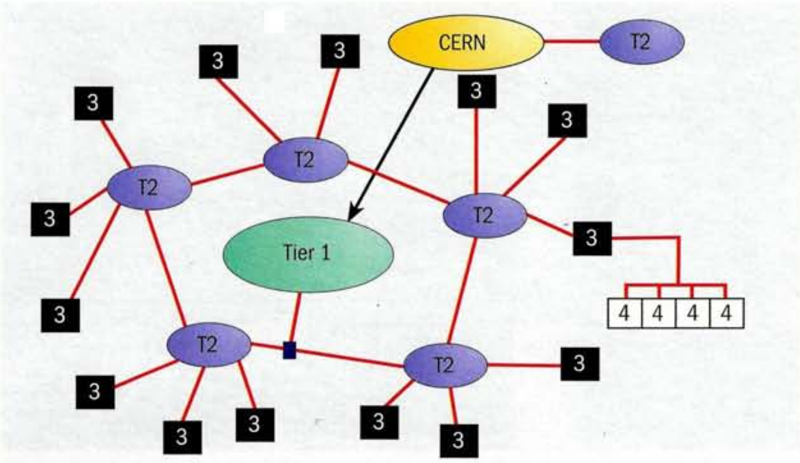
CERN

Data Grid project gets EU funding

Plans for the next generation of network-based information-handling systems took a major step forward when the European Union's Fifth Framework Information Society Technologies programme concluded negotiations to fund the Data Grid research and development project. The project was submitted to the EU by a consortium of 21 bodies involved in a variety of sciences, from high-energy physics to Earth observation and biology, as well as computer sciences and industry. CERN is the leading and coordinating partner in the project.



An initiative to build a prototype computer grid infrastructure for handling the data produced by experiments at CERN's LHC collider is well under way. Only one Tier 1 centre is shown here, but in fact there will be Tier 1 centres in France, Italy, the Netherlands and the UK, with two or more Tier 2 regional centres elsewhere in each country. A number of Tier 3 centres will be implemented at university campus level, while Tier 4 centres will be located inside research departments.

Starting from this year, the Data Grid project will receive in excess of €9.8 million for three years to develop middleware (software) to deploy applications on widely distributed computing systems. In addition to receiving EU support, the enterprise is being substantially underwritten by funding agencies from a number of CERN's member states. Due to the large volume of data that it will produce, CERN's LHC collider will be an important component of the Data Grid (June 2000 p17).

As far as CERN is concerned, this programme of work will integrate well into the computing testbed activity already planned for the LHC. Indeed, the model for the distributed computing architecture that Data Grid will implement is largely based on the results of the MONARC (Models of Networked Analysis at Regional Centres for LHC experiments) project. CERN's part in the Data Grid project will be integrated into its ongoing programme of work and will be jointly staffed by EU- and CERN-funded personnel.

The work that the project will involve has been divided into numbered subsections, or "work packages". CERN's main contribution will be to three of these work packages: WP 2, dedicated to data management and data replication; WP 4, which will look at computing fabric management; and WP 8, which will deal with high-energy physics applications. Most of the resources for WP 8 will come from the four major LHC experimental collaborations: ATLAS, CMS, ALICE and LHCb.

Other work will cover areas such as workload management (coordinated by the INFN in Italy), monitoring and mass storage (coordinated in the UK by the PPARC funding authority and the UK Rutherford Appleton Laboratory) and testbed and networking (coordinated in France by IN2P3 and the CNRS). CERN is also contributing to the work on testbeds and networking, and it is responsible for the overall management and administration of the project with resources partially funded by the EU.

The data management work package will develop and demonstrate the necessary middleware to ensure secure access to petabyte databases, enabling the efficient movement of data between Grid sites with caching and replication of data. Strategies will be developed for optimizing and costing queries on the data, including the effect of dynamic usage patterns. A generic interface to various mass storage management systems in use at different Grid sites will also be provided.

The objective of the fabric management work package is to develop new automated system management techniques. This will enable the deployment of very large computing fabrics constructed from tens of thousands of mass-market components, with reduced systems administration and operations costs. All aspects of management will be covered, from system installation and configuration through monitoring, alarms and troubleshooting.

WP 8 aims to deploy and run distributed simulation, reconstruction and analysis programs using Grid technology. This package is central to the project because it is among those that enable the large-scale testing of the middleware being developed by the other work package groups and it provides the user requirements that drive the definition of the architecture of the project.

Dozens of physicists, mostly from Europe, will participate in the endeavour while continuing to perform their day-to-day research activities.

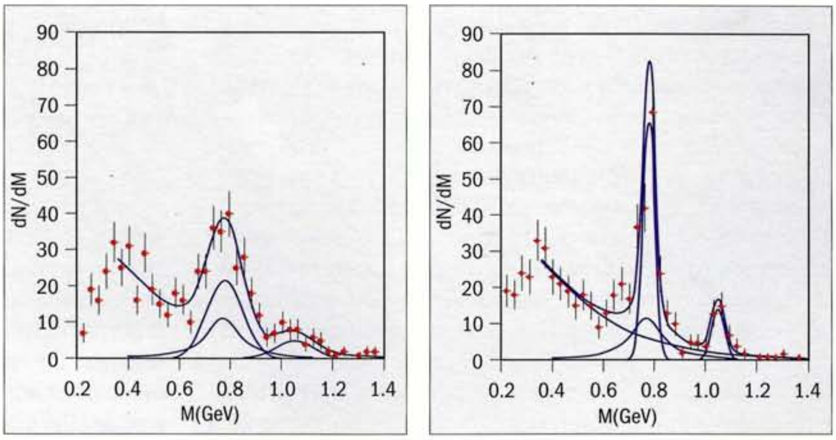
A project architecture task force has recently been appointed, with participants from the relevant middleware work packages and a representative from the applications. Leading US computer scientists are also participating in this effort to ensure that developments in the US continue in parallel with work being carried out in Europe. Data Grid is hosting the first Global Grid Forum in Amsterdam in March, which will aim to coordinate Grid activity on a worldwide scale.

Visit "http://www.cern.ch/grid" for further information on Data Grid.

CERN

Experiments revisit the quark–gluon soup

The NA50 experiment at CERN saw compelling evidence that heavy-ion collisions were recreating the onset of quark–gluon plasma production. NA60 will now take up the baton.



The NA60 experiment's silicon pixel telescope greatly improves dimuon resolution, as demonstrated by these measurements with a proton beam in 1998. Left: normal signal. Right: the signal after adding the pixel telescope. The omega (782 GeV) and phi (1020) mesons stand out clearly.

The RHIC collider at Brookhaven now dominates the world stage for high-energy, heavy-ion collisions. It is set to run later this year with its sights on the full design energy of 200 GeV per nucleon, following its initial running at a lower energy in 2000 (October 2000 p5). The main goal of this research is to explore the transition from ordinary hadronic matter to quark-gluon plasma (QGP) - matter as it is thought to have existed at the birth of the universe.

Meanwhile, a new experiment at CERN's Super Proton Synchrotron is also poised to provide new results, following a decision last November to continue CERN's heavy-ion programme.

The NA60 experiment will complement the new research programme at RHIC, meaning that CERN will continue to be a player in a field currently awaiting the big ALICE experiment at the Large Hadron Collider.

CERN's heavy-ion programme began in 1986, with the initial goal of identifying the phase transition from confined hadronic matter to the deconfined QGP state. Last year, those conducting the experiments concluded that they had produced compelling evidence for a new deconfined state of matter in which quarks roam freely (June 2000 p25).

Several signals for the formation of QGP had been anticipated, and many of them were observed by CERN experiments. Among the most important of these was a sharp reduction in the number of charm-anticharm mesons, J/psi and psi primes emerging from the highest energy-density collisions. This was caused by the tumultuous conditions of the plasma preventing the charm quarks and antiquarks from binding together. Another signal that was observed was an increase in the number of lepton pairs emerging from the collisions. These are the signals on which NA60 will focus.

The NA60 detector builds on the existing apparatus of the NA50 experiment with the addition of two new silicon detectors. One is placed in the beam and measures the interaction point with a precision of 20 μm. The other, placed after the target, is a silicon pixel telescope of almost 1 million channels in a 2.5 T magnetic field, which will vastly improve the mass resolution for muon pairs. Together these detectors will enable the experiment to measure J/psi and psi prime suppression more cleanly, and to measure charmed D-meson production in heavy-ion collisions for the first time.

NA60 will run with protons this year, followed by indium and lead ions in 2002 and 2003. NA60 has chosen indium to test the current interpretation of the pattern of suppression observed by NA50 in lead-lead collisions. Verification of the effect seen by NA50 would bring conclusive evidence that the deconfined quark-gluon phase sets in under SPS conditions. It would also provide fundamental information on the mechanisms driving the transition. Furthermore, NA60's excellent dimuon mass-resolution will allow the experiment to investigate other signals for deconfined matter, including the production of rho, omega and phi mesons, and to check whether the observed intermediate-mass dimuon excess is due to thermal dimuons emitted from free quarks in the plasma.

The NA49 experiment has also received a short extension to complete its data at 40, 80 and 158 GeV per nucleon study with points at 20 and 30 GeV per nucleon. This should allow the onset of the transition to be ascertained with a greater degree of certainty.

RUSSIA

Moscow accelerator creates first beam

The TeraWatt Accumulator (TWAC) project at Moscow's Institute for Theoretical and Experimental Physics (ITEP) has successfully passed its proof-of-principle test. A bunch of carbon-4+ ions from near the laser ion source were pre-accelerated in the accelerator/accumulator facility's new U-3 pre-injector (May 1998 p16), injected and accelerated in the UK booster ring to 300 MeV per nucleon, stripped down to 6+ and stacked into the U-10 storage ring.

First beams have been obtained in the TeraWatt Accumulator project at Moscow's Institute for Theoretical and Experimental Physics. Seen here are project leader Boris Sharkov (left) and project coordinator Nikolay Alexeev in front of the beamline leading from the UK booster ring to the U-10 storage ring.

This marks the completion and commissioning of the new facility's main systems – ion source, ion pre-injector, radiofrequency and power supply for the booster ring, beam transport lines and pulsed magnetic elements.

The essence of ITEP's TWAC project is to upgrade and modify the ITEP accelerator complex so that it will have a new unique capability for investigating the following fields:
- extreme states of matter with high density and temperature, and their relation to the physics stellar interiors;
- basic research into the properties of the nuclear matter (relativistic nuclear physics);
- medicine and radiobiology for tumour therapy using carbon ions.

The project takes advantage of a heavy-ion accelerator facility based on two existing synchrotron rings, and it uses a special stripping technique for stacking pulses accelerated in the UK booster into the U-10 storage ring.

For this first phase the ion source, based on a 5J/0.5 Hz TEA CO_2 laser, has been operated and installed in the U-3 pre-injector area. The 20 mA/20 μs carbon ion beam was matched to the 2 MV/2.5 MHz pre-injector.

The accelerated 16 MeV carbon-4+ ion beam was guided by the new beam transport line to the UK ring and injected. The intensity measured at the injection point is around 1.5×10^{10}/15 μs. The carbon beam is then circulated in the UK ring at constant field.

The power supply of the UK booster ring magnets, of the vacuum system and of the radiofrequency accelerating cavities has been upgraded and the carbon beam accelerated to 300 MeV per nucleon.

Magnetic components of the beam-transfer line connecting the UK and U-10 rings required for the multi-turn injection scheme have been manufactured, installed and adjusted.

For the second phase of the project, the beamline for extraction to the beam-target interaction area will be designed and constructed this year. Focusing elements and the interaction vacuum chamber will be manufactured and installed in the experimental area.

Special attention will be paid to research and development for modern and sophisticated diagnostics for measurements of dense plasma parameters under unique conditions.

Two new beam transport lines and related slow extraction systems will be designed for beam delivery to the medical and nuclear physics experimental areas. The application of electron cooling for increasing the phase space density of accumulated beam will be investigated and the design of the new linac-injector will be completed.

During the third phase (January 2002 – December 2003), experimental facilities for medical physics and for relativistic nuclear physics will be commissioned. A powerful CO_2 laser with 100 J/20 ns output at 1 Hz will be set in operation.

Together with the upgrading of the main accelerator-accumulator systems and with implementation of the pulse compression system, the intensity of the heavy-ion beam will then reach the maximal (target) values:
- in ion acceleration mode, supplying up to 4.3 GeV/nucleon and up to 10^{11} particles/s;
- in ion accumulation mode, 300–700 MeV/nucleon and 10^{12}–10^{13} particles per 100 ns (approximately) pulse
- in medical application mode, some 250 MeV/nucleon, 10^9–10^{10} particles/s.

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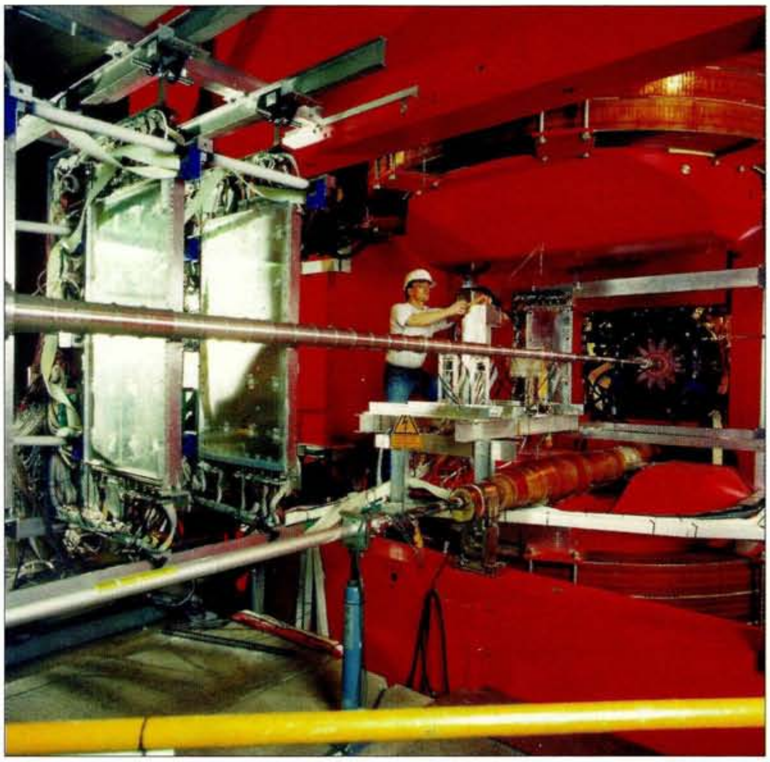
GERMANY

HERA–B finds a new direction

The DESY laboratory in Hamburg has accepted a proposal from the HERA-B experiment for a revised programme of research. This follows the recent commissioning of the B-meson factories at SLAC, Stanford and KEK in Japan, and an earlier recommendation by DESY's Extended Scientific Council to bring HERA-B to an orderly conclusion in the near future.



Drawing to a close – the HERA-B detector at DESY.

The HERA-B experiment was approved in 1995 as a dedicated CP-violation experiment. At the time, the only measurement of this phenomenon, which gives a handle on why nature apparently prefers matter to antimatter, came from experiments on kaon decays at CERN and Fermilab. B-mesons (containing the fifth, beauty or "b" quark) were considered to be richer ground for probing CP-violation, and at DESY a copious source of B-mesons could be provided by a wire target in the halo of the proton beam of the HERA electron-proton collider.

Two "B-factories" were also in preparation in the mid-1990s at SLAC and KEK – each of them single-experiment projects based on novel asymmetric electron-positron colliders. While the B-factories were challenging on the accelerator front, HERA-B was faced with the formidable task of finding its signal amid a background some 12 orders of magnitude as large.

Detecting this signal required a detector of unprecedented radiation hardness that was capable of handling equally unprecedented amounts of data. The ensuing search for radiation-hard technologies has led to important advances in tracking-detector technology, but it has also resulted in substantial delays to the physics programme.

Both B-factories started collecting data in 1999, leading to first results being presented in the summer of 2000 (September 2000 p5). HERA-B, however, had not achieved the required level of sensitivity by the end of HERA's run in August 2000. In response to the recommendation to conclude the HERA-B programme, the collaboration drew up a two-year plan of alternative research that exploits the unique features of the HERA-B spectrometer and trigger systems, and this was approved in December.

The new programme addresses open questions in strong interaction physics and rare decays of charm quarks. The first results are expected in 2002, when a decision will be taken on continuing, possibly with an enlarged programme to include some of the original goals of the experiment.

JAPAN

JAERI/KEK project gets government approval

Phase 1 of the new joint project between the Japanese Atomic Energy Research Institute (JAERI) and the national KEK laboratory on high-intensity proton accelerators (October 2000 p23) has been given the go-ahead to begin construction.

Although formal approval of the budget has not yet been given, notice from the government means that Phase 1 of the project has effectively already been approved.

Phase 1 of the new project will include:
- a 400 MeV normal conducting Linac;
- a 3 GeV rapid cycling Proton Synchrotron operating at 1 MW;
- a 50 GeV PS operating at 0.75 MW;
- a major part of the 3 GeV neutron/meson facility;
- a portion of the 50 GeV experimental facility.

The total budget for Phase 1 is 1335 Oku Yen (1 Oku Yen is equal to 10^8 yen, or approximately $860 000) and it is expected to be completed within six years. The entire cost of the project, including Phase 2, is expected to be in the region of 1890 Oku Yen.

For full details on this far-reaching project, see the article in the October 2000 issue of *CERN Courier*.

VIETNAM

Physics meeting reflects Vietnam's prosperity

Left: Vice Prime Minister Pham Gia Khiêm (second from left) greets distinguished visitor Norman Ramsey. With them are Nguyên Van Hiêu (left) and meeting organizer Trân Than Vân. Right: Nobel laureate Jerome Friedman (front, right) gave a public lecture.

The latest of the now traditional Rencontres du Vietnam, organized by Trân Than Vân, took place in Hanoi last summer. Some 200 participants from all over the world attended, including a conspicuous number of Vietnamese physicists. The conference on Physics at Extreme Energies was held in the Horizon Hotel in central Hanoi, one of the new hotels signalling the rapid economic development of Vietnam. The change was especially evident to participants who were present at the first event of the series in 1993.

Two Nobel prizewinners, Jerome Friedman (who gave a very successful public talk entitled "Are we made of quarks?") and Norman Ramsey, attended. The packed programme covered all of the most significant recent results in particle physics and cosmology.

Roberto Peccei (UCLA) gave the introductory talk on the fundamental energy scales in particle physics and in the universe. Highlights of the meeting included the recent breakthroughs in the measurement of cosmological parameters; the results of experiments on neutrino oscillations; the latest news from LEP (especially on the search for the Higgs particle and for new physics); and the review of the indications for quark-gluon plasma in heavy-ion collisions. Also of interest were the updates on flavour physics, with the results on CP violation in K decay and the start of the BaBar and Belle "beauty factories" that will unveil CP violation in B decays; and the summaries on the status of such diverse fields as QCD, electroweak theory, quantum gravity, astrophysics and cosmic rays.

Nguyên Van Hiêu, chairman of the local organizing committee, described the development and present status of physics in Vietnam. The concluding talks, one on experiment and one on theory, were given by Pierre Darriulat (formerly of CERN and now a distinguished professor at Hanoi) and Guido Altarelli of CERN. Away from the science, concerts of Vietnamese music were organized, introduced and explained by talented musicologist Tran Van Khe, who has become a feature of the whole series of Rencontres.

School for science

Since the first Rencontres meeting in Hanoi in December 1993, an international school in theoretical physics has been held there annually. This attracts not only Vietnamese scientists, but also those from the Association of South East Asian Nations, China and Bangladesh. The seventh such school was held last year under the direction of Patrick Aurenche (Annecy).

In September 1994 Jim Cronin (Chicago) and Alan Watson (Leeds) were invited to look at the possibility of including a Vietnamese group in the international Pierre Auger high-energy cosmic-ray collaboration. For three years now a group led by Vo Van Thuan has been part of this project. Its activities have increased, thanks to the arrival of former CERN physicist Pierre Darriulat, who plays an important role in directing the research of the group.

An advanced technology school, directed by Jean Badier of the Ecole Polytechnique, began in 1996, just after the second Vietnam Rencontres. The first two such schools focused on the physics of silicon, while the latest two covered electrochemical sensors to measure water quality.

During this year's summer meeting, numerous new contacts were made between local laboratories and international research centres. A collaboration between physicists from Ho Chi Minh City and Fermilab is under study to enable Vietnamese scientists to work in major groups at Fermilab.

An important aspect of these meetings is the enthusiasm that they generate among young scientists. Since 1995, talented Vietnamese students have entered the entry exams for the prestigious Paris Ecole Polytechnique. About 20 of them are currently studying there, and many others are attending French and US universities.

MANAGEMENT

Scientists seek the secret of start-up and spin-off success

Basic science does not usually have immediate benefits for industry or the economic world in general, and delays in visible return are often difficult to reconcile with the short-term expectations of market-driven activities.

However, during the last decade the jobs that have been generated by start-up companies have injected extra liquidity into a once stagnant labour market. Since the early 1970s, universities and their incubator schemes, particularly in the US, have been supporting young entrepreneurs. This new culture has led to the establishment of a large number of start-up companies. However, the gold rush aspects of such mass migration can also have negative implications.

Aspects of this new scene were reflected in a Basic Science and Entrepreneurship workshop that was held during the recent IEEE Nuclear Science Symposium and Medical Imaging Conference in Lyon, France, and organized by François Bourgeois, CERN; Alan Jeavons, Oxford Positron Systems (UK); Yves Jongen, Ion Beam Applications (Belgium); and Gert Muehllehner, UGM (US).

The workshop aimed to highlight the factors that are necessary for success in entrepreneurship and the best practices to be adopted in the research and development environment. During a session entitled "The do's and the don'ts of entrepreneurship", five founders of spin-off companies reported on the problems they faced when developing their businesses. In addition to the well known problems – establishment of a business plan, funding, marketing and growth – the panel discussion gave useful indications on requirements of particular relevance to scientist-entrepreneurs: to match a high-tech product with market and customer needs; to team up with third parties knowledgeable in business and administration (e.g. local business schools); and to know how to produce a business plan.

As Muehllehner said: "To succeed, the scientist-entrepreneur needs to have a finished product, an established market, a team of people (finance, marketing and sales) and a source of money. Failing to have one of these [means] the chance of success drops to 80%; failing to have two [means] it is only 25%; and don't even start if you're missing more than two."

Benefiting from science – speakers at a Basic Science and Entrepreneurship workshop held during the recent IEEE Nuclear Science Symposium and Medical Imaging Conference in Lyon, France.

During the session entitled "How to turn a scientist into an entrepreneur", representatives of major research and development laboratories and European institutes presented their most recent initiatives. The oral presentations gave special attention to training actions, support given to entrepreneurs (identification of nascent technologies, intellectual property, seed capital and funding), and measures aimed at fostering a more entrepreneurial spirit.

Panel discussions agreed that there was substantial value in the direct exploitation of technology as compared to licensing. The need to foster an entrepreneurial spirit among scientists and their evident willingness to transfer technology was also examined. The raising of their awareness of the value of intellectual property and of exploiting its worth, together with the need for networking with other entrepreneurs and venture capitalists, were seen as key measures likely to foster a change of culture, at least in Europe.

For further details visit "http://www.cern.ch/CERN/Technology/NSS 2000/entrepreneurship/".

USA

CESR set to bow out of B-particle business

After some 20 years of making milestone contributions to the physics of B-particles (containing the fifth beauty or "b" quark), the CLEO collaboration at Cornell's CESR electron-positron collider is now looking to step down in energy.

It has identified a broad programme of important physics that can be studied in the tau/charm threshold region with a luminosity of 3×10^{32} per cm^2 per s. Simultaneously, Cornell is studying the feasibility of converting CESR to such a facility.

A workshop will be held at Cornell on 5–7 May to provide an opportunity for the elementary particle physics community to explore the opportunities provided by the CLEO III detector operating in this energy/luminosity region. More information is available at "http://lns.cornell.edu", or e-mail "spoke@mail.lns.cornell.edu".

With high luminosity B-factories now in operation at PEP-II, SLAC, Stanford, and KEKB in Japan, CESR is looking for alternative research topics.

CANADA

Isotope source reaches full energy

The new Isotope Separator and Accelerator (ISAC-I) at the Canadian TRIUMF laboratory in Vancouver has reached its maximum energy on schedule.

On 21 December 2000 a beam of singly charged helium-4 ions was accelerated through the ISAC drift-tube linac to 1.5 MeV per nucleon.

A major component of the laboratory's programme over the coming years will be the planned upgrade to ISAC-II, boosting the energy to 6.5 MeV per nucleon and extending the menu to cover isotopes in the mass range 30–150.

A forthcoming article will cover ISAC commissioning in more detail.

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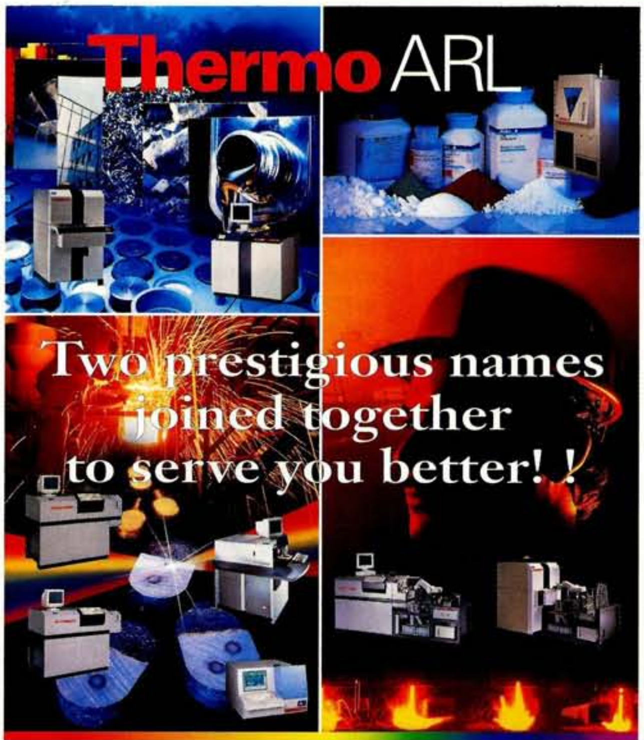

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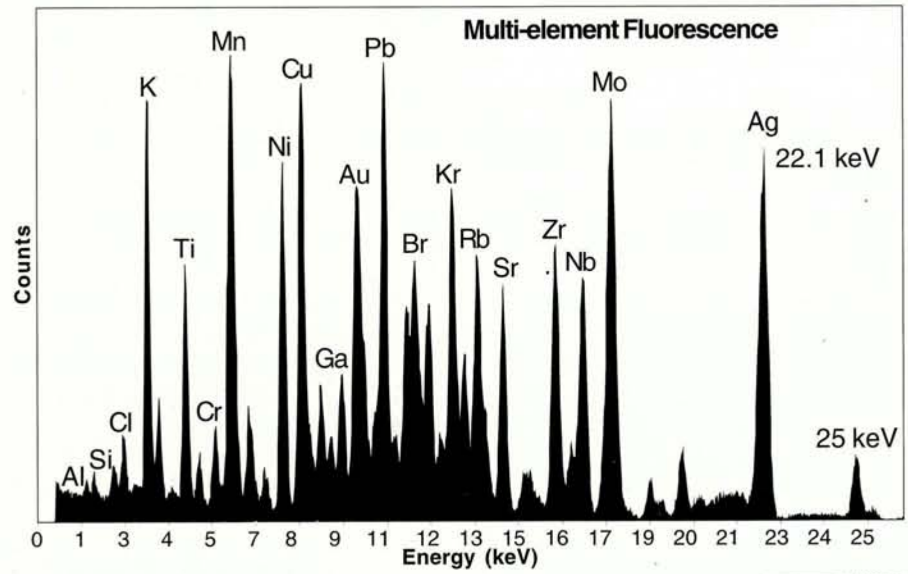

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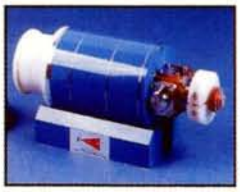

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Edited by Emma Sanders

Hubble Telescope explores the event horizon

Observations using the Hubble Space Telescope show matter disappearing as it falls beyond an event horizon. If correct, this would be the first direct evidence for the existence of black holes.

An event horizon is the predicted boundary round a black hole beyond which nothing – not even light – can escape. In the past, the existence of black holes was inferred by observing orbiting stars and clouds of gas. The mass of the central object can be estimated from the rotation velocity of the orbiting matter.

The new results, presented at the American Astronomical Society meeting in San Diego earlier this year, track the ultraviolet emission from hot clumps of gas circling the known black hole candidate Cygnus XR-1.

In two cases the signature of the emission dims rapidly, exhibiting the "dying pulse train" predicted by theory, before disappearing as it dips below the event horizon. The light dims as it is stretched by gravity to ever-longer wavelengths in the approach to the black hole. The discovery was made during a new analysis of observations dating from 1992. Work continues to find more such events and eliminate the possibility of errors.

Observations using the Chandra X-ray satellite, also presented at the San Diego meeting, confirm this picture. Chandra found a prodigious energy output from 12 X-ray neutron star systems – a hundred times that from more massive black hole candidates.

ESA launches Lobster

As ESA headquarters in Paris celebrated the first birthday of its XMM-Newton X-ray space observatory, astronomers were already planning the next generation of X-ray telescopes.

Lobster is on the cards for the ESA lab on the International Space Station, due for launch in 2004. The X-ray telescope's new design was inspired by lobsters, which have eyes without lenses, and work by reflecting light from the inside of a large number of square tubes arranged on the surface of a sphere.

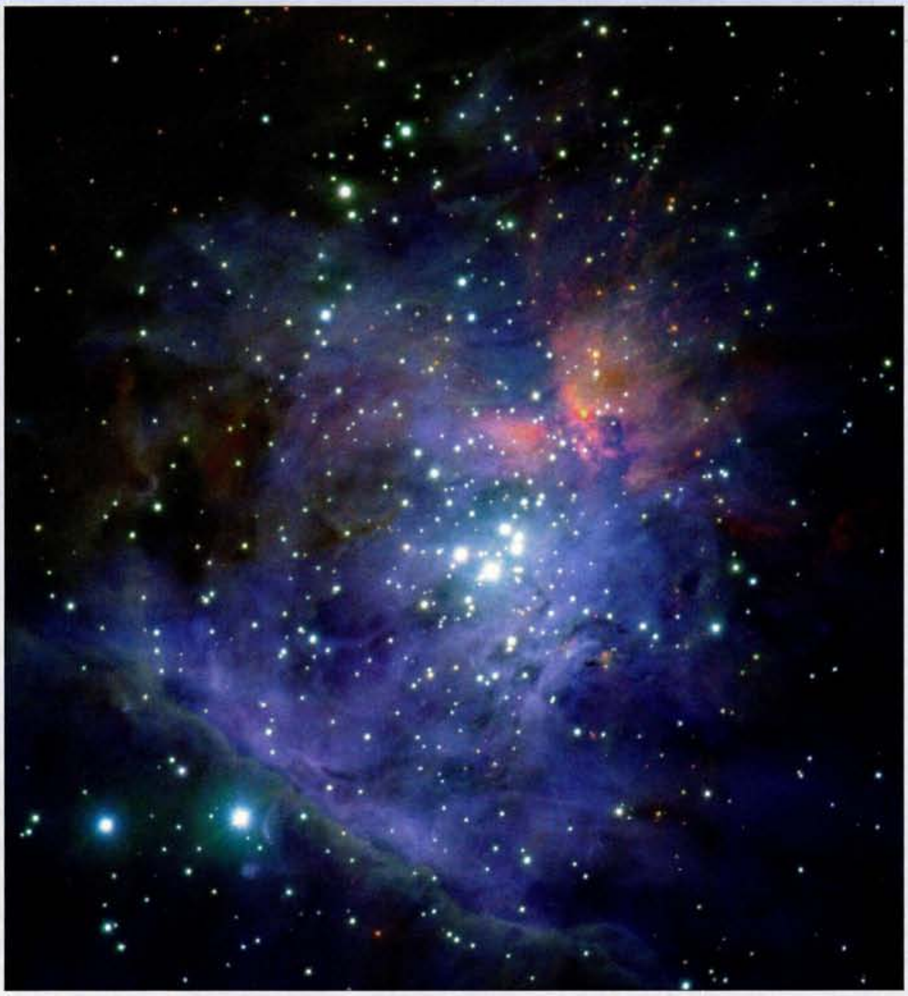
The design will give an instantaneous field of view of $180 \times 30°$ with a resolution of about 4 arc min. It will be able to map the whole sky every 90 min – ideal for detecting transient events such as the X-ray output from active galaxies and gamma-ray bursts.

In the US there are plans to build an X-ray interferometer. A NASA team at the Goddard Space Flight Center has achieved 100 milliarc second resolution in the lab – similar to the Hubble Space Telescope and five times as good as conventional X-ray telescopes.

Background hots up

The spectrum of a distant quasar reveals the presence of cosmic microwave background radiation when the universe was just 2.5 billion years old. The observations allow astronomers to place limits on the temperature of the radiation at this epoch – 6–14K. This is consistent with Big Bang theory, which predicts 9K. The quasar was imaged using the 8.2m Kueyen telescope.

Picture of the month



This image of the central part of the Orion Nebula is a combination of 81 separate infrared observations using European Southern Observatory's Very Large Telescope in Chile. The heart of the nebula contains around a thousand very young stars, which are invisible at optical wavelengths. They are crowded into a space less than the distance between our Sun and its nearest star neighbour. (ESO.)

Micropattern detectors promise a big future

As well as being important in particle physics, multiwire detectors have been applied in other fields: X-rays for medical imaging, ultraviolet and single-photon detection, neutron and crystal diffraction studies and so on. Now their major limitation of modest rate capability has been overcome through the introduction of micropattern devices.

The pioneering work at the beginning of the 20th century by Thomson, Rutherford and Geiger, just after the discovery of electromagnetic radiation, focused attention on the development of tools to detect this radiation. The single-wire proportional counter (Geiger counter) became an essential physics tool.

Georges Charpak's 1968 invention of the multiwire proportional chamber (MWPC) ushered in a new era, with a major impact on high-energy physics. The main performance features of the MWPC are a space resolution of few hundred micrometres, the two- and three-dimensional localization of incident radiation, excellent energy resolution and rates of a few kilohertz per square millimetre.

Other MWPC applications include crystal diffraction, beta chromatography and dual-energy angiography. A low-dose X-ray digital radiography scanner based on the MWPC developed at Novosibirsk is currently being used routinely in hospitals in Russia and France.

Despite this success, some basic limitations of MWPCs restrict their use at high rates. The wire spacing defines the best achievable position accuracy and gives two-track resolution to about 1 mm. Electrostatic instability limits the stable wire lengths. The widths of the induced charges define the pad response function and, at high rates the accumulation of positive ions spoils rate capability.

The advent of high-luminosity colliders demands fast, high-performance position-sensitive detectors. Key requirements are unsurpassed position localization; good two-track, two-dimensional and time resolutions; and the ability to withstand hostile radiation over a considerable period of time.

The microstrip generation

The invention of the microstrip gas chamber (MSGC) by Anton Oed marked another era of gaseous detectors. An MSGC comprises a pattern of thin anode and cathode strips on an insulating substrate with a pitch of a few hundred micrometres. With a drift electrode and with appropriate potentials applied, the electric field is such that positive ions are removed immediately from the avalanches, increasing rate capability by some two orders of magnitude.

The salient features are localization accuracy of some 30 μm, double-track resolution of 400 μm and good energy resolution. Long-term and magnetic field operations have been demonstrated, and these devices have found applications in many fields of X-ray spectrometry digital radiography and high-energy physics.

Difficulties began when MSGCs were exposed to the highly ionizing particles that are usually present in a high-luminosity machine. These particles deposit in the detection volume almost three orders of magnitude as much charge as a minimum ionizing particle.

In the case of microstrip detectors, the anode–cathode distance is small compared with that in a wire chamber, and, with electric fields at the tip of the streamer and along the surface being high, the streamer is likely to be followed by a voltage- and ionization density-dependent discharge. The charging up of surface defects, long-lived excited states and overlapping avalanches seems to be the culprit, lowering the discharge limits of operation. With this insight, several novel designs appeared.

The detection of micropatterns

Advances in photolithography and the application of silicon foundry techniques heralded a new era in the design and fabrication of "micropattern detectors". The microdot (introduced by Biagi) is the ultimate gaseous pixel device, with anode dots surrounded by cathode rings. Although achieving gains of about 1 million, it does not discharge, probably because the field emulates the 1/r field of an anode wire.

A very asymmetric parallel plate chamber, the MICROMEGAS detector invented by Charpak and Giomataris, takes advantage of the behaviour at high fields (100 kV/cm) in several gas mixtures, thus achieving stable operation with the minimum of ionizing particles at high gains and rates. Large MICROMEGAS detectors are being made and tested for the COMPASS experiment at CERN (September 1999 p22).

A new detector invented by Lemonnier is the CAT (*compteur à trous*). This comprises a narrow hole micromachined into an insula-

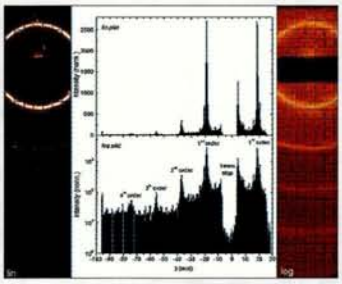


Fig. 1. Diffraction pattern of a lipid membrane made with a VIP micropattern detector at the Elettra synchrotron source in Trieste, Italy. Complex algorithms made for the read-out cell border and superposition of several images allow great detail to be obtained from the patterns. A linear and logarithmic profile of the pattern are in the centre. (N Pavel, Siegen.)

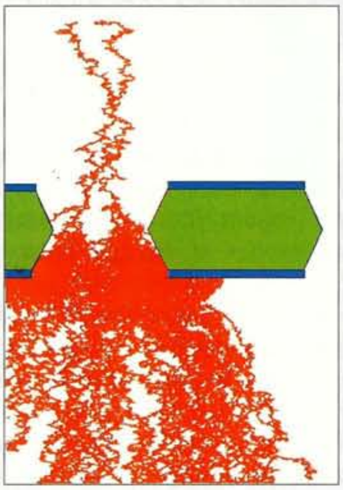


Fig. 2. Electron avalanche through a channel in a gas electron multiplier.

Fig. 3. Image of a small bat (width 32 mm with a pixel size of 50 μm). Two-dimensional read-out boards made using GEM technology have been made for digital absorption radiography. (F Sauli, CERN.)

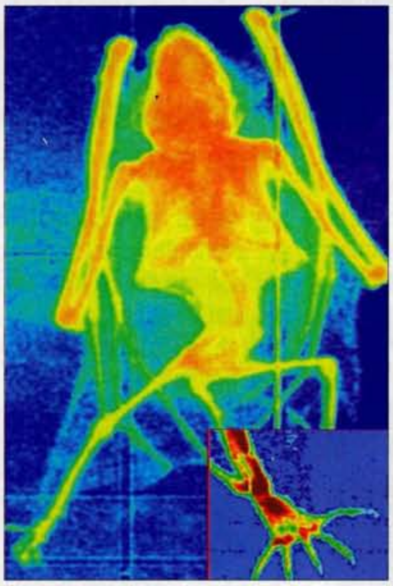
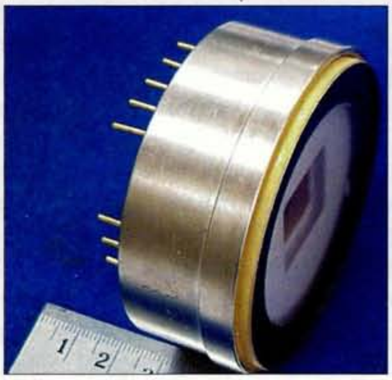


Fig. 5. Sealed photocathode coupled to a micropattern detector (A Breskin, Weizmann Institute).



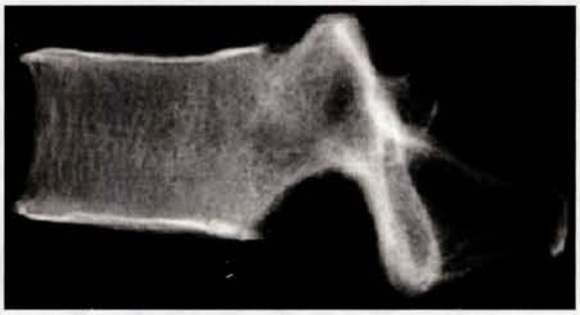


Fig. 4. Operating in pure xenon at atmospheric pressure, MICROMEGAS detectors have been developed for X-ray imaging. This shows a human vertebra (70 × 25 mm) scanned by a MICROMEGAS, giving a resolution of 250 μm. (G Charpak and M Meynadier, Biospace.)

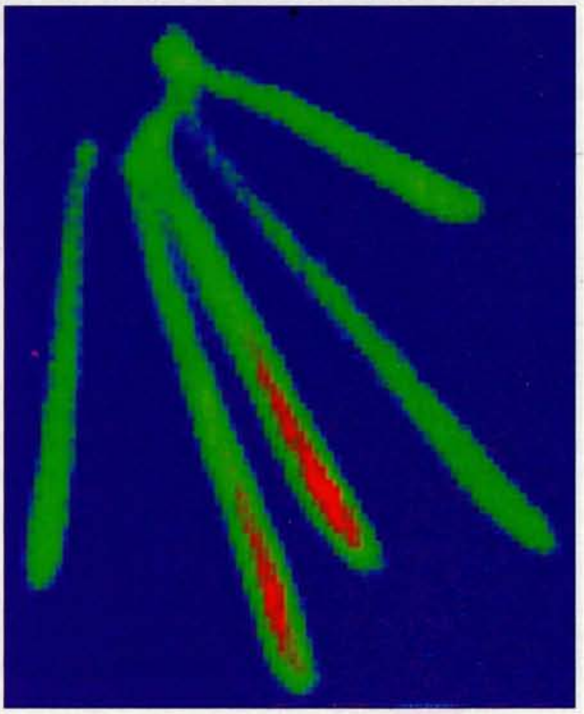


Fig. 6. Scintillation images of alpha tracks using a GEM (LIP, Coimbra).

tor metallized on the surface, which acts as the cathode, while the metal at the bottom of the hole constitutes the anode. With appropriate potentials and a drift electrode, this scheme acts as a focusing lens for the drifting electrons left in the wake of ionizing radiation.

Removing the insulator leaves the cathode as a micromesh, which, with a thin gap between it and the read-out electrode, emulates CAT operation (hence microCAT or μCAT). This structure offers gains of several 10^4. Another option uses ingenious read-out from "virtual pixels" made by current sharing, giving 20 times as fine resolution compared with the read-out cell and 400 times as many virtual pixels. The μCAT combined with the pixels is called the VIP (figure 1).

A new concept of gas amplification introduced by Sauli in 1996 is the gas electron multiplier (GEM; December 1998 p19) manufactured using printed circuit wet etching techniques. A thin (50 μm) Kapton foil clad on both sides with copper is perforated and the two surfaces maintained at a potential gradient, thus providing the necessary field for electron amplification (figure 2).

Coupled with a drift electrode above and a read-out electrode below, it acts as a high-performance electron amplifier. The essential features of this detector are that amplification and detection are decoupled and the read-out is at zero potential. Charge transfer to a second amplification device opens up the possibility of using a GEM in tandem with an MSGC or a second GEM.

With these developments and a better understanding of the discharge phenomena, new detectors have appeared: Micro-Wire, an extension of the μDOT in the third dimension, Micro-Pin Array, Micro-Tube, Micro Well, Micro Trench and Micro Groove. All aim for minimal insulator between the anode and cathode to reduce discharges. ▷

The Micro-Tube uses a combination of laser micromachining and nickel electroplating, and gives an electric field that increases rapidly at the anode, similar to the μDOT. However, there is no insulating material on the direct line of sight from cathode to anode. These features are predicted to lead to higher gas gains, better stability with fewer discharges and the reduction of charging effects.

Micropatterns in particle physics

Highly ionizing particles produce discharges in all micropattern detectors with a typical gain of several thousand. It is possible to obtain higher gains with gases that permit a lower operating voltage and have higher diffusion, thus lowering the charge density and photon feedback probability. Combining the MSGC with a GEM, reliable operation has been demonstrated up to gains of several 10^4. Some 200 large detectors are operating at HERA-B at DESY for inner tracking. The DIRAC experiment at the CERN PS also employs MSGC + GEM detectors, which improved momentum resolution by a factor of two.

Two GEMs in tandem provide a robust detector. Large ones are being built for CERN's COMPASS experiment. Adding a third GEM (e.g. the possible LHCb tracker at CERN) offers even more stable operation in a hostile beam environment. At gains of 10^4, spark probabilities as low as 10^{-10} have been measured.

For experiments at the future TESLA linear collider, a double or triple GEM configuration is under consideration owing to its fast electron signal, minimal magnetic distortion effects and suppression of ion feedback. Special hexagonal pads are being developed, aiming at unprecedented 50–60 μm resolution in a time projection chamber using charge sharing and induction signals.

A feasibility study aimed at improving the detection of Cherenkov light has been carried out at SLAC, and a cascade of four GEMs in pure ethane has given very high gains.

Beyond high-energy physics

Conventional film radiography has very good spatial resolution but limited dynamic range. For film, the storage and display media are the same, and the film image saturates (additional photons do not cause proportional film darkening). The display contrast is thus fixed at the time of film exposure, and one sees little difference in visible contrast in different parts of a film image that receive widely different signals. On the other hand, in a digital system, the storage medium (computer) does not saturate and has infinite dynamic range. The display media being different from storage, the display contrast can be varied at will.

Digital scanned projection radiography thus offers improved range and adjustable contrast. The image can be enhanced using photon energy information. A GEM + MSGC combination operating in xenon/methane at 4 atm yields good diagnostic X-ray images. Specialized two-dimensional read-out boards have been made with the GEM technology for use in digital absorption radiography (figure 3).

X-ray diffraction studies using MSGCs have yielded the rapid analysis of single-crystal structures using both position and time information from the incident X-rays. Crystal structures of organic molecules can be obtained in a matter of minutes. Fast time-resolved X-ray diffraction measurements offer a time variation of the small angle X-ray scattering pattern of a protein solution within 10 ms. MICROMEGAS detectors have been developed for X-ray imaging (figure 4).

Progress in rate capability and radiation tolerance has revolutionized the potential applications of these detectors.

A combination of an X-ray converter, an MSGC and a visible photocathode shows great promise for use in digital mammography. The essential features are a large, flat area and high resolution. With a photocathode (that is sensitive to both ultraviolet and visible light) coupled to a micropattern detector, sealed gas avalanche photomultipliers are being developed for fast imaging, flat read-out devices for scintillator and scintillating fibre arrays, and medical imaging.

Here, single photon detection has been actively pursued. With low preamplification in the drift region, combined with high diffusion, fully efficient single photon detection is possible. Using a CsI photocathode coupled to three or four GEMs in tandem, large gains (10^5) have been obtained in pure argon, and even larger (10^6) with an admixture of few percent of methane (figure 5).

Scintillation light and X-rays

With a GEM as amplifier and a CCD camera, X-ray images of individual alpha tracks have been seen via scintillation in argon and CF_4 (figure 6). The spectral distribution of the emitted light is analysed in terms of the number of photons emitted per electron in the visible and near-infrared regions (wavelength range 400–1000 nm). The maximum number of emitted photons decreases with pressure.

In X-ray astronomy, measurements of X-ray polarization are useful to investigate features of magnetic fields in pulsars, nebulae, etc. X-ray polarimeters have been developed using glass capillary proportional counters (GCPs) and GEMs.

The emission direction of the primary electron depends on the polarization of the incident X-rays, so information on polarization can be extracted. Polarimeter performance is expressed as a function of detection efficiency and modulation, and hence gas pressure and gas depth.

Exploiting the time resolution and the selective GEM sensitivity to soft X-rays, imaging the dynamics of fusion plasmas has been attempted by a Frascati-Pisa group for the Frascati Tokamak Upgrade. With a GEM and individual pixel read-out, time-resolved plasma diagnostics give information on temperature and turbulence.

Gaseous chambers have matured over the past few decades, resulting in several applications in particle physics and diagnostics. The past 10 years in particular have seen novel developments in micropattern gaseous detectors. Our understanding of the discharge mechanisms in these devices has also increased, leading to design improvements. Progress in rate capability and radiation tolerance has revolutionized the potential applications of these detectors in radiology, diagnostics, astrophysics and other fields. Micropatterns are thus assured of a big future.

Archana Sharma, *University of Maryland.*

Listening for the music of gravity

The latest generation of high-precision experiments is bringing observers one step closer to detecting the elusive song of gravity waves.

Two of the world's interferometric gravitational wave detectors – Japan's TAMA project and the LIGO laboratory in the US – have recently attained two significant milestones in the ongoing quest to detect the waves produced by gravity in transit.

The 300 m TAMA interferometer near Tokyo, which achieved extended servo lock in 1999 (March 1999 p10), has continued to pioneer the field. Last September, in a thrilling two-week test run, TAMA logged 160 h of interferometer "in-lock" operation, proving the viability of the technique as well as its reliability.

Left: The Hanford Gravitational Wave Interferometric Observatory. The Corner station with one of its 4 km arms extending into the desert is visible, with the perpendicular arm disappearing on the right. Right: Robert Schofield, Ray Weiss and Bill Kells watch the beam monitors in the Hanford control room during one of the LIGO 2 km full-lock acquisitions.

Not only did the TAMA team by far surpass its target of 100 h in-lock, but it was able to maintain individual lock periods lasting as long as 12 h, in spite of the dauntingly noisy local seismic environment.

During the in-lock time of an interferometer – equivalent to the storage time of a particle collider – the instrument listens intently for the whispers of the universe. Longer in-lock time means more efficient listening capabilities.

Greater sensitivity

Even more important is the fact that in less than two years, the TAMA group has lowered the noise floor by more than two orders of magnitude, to an astonishing 10^{-21} strain sensitivity. In a small frequency range, this is close to the design value.

The strain sensitivity of an interferometric gravitational wave detector is analogous to the luminosity (collision rate) of a particle collider. The greater the sensitivity, the greater the range of the interferometer, and the shorter the time it must wait to register any signal of a stellar collision or an explosive event.

LIGO laser beams

Meanwhile, in the desert near Hanford, Washington State, the LIGO group has been chasing laser beams down the twin 2 km beam tubes of the first, and smallest, of LIGO's three gravitational wave interferometers.

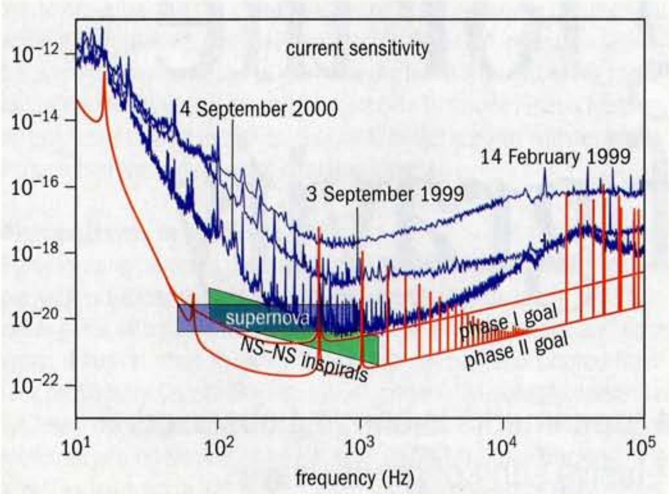
Various partial configurations have been tested during recent months, including a recombined Michelson–Morley interferometer with Fabry–Perot arms. Lock periods of several hours were solidly achieved, although without the power recycling system that was planned for the final configuration.

Then, in a momentous week last October, both Fabry–Perot arms of the complete Michelson–Morley interferometer came alive, with the power recycling cavity fully operational.

The latter is so named because it gathers the return laser power from the interferometer and recycles it. When operating, this configuration stores up to 30 times as much power in the arms, thereby increasing the interferometer's high-frequency sensitivity. One drawback is that the power recycling mirror makes the interferometer controls an order of magnitude more difficult.

As these breakthroughs were being made, the atmosphere at LIGO was tense but cautiously optimistic. The locks achieved were somewhat unstable – lasting a few minutes at the most – and the stored beam power was always very low. Nevertheless, it was reassuring to see that everything was working, even if only for a short length of time.

The importance of these locks for LIGO is comparable with the first flight of the Wright brothers, of which an observer said: "It ▷



TAMA sensitivity spectra. The TAMA interferometer started with 100 times less space strain sensitivity than the design value. After less than two years it is already close to the design figure at 1 kHz. The nominal sensitivity is expected to be reached in the next few months by means of advances in laser stability and the introduction of the power recycling mirror at high frequencies. At low frequencies the solution will come with an advanced, passive seismic attenuation system. In a second phase the strain sensitivity will be improved by another order of magnitude.

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doesn't stay up long. It isn't very far off the ground. But it does fly!"

A long and challenging road must still be travelled before gravitational wave physicists can hope to snare these elusive ripples. The TAMA group must improve the interferometer's high-frequency sensitivity curve by enhancing laser stability and introducing their power recycling cavity, while also implementing a state-of-the-art seismic attenuation system on the low-frequency end.

With the start-up of the Hanford 2 km interferometer, LIGO's commissioning team has only just begun the work that will be required to render it fully operational. The LIGO crew will have to follow the same troubleshooting and improvement route as their Japanese colleagues. A series of engineering runs will be used to collect data and pinpoint any sources of trouble.

Big brothers

In the meantime, the LIGO 4 km interferometer "bigger brothers" are rapidly nearing completion. The LIGO team stationed at the Livingston, Louisiana laboratory has concluded installation of its interferometer, and light is already bouncing back from the end mirrors. Interferometric lock is expected in the next few months. Back in Hanford, work on the second 4 km interferometer is well under way.

Indeed, gravitational wave scientists seem to be busy all around the world. The GEO group in Hannover, Germany, has already established lock in the first of its folded 1200 m cavities, and preparations are under way to install the first monolithic test mass suspension. In this configuration, the fused silica masses are suspended on fibres of the same material for thermal noise suppression.

Last but not least, in Cascina, Italy, members of the Virgo team are preparing to start up their central interferometer, even as their twin 3 km arms continue to stretch north and west. Virgo's advanced seismic attenuation systems, which are virtually complete, will follow the start-up procedures, while continuing problems in the beam injection system are expected to be resolved by early spring this year.

There has also been rapid progress from the data analysis end. Computer specialists and gravitational wave theorists are sharing their efforts and stretching their imaginations, producing algorithms and templates that are capable of extracting the cosmic signal from the vast amount of interferometer background noise.

While construction and commissioning advance, the different observatories are looking forward to the time when they will be able to synchronize their operations and operate a precisely pointable global gravitational wave array.

Within a couple of years, the ultra sensitive ears of interferometers around the world should be poised to listen at last to the song of gravitational waves – although the low sensitivity of our first efforts suggests that this may be a thin and fuzzy tune.

However, plans are under way to upgrade our antennas. Detector upgrades allowing high-sensitivity observation runs are already scheduled for the second half of the decade. And with this improvement comes the hope that one day we will be able to listen in awe to the symphony of the stars.

Riccardo DeSalvo *and* **Dave Beckett**, *LIGO project, California Institute of Technology.*

The recent symposium at Minnesota, US, to celebrate 30 years of supersymmetry theory, attracted many key figures in the field.

Glimpses of superhistory

Nearly 30 years after its discovery, supersymmetry remains the prime candidate to cure all of the ills of our understanding of elementary particle behaviour. Putting aside the question of experimental evidence, a recent meeting looked at the history of supersymmetry.

The word according to Ed Witten

"Supersymmetry, if it holds in nature, is part of the quantum structure of space and time...The discovery of quantum mechanics changed our understanding of almost everything in physics, but our basic way of thinking about space and time has not yet been affected...Showing that nature is supersymmetric would change that, by revealing a quantum dimension of space and time, not measurable by ordinary numbers...Discovery of supersymmetry would be one of the real milestones in physics."

Supersymmetry is now 30 years old. The first supersymmetric field theory in four dimensions – a version of supersymmetric quantum electrodynamics (QED) – was found by Golfand and Likhtman in 1970 and published in 1971. At that time the use of graded algebras in the extension of the *Poincaré group** was far outside the mainstream of high-energy physics

Three decades later, it would not be an exaggeration to say that supersymmetry dominates high-energy physics theoretically and has the potential to dominate experimentally as well. In fact, many people believe that it will play the same revolutionary role in the physics of the 21st century as special and general relativity did in the physics of the 20th century.

This belief is based on the aesthetic appeal of the theory, on some indirect evidence and on the fact that there is no theoretical alternative in sight. Since the discovery of supersymmetry, immense theoretical effort has been invested in this field. More than 30 000 theoretical papers have been published and we are about to enter a new stage of direct experimental searches.

The largest-scale experiments in fundamental science are those that are being prepared now at the LHC at CERN, of which one of the primary targets is the experimental discovery of supersymmetry.

The history of supersymmetry is exceptional. In the past, virtually all major conceptual breakthroughs have occurred because physicists were trying to understand some established aspect of nature. In contrast, the discovery of supersymmetry in the early 1970s was a purely intellectual achievement, driven by the logic of theoretical development rather than by the pressure of existing data.

Simultaneous discovery

To an extent, this remains true today. The history of supersymmetry is unique because it was discovered practically simultaneously and independently on the both sides of the Iron Curtain. There was very little cross-fertilization – at least in the initial stages. As such, it is not surprising that eastern and western research arrived at this discovery from totally different directions.

While scientific interactions could have been mutually beneficial, they did not occur. Indeed, the political climate of the 1970s precluded such interactions. Of course, once it was recognized that supersymmetry could be integrated into and extend the standard ▷

* Words in italics are explained in the superglossary, p21.



Pioneers of supersymmetry (left to right): Vyacheslav Soroka, Evgeny Lichtmann, Vladimir Akulov, Bunji Sakita, Jean-Loup Gervais, Lochlainn O'Raifeartaigh, Pierre Fayet and John Iliopolous. This Minnesota meeting was one of O'Raifeartaigh's last public appearances before his death last year on 18 November (January p40).

Superworkshop

Last October, Minnesota's Theoretical Physics Institute hosted a symposium and workshop celebrating 30 years of supersymmetry. The opening days featured many of the founding fathers of supersymmetry, including Evgeny Likhtman, Vladimir Akulov and Vyacheslav Soroka representing the Eastern origins of supersymmetry.

From the West, speakers included Pierre Ramond, Jean-Loup Gervais, Bunji Sakita, Pierre Fayet, John Iliopoulos, Lochlainn O'Raifeartaigh, Sergio Ferrara, Peter Van Nieuwenhuizen, Martin Sohnius, S James Gates, John Schwarz, Peter West, Bernard de Wit, Ali Chamsedine, Bernard Julia and Gabriele Veneziano. These historical accounts of, or by, early participants whose successes and failures shaped the modern understanding of high-energy physics, were both emotional and instructive.

One focal presentation was the talk delivered by Mrs Koretz-Golfand, the widow of Yuri Golfand, who shared her recollections of her husband's life and work. This theme was continued by Evgeny Likhtman, Golfand's student. His talk combined anecdotal evidence with a summary of the Golfand–Likhtman results "before Wess–Zumino". It was also a remarkable testimony to how free scientific thought can resist the most oppressive of regimes.

For Evgeny Likhtman, this trip was his first to the West. The historical talks were intertwined with topical reviews devoted to the most exciting modern developments.

model of fundamental interactions, progress on both sides of the Iron Curtain were recognized. However, it was only recently that some of the pioneers who opened the gates to the superworld in the early 1970s met face to face for the first time – in Minnesota.

As so often when exploring new ground, some early work on supersymmetry was hit and miss. Golfand and Likhtman initially reported a construction of the super-Poincaré algebra and a version of massive super-QED. The formalism contained a massive photon and photino, a charged *Dirac spinor* and two charged scalars (spin-0 particles).

Likhtman found algebraic representations that could be viewed as supersymmetric multiplets and he observed the vanishing of the vacuum energy in supersymmetric theories. It is interesting to note that this latter work still only exists in Russian.

Subsequent to the work of Golfand and Likhtman, contributions from the East were made by Akulov and Volkov, who in 1972 tried to associate the massless fermion – appearing due to *spontaneous supersymmetry breaking* – with the neutrino. Within a year, Volkov and Soroka gauged the super-Poincaré group, which led to elements of *supergravity*. They suggested that a spin 3/2 graviton's superpartner becomes massive on "eating" the Goldstino that Akulov and Volkov had discussed earlier. The existence of this "super-*Higgs mechanism*" in full-blown supergravity was later established in the West.

A mathematical basis for the work of Volkov and collaborators was provided by the 1969 paper by Berezin and Katz (published in 1970), where graded algebras were studied thoroughly. In his memoirs, Volkov also mentions the impact of Heisenberg's ideas on the making of Volkov–Akulov supersymmetry.

In the West, a completely different approach was taken. A breakthrough into the superworld was made by Wess and Zumino in 1973. This work was done independently, because western researchers knew little if anything about the work done in the Soviet Union. The prehistory on which Wess and Zumino based their inspiration has common roots with string theory – another pillar of modern theory – which in those days was referred to as the "dual model".

Around 1969, the dual-resonance model of strong interactions, found by Veneziano, was formulated in terms of four-dimensional harmonic oscillators. Nambu advanced the idea that these oscillators represented a relativistic string. After that the scheme was reformulated as a field theory on the string world sheet. The theory was plagued by the fact that the spectrum contained a *tachyon* but no fermions and it was consistent only in 26 dimensions. These problems motivated the search for a more realistic string theory.

A leap into the superworld

The first success was achieved in 1971 by Ramond, who constructed a string analogue of the *Dirac equation*. Shortly afterwards, Neveu and Schwarz constructed a new bosonic string theory. They realized that the two constructions were different facets of a single theory – an interacting superstring theory containing Neveu and Schwarz's bosons and Ramond's fermions.

What are superparticles?

The known elementary particles come in two kinds – fermions, such as quarks, electrons, muons, etc (matter particles), and bosons, such as photons, gluons, Ws and Zs (force carriers). The key feature of supersymmetry is that every matter particle (quark, electron, etc) has a boson counterpart (squark, selectron, etc) and every force carrier (photon, gluon) has a fermion counterpart (photino, gluino, chargino, neutralino, etc). This doubling of the particle gene pool is because supersymmetry is a quantum-mechanical enhancement of the properties and symmetries of the space–time of our everyday experience, such as translations, rotations and relativistic transformations.

Supersymmetry introduces a new dimension – one that is only defined quantum mechanically and does not possess classical properties, such as continuous extent. The particle–superparticle twinning can assuage several theoretical headaches, such as why the different forces – gravity and electromagnetism – appear to operate at such vastly different and apparently arbitrary scales ("the Hierarchy Problem"). The extra particles provided by supersymmetry are also natural candidates for exotica, such as the missing dark matter of the universe.

Superglossary of terms

Anticommutators for two operators, P and Q, the anticommutator is {P,Q} = PQ + QP
Commutators for two operators, P and Q, the commutator is [P,Q] = PQ – QP
Dirac equation equation of motion for a Dirac spinor
Dirac spinor spin 1/2 particle with both left- and right-handed spin components
Higgs mechanism spontaneous symmetry breaking by means of the Higgs boson acquiring a vacuum expectation value
Poincaré group symmetry group that forms the basis of co-ordinate transformations in special relativity
Renormalizability the ability to "cleanse" a theory of mathematical divergences
Spontaneous symmetry breaking the breaking of a symmetry by states rather than interactions
Supergravity gauged supersymmetry. Just as supersymmetry is an extension of special relativity, supergravity is an extension of general relativity
Tachyon a particle that can move faster than the speed of light

In 1972 Schwarz demonstrated the consistency of the theory in 10 dimensions. It was in the study of this theory that algebras with both *commutators* and *anticommutators* first appeared in the western literature. A supersymmetry on the two-dimensional string world sheet was recognized by Gervais and Sakita in 1971. This property of the boson and fermion fields on the string world sheet was called the supergauge invariance, which was probably the first application of the prefix "super" in this context.

Supergravity

The Gervais–Sakita supergauge invariance in two dimensions was the point of departure for Wess and Zumino. Starting in 1973, Wess and Zumino wrote a series of revolutionary papers that set the course for future research. Among these was the construction of a "modern" linear version of supersymmetry in four dimensions. They suggested a scalar-spinor model, which now goes under the name of the Wess–Zumino model. They also formulated the linear version of the supersymmetric extension to QED. In fact, as we know now, string theory contains local four-dimensional supersymmetry (supergravity), but string theorists were very slow to realize this.

The realization came only after supersymmetry in four dimensions was studied thoroughly. In these initial stages the geographic distribution of supersymmetry practitioners was very skewed. The lion's share of early research was carried out at CERN, Trieste, London and Paris. The name "supersymmetry" was coined by Salam and Strathdee in Trieste in 1974. It first appeared in the title of their paper that was devoted to supersymmetric gauge theories.

In the body of the paper they settled for the old-fashioned name, "supergauge". Subsequent progress was rapid. In a series of papers, Wess and Zumino; Iliopoulos and Zumino; and Ferrara, Iliopoulos, and Zumino described miraculous cancellations concerning the *renormalizability* of supersymmetric theories. The superspace/superfield formalism was worked out by Salam and Strathdee. Key non-renormalization theorems were proven by West and others.

Non-Abelian gauge theories were supersymmetrized, simultaneously, by Ferrara and Zumino; and Salam and Strathdee in 1974. Mechanisms for the spontaneous breaking of supersymmetry through F- and D-terms were found by O'Raifeartaigh; and Fayet and Iliopoulos. The foundations of what is now known as the minimal supersymmetric standard model were laid by Fayet.

Supergravity was being developed in parallel. This culminated in 1976 with the publication of two papers by Ferrara, Freedman and van Nieuwenhuizen; and Deser and Zumino. These authors assembled various "superelements" that were in circulation at that time, completing the elegant construction of modern supergravity.

A detailed account of the early history of supersymmetry can be found in *The Supersymmetric World: the Beginnings of the Theory,* which has just been published by World Scientific.

Keith Olive *and* **Misha Shifman**, *Minnesota, US.*

Strength in numbers: particle physics goes global

Particle physics has been "big science" for a long time. Its ambitious projects are also becoming more and more international, for it is only this way that the necessary resources can be amassed. A recent meeting of a special working group of the Organization for Economic Cooperation and Development assessed future needs.

If science knows no geographical frontiers, then its parliaments too need to be international. One such platform is the Global Science Forum (GSF) of the influential Organization for Economic Cooperation and Development (OECD). The GSF, the successor to the OECD's Megascience Forum, which was established in 1992, has set up working groups in several specialist areas, in which particle physics has always featured prominently.

A GSF meeting in London on 13–15 April 2000 agreed to form a Consultative Group to advise the GSF on charting a "roadmap" for high-energy physics over the coming 20–30 years to prepare the way for new large facilities.

Meeting at DESY, Hamburg, of the the Consultative Group of the Global Science Forum of the Organization for Economic Cooperation and Development (OECD). The Chairman was Ian Corbett (left) of the UK.

The group's membership of active physicists and scientific administrators represents OECD member states and also non-member states that have an active high-energy physics programme.

At the London meeting, the group was mandated to consider both accelerator- and non-accelerator-based experimental and theoretical particle physics, plus particle astrophysics, and to report to the GSF in mid-2002.

The GSF initiative has come during a period of rapid innovation in high-energy physics. The Large Hadron Collider is now being constructed at CERN with a collision energy seven times that of the Fermilab Tevatron. Japan, the US and Europe have all developed plans for the construction of a 0.5–1 TeV electron–positron linear collider. The physics case for such a collider is strong and complements that of the LHC. However, the construction costs of such a machine are high.

At the same time, new accelerator ideas have prompted promising R&D on muon storage rings and the resultant creation of intense neutrino beams. At higher energies, R&D on a multi-TeV electron–positron linear collider (CLIC) is continuing, and R&D is starting on muon colliders and higher-energy hadron colliders. In parallel, the marriage of astrophysics and particle physics at both the experimental and the theoretical level is resulting in a significant programme.

First meeting

Approximately 50 delegates attended the first meeting of the Consultative Group at DESY, Hamburg, on 9–11 November 2000, which was chaired by Ian Corbett of the UK. The meeting was also attended by observers from CERN; the various Asian, US, European and international high-energy physics communities (the Asian Committee for Future Accelerators, ACFA; the US High Energy Physics Advisory Panel, HEPAP; the European Committee for Future Accelerators ECFA; and the International Committee for Future Accelerators, ICFA); the particle astrophysics branch of the International Union of Pure and Applied Physics (IUPAP–PANAGIC); and the European Union. Future meetings of the group will be held at CERN, in Japan and in the US before the group reports to the GSF.

The meeting at DESY was especially relevant because of the proposed construction of a 500–800 GeV electron–positron superconducting linear collider (TESLA) by an international collaboration in which DESY plays a central role. Following an introduction by

Hermann-Friedrich Wagner of the German delegation, and a physics perspective by Brian Foster (Bristol), DESY director Albrecht Wagner described in detail the planning and prototype activities of the project. In particular, he showed impressive results achieved by the collaboration on the development of high-gradient accelerator cavities as part of the Tesla Test Facility (TTF2). This will be used as a high-intensity X-ray source from 2003 (the SASE FEL project; July 2000 p26). Wagner announced the submission in March of a Technical Design Report for consideration by the German Government, and he expressed ideas on how such a machine might be built (in particular, involving a Global Accelerator Network of national laboratories in the construction of the machine; June 2000 p19).

Peter Rosen from the US Department of Energy (DOE) pointed out the impressive new particle and nuclear physics facilities coming on line in the US (the upgraded TeV2 proton–antiproton collider at Fermilab; the B-factory at SLAC, Stanford; and Brookhaven's RHIC heavy ion collider) and the need to exploit these facilities. He noted ongoing R&D towards a high-energy electron–positron linear collider, towards the development of muon storage rings and hadron colliders beyond the LHC (VLHC). He said that the US community would discuss future perspectives at a Workshop in Snowmass in June–July, to be followed by an HEPAP panel that would report to the DOE and National Science Foundation later this year.

Long-term health

Ger van Middelkoop (NIKHEF), expressing the viewpoint of smaller European nations that have an active high-energy physics activity, emphasized the importance of CERN to the long-term health of both European and international particle physics.

Noting the increasing international character of Japanese activities (the KEK B Factory and the K2K neutrino project in Japan; LEP and the LHC at CERN; and CDF at Fermilab), Sakue Yamada (KEK) described the major accelerator R&D in Japan towards a high-energy electron–positron linear collider design using the Accelerator Test Facility (ATF) at KEK. He emphasized the importance of input from the physics communities before reaching decisions on the construction of the next accelerator facility.

Finally, Kurt Hübner from CERN described longer-term R&D towards CLIC, a CERN design for a multi-TeV electron–positron linear collider, and collaborations with other European laboratories on R&D towards a muon storage ring and intense neutrino beam. He also noted studies towards upgrading the intensity and/or energy of LHC beams.

In the following discussion there was vigorous support for increasing the R&D expenditure on accelerator technologies. There was also a strong plea to maintain some regional competition in the development of promising physics and accelerator programmes.

Owing to the overlapping R&D activities in Europe, the US and Japan towards a 0.5–1 TeV electron–positron linear collider design, and with parties in each region pushing to build such a machine, "bottom-up" assessments of the high-energy physics situation have been requested. Reports from these bodies are expected during 2001. In particular, ECFA:

- is sponsoring an ECFA-DESY working group on physics and detectors at an electron–positron linear collider that will form part of the Technical Design Report for TESLA;
- is supporting a series of European R&D initiatives towards a muon storage ring and intense neutrino beam complex;
- has formed a working group chaired by Lorenzo Foà on the future of accelerator-based high-energy physics activities in Europe.

The working group, with its membership representing the different CERN member states, has been requested to reach a European physicist consensus on a roadmap for accelerator-based particle physics beyond LHC, as well as the infrastructure required and the R&D still needed. The group expects to be in a position to complete its report in in the middle of this year. At the same time, ICFA has created subgroups to study the technical and organizational issues related to Wagner's Global Accelerator Network of accelerator construction.

The PANAGIC subgroup of IUPAP has recently reported to IUPAP the progress in charting its roadmap outlining key activities, and this was distributed by PANAGIC chairman Alessandro Bettini.

The GSF consultative group also set up a small subgroup to work with the OECD on the organizational and sociological issues of a "world laboratory", and data will be collected on the funding and governmental policies of participating countries. These studies, together with the reports of ICFA, ECFA, ACFA, HEPAP and PANAGIC, will provide the major input to the consultative group.

Allan Clark, *University of Geneva.*

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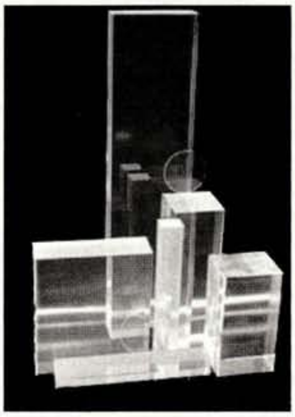

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Season of Higgs

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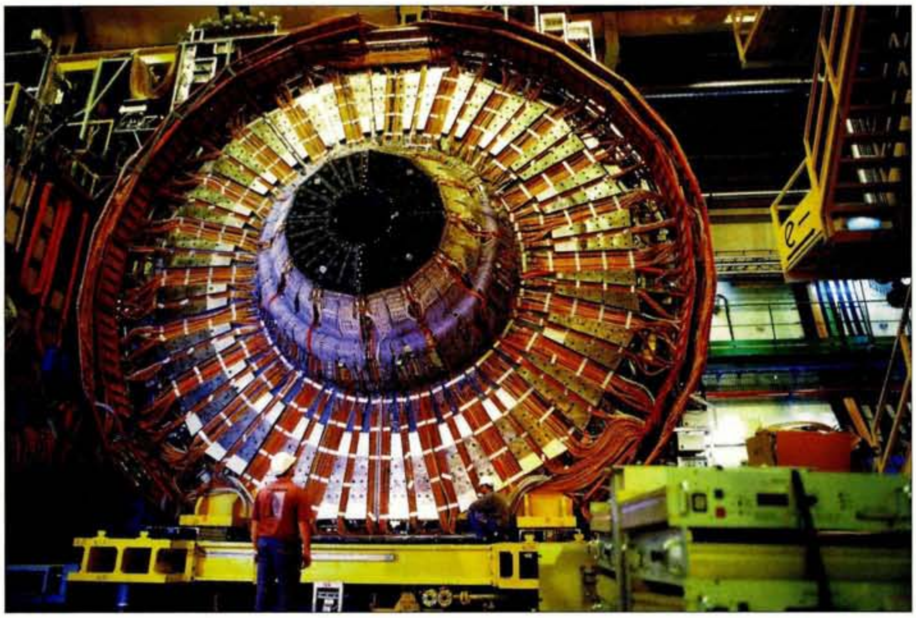
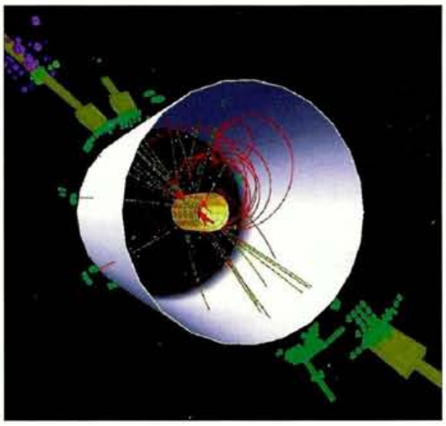




Left: undressing the Delphi detector. Right: a view of the candidate Higgs production event from the L3 experiment. Some of the energy is dissipated as neutrinos and is therefore not visible.

"Season of mists and mellow fruitfulness," wrote the English poet John Keats (1795–1821) in his famous ode "To autumn". At CERN, the autumn of the year 2000 brought a very different scenario.

During the latter months of 2000, *CERN Courier*'s news coverage followed the progress of the experiments at the LEP electron–positron collider as its energy was pushed to unprecedented and unforeseen levels. In the lead-up to the ultimate closure of LEP, several experiments produced some interesting evidence for the long-awaited Higgs particle – a keystone of modern physics theory.

Originally scheduled to close in September 2000, LEP was given a six-week "stay of Higgs execution" so that it could investigate the candidate Higgs signals further. Some additional evidence was found during the extra running time, but not enough to claim a discovery. With the need to commence construction work for CERN's LHC collider (to be built in the same 27 km tunnel as LEP) becoming increasingly urgent, the decision was finally taken to close LEP for good.

A brief history of LEP

CERN's 27 km LEP storage ring was built with the initial objective of making precision measurements on the Z particle (the electrically neutral carrier of the weak force discovered at CERN's proton–antiproton collider in 1983). For this, LEP had energies of about 45 GeV per electron and positron beam when it began operations in 1989.

However, LEP was designed to explore much more than just the Z particle. Even before the machine was formally approved for construction in 1981, a far-sighted programme of research and development had begun to develop superconducting radiofrequency cavities, which would boost the machine's beams towards 100 GeV per beam and probe far beyond the Z production threshold.

By 1996 the necessary technology had been established and LEP was equipped with a number of gleaming new niobium-covered accelerating cavities. By 1998, 272 of these cavities had been installed in the machine, and the collision energy (the sum of the two colliding beam energies) had attained 189 GeV. This was more than enough for LEP to start seeing production of the W particle, the electrically charged companion of the Z (in electron–positron collisions the W has to be produced in oppositely charged pairs).

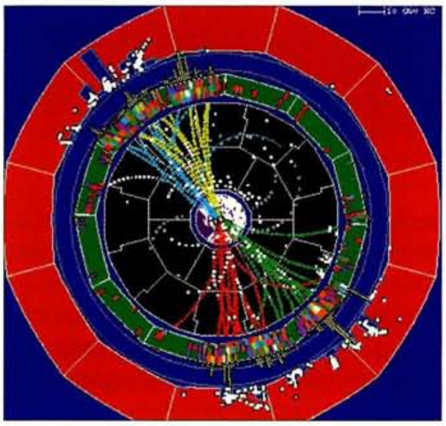
By the beginning of its 1999 run, LEP had been equipped with an additional 16 superconducting cavities, bringing the collision energy to 192 GeV. The supercavities lived up to their name and soon began providing accelerating fields greater than the 6 MV m^{-1} originally planned, and in the summer of 1999 the machine delivered its first 100 GeV beams.

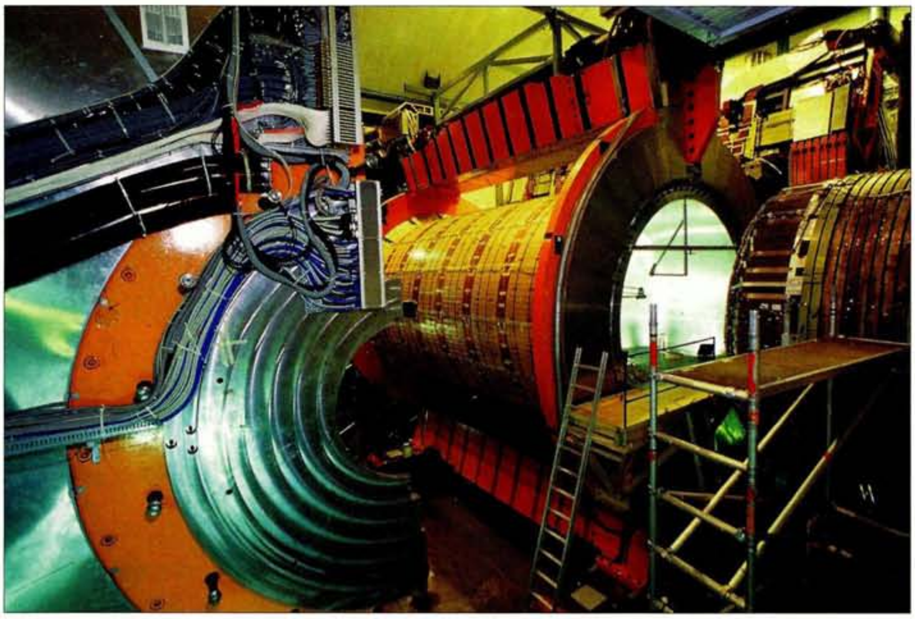
The ultimate goal is to find the missing link in today's Standard Model picture of particle physics: the Higgs particle, which breaks the underlying electroweak symmetry and makes everyday electromagnetism look very different from weak interactions, ensuring that light and nuclear beta decay look so different that it took most of the 20th century for the connection between them to be recognized.

The Higgs endows particles with mass, so that the photon carrier

and melodrama

llider closed last year after a tantalizing 'evealed hints of the long-awaited Higgs today's picture of particle physics.





Left: a possible Higgs glimpsed by the Aleph detector, with four emerging sprays of particles. The red/yellow pair and the blue/green pair emerge back to back, suggesting the production of a Higgs and a Z boson. Right: the Opal detector comes apart.

of electromagnetism is free to roam, while the weak interaction is mediated by very heavy particles which are confined to subnuclear dimensions. Unfortunately the electroweak theory makes no direct prediction as to what or even where the Higgs may be.

However, the quest is not entirely unguided. All of the parameters of the electroweak theory have to fit together in a consistent way. As these parameters were measured with increasing precision, the region in which the Higgs had to lie became progressively smaller.

By 1999 it had become clear that LEP was operating in the very collision energy region in which the Higgs was most likely to be found. Eagerly, the teams working on the four experiments – Aleph, Delphi, L3 and Opal – scrutinized their new data.

In the mutual annihilation of an electron and a positron, the Higgs particle could emerge back to back with a Z particle. The possibility had been pointed out long before in several prophetic papers, the first published in 1976 by John Ellis, Mary K Gaillard and Dimitri Nanopoulos at CERN.

Shakespeare wrote: "Rumour is a pipe blown by surmises, jealousies, conjectures...that...the still-discordant wavering multitude can play upon." By the autumn of 1999 the first of such whispers were heard about the Higgs, first in CERN corridors, then on the Internet. Behind the scenes, the CERN publicity machine began to compile material for a Higgs announcement, just in case.

Physicists at CERN report the progress of their experiments via special platforms, in this case the public sessions of the LEP Experiments Committee. Normally held a few times per year, these sessions were traditionally opened by representatives from the machine operations team, who would give the latest news on the machine front, followed by a slot for each of the four major experiments to present their latest findings.

The meeting on 9 November 1999 was particularly well attended, due to the rumours that abounded about the Higgs. However, in spite of these rumblings, nothing new emerged in public that day on the Higgs front.

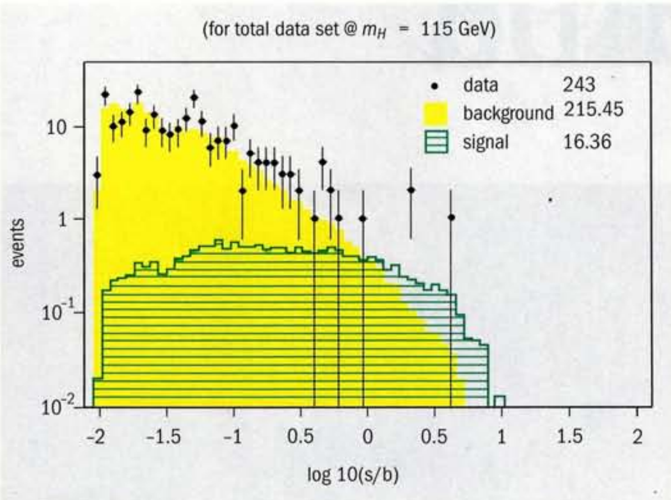
Closing in on Higgs

LEP began 2000 with a bang. With some old-style copper cavities brought back to add a few more accelerating volts, LEP was soon routinely delivering beams of more than 100 GeV and as high as 104 GeV. The Higgs hunt recommenced with increased vigour.

The normally dry-as-dust open sessions of the LEP Experiments Committee increased spectacularly in popularity, and one needed to arrive very early to get a good seat in CERN's 500-capacity auditorium. (The sessions were also broadcast on the Web, but these images do not catch the effervescent audience atmosphere.)

Despite a new wave of rumours, the July 2000 meeting had nothing definite to report, but the remaining territory where the Higgs was likely to be found had narrowed. The LEP 2000 run was therefore accorded a few additional weeks, giving it until 1 October.

On 1 August, at the major International Conference on High Energy Physics in Osaka, Japan, the audience was again braced for Higgs news. However, Peter Igo-Kemenes of Heidelberg, who ▷



Did the experiments at LEP see a Higgs particle at 115 GeV? This plot shows the excess of signal (in green) to expected background (yellow).

CERN's LEP electron–positron collider begins to be dismantled.

was giving the review talk on new physics at electron-positron colliders, reported no Higgs below 113 GeV.

No sooner had the Osaka delegates returned to their home laboratories than Higgs rumours began to surface again. On 5 September came a special seminar, with a summary talk by the LEP Higgs Working Group, the role of which was to pull together data from the different experiments to give an overall picture.

At that meeting the tone was set by the first experimental talk from Aleph. Aleph reported three Higgs candidate events at a mass of around 114 GeV, against an expected background of 0.3 events. It was a large signal – too large even – but the first time that suggestive Higgs evidence had ever been presented. The signature comes from electron-positron collisions yielding four tightly confined sprays of particles ("jets") including the characteristic fingerprint of short-lived B particles (containing the heavy b-quark), which the Higgs is expected to produce.

Delphi too had two such events. The other two experiments did not present any clear evidence. Despite the irregularity and uncertainty of these results, Chris Tully for the LEP Higgs Working Group claimed that "the Higgs is on the horizon", a remark that echoed in the media. LEP was awarded an additional stay of execution, continuing to run until 2 November.

Overtaken by events

The next arena for Higgs results was at CERN's official LEP celebration, which ran on 9–11 October and had originally been intended to mark the closure of the machine. At an LEP Experiments Committee meeting held in parallel with the celebration, the experimental situation had not changed significantly, despite having more Higgs-sensitive statistics at hand. L3 and Opal reported no four-jet excess of Higgs events, and no additional excess had been seen in other channels, anywhere.

With LEP's total six-week bonus period complete, excitement mounted as another open LEP Experiments Committee meeting was held on 3 November. Aleph's three four-jet events were still there, but had not been augmented by the latest data, bringing the initial candidate signal more in line with expectations.

After reprocessing the data with new tracking calibrations, the Delphi events had decreased in significance. However, L3 displayed a Higgs candidate from an alternative channel producing two jets and missing energy, possibly two neutrinos, while Opal, silent so far on the Higgs front, displayed several lukewarm four-jet candidates. For the LEP Higgs Working Group, Peter Igo-Kimenes made a convincing case from this confusing evidence.

As if to compensate for the sparse authoritative announcements, the global media held a festival of Higgs speculation.

All of CERN's machines were to close over the winter period, so the LEP community began to push enthusiastically for LEP to continue running into 2001 – a request that ran counter to CERN's committed schedule for the LHC.

Meanwhile, the L3 evidence was described in a CERN mini-seminar by Chris Tully of Princeton, which led to a lively confrontation between those eager to continue LEP running and CERN management, which, after discussion with its advisory committees, insisted that the LHC was the way forward (see following article).

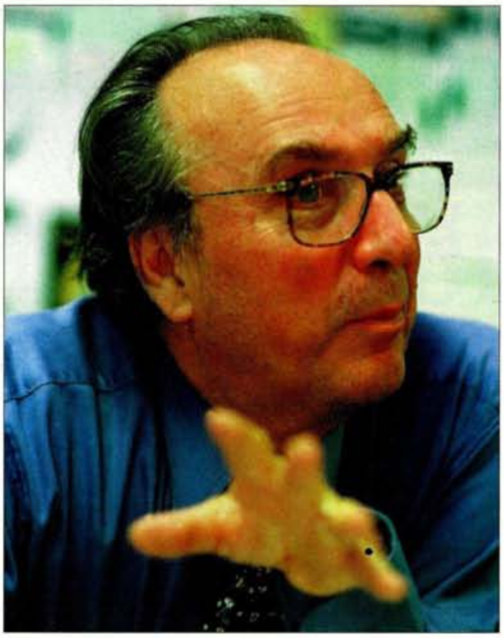
Overall, the data collected in the six additional weeks had slightly increased the significance of the Higgs signal. To stake their claims, Aleph and L3 submitted research papers for publication (*Phys. Lett. B* **495** 1–17 and *Phys. Lett. B* **495** 18–25 respectively).

Despite continued vociferous pressure to keep LEP going in 2001, and with a hierarchy of authorities – the LEP Experiments Committee, the Research Board, and the Scientific Policy Committee – finely balanced, CERN's governing council endorsed CERN management's decision to close LEP for ever and prepare the way for the construction of the LHC, which is seen as the best route to progress in this field. LEP duly closed on 2 November (January p6).

Was it right to keep the LHC on track and close LEP in the face of inconclusive data? History alone will be the ultimate judge.

Gordon Fraser, *CERN.*

The road ahead



CERN director-general Luciano Maiani – "The LHC will be the ideal instrument to put CERN and the physics community in a position to explore fully the new frontier in particle physics."

In this article, CERN director-general *Luciano Maiani* explains why CERN's commitment to building the LHC collider overcame all pressures to prolong running the LEP electron–positron machine.

CERN is fortunate to have a major accelerator project, the LHC, under active construction. This will take particle physics into a new energy regime, where we are confident that it will resolve many of the puzzles raised by the brilliant confirmation of the Standard Model by experiments at LEP and elsewhere. The LHC is the key to the future of high-energy physics and of CERN, and it offers bright prospects to the new generation of young particle physicists.

The LHC is a highly complex project, both technically and organizationally. The accelerator and the detectors involve sophisticated technologies, in many cases on industrial scales never attempted before in a scientific project.

Moreover, the LHC is truly a global project, with contributions to the accelerator from many countries outside Europe, as well as CERN and its member states, posing difficult problems of coordination and planning. One should also not forget that the long-term plan approved in 1996 left CERN with a reduced budget and no adequate contingency for the LHC.

There have already been unforeseeable delays in the civil engineering for the LHC. The industrialization of the successful prototype magnet technologies remains a challenge, and there are undoubtedly many more obstacles ahead.

Nonetheless, the LHC project is progressing steadily, contracts for a large fraction of subsystems have been adjudicated on schedule, and I consider it one of my primary responsibilities as director-general of CERN to further it as best I can, and, as the doctors vow, avoid doing it any harm.

Weighing the implications

Over the past two years, dedicated work by CERN's accelerator staff and the installation of advanced LHC cryogenics made it possible to run LEP at energies greater than design, and for one year longer than originally planned.

When data from LEP in the first part of 2000 revealed hints of new physics, the CERN management extended its run twice, in all from mid-September to the beginning of November, after first reassuring itself that these extensions would have no significant impact on the LHC. I was delighted to hear that the rapid and innovative combination of data from the four LEP experiments by their joint Higgs working group found that these early hints were strengthened, with the most likely interpretation being a Higgs boson weighing about 115 GeV.

In parallel with these extensions of the LEP run, the CERN directorate commissioned a study of the possible implications for the LHC, if LEP were to run in 2001. Two aspects needed to be considered. The LHC will be housed in the same tunnel as LEP, and the dismantling of LEP and modifications to the tunnel to accommodate the LHC are on the critical path. Also, the staff required for the operation of LEP would not be transferred as foreseen to LHC construction. Several ingenious ways to reschedule part of the essential work were tried, but finally we came to the conclusion that the LHC would inevitably be delayed by about a year if LEP was to run a full year in 2001.

Extra cost

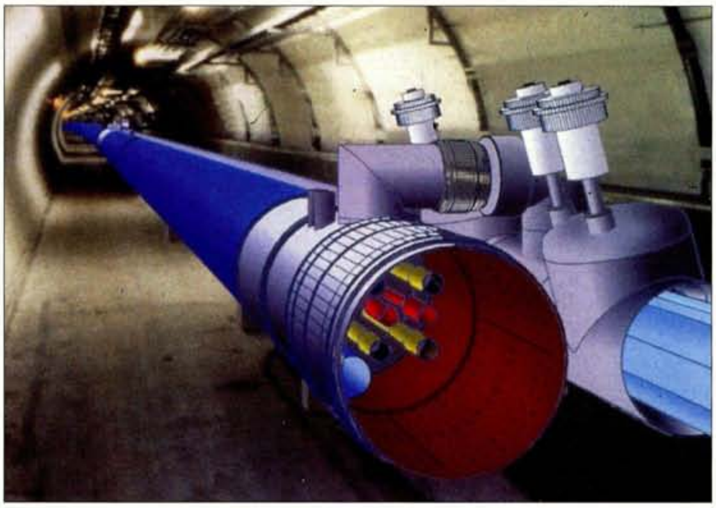
There were also financial and personnel problems with a further LEP extension. It would have required around 100 million Swiss francs (about 40 million in running costs, and the rest in penalties for civil engineering contracts that are difficult to quantify *a priori*, additional expenses for rescheduling, etc).

I was grateful to see that some CERN delegations were willing to consider providing their share of these extra costs, but the bulk would inevitably have been borne by the regular CERN budget. Thus I came equally reluctantly to the conclusion that an LEP extension would be a major squeeze on the resources needed for the LHC project.

Projections of the signal seen at LEP in 2000 indicated that a year's running might not lead to a conclusive result, particularly if the mass of the Higgs boson was in the upper part of the indicated range, namely around 116 GeV. This reflects the fact that the signal is seen at the very end of the LEP energy range.

To put this region under real scrutiny would require a significant energy increase, which in turn implies significant further ▷

expense and a prolongation of at least a two years, one year being approximately the time needed for the industrial production of new accelerating cavities. That would have led to a major disruption of the LHC project.



CERN's LHC is on track to provide its first proton–proton collisions in 2006.

Overall

Putting all of these reasons together, and after consultation with the scientific committees, my colleagues in the CERN directorate and I became convinced that running LEP in the year 2001 would put the LHC under unacceptable pressure, and we decided that the CERN programme should not be changed to accommodate it. This decision had to be taken rapidly, precisely so as not to impact on the LHC schedule. I appreciated the efforts of the scientific review committees, which provided their advice and presented vigorously a variety of views, under the pressure of time.

Unlike the running of LEP in the year 2000, the issue of whether one should prolong LEP in 2001 divided the community and the scientific committees, and no consensus solution could be proposed. CERN management eventually cut the Gordian knot in favour of the LHC.

I understand the frustration and sadness of those who feel that they had the Higgs boson within their grasp, and fear that it may be years before their work can be confirmed.

Nevertheless, I am convinced that the best way forward for particle physics is the LHC. A Higgs boson as light as 115 GeV is most likely the signal of a rich supersymmetric particle spectrum at low energy, and the LHC will be the ideal instrument to put CERN and the physics community in a position to explore fully the new frontier in particle physics, which we may have glimpsed through the fascinating LEP events.

I hope that the high-energy physics community will join us in working wholeheartedly towards this exciting and challenging goal.

Luciano Maiani, *director-general, CERN.*

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Looking at physics in a rarefied atmosphere

Last year the annual DESY Theory Workshop focused on rare physics – the physics that's hardest to do and sometimes difficult to understand. *Andrzej Buras* reports.

Rare processes and the violation of CP symmetry provided the focus for the recent Theory Workshop at the DESY Laboratory in Hamburg. As emphasized by Chris Quigg (Fermilab) in the opening lecture, discrete symmetries (box 1) and their violation, in particular CP symmetry, play an important role in a deeper understanding of nature at both very small and large distances. Studying these violations in rare processes may give hints to what lies beyond the Standard Model of particle physics.

Relaxed atmosphere during the break. Left to right: Luca Silvestrini (Rome), chairman of the organizing comittee Andrzej Buras (Munich), Yosef Nir (Weizmann) and Gino Isidori (Frascati).

In the Standard Model, CP violation is attributed to quark transitions, which are described by the three-dimensional (Cabbibo-Kobayashi-Maskawa; CKM) matrix. The classic effect in the decays of neutral kaons into two pions, which was first seen in 1964, is attributed to "indirect" CP violation through the mixing of the neutral kaon and its antiparticle (box 2). This type of violation is usually characterized by a small parameter, which is measured to be roughly 2.3×10^{-3}. However, the Standard Model also allows "direct" CP violation, governed by quark mechanisms involving the exchange of the sixth "top" quark.

The theoretical status of these effects was summarized by Matthias Jamin (Heidelberg). Refined gluon corrections and a more accurate top quark mass (174 ± 5 GeV) from the CDF and D0 collaborations at Fermilab have both considerably improved the evaluation of CP violation parameters. While indirect CP violation in the Standard Model is consistent with experimental data, large uncertainties currently preclude a precise comparison of direct and indirect CP violation.

Despite intensive efforts by theorists, estimates of this ratio (which is known in the trade as ε'/ε) by various groups range between 5×10^{-4} and 30×10^{-4}.

As discussed by Guido Martinelli (Rome), Laurent Lellouch (Marseille) and Amarjit Soni (Brookhaven), advanced numerical lattice calculations could considerably improve the estimates in the coming years. However, as stressed by Jamin, it is important to develop further the existing analytical tools in order to confront the lattice results.

Difficult measurements

The experimental situation for ε'/ε, described by Martin Holder (Siegen), improved considerably in the past two years due to measurements by the KTeV collaboration at Fermilab $(28 \pm 4) \times 10^{-4}$ and the NA48 collaboration at CERN $(14 \pm 4) \times 10^{-4}$. These measurements confirm the previous result of the NA31 collaboration at CERN $(23 \pm 7) \times 10^{-4}$ that ε'/ε is not zero, confidently ruling out certain hypotheses.

Also taking into account the older inconclusive measurement of the E731 collaboration $(7 \pm 5) \times 10^{-4}$, one arrives at the world average of $(19 \pm 3) \times 10^{-4}$. In view of the spread in values obtained by various experimental groups, the resulting small error should be treated with caution.

Within the next few years the experimental situation should improve considerably through the new data from KTeV and NA48, and in particular from the KLOE experiment at DAFNE in Frascati.

New channels

While the theoretical estimates of ε'/ε in the Standard Model are compatible with the experimental data within the theoretical and experimental uncertainties, there is still a lot of room for new physics. As discussed by Luca Silvestrini (Rome), important ▷

new contributions are still possible within supersymmetric (box 3) extensions of the Standard Model.

The present bounds on CP violation in various processes already give very important limits for the masses and weak couplings of supersymmetric particles. In particular, the pattern of the masses of squarks – the supersymmetric partners of quarks – is severely restricted. However, in spite of these constraints, large supersymmetric effects in CP-violating processes are possible.

It is important to study CP violating decays and CP conserving rare decays, which are theoretically far cleaner than those traditionally studied. As stressed by Gino Isidori (Frascati), a "gold-plated" decay in this respect is that of the long-lived kaon into a neutral pion, neutrino and antineutrino, proceeding almost exclusively through direct CP violation. The predicted branching ratio within the Standard Model (3×10^{-11}) and the presence of neutrinos and the neutral pion make the measurement of this decay formidable.

DESY Theory Workshop 2000 - Peter Zerwas (DESY) (right) tells Martin Holder (Siegen) to measure CP violation more precisely.

On the other hand, in certain supersymmetric models the branching ratio could be one order of magnitude higher. Most important is that the newly approved KOPIO experiment at Brookhaven should be able to measure this decay in the first half of this decade even if the branching ratio is at the predicted level. There are also plans to measure this decay at Fermilab and at KEK in Japan. The optimism in measuring this branching ratio is strengthened by the observation of one event in the CP-conserving decay of the charged kaon into a charged pion, neutrino and antineutrino by the E787 at Brookhaven, dating from 1997.

The branching ratio for this rare decay as of the end of 2000 is around 1.5×10^{-10} – slightly higher but fully compatible with expectations. As this decay is also theoretically very clean, the improved measurements of its branching ratio expected in the coming years at Brookhaven, and later at Fermilab, will provide powerful constraints on the elements of the CKM quark transition matrix and the parameters of new physics.

Beauty quark

In the coming years, some of the most promising tests of the Standard Model and its extensions will come from studying the decays of B-mesons (containing the fifth – "beauty" – quark) into strange hadrons and either a photon or a lepton–antilepton pair. As reviewed by Christoph Greub (Bern), refined calculations of gluon corrections and new physics contributions, in particular in supersymmetric models, during the last years will allow for stringent tests of the theory once the experimental branching ratios become precise.

The channel with the final photon was observed in 1993 by the CLEO collaboration at Cornell, and these data have been improved considerably since by CLEO and by the ALEPH collaboration at CERN. Recently the efforts to measure this channel precisely have been joined by the new B-factories at SLAC (Stanford) and KEK (Japan), so that in a few years a rather precise branching ratio should become available.

However, as emphasized by Greub, the available data, while being consistent with current expectations, already put powerful constraints on supersymmetric extensions. The second channel, with a muon–antimuon pair in the final state, should be observed this year at the B-factories and at Fermilab. For new physics, this is even more interesting than the photon-yielding decay.

Larger effects

While CP violation has been observed so far only in kaon decays, where the effects are rather small, much larger effects are predicted for B-mesons. As stressed by Roy Aleksan (Saclay), Yosef Nir (Weizmann) and Robert Fleischer (DESY), there are several decays where measurements should fix CP violation without almost any hadronic uncertainties. Here the central role is played by the "gold-plated" decay of the B_d-mesons (bound states of an b-antiquark and a down quark) into a short-lived kaon and a Ψ (charm quark–antiquark bound state). The corresponding CP violating asymmetry is parametrized by an angle, β, in the so-called unitarity triangle, which is related to the CKM matrix.

The present bounds on CP violation in various processes already give very important limits for the masses and weak couplings of supersymmetric particles.

The most recent data – which were reviewed by Aleksan – from the BaBar and Belle experiments at SLAC and KEK respectively give values of $\sin 2\beta$ somewhat lower than expected and lower than earlier measurements by the CDF collaboration at Fermilab. The three experiments taken together give $\sin 2\beta = 0.42 \pm 0.24$, compared with the Standard Model-expected $\sin 2\beta = 0.7 \pm 0.15$, and discussed by Nir and Ali (DESY). Clearly, within the experimental uncertainties, the measured value is consistent with expectations, which, using among other inputs the observed CP violation in kaon decays, is subject to theoretical uncertainties.

On the other hand, as stressed by Ali, Nir and Silvestrini, improved measurements of $\sin 2\beta$ significantly below 0.5 would signal the presence of new physics contributions - in particular new CP violating phases.

The large variety of CP-violating asymmetries in B-decays should allow for decisive tests of the Standard Model and its extensions. Other CP-violation parameters could be measured, initially by BaBar and Belle in the coming years, as reviewed by Aleksan. The decays of the heavier B_s meson, containing a strange quark, will open up more possibilities. These measurements can only be done by the dedicated experiments LHCB at CERN and BeTeV at Fermilab around the year 2005. Several strategies were reviewed by Robert Fleischer (DESY). However, he also emphasized that the two-body decays of B_d mesons into pions and kaons, measured first by CLEO at Cornell and now studied by BaBar and Belle, despite some hadronic uncertainties, are likely to provide very valuable constraints.

Other goals

While CP violation in B-decays is the main aim of B physics in the near future, there are other important goals. These were reviewed by Henning Schroeder (Rostock). In addition to the rare B-meson decays already mentioned, a central role is played by B_s mixing. While electron–positron collider experiments have put a stringent lower bound on this mixing, its first actual measurement is expected this year at Fermilab. The knowledge of this mixing will provide a valuable additional constraint, as stressed by Ali and Silvestrini.

According to the Standard Model, CP violation outside the kaon and B-meson systems is expected to be invisible. However, as reviewed by Werner Bernreuther (Aachen), new sources of CP violation, present in exotic multi-Higgs models or models with supersymmetry, could give rise to measurable effects.

Tracing interactions

Extensions of the Standard Model predict new CP-violating interactions for quarks and for leptons. Attempts to trace such interactions include charm meson (D) decays and the search for neutral D mixing; a high statistics hyperon experiment at Fermilab (E756); and the "classic" low-energy searches for electron and neutron electric dipole moments and of certain atoms. Top quarks may also be used to probe CP violation once they are produced in large numbers at the Tevatron and CERN's LHC.

The most interesting at present are the results from CLEO (Cornell) and FOCUS (Fermilab), which possibly indicate neutral D mixing at a much higher level than expected and in the area of some supersymmetric scenarios.

CPT invariance - the combination of CP symmetry with time-reversal symmetry - is the bedrock theorem of quantum field theory, enforcing, for instance, equal masses for particles and antiparticles. Ludwig Tauscher (Basle) reviewed various tests of CPT and time-reversal symmetry in the CPLEAR experiment at CERN.

Time-reversal violation has been seen for the first time in this experiment (March 1999 p21). While no violation of CPT symmetry has been found, CPLEAR has provided very precise values of various CPT-parameters and unprecedented CPT tests of mass differences of the order of 10^{-19} GeV. ▷

1. When symmetries fall

In CP (charge/parity) symmetry, the physics of left-handed particles is the same as that of right-handed antiparticles. Changing right to left (a parity, P, transformation), or particle to antiparticle (a charge conjugation, C, transformation), are examples of what physicists call "discrete symmetries" – operations that either you do or you don't – there is no halfway point between left and right.

The combined CP symmetry became popular after physicists had been shocked in 1956 to discover that nuclear beta decay – a fundamental weak interaction – is spectacularly left–right asymmetric (P-violating).

The confusion grew in 1964 when new experiments found that the new CP criterion was not 100% reliable either. Ever since, physicists have sought to understand how and why this symmetry is flawed.

2. Indirect and direct routes to CP violation

The neutral kaon provides the classic examples of CP violation. However, understanding the physics of the neutral kaon is not easy. With no electric charge, the neutral kaon particle and antiparticle can only be distinguished by their strangeness quantum label. Unfortunately, strangeness is only conserved in strong interactions, not in weak decays. Because of this, the neutral kaon and its antiparticle get mixed up.

Such mixing can produce a special kind of CP violation, called "indirect" because it is due not to the explicit breaking of the symmetry in the decay itself, but instead through the particle–antiparticle mixing before the decay. More CP violation (the "direct" kind) occurs via the decays of the strange quarks inside the neutral kaons.

3. Supersymmetry

The known elementary particles come in two kinds – fermions, such as quarks, electrons and muons (matter particles), and bosons, such as photons, gluons, Ws and Zs (force carriers). The key feature of supersymmetry is that every matter particle (quark, electron,...) has a boson counterpart (squark, selectron,...), and every force carrier (photon, gluon, W, Z) has a fermion counterpart (photino, gluino, chargino, neutralino,...). Supersymmetry is intellectually appealing and could solve several outstanding physics problems, but no direct evidence for these additional superparticles has yet been seen.

Graham Ross (Oxford) reviewed current progress in understanding quark and lepton masses and mixings. New ideas will soon be tested in B-factories, and in particular in neutrino experiments, from which an improved knowledge of neutrino masses and mixings should be achieved.

The status of neutrino masses and mixings was reviewed by Walter Grimus (Vienna). He showed that the latest results, especially from SuperKamiokande in Japan, give very strong indications for neutrino oscillations and imply that the pattern of neutrino masses and mixings differs substantially from the quark sector. This could suggest large CP-violating effects in neutrino oscillations, reviewed by Manfred Lindner (Munich). He described various possibilities to search for leptonic CP-violation in future long-baseline experiments and stressed that several CP-violating effects have to be taken into account in future analyses of oscillation data.

Flavour violation

Given convincing data from SuperKamiokande on atmospheric neutrino oscillation, there is more than ever reason to search for anomalous lepton effects (flavour violation). Especially with supersymmetry, there is a good chance that lepton flavour-violating transmutations between electrons, muons and taus will be seen in the next round of experiments. A review was presented by Hitoshi Murayama (Berkeley).

The matter-antimatter asymmetry of the universe, in which CP violation is believed to play an important role, was highlighted in the final talk of the workshop by Wilfried Buchmueller (DESY). Different scenarios for baryogenesis (nuclear matter production) differ in the way in which Sakharov's basic conditions for matter-antimatter asymmetry (baryon number violation, C- and CP-violation, deviation from thermal equilibrium) are satisfied.

An attractive scenario is electroweak baryogenesis during the initial electroweak phase transition of the universe. Here the baryon asymmetry can be calculated in terms of low-energy CP-violation. Unfortunately, this situation does not work within the Standard Model. However, even if the parameter space is already rather constrained, it may work within its Minimal Supersymmetric extension.

A very interesting alternative – so-called "leptogenesis" – is to produce an initial lepton asymmetry through the decay of a special heavy neutrino that can then be reprocessed into a baryon asymmetry by non-perburtative "sphaleron" electroweak effects.

Introductory lectures by Thomas Mannel (Karlsruhe), Lalit Sehgal (Aachen), Roland Waldi (Rostock) and Gerhard Buchalla (CERN) were appreciated. The DESY workshop certainly showed that CP violation, rare processes and related issues remain key questions of particle physics.

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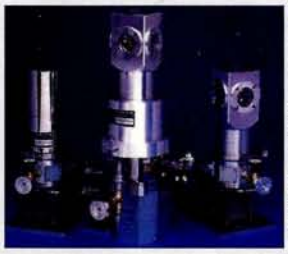

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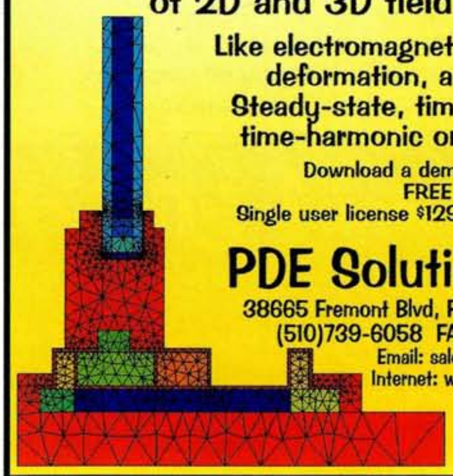

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APPOINTMENTS & AWARDS

Cornell gets a new chair

David Rubin is the first incumbent of the new Boyce McDaniel Chair of Physics at Cornell, endowed by Helen and Donald Edwards. The chair is named after Boyce D McDaniel. Left to right: Boyce McDaniel, Donald Edwards, David Rubin, Helen Edwards and Maury Tigner, director of Cornell's Laboratory of Nuclear Studies.

Two prominent accelerator physicists and Cornell alumni, Helen T Edwards and her husband, Donald A Edwards, have endowed a chair in accelerator physics at Cornell. The chair is named after Boyce D McDaniel, professor emeritus at Cornell.

The first holder of the new chair is David L Rubin, professor of physics and director of accelerator physics at Cornell. The donors asked that the new professorship should be awarded to a Cornell faculty member whose discipline is particle-beam physics and who would teach both graduate and undergraduate students in addition to doing research.

Helen Edwards is a 1957 graduate of Cornell, where she also earned her PhD in 1966. She works at Fermilab and at DESY in Germany. She played a prominent role in the construction of Fermilab's Tevatron and has been the recipient of a MacArthur Foundation Genius Award and an E O Lawrence Award.

Donald Edwards, who also works at DESY, is considered to be a major voice in accelerator theory and was responsible for the technical design of the Cornell synchrotron. He received his PhD from Cornell in 1961.

Helen and Donald Edwards have been actively involved with the TESLA superconducting linear collider project at DESY.

McDaniel, a previous director of nuclear science at Cornell, was Helen Edwards' thesis adviser. Initially a graduate student at Cornell, he left during the Second World War to join the Manhattan Project and returned to complete his PhD, joining the faculty in 1946. He became a full professor in 1956 and was named the Floyd R Newman Professor in Nuclear Studies in 1977. He was director of the laboratory from 1967 to 1985, leading it through the completion of its 10 GeV electron synchrotron and the design and construction of the Cornell Electron Storage Ring (CESR) and the CLEO detector. McDaniel enjoys an international reputation for his distinguished career in accelerator physics, including leading the commissioning of the Main Ring at Fermilab and providing advice for numerous accelerator projects throughout the US, in addition to his notable contributions to the accelerator and elementary particle physics programs at Cornell.

Rubin was recruited by Cornell after receiving his PhD from Michigan in 1983. For more than a decade he has been the leader of the large group of physicists and engineers responsible for designing and implementing upgrades of CESR. This has provided the backbone for a very successful programme in heavy quark and lepton physics and has enabled Cornell to remain the foremost centre for the training of US accelerator physicists.

2000 Grand Prix

The 2000 Grand Prix européen de l'innovation was awarded to Carlo Rubbia, 1984 Nobel prizewinner and former CERN director-general, for his energy amplifier, a subcritical fast neutron system driven by a proton accelerator. The device can run on a mixture of natural thorium and nuclear waste. The destruction of long-lived fission fragments (technicium-99, iodine-129, etc) would be achieved via the adiabatic crossing of neutron-capture resonances in lead around the core of the amplifier. This process, demonstrated by the TARC experiment at CERN (April 1997 p8), would also allow the production of radio-isotopes for industry and medical purposes.

The 2000 Grand Prix européen de l'innovation was awarded to Carlo Rubbia, 1984. Holding their awards are the three winners of the competition (left to right): Michael Graetzel of EPF Lausanne (Prix européen de l'innovation), Carlo Rubbia (Grand Prix) and Bernard Spinner of the French CNRS (Prix du Jury).

AMA awards prize for innovation

On the occasion of SENSOR 2001 (8–10 May), the AMA Prize for Innovation 2001 will be awarded. The prize, for exceptional application-related research and development activities in the sensors area, has been endowed with DM 25 000 by the AMA Association for Sensor Technology, Göttingen. The prize is being offered to give prominence to excellent R&D activities with a visibly good market approach. Companies and institutes may apply. The application deadline is 31 March. See "http://www.ama-sensorik.de" under "Aktuell".

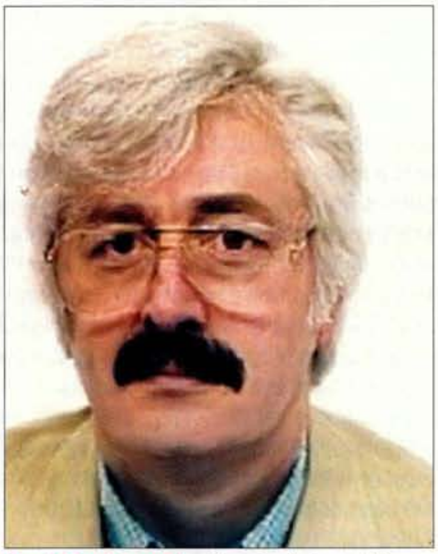
Bogoliubov prize goes to young scientists

The Joint Institute for Nuclear Research announces the N N Bogoliubov prize for young scientists. The prize, established in 1999 in memory of the eminent physicist and mathematician Nikolai Nikolaevich Bogoliubov (1909–1992), is awarded to researchers up to 33 years old for outstanding contributions in the fields of theoretical physics related to Bogoliubov's interests. As a rule, it is awarded to a scientist who has shown early scientific maturity and whose results are recognized worldwide.

Entries should try to emulate Bogoliubov's skill in using sophisticated mathematics to attack concrete physical problems. The first prize was awarded in the summer of 1999 and presented at the Dubna conference in September that was held to commemorate Bogoliubov's 90th anniversary.

Entries for the 2001 prize (including CV and a one- or two-page abstract of submitted papers) should be sent to the Directorate of the Bogoliubov Laboratory of Theoretical Physics of the Joint Institute for Nuclear Research before 1 May 2001 (Dr V I Zhuravlev, Scientific Secretary of Bogoliubov Laboratory of Theoretical Physics, JINR, Joliot-Curie str. 6, 141980 Dubna, Moscow Region, Russia; e-mail premia01@thsun1.jinr.ru).

Bogoliubov's scientific activity began in Kiev at 14 and key results followed from the age of 20. His main interests were nonlinear mechanics, statistical physics, quantum field theory and elementary particle theory.



David Southwood of London's Imperial College has been elected Director of Science at the European Space Agency (ESA) for the next four years. He takes over from Roger-Maurice Bonnet on 1 May.

January 2001 marked the 70th birthday of eminent Armenian theoretician **Sergei Matinyan.** Born in Georgia, he established the first theoretical physics group before moving to Yerevan in 1970 to pioneer a theory group. He has been visiting professor at Duke University in the US since 1993.

At the recent annual Users' Meeting of the Stanford Synchrotron Radiation Laboratory (SSRL), former deputy director of the SSRL, **Herman Winick**, was the surprise recipient of the US Department of Energy's prestigious Distinguished Associate Award. Pat Dehmer, director of the DOE Office of Basic Energy Sciences, presented it to him for his "many accomplishments, contributions and leadership in the development of modern synchrotron radiation sources and insertion devices". Previous winners of this award include Sid Drell, Leon Lederman,and Sir Chris Llewellyn Smith.

C N Yang shares the prestigious 2001 King Faisal International Prize for Science for his lifelong contribution to theoretical particle physics. He shares the prize with photonics specialist **Sajeev John**.

Chien-Shiung Wu is well remembered

The C S Wu and L C L Yuan Natural Science Foundation, New York, has established a lecture series at the Southeast University at Nanjing, China, where Chien-Shiung Wu, the discoverer of parity violation and of Yuan, started her university education 70 years ago. The first two lectures were given in November by 1976 Nobel prizewinner Sam Ting and former CERN director-general Herwig Schopper, who also became honorary professors of the university.

The Chinese Government has decided to establish a C S Wu Memorial Hall, which is to be designed with the help of renowned architect I M Pei, in a prominent position at the university to house C S Wu memorabilia, including the original equipment of the 1956 parity experiment. The opening of the building is scheduled for spring 2002.

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http://cern.web.cern.ch/CERN/Divisions/EP/UsersOffice

Louis Leprince-Ringuet 1901–2000

Louis Leprince-Ringuet died on 23 December 2000. His popularity was enormous. He was well known to the general public through his frequent television appearances, articles in the newspapers and his art exhibitions, and as an avid spectator of international tennis tournaments at the Roland Garros stadium in Paris. In his speeches he presented science as something vital, exciting and enterprising. The scientific community owes him a debt of thanks for his contribution to stimulating public interest in science.

His career was no ordinary one. After graduating from the Ecole Polytechnique, he joined the French post office and telecommunications services and worked for five years until 1929 on maintaining submarine cables. It was at this point that he decided to move to Maurice de Broglie's lab, where he got his first taste of nuclear physics, building an amplifier that was sufficiently sensitive to detect an isolated particle. Following Bruno Rossi's period in Paris, Leprince-Ringuet turned to cosmic-ray research. He placed a cloud chamber in the Bellevue electromagnet gap to look for the highest-energy particles. In 1933 he set off on a cargo ship with Pierre Auger to measure the effect of latitude on cosmic rays between Hamburg and Buenos Aires.

Appointed professor at the Ecole Polytechnique in 1936, he attracted young pupils to experimental physics, including Charles Peyrou, Michel Lhéritier and Robert Richard-Foy, who would form the nucleus of a lab that would rapidly develop into a reputed physics centre. Experiments continued at Bellevue until 1939. During the Second World War, work continued in the Alps at Argentière-la Bessée with a large cloud chamber placed inside a magnetic coil powered by an electric generator of the Pechiney aluminium factory. There is a famous picture showing the collision of a rapid particle on an electron. From the kinematics of the reaction, the mass of the incident particle could be calculated, estimated at half that of the proton, which provided the first K meson candidate.

Research into more intense primary cosmic radiation drove him to seek sites at higher altitudes. During the war, a team led by Paul Chanson created a mountain lab perched on the Aiguille du Midi in Chamonix. In 1950 another team, initially consisting of Charles Peyrou, Bernard Grégory, André Lagarrigue and Francis Muller, chose the observatory on the Pic du Midi in the Bigorre region of the Pyrenees mountains to set up a system of two superimposed cloud chambers. The most important result obtained in this installation was the identification of the disintegration of the K meson into a muon and a neutrino. Another team, led by Jean Crussard, experimented with the use of sounding balloons carrying photographic emulsions to expose them to cosmic radiation for several hours.

At the end of the 1950s the building of accelerators at Saclay and in Geneva led to the lab converting from cloud chambers to bubble chambers. André Lagarrigue started a programme to build several heavy liquid bubble chambers, the last of which, Gargamelle, would lead to the discovery of weak neutral currents in 1973. Returning from a period at Brookhaven in 1957, Bernard Grégory got the Commissariat à l'Energie Atomique to build the 81 cm hydrogen bubble chamber, which would operate for several years at CERN and where the ksi hyperon antiparticle was discovered. The analysis of the photographs and the emulsions encouraged the physicists, engineers and technicians to build and use projectors, microscopes and measuring apparatus. In 1959 Leprince-Ringuet and the CERN management signed an agreement under which bubble chamber experiments were to be conducted for the benefit of the whole European scientific community.

The lab continued to grow rapidly, attracting physicists from various sources. With his sense of team spirit that had been fostered by his involvement in the student-worker mutual understanding groups (équipes sociales) in the post-war period, Leprince-Ringuet encouraged the new physicists to join the mountain lab or bubble chamber teams. In 1959, as successor to Frédéric Joliot-Curie, he set up new teams at the Collège de France. By the time of his retirement in 1972, the combined staffs of the two labs totalled 200, including some 50 physicists, most of whom, such as Rafael Armenteros, André Astier, Paul Musset, Violette Brisson, Jean Badier, Patrick Fleury, Pierre Petiau, Jean-Jacques Veillet, Henri Videau, Bernard Aubert and other younger physicists, would go on to work on CERN's accelerators.

French scientific heavyweights – Louis Leprince-Ringuet (right) with Francis Perrin at CERN in 1963.

As laboratory director, Leprince-Ringuet entrusted the choice of experiments to his close colleagues. However, it was he who found the necessary resources to cover major investments by applying to the Ecole Polytechnique, the CNRS or the Commissariat à l'Energie Atomique. His judgement on projects was never based on an appreciation of theoretical ideas but on the quality of the men and on the realism of the undertaking. It is a mark of his judgement never to have been wrong on important decisions, as evidenced by his own conversion from nuclear physics to cosmic radiation and the complete conversion of his teams to accelerators.

As a pupil at the Ecole Polytechnique in 1951, I studied under Leprince-Ringuet. The older-style physics course developed under the aegis of the previous professor, Charles Fabry, was still being taught there, but the curriculum also comprised more contemporary components, such as relativity, quantum mechanics and nuclear physics. The great merit of his teaching was that it left you with a desire to know more, which inspired several of us to enter the lab. In 1958 he secured the appointment of a third professor, Bernard Grégory, which allowed the opportunity for a complete overhaul of physics teaching to include more active participation of lecturers and a more coherent and unified course structure.

During the 1968 revolution, Leprince-Ringuet took part with his pupils in proposals for reform of the teaching of the Ecole

Polytechnique. This stance was not appreciated by the Directorate of Studies, which threatened him with the sack. Fearing that the lab was under threat, the physicists unanimously supported and signed a petition that I had drafted requesting the Minister of Defence to keep the director in his post. In early 1969 he was stripped of his professorial chair but was kept on as director of the lab. In 1972 the Administrative Tribunal found for the professor and annulled the minister's decision.

Leprince-Ringuet's role was decisive in the support for the accelerator projects at Saclay and CERN. He pleaded for an increase in Saturne's energy to 3 GeV, above the production threshold for strange particles. Consulted by the French authorities on the creation of CERN or the construction of a 30 GeV proton synchrotron, his support for these undertakings never wavered. He was a member of CERN's Scientific Policy Committee from its establishment in 1954, becoming its chairman in 1964 and 1965. He took part in the definition of CERN programmes such as the proton storage ring and the future 300 GeV machine. As a former member of the SPC, he was invited to attend the September meeting each year. He never missed this opportunity to manifest his unshakeable confidence in the future of CERN. His strong pro-European credentials earned him the appointment as president of the French branch of the European Movement from 1974 to 1989 as successor to Gaston Defferre.

Louis Leprince-Ringuet demonstrated an astonishing open-mindedness in listening carefully to what those around him had to say, be they experienced physicists or technicians. He liked to hear about developments outside his own laboratory, in industry, and the world of politics. He was attentive to social problems and developed his own personal philosophy which he set forth in his many books or in television appearances. He was much in demand as a conference speaker on a wide range of subjects. He was elected to the Academy of Sciences in 1949 and to the Académie Française in 1966. In all his activities, whether in science, the media, the arts or in the field of sport, he demonstrated an exceptional ability to adapt to new situations and an inflexible will to overcome difficulties. All those who had the opportunity to work with him will never forget his example.

André Rousset.

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Herman Feshbach 1917–2000

Renowned nuclear physicist Herman Feshbach died on 22 December in Cambridge, Massachusetts, aged 83. He served on MIT's physics faculty for more than 50 years and was department chairman for 10 years from 1973. He also directed the MIT Center for Theoretical Physics (which he helped to create) from 1967 to 1973.

Feshbach won many awards, including the US National Medal of Science in 1986. He notably worked to open communications between western and Soviet scientists during the height of the Cold War and he championed the cause of "refuseniks", including Andrei Sakharov.

A native of New York, Feshbach received his BSc from the City College of New York in 1937 and then moved to MIT for graduate study, subsequently remaining there for his entire career. He received his PhD in 1942, became assistant professor in 1945, associate professor in 1947 and full professor in 1955, and he was named an Institute Professor in 1983. He retired in 1987.

Feshbach was one of the world's foremost nuclear theoreticians. He was one of the leaders in developing nuclear reaction theory, and he contributed significantly to the statistical description of nuclear states and reactions, as well as furthering the understanding of nuclear structure. He co-authored two seminal textbooks: *Methods of Theoretical Physics* (1953) with Phillip M Morse and *Theoretical Nuclear Physics* with Amos deShalit.

Feshbach was a member of the US National Academy of Sciences from 1969 and he headed the physics section of the American Association for the Advancement of Science in 1987. He was president of the American Physical Society from 1980 to 1981 and of the American Academy of Arts and Sciences from 1982 to 1986. He served on several government and professional committees and was a consultant to the Brookhaven, Los Alamos and Argonne National Laboratories, as well as the Lawrence Berkeley Laboratory. He was also editor of *Annals of Physics*.

MIT recently established the Herman Feshbach Chair, the first incumbent being distinguished theoretician Frank Wilczek.

Heinz Maier-Leibnitz 1911 – 2000


Heinz Maier-Leibnitz.

Heinz Maier-Leibnitz, Nestor of modern neutron physics, founder and first scientific director of the Institute Max von Laue-Paul Langevin (ILL) in Grenoble, died on 16 December in Allensbach, Germany.

Born in Esslingen, Germany, Maier-Leibnitz studied physics in Stuttgart and Göttingen and graduated in 1935 as the last doctorand of James Franck with a thesis in which he discovered resonance states in negative helium. Subsequently he joined Walter Bothe in Heidelberg and improved the coincidence method with which they showed the energy conservation for Compton scattering, and began nuclear spectroscopy.

After the Second World War, Maier-Leibnitz continued nuclear spectroscopy, applied radioactive tracers in biochemistry and medicine, studied Bhaba-scattering and introduced positron annihilation as a tool to study the momentum distribution of bound electrons in condensed matter. The measurement of the antineutrino angular distribution in lithium-8 beta decay led to the discovery of the right-handedness of the antineutrino in 1958. In 1952 he became Professor for Technical Physics at the Technische Hochschule München and founded a school of nuclear physics in Munich. One of his young students, Rudolf Mössbauer, discovered the recoil free resonance absorption of gamma rays in solids and went on to receive the Nobel price in1961.

In 1957 Maier-Leibnitz took the first German research reactor in Garching near Munich to operation and developed neutron optics, which lead to neutron guide tubes, interferometers, refractometers and turbines for the production and bottles for storing ultracold neutrons, novel instrumentation that was used for fundamental studies of properties of neutrons and for the investigation of the dynamics and structure of condensed matter and nuclei.

To improve the facilities for research with neutrons, Maier-Leibnitz initiated, together with Louis E F Néel, the construction of a high flux reactor in Grenoble and became the first scientific director of the new ILL. With his Munich experience, he established a novel instrumentation at the ILL, including a hall with low background neutron guide tubes, a source of cold neutrons, a facility for experiments with ultracold neutrons and instruments for high-resolution inelastic neutron scattering, nuclear spectroscopy and fission studies. This made the ILL the world's premier user facility for experiments with neutrons.

From 1974 to 1979 Maier-Leibnitz served as president of the Deutsche Forschungsgemeinschaft. His integrity and high scientific standards regained lost confidence in science. He devoted much effort to improving the education of young students and scientists by original scientific work and by international collaboration.

Maier-Leibnitz was an eminent scientist and teacher who unselfishly did everything for his students, so that they become independent, creative scientists. He educated many and we are very grateful to this great man who loved people and nature so deeply.

Maier-Leibnitz held many official duties, including president of IUPAP and a member of three German and seven foreign scientific academies. He received many honours in Germany and abroad, such as the Otto-Hahn prize and the Stern-Gerlach medal of the German Physical Society, and the Austrian Medal for Science and Art, and he was honorary doctor of the universities of Vienna, Grenoble and Reading. He was member and chancellor of the Order Pour le Mérite and officer of the French Legion of Honour.

Paul Kienle, Munich Technical University.

MEETINGS

A special **International Conference on Theoretical Physics** will be held at UNESCO, Paris, fon 22–26 July 2002. This major meeting will underline the importance of theoretical physics from conceptual, cultural and applications viewpoints; emphasize the unity of physics through its various domains; and promote the dissemination of general ideas, concepts and methods between specialist branches.

TH-2002 is organized with the scientific sponsorship of the International Union for Pure and Applied Physics, the European Physical Society and the French Physical Society. It will include 12–15 one-hour plenary lectures and further invited lectures (around 40 minutes each) in three parallel sessions. Invited lectures, while presenting the most recent results and directions of research, should be aimed at a broad audience of theoreticians.

In addition there will be around 100–150 shorter presentations (15–20 minutes in duration), partly invited and partly selected from proposals received from participants, and posters. Public lectures of general interest, possibly on the morning of 27 July, will be considered.

TH-2002 will follow the **International Conferences on Mathematical and Statistical Physics** organized at UNESCO in 1994 and 1998, which attracted 1000 and 1800 participants respectively.

The main organizers of the meeting are Daniel Iagolnitzer and Jean Zinn-Justin, who can be contacted at Service de Physique Theorique, CEA-Saclay, F-91191 Gif-sur-Yvette Cedex France, e-mail th2002@spht.saclay.cea.fr See "http://www-spht.cea.fr/spht/th2002/".

The International Nuclear Physics Conference will be hosted by the Lawrence Berkeley National Laboratory on 30 July – 3 August. Visit "http://www.lbl.gov/~inpc2001/" for more information.

The 10th International Lomonosov Conference on Elementary Particle Physics, organized by the Interregional Centre for Advanced Studies in co-operation with the Faculty of Physics and Institute of Theoretical Microphysics of Moscow State University, the Joint Institute for Nuclear Research in Dubna, the Instituto Superior Tecnico/CENTRA, Lisbon, the Institute of Theoretical and Experimental Physics, Moscow, the Institute for Nuclear Research, also in Moscow, and the Institute for High Energy Physics in Protvino, will be held at Moscow State University on 23–29 August.

The programme will include electroweak theory, tests of the standard model and beyond, heavy quark physics, non-perturbative QCD, neutrino physics, astroparticle physics, quantum gravity effects and physics at the future accelerators. The Lomonosov Conferences bring together about 150 theorists and experimentalists to review the present status and future prospects in elementary particle physics. Further information is available from e-mail "studenik@srdlan.npi.msu.su", "ane@srdlan.npi.msu.su" and at "http://www.icas.ru".

The Fourth International Conference on the Physics and Astrophysics of Quark-Gluon Plasma will be held in Jaipur in India on 26–30 November. The conference, as on previous occasions, will cover experimental and theoretical studies of signals of QGP and hadronic matter at very high temperature and density in astrophysical and laboratory conditions. Previous meetings in the ICPAQGP series were in Bombay (1988), Calcutta (1993) and Jaipur (1997). The coming conference will be a good showcase for results from experiments at the new RHIC collider at Brookhaven. The talks will be in plenary and parallel sessions. For further information see "http://veccal.ernet.in/~icpaqgp".

Quantum (Un)speakables was the title of a memorable meeting on 10–14 November to commemorate the 10th aniversary of the death of CERN quantum authority John Bell (1928–1990). The meeting was organized in the framework of the Quantum Measurement and Information Programme organized by the International Erwin Schrödinger Institute for Mathematical Physics, and it was held at Vienna's Institute for Experimental Physics. The title of the meeting was a take on Bell's milestone book, *Speakable and Unspeakable in Quantum Mechanics* (1987 Cambridge). The meeting included a long list of distinguished speakers, including many who worked with Bell.

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POSTDOCTORAL POSITION IN GAMMA-RAY ASTRONOMY

The Nuclear and Particle Astrophysics Team is seeking a postdoc in the field of high-energy gamma-ray astronomy and cosmic-ray physics to work with the Milagro gamma-ray observatory and a new, large-aperture air Cerenkov telescope (WACT) array that will operate in conjunction with Milagro.

The Milagro TeV gamma-ray observatory http://www.lanl.gov/milagro/) is a large, water-Cerenkov air-shower detector in the Jemez mountains west of Los Alamos. Milagro continuously monitors the entire overhead sky in the energy region above 500 GeV. Ongoing projects include enhancements to lower the energy threshold of Milagro and to increase the sensitivity of the instrument through improved discrimination of the cosmic-ray background. The WACT telescope array is nearing completion at the Milagro site. WACT consists of 6 large aperture telescopes and will be used to study the cosmic-ray composition from 50 TeV to 5 PeV. The successful candidate will assume a leading role in these efforts and in the analysis of data from Milagro. For additional technical information contact Cy Hoffman at cy@lanl.gov.

A Ph.D. completed within the last three years, or soon to be completed, is required. See further details about the Postdoctoral Program at: http://www.hr.lanl.gov/postdoc/.

For consideration, submit a resume and publications list with a cover letter outlining current research interests to: postdoc-jobs@lanl.gov (reference job #CERN-PD016558) OR SUBMIT TWO COPIES to: Postdoc Program Office, CERN-PD016558, MS-P290, Los Alamos National Laboratory, Los Alamos, NM 87545

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The Niels Bohr Institute for Astronomy, Physics and Geophysics

University of Copenhagen

Postdoctoral position in Experimental Particle Physics

A postdoctoral position is available from June 1, 2001 with the Experimental Particle Physics group at the Niels Bohr Institute, University of Copenhagen. The position is for two years with a possibility of extension, however, not exceeding five years.

The particle physics group is located at the Niels Bohr Institute, and its experiments ALEPH and ATLAS are performed at CERN and HERA-B at DESY.

It is expected that the appointed candidate will participate in the ATLAS activities. More specific she/he should contribute to the physics analysis and the groups involvement in the GRID project. More information can be found at **http://www.nbi.dk/HEP/**. The Position also demands participation in the university teaching program. The candidate will be based in Copenhagen.

Deadline for applications is April 6, 2001, at noon.

Further information can be obtained from professors John Renner Hansen (renner@nbi.dk) and Jørn Dines Hansen (dines@nbi.dk). If you consider applying for the position, read the full text of the advertisement on the Internet address

http://www.ku.dk/led/stillinger/.

Applications should be sent to:

Professor Jørn Dines Hansen
The Niels Bohr Institute
Blegdamsvej 17
DK-2100 Copenhagen, Denmark.

POSTDOCTORAL RESEARCH POSITION

Experimental High Energy Physics with BaBar

Universite de Montreal

The experimental high energy physics group at Universite de Montreal has an immediate opening for a research associate to take a leading role in our ongoing effort in BaBar. Applicants must have a recent Ph. D. in elementary particle physics, strong interest in heavy quark physics and demonstrated software experience, preferably with object-oriented C++ software. The successful candidate will be based at SLAC. He will share in the responsibility for the global alignment of the Silicon Vertex Detector to the Drift Chamber of the BaBar detector and be very involved in the physics analyses of the UdeM students. Interested candidates should send a curriculum vitae and arrange to have three letters of recommendation sent to :

Prof. Paul Taras, Laboratoire Rene J. A. Levesque, C. P. 6128, Succ. Centre-Ville, Montreal, Quebec H3C 3J7, Canada.
E-mail enquiries can be directed to taras@lps.umontreal.ca.

Screening of candidates will begin immediately.

In accordance with Canadian immigration regulations, priority will be given to Canadian citizens or permanent residents. Nevertheless, all qualified physicists are encouraged to apply.

MIT

POSTDOCTORAL ASSOCIATE

The Particle Physics Collaboration within the MIT Laboratory for Nuclear Science is seeking a Postdoctoral Associate to join an ongoing large-scale dark matter axion search experiment. The successful candidate will participate in data-taking and analysis, and in construction of a major upgrade of the experiment. Relevant skills include RF electronics, signal processing and spectral estimation, quantum-electronic device fabrication, and low temperature physics. A Ph.D. in Physics or a related field, and travel to our collaborators at Lawrence Livermore Laboratory, California, is required. The Particle Physics Collaboration also participates in the CERN LHC proton-proton and heavy-ion programs and we would consider candidates with a shared interest in dark matter and collider research.

Candidates should submit their curriculum vitae, publication list, and names of three references to: **Leslie J. Rosenberg, Associate Professor of Physics, MIT, Room 24-506, 77 Massachusetts Avenue, Cambridge, MA 02139-4307; e-mail: ljr@mitlns.mit.edu.**

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Demonstrated track record in leading groups and delivering results in development projects and mission critical tasks an advantage. Extensive knowledge of network technologies, including TCP/IP, LAN and WAN routing protocols, switched environments, quality of service. Knowledge of network management techniques including use of software packages such as HP OpenView. Working knowledge of Unix and NT platforms essential, and distributed computing technologies highly desirable. In depth knowledge of computer and network security issues. Excellent written and verbal communication skills are essential.

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Postdoctoral Position in Experimental Particle Physics/Particle Astrophysics

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Please, send applications to: Prof. Dr. T. Lohse
Humboldt-Universität zu Berlin
Institut für Physik
Invalidenstraße 110
D-10115 Berlin
e-mail: lohse@ifh.de

RHEINISCHE FRIEDRICH - WILHELMS - UNIVERSITÄT BONN

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UNIVERSITY OF OXFORD

Mathematical and Physical Sciences Division
Department of Physics in association with Balliol College

University Lecturership in Experimental Particle Physics

The University proposes to appoint a University Lecturer in the field of experimental particle physics. This is a permanent post and may be associated with a Tutorial Fellowship at Balliol College. The combined University and College salary will be according to age on a scale up to £39,564.

The successful candidate will be expected to make substantial contributions to our research programme, which covers experiments at accelerators as well as in particle astrophysics. We are currently involved in preparations for the MINOS, ATLAS and LHCb experiments, while continuing participation in ZEUS, DELPHI and CDF. Some work has been started on accelerator aspects of a future neutrino factory and linear collider. Particle astrophysics activities include the SNO solar neutrino experiment and the CRESST dark matter search. We are interested in developing major new activities that take advantage of our strengths in hardware development, both mechanical and electronic. More information on our programme can be obtained from our web page: http://www2.physics.ox.ac.uk/pnp/ and further particulars of this post are available on http://www2.physics.ox.ac.uk/pnp/lect01-fp.htm or from Mrs Sue Geddes, Nuclear and Astrophysics Laboratory, Keble Road, Oxford OX1 3RH, UK, e-mail: s.geddes@physics.ox.ac.uk fax 00 44 (01865) 273417.

Applications should include a description of research and teaching experience, a statement of future research interests, a list of up to ten major publications, the names of three referees and a curriculum vitae. They should be sent to Mrs Geddes at the above address to arrive no later than 30 April 2001. No more than two of the three referees should be from the same institution; they should all be asked to consider the selection criteria in the further particulars and send letters of reference directly to the above address to arrive by the closing date (a letter by e-mail or fax is sufficient). Shortlisted candidates will be invited for interview in Oxford within 1-2 months after the closing date; applicants are asked to provide an e-mail address, fax or telephone number where they can be contacted during that time. Questions can be addressed to Prof Susan Cooper, e-mail: s.cooper@physics.ox.ac.uk

The University is an Equal Opportunities Employer.

Peoples Fellowships at Fermilab

Fermilab invites outstanding accelerator and accelerator-related technology scientists and high energy physicists to apply to the Peoples Fellowship program. The Peoples Fellowship has been created to facilitate the entry of scientists into the realm of accelerator science and technology at Fermilab. The program targets scientists early in their careers with the following criteria for eligibility:

1. Recipient within the prior three years of a PhD in accelerator physics or accelerator-related technology. Post-doctoral experience not necessarily required.
2. Recipient within the prior five years of a PhD, and normally with subsequent post-doctoral experience of at least three years, in high energy physics or a related field.

Approximately one award will be made annually.

Peoples Fellows will normally be assigned to either the Beams or Technical Divisions at Fermilab. These organizations retain responsibility for operating the existing accelerator complex, featuring the highest energy particle accelerator in the world, while simultaneously engaging in accelerator R&D aimed at developing the forefront accelerator facilities of the future. The successful Peoples Fellow candidate will propose a research project directed toward assisting Fermilab in achieving success in either of these directions and will be provided with support to execute this project. Current representative areas of research include stochastic and electron cooling, muon storage rings, superconducting magnet R&D, superconducting RF R&D, linear colliders, large hadron colliders, advanced acceleration methods, accelerator controls and feedback, and computational physics and modeling. Peoples Fellows are classified as Associate Scientists—a scientific tenure track position.

Term of Appointment

The initial term of the fellowship is three years, extendible for an additional term if justified.

Applications

Fermilab invites candidates for Peoples Fellowships to forward applications to:
Dr. James Strait, Chair, Peoples Fellows Committee
Fermilab, MS 343
P.O. Box 500
Batavia, IL 60510

Applications should include a current curriculum vitae, four references, and an indication of a potential area of research interest.

Located 40 miles west of downtown Chicago on a campus-like setting, Fermilab provides its employees with opportunities for personal and professional growth, competitive salaries, and an attractive benefits package.

Fermilab

University of Massachusetts, Amherst
Postdoctoral Research Position
Experimental High Energy Nuclear Physics

Applications are invited for a postdoctoral position in experimental nuclear physics. The position is for one year initially, with the possibility of renewal for up to three years upon mutual agreement and availability of funds. The primary responsibility of the successful candidate will be to participate in design, testing, commissioning and data taking of the approved parity violating electron scattering experiments in Hall A at Jefferson Laboratory, in which our group plays a leadership role. These experiments will test low energy QCD by probing the strangeness content of the nucleon and the neutron distribution inside nuclei with unprecedented precision. Testing of the experimental apparatus is likely to begin in late 2001 with data taking tentatively scheduled for Fall 2002.

This is a joint Jefferson Lab. - Univ. of Mass. position. The successful candidate is expected to be resident at Jefferson Laboratory and will have the opportunity to participate in other ongoing research programs in Hall A. In addition, participation in the E158 experiment at the Stanford Linear Accelerator Center will be encouraged.

Applicants must have a Ph.D. in experimental nuclear or particle physics. Prior experience with both software and hardware in accelerator-based experiments is desirable.

Applicants should send a CV, a description of research interests, and arrange for three letters of recommendation to be sent directly to

Prof. Krishna S. Kumar, Department of Physics,
University of Massachusetts, Amherst, MA 01003.

Review of applications will begin April 1, 2001.
Position remains open until filled.

Women and members of minority groups are encouraged to apply. AA/EOE.

QUEEN MARY UNIVERSITY OF LONDON
opportunities in
EXPERIMENTAL PARTICLE PHYSICS

RESEARCH ASSOCIATE IN ATLAS

A Post doctoral Research Associate post is available now in the QM Particle Physics Group to work on the ATLAS experiment for the CERN LHC.
The QM Group has active projects with major responsibilities, in the SemiConductor Tracker (SCT), and in the Level 1 Calorimeter Trigger, and additional projects in the ATLAS beampipe implementation and in Physics Studies. Candidates with interests and experience in any, or all, of these areas are encouraged to apply.
The research associate is expected to become knowledgeable across the programme of the QM Group, but will have personal responsibilities within one or more specific activities, and be encouraged to initiate and lead physics studies. He/she will also need to become experienced in data acquisition software and in the testing and implementation of hardware.
The post is based at Queen Mary, London, but travel to CERN and to other collaborating laboratories will be required. More extensive periods will also be necessary at CERN, in connection with test beam studies, and in later years long-term attachment, for installation and commissioning within ATLAS.
The initial contract will be for a period of three years, with the expectation of an extension that would allow the successful candidate to participate in projects through to their full implementation in ATLAS and into data taking and physics analysis.
Further information and application forms can be obtained from Prof. Tony Carter <a.a.carter@qmw.ac.uk>, or at CERN by phone: 0041 22 767 6361.
Candidates should have, or be about to gain, a PhD in experimental particle physics, and should be familiar with current particle physics software techniques. Relevant experimental hardware experience would also be an advantage. The initial salary, including London allowance, will be in the RA1A range £18,909 to £23,569 depending on age and experience.
For an application form and further details, please e-mail coll-recruit@qmw.ac.uk or telephone the 24-hour Recruitment Line on 0044 (0) 20 7882 5171, quoting reference 00097. Completed applications should be returned, as soon as possible, to the Personnel Office, Queen Mary, University of London, Mile End Road, London E1 4NS.

POSTGRADUATE RESEARCH STUDENTSHIPS

The Experimental Particle Physics Group at Queen Mary, University of London, is inviting applications for Postgraduate Studentships that are available from October 1st 2001.
Successful candidates who wish to have a period of one to two months, in the Summer of 2001, resident at one of the Group's International Collider Facilities will have the opportunity of working as members of the Queen Mary team, together with their collaborators, before taking up the official award.
Accepted students will become registered for a PhD in the University of London, after an initial probationary period, and the detailed topics of the doctorate project will be decided between the Supervisor and the Student after a period of post graduate training in London. The central topics for the PhD thesis are expected to be one or more of the following:

1. Studying physics interaction processes of fundamental particles and developing the appropriate software programs for analysing simulated and real data.
2. Development and testing of experimental instrumentation.
3. Taking and analysing experimental data within active experiments or test beams.
4. Developments of software and hardware within data-acquisition systems for experiments.
5. Implementation and evaluation of components of the Particle Physics distributed computing and data Grid system.

To carry out their research the students will join one of the following international experiments:
BaBar: studying electron-positron interactions at SLAC, California, with particular emphasis in b-quark physics and in quantitive measurements of CP-violation processes.
H1: studying electron-proton interactions at the highest energies at DESY, Hamburg, with particular emphasis on hadronic fragmentation in deep inelastic processes.
ATLAS: preparing detector and trigger instrumentation, and physics simulation and analysis software, for the future studies of proton-proton interactions in the TeV energy domain at CERN, Geneva.
These activities cover a wide range of topics, from fundamental particle physics, through hardware/software design and implementation to data analysis and state-of-the-art computing technology within the UK e-Science programme.
The details of financial arrangements for the studentship will be provided to all interested applicants.
For further details of the Post Graduate programme please contact Dr Alex Martin (a.j.martin@qmw.ac.uk) and for general information or application forms contact Mrs Denise Paige (d.paige@qmw.ac.uk). General information about research opportunities in the Physics Department can be found in the Queen Mary Research Handbook.

C O N F E R E N C E

CERN Accelerator School
Academy of Sciences of the
Czech Republic Nuclear Physics Institute, Řež
will hold a course on

Particle Accelerators for Medicine and Industry.

Congress and Educational Centre Průhonice, Czech Republic 9 -17 May.
This course will be of interest to staff from laboratories, hospitals, universities and manufacturing companies associated with medical and industrial applications of particle accelerators.
http://cern.web.cern.ch/Schools/CAS/
For further information and application forms contact
Suzanne.von.Wartburg@cern.ch

The **Deutsche Elektronen-Synchrotron DESY** in Hamburg, member of the association of national research centers Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren, is a national center of basic research in physics with app. 1,400 employees and more than 3,000 scientific guests from Germany and foreign countries per year. The accelerators in operation are dedicated to particle physics and research with synchrotron radiation.

DESY offers two positions for

Scientists (m/f) with Ph.D.

The candidates are expected to take part in the operation and in the research programme of the H1 experiment on the ep storage ring HERA.

For the first position the candidate should be willing to take a leading role in the development of the online event filters of the H1 experiment. He or she should take part in the preparation and the refinement of the overall H1 computing environment for the time after the HERA upgrade. The applicants should have an established record in interpreting physics data.

Job offer 11/2001

For the second position the candidate should be willing to take over considerable responsibilities in the introduction of object-oriented software analysis methods for the H1 experiment. The applicants should have an established record in handling large software packages.

Job offer 12/2001

Applicants should have a Ph.D. in physics and several years of experience in experimental particle physics. They should have an established record in physics analysis.

The positions are unlimited, payment and social benefits correspond to those in public services.

Handicapped applicants will be given preference to other applicants with the same qualifications. DESY supports the careers of women and encourages especially women to apply.

Please send your application documents until March 31 to:

DESY
Personalabteilung
Notkestraße 85, D-22607 Hamburg
Tel.: +49-(0)40/8998 2565
www.desy.de

University of Wisconsin-Madison

Postdoctoral Position in Experimental Particle Physics

A University of Wisconsin-Madison research group on the BaBar experiment at SLAC seeks outstanding applicants for one or more positions of postdoctoral Research Associate. Applicants should have a Ph.D. in high energy physics with significant research experience in the area of analysis, preferably on a colliding beam experiment.

The successful candidate will be based at SLAC and participate in the measurement of the CP asymmetry in B decays.

Please send a full CV and three letters of recommendation to the following address (preferably by e-mail or by fax):

Prof. Sau Lan Wu, CERN, PPE Division, Bldg. 32,
R-A05, CH-1217 Geneva 23
Switzerland

wu@wisconsin.cern.ch
Tel: (4122) 767-7171 Fax: (4122) 782-8395

University of Wisconsin is an Affirmative Action/Equal Opportunity Employer.

University of Hamburg
Institute for Experimental Physics

Faculty Position in Experimental Particle Physics

The Institute for Experimental Physics invites applications for

C3-Professor (tenure) for Experimental Particle Physics

The candidate is expected to play a leading role in the Institute's group participating in the ZEUS experiment at the HERA e-p collider at DESY and to participate actively in shaping the future research program of the Institute including physics with TESLA. The teaching requirement of 8 hours/week during the semesters includes lectures, tutoring, labs, seminars and the supervision of diploma-students.

Candidates should have a PhD in physics, a demonstrated excellence in research in experimental particle physics and experience in teaching and working with students.

The University of Hamburg is an equal opportunity/affirmative action employer and welcomes the applications from qualified women. Handicapped applicants will be given preference in case of equal qualifications.

The expected starting date is September 2001. Applications including a CV, academic records, teaching experience and the list of publications should be sent by May 2, 2001 to:

Präsident der Universität Hamburg
Referat Personal & Organisation - 332.11/12
Kennziffer 1732/3
Moorweidenstr. 18
D-20148 Hamburg

E-mail information: Robert.Klanner@desy.de

MIT

The MIT-Bates Linear Accelerator Center, operated by the Massachusetts Institute of Technology, is a high energy particle accelerator, peformingworld-class research in fundamental aspects of nuclear physics. It comprises a linear accelerator/recirculator system, a pulse stretcher/ storage ring, and experimental halls. The facility operates 24 hours a day, 7 days a week, for roughly 8 out of 12 months each year.

ACCELERATOR OPERATIONS GROUP LEADER

A motivated individual is sought to lead the Accelerator Operations Group. Responsibilities include coordinating daily control room activities; arranging shift schedules of the operations crews to guarantee 24/7 coverage; becoming qualified (through on-the-job training) to cover both Crew Chief and Operator Technician shifts and covering shifts as needed; training new Operators; writing and updating standard operating procedures; documenting operational efficiency; and working with accelerator Physicists, controls and instrumentation engineers, and laboratory management to improve accelerator operations.

Requirements: a BS degree or higher in Physics or a relevant engineering discipline or comparable experience. The capability to manage a group of professionals in a highly technical setting and excellent communications and interpersonal skills are essential. Additional desirable qualifications include experience supervising shift personnel and/or working shifts and familiarity with Unix and Windows operating systems, high voltage electronics, vacuum systems, and RF systems. In special situations, this appointment may be made at the Assistant Group Leader level.

MIT offers excellent benefits. This position is located in Middleton, MA. For more information about the MIT-Bates Linear Accelerator Center, visit: **http://mitbates.mit.edu.**

Interested candidates should submit a resume and cover letter referencing Job No. 01-0063 to: **Etaine Smith, MIT Human Resources, PO Box 391229, Cambridge, MA 02139-0013. To apply on-line: web.mit.edu/personnel/www/resume.htm.**

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The vital link between pure science and public opinion

The world looks to the Stanford Linear Accelerator Center (SLAC) for world-class research in high-energy physics and synchrotron radiation programs. On behalf of the Department of Energy, the SLAC performs experimental and theoretical research that has the potential to alter the way we interact with the basic forces of the universe. To make certain all aspects of our story see the light of day, we are seeking a:

Director of Communications

Leading a staff of 10-15, will organize and lead the communications effort at the Laboratory.Reporting to the Head of the Laboratory, this individual will develop and implement policies and strategic directions for internal and external communications in support of the Laboratory's scientific and educational mission. This position will require you to have vision and experience with the management of all aspects of SLAC's internal and external communications. You will also develop and manage community and media relations to employee communications.

Requires 5+ years' management experience in a complex and diverse environment, preferably a scientific research environment; advanced knowledge of communications principles/methods; experience in media relations and conducting press conferences; excellent interpersonal and written/verbal communications skills; and a Master's in Communications, PR, Journalism or the equivalent.

SLAC offers competitive compensation and excellent benefits. Please send resumes to: **SLAC, Attn: Employment, 2575 Sand Hill Rd., Menlo Park, CA 94025, M/S 11, Fax: 650-926-4999.**

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Post Doctoral Position in Experimental Particle Astrophysics

The Fermi National Accelerator Laboratory (Fermilab) has an opening for a post doctoral research associate on the Cryogenic Dark Matter Search (CDMS). Data taking is currently underway at the Stanford Underground Facility (SUF) and will continue during 2001. Results from early running have already yielded the most competitive limits published for dark matter searches. Concurrently, a new installation is being prepared for CDMS II at a deep site located in the Soudan Laboratory in Northern Minnesota. Cryogenic detectors are expected to begin arriving at Soudan in 2001 for commissioning. Data taking will begin in 2002 and the full complement of 42 detectors is expected to be in place by 2004. Substantial coverage of the allowed SUSY parameter space will be possible in CDMS II due to a factor of 30 increase in sensitivity over the CDMS I. Opportunities are available for participating in the development of the data acquisition system, the experimental installation operations at Soudan, and in the data analysis for both SUF and Soudan data sets.

The appointment will be for 3 years with one year renewals possible thereafter. Every effort is made to keep Fermilab Research Associates until they have had the opportunity to obtain physics results from their experiments.

Applications should include a curriculum vitae, publication list and the names of three references. Applications and requests for information should be directed to Dr. Michael Albrow, Head-Experimental Physics Projects Department, Particle Physics Division [Albrow@fnal.gov], Fermi National Accelerator Laboratory, M.S. 122, P.O. Box 500, Batavia, IL 60510-0500. EOE M/F/D/V

Fermilab

POSTDOCTORAL POSITION IN EXPERIMENTAL PARTICLE PHYSICS

LAWRENCE BERKELEY NATIONAL LABORATORY

The Physics Division at LBNL has an opening for a postdoctoral physicist in the D-Zero Group. We seek an exceptionally talented individual who can play a strong role in the physics analysis of the data from Run 2 with the D-Zero Experiment at the Fermilab Tevatron Collider. This is a timely opportunity for a motivated researcher to explore fundamental physics at the world's highest energy collider.

Applicants should have a PhD in Experimental Particle Physics and demonstrate strong potential for outstanding achievement as an independent researcher. This is a two-year term appointment with the possibility of renewal.

Interested candidates should send a letter of application (refer to Job #PH/013194/JCERN), *curriculum vitae*, publication list, and three letters of recommendation to: Dr. Ronald J. Madaras, c/o Physics Division HR Administrator, MS 50-4037, Lawrence Berkeley National Laboratory, University of California, 1 Cyclotron Road, Berkeley, CA 94720. Berkeley Lab is an AA/EEO employer committed to a diverse workforce.

BERKELEY LAB

At the Instituut voor Kern- en Stralingsfysica of the University of Leuven

A POSTDOCTORAL POSITION IN EXPERIMENTAL NUCLEAR PHYSICS

is available.

This position is for two years with a possible extension and will be in connection with the WITCH experiment that is currently being set up at ISOLDE, CERN. The aim of this experiment is to search for physics beyond the standard electroweak model by performing high precision beta decay experiments. The position covers all areas of the experiment from setting it up at CERN and tuning to operation and data analysis. The experiment is in the context of a European collaboration and will make use of the beams of ISOLDE, CERN, Geneva.

Interested applicants should have a PhD in experimental nuclear physics and send their C.V. to Prof. N. Severijns, Instituut voor Kern- en Stralingsfysica, K.U. Leuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium, or e-mail it to nathal.severijns@fys.kuleuven.ac.be, no later than 30th April 2001.

KATHOLIEKE UNIVERSITEIT LEUVEN

Further information can be obtained on our web page **http://www.fys.kuleuven.ac.be/iks/ko.**

UNIVERSITY OF WÜRZBURG

PHD STUDENT

DEPARTMENT OF CARDIOLOGY, GERMAN CANCER RESEARCH CENTER HEIDELBERG

The interdisciplinary cardiac nuclear magnetic resonance group located at the Department of Cardiology (PD Wolfgang R. Bauer (MD, PhD), University of Würzburg) and at the German Cancer Research Center Heidelberg (Prof. Lothar Schad (PhD)) looks for a PhD (doctorand) student (physics) for a project funded by the Deutsche Forschungsgemeinschaft. The payment is BAT IIa/2 .

The research is focused on the development of oxygenation (T2*, T2) and perfusion (T1) sensitive NMR imaging techniques of the heart. This is of special interest since these parameters reflect the state of myocardial microcirculation which is involved in many pathological processes of the heart (information the web sites: http://ernst.physik.uni-wuerzburg.de/~kh/AG.html and http://www.dkfz-heidelberg.de/mrphys/). Applicants should hold a Masters or Diploma in Physics. Experience in NMR techniques is of advantage but not necessary.

Please remember to note that you refer to this advertisement in your application.

Applications should be sent to
PD Dr. Wolfgang R. Bauer
Medizinische Universitätsklinik Würzburg
Josef Schneider Str. 2, 97080 Würzburg, Germany
Tel.: +49-931-201-5327, Fax: +49-931-201-2291

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E-mail: andrew.hardie@iop.org

UNIVERSITY OF VICTORIA

POSTDOCTORAL RESEARCH ASSOCIATE POSITION IN EXPERIMENTAL HIGH ENERGY PHYSICS

The University of Victoria high energy physics group has a vacancy for a Research Associate position in experimental physics to work on software development for the ATLAS experiment. The group is developing object-oriented software for the analysis of test beam data for the hadronic endcap (liquid argon) calorimeter and contributing to the database development for the entire ATLAS liquid argon calorimeter. The group is very active in the calorimeter test beam R&D program and the analysis of the test beam data. The Victoria group is also exploring the use of LINUX farms and Grid software for the ATLAS physics analysis in Canada.

The position has a two-year term with a possible one-year extension and is available immediately. The successful candidate is expected to take a leading role in developing object oriented software for the calorimeter and take an active interest in the test beam program. Candidates should have a recent Ph.D. in particle physics and experience with UNIX and LINUX operating systems. Familiarity with the C++ programming language would be an asset. Further inquiries can be made to Prof. M. Lefebvre (lefebvre@uvic.ca), or Dr R. Sobie (rsobie@uvic.ca).

Applications will be accepted until the position is filled, and will be assured of full consideration if received by 30 April 2001. Interested candidates should send their curriculum vitae and arrange for two letters of recommendation to be sent to:

Dr Randall Sobie
Department of Physics and Astronomy
University of Victoria
P.O. Box 3055 Stn CSC
Victoria, BC CANADA V8W 3P6
e-mail: rsobie@uvic.ca
Telephone: (250) 721-7733
Fax (250) 721-7752

Applications will be accepted until the position is filled. In accordance with Canadian immigration regulations, priority will be given to Canadian citizens and permanent residents. All qualified individuals are encouraged to reply.

University of Pennsylvania

The ATLAS group at the University of Pennsylvania has a position open for a postdoctoral fellow to work on electronics for the Transition Radiation Tracker. While our responsibilities also include development of custom integrated circuits and printed circuit boards for those chips, the present activities focus increasingly on system tests of large size, as well as beam tests at very high particle rates. The successful candidate will have a strong interest in detector and/or electronic systems.

Interested candidates who possess a PhD. may contact Prof H. H. Williams (williams@williams.hep.upenn.edu, 215 898 6284) and/or the Web site http://www.hep.upenn.edu/atlas for additional details. They should send a CV and arrange for three letters of recommendation to be sent to

Prof. H. H. Williams,
Department of Physics,
University of Pennsylvania,
209 S. 33rd St, Philadelphia,
PA 19104.

The University of Pennsylvania is an equal opportunity employer and especially encourages applications from women and minorities.

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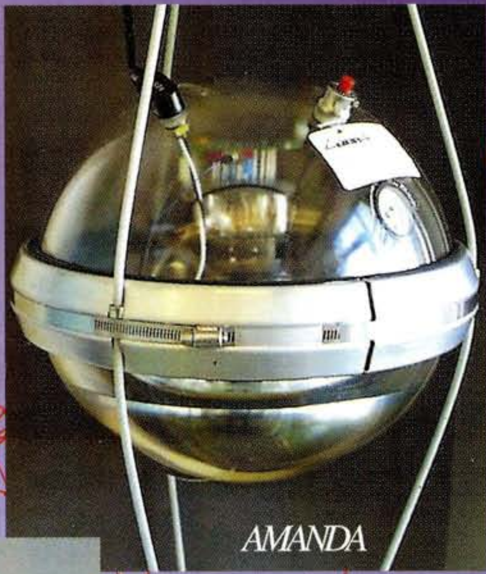
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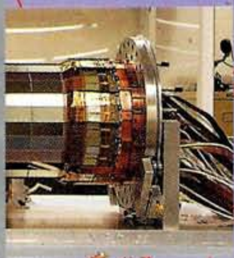
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Helping high energy physics for more than 35 years

P · S · L

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