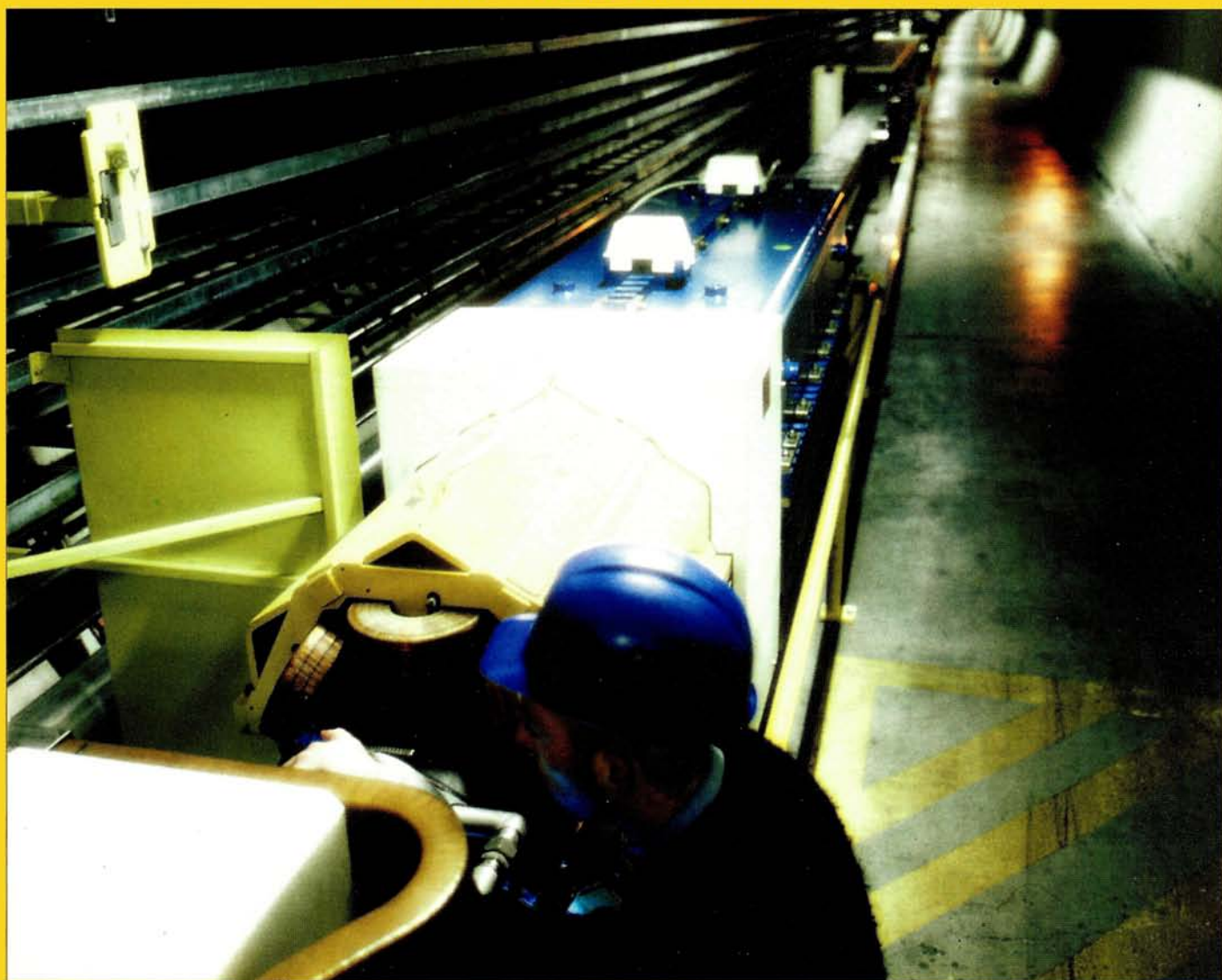


CERN COURIER

VOLUME 40 NUMBER 5 JUNE 2000



LEP's last lap sprint

THE GRID

The new computer world after the World Wide Web p17

GOING INTERNATIONAL

Accelerator scheme which could span the globe p19

NEUTRINOS

Detecting extraterrestrial particles underwater p28

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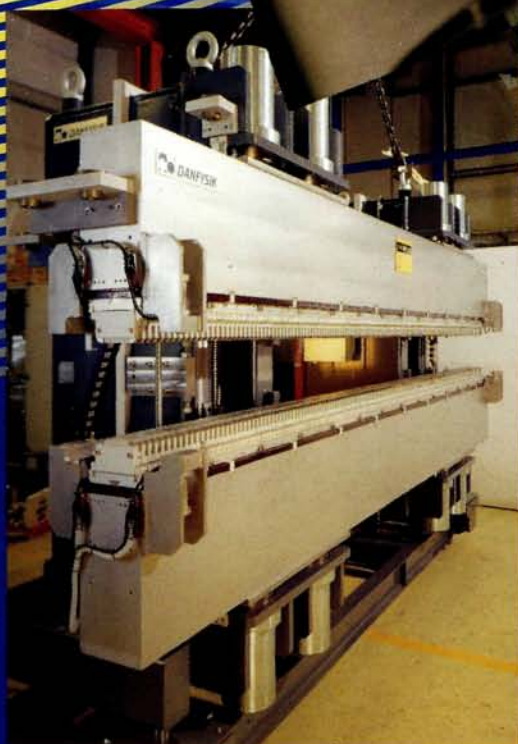
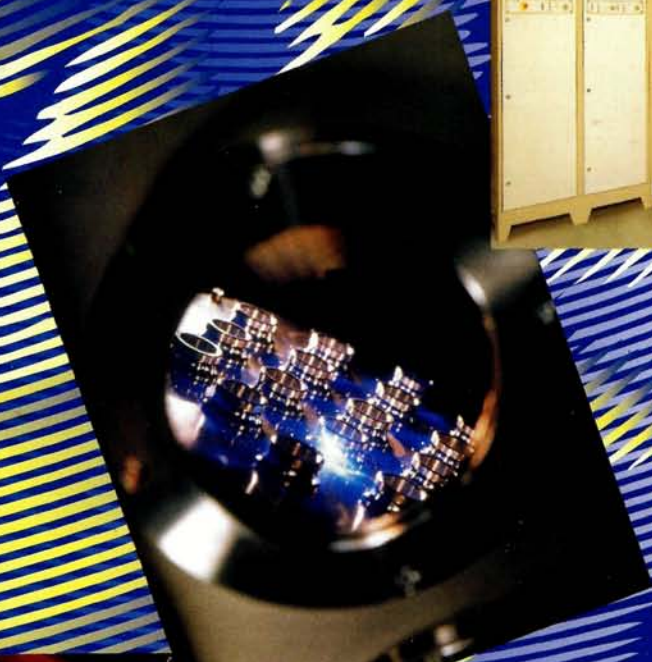
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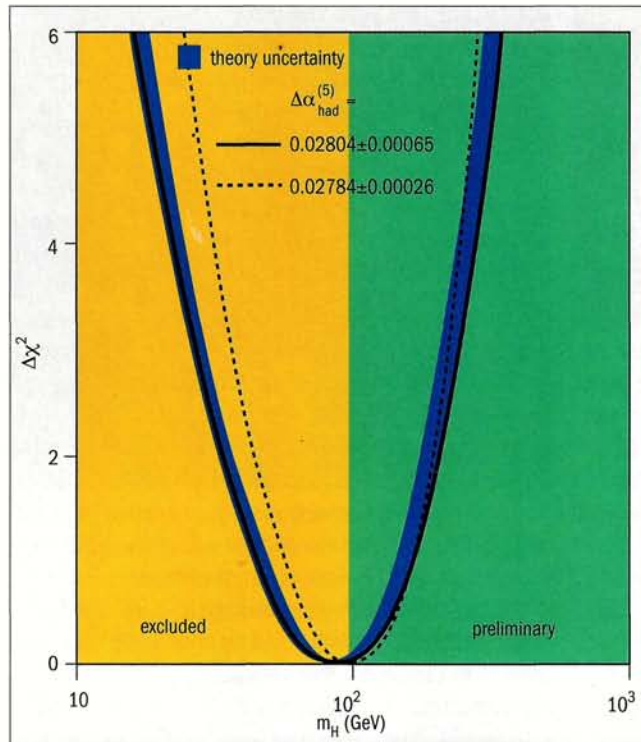
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LEP achieves record energy levels

CERN's flagship accelerator, the 27 km Large Electron Positron collider (LEP), began its final year in fine style in April colliding beams at a record 104 GeV per beam, just three weeks after start-up. With the search for the elusive Higgs particle top of the LEP physics agenda for 2000, high-energy running is receiving maximum attention.

LEP's full complement of superconducting accelerating cavities, all running at their maximum design gradient, gives the machine an energy reach of 96 GeV per beam. To reach the magic figure of 100 GeV in 1999, LEP's engineers had to push most of the cavities to 7 MV/m, more than 16% beyond the design gradient.

To extract yet higher energies this year has required some ingenuity on the part of the LEP team. Eight of the old (normal conducting) copper cavities, which provided LEP's energy for the years that it ran at around 50 GeV per beam, have been reinstalled. The superconducting cavities are being pushed still further. Magnets designed to pro-



Knocking on Higgs' door: many years of careful physics have shown that the Higgs, the mysterious particle that breaks electroweak symmetry, must lie within the curves shown. Direct searches have also excluded the yellow region, further restricting the Higgs territory. CERN's LEP collider, operating at higher beam energies, is treading potentially promising ground, up to a Higgs mass of about 115 GeV.

vide small corrections to beam orbits will also be used to reduce the amount of energy lost by the beams as they travel round the ring.

All this adds up to a high-risk strategy - there is literally no spare capacity left in the machine - but the rewards could be high. Results from LEP have already tied down the mass of the Higgs particle to the 108-190 GeV range. With collisions at 104 GeV per beam, the experiments are sensitive to a Higgs mass of up to about 115 GeV. Before the machine is switched off to make room for the LHC proton collider, the least that can be expected from LEP is a smaller mass range for future physicists to aim for. The best might be a major discovery to crown LEP's already illustrious career.

LEP is treading on fertile physics ground. According to orthodox physics, the Higgs should be lighter than two hundred giga-electronvolts (see figure). The minimal supersymmetric model requires at least one Higgs particle lighter than 1.5 times the mass of the Z - less than about 135 GeV.

Canadian isotope source is to be upgraded

The new Isotope Separator and Accelerator (ISAC) is now operational at the Canadian TRIUMF laboratory, producing intense beams of short-lived, exotic nuclei (*CERN Courier* October 1999 p8). A major component in the laboratory's programme over the next five years will be the upgrade of ISAC to ISAC-II, raising the energy from 1.5 to 6.5 MeV/nucleon and extending the mass range, which will enable many more exotic isotopes and nuclear reactions to be studied.

At the laboratory on 18 April for the formal opening of ISAC, Canadian industry minister John Manley announced that the Canadian federal government will give \$200 million to TRIUMF over the next five years. The money - \$40 million per year over five years - represents a 20% increase from the federal



Canadian industry minister John Manley opens the new Isotope Separator and Accelerator at the Canadian TRIUMF laboratory. Behind the podium is the 8 m 35 MHz radiofrequency quadrupole which serves as the first accelerating stage of ISAC. (Hapke/TRIUMF.)

government. As well as allowing TRIUMF to build ISAC-II, the funding will also enable a second phase of the Canadian contribution to CERN's LHC project, including the provision of the warm twin-aperture quadrupoles for the two beam-cleaning insertions, and the resonant charging power supplies and the pulse-forming networks for the injection kickers.

Further funding for ISAC-II civil construction is expected from the province of British Columbia. The promise of ISAC-II has already repatriated young Canadians back to Canadian universities and brought equipment, previously built in Canada, back into the country from US facilities. It has also attracted experiments from the US and Europe.

Straight section on full current



The LHC straight section. Left to right: Andrzej Siemko; Aniello Russo; Carlo Wyss; DAPNIA (Saclay) head Joel Feltesse; Peter Rohmig; Peter Sievers; CERN director-general Luciano Maiani; Theodor Tortschanoff; French IN2P3 scientific director Jean-Jacques Aubert; Marc Peyrot of Saclay; CERN LHC division leader Philippe Lebrun; and Emmanuel Roy.

The first of 420 short straight sections for CERN's LHC collider to be put on test at CERN has been successfully ramped to full current. These short straight sections, containing superconducting quadrupole magnets to keep the beams tightly focused, have been designed and prototyped by the French Atomic Energy Commission laboratory in Saclay and the neighbouring CNRS-IN2P3 laboratory at Orsay. These laboratories will also be responsible for their industrial follow-up as part of France's special host-state

contribution to the LHC project.

After preliminary tests at 9000 A and brief training, the first short straight section was soon ramped up to 13 000 A, the maximum current delivered by the LHC power converters and well above its nominal operating current of 11 870 A, which corresponds to a field gradient of 223 T/m. Following a thermal cycle to room temperature and back to 1.8 K, the short straight section could be ramped up directly to 13 000 A without any further training quenches.

New prospects for the Dubna Nuclotron

A new beam-extraction system considerably extends the capabilities of the unique Nuclotron accelerator at the Joint Institute for Nuclear Research in Dubna near Moscow. In the past several years the Nuclotron has provided circulating beams of hydrogen, deuterium, helium, carbon and krypton nuclei inside its 250 m superconducting ring with an energy up to 4.2 GeV per nucleon and an intensity of up to 10^{11} particles per second (for light nuclei).

Initial experiments used targets inside the ring, but the construction of a special system for beam extraction to external detectors is now complete. Last year the system was tested and first extraction of proton beam from the ring achieved.

March saw the second full-scale Nuclotron run with the new nuclear beam-extraction system. The parameters of an extracted deuterium beam with the intensity above 10^9



At the Joint Institute for Nuclear Research in Dubna near Moscow on 16 March, members of the institute's Committee of Plenipotentiaries visit the superconducting Nuclotron. A Malakhov explains the Nuclotron's new beam slow extraction system.

particles per second were studied and the beam was supplied to several experiments. The new data are being processed.

The Nuclotron beam-extraction system opens up new horizons for physics research. The Nuclotron construction and physics research are in the framework of a wider international collaboration among the JINR member states.

Jordan is first choice for SESAME synchrotron site

In a meeting at CERN on 10–11 April, a restricted interim council of the SESAME (Synchrotron Radiation Light for Experimental Science and Applications in the Middle East) project, after extensive discussions on the technical, political and financial considerations and by a series of votes, selected Jordan as its first choice by a large majority and Armenia as its second choice.

Proposals were received from seven members, namely Armenia, Egypt, Iran, Jordan, Oman, the Palestinian Authority and Turkey. Egypt and Iran withdrew their proposals before the final round of voting.

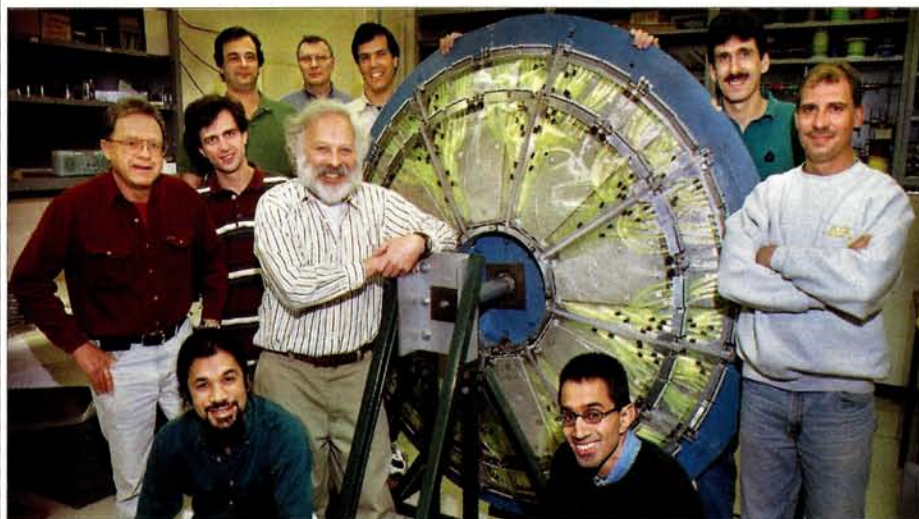
In recommending Jordan as the preferred host nation, it was understood that collaboration will take place with other members, in particular with the Palestinian Authority, to assist the recommended host nation in fulfilling its commitments. The recommendation of the restricted interim council is now forwarded to the interim council for final ratification. The SESAME interim council operates under the auspices of UNESCO.

The BESSY I synchrotron facility at Berlin was decommissioned in 1999 and the German government was prepared to make it available for another project. The decision to upgrade and relocate this facility to a Middle East nation to promote peace through science gave birth to the SESAME Project (*CERN Courier* March 2000 p17).

The interim council sought proposals from Middle East nations interested in housing the SESAME project. A restricted meeting of the interim council, with one representative from each of the 11 members, was charged with the task of evaluating the merits of each proposal and making a final recommendation to the full interim council.

The meeting at CERN was chaired by former CERN director-general Herwig Schopper and was attended by delegates from Armenia, Cyprus, Egypt, Greece, Iran, Israel, Jordan, Oman, the Palestinian Authority and Turkey; by the co-chairmen of the technical committee, the UNESCO secretary of the interim council and the director of the UNESCO regional office in Cairo.

Brookhaven detector goes to Fermilab

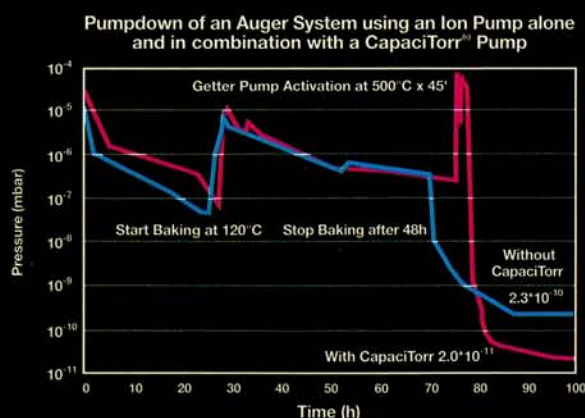


The Brookhaven/Stony Brook FPS team. Back row, left to right: sub-project manager Jonathan Kotcher, project engineer Anatoli Gordeev, Robert Soja and Neil Donahue (Brookhaven Physics Department); middle row: Bob Wheeler (Brookhaven Physics), Andrei Talalaevskii (Stony Brook), Peter Yamin (CERN Courier correspondent) of Brookhaven's director's office and Russell Burns (Brookhaven Physics). Front row: Satish Desai and production manager Abid Patwa (Stony Brook). Other Stony Brook collaborators (not pictured) include Michael Rijssenbeek, Jack Steffens and Julian Brody.



The Forward Preshower Detector (FPS) built at Brookhaven.

Physicists at Brookhaven and the State University of New York, Stony Brook, have just completed the construction of the Forward Preshower Detector (FPS), one of four inner tracking subdetectors for the D0 experiment at Fermilab's Tevatron proton-antiproton collider. Both D0 and the Tevatron are currently undergoing major upgrades prior to the next run, which is set for March 2001.



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ELFE: an electron machine for Europe

As experiments at CERN using high-energy nuclear beams have shown (*CERN Courier* April 2000 p13), about one ten-thousandth of a second after the Big Bang, its quarks and gluons crystallized into protons and neutrons, changing for ever the texture of the microworld and casting the form for the nuclear matter that dominates our universe. In physics-speak, free quarks became "confined" in subnuclear particles, where they have remained ever since.

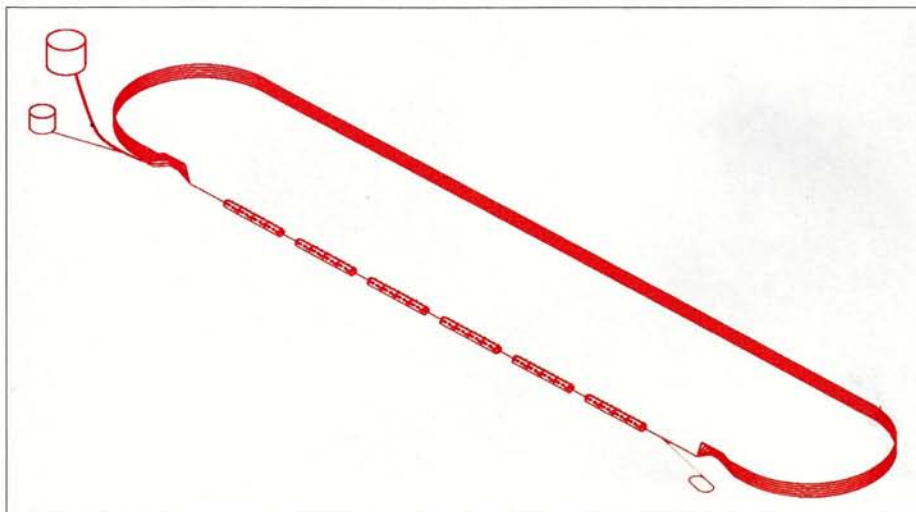
Once accomplished, this quark confinement is extremely difficult to unravel, and CERN's experimental programme using high-energy nuclear beams has shown that recreating these initial Big Bang conditions requires energy, perseverance and insight.

However, the quark/gluon origins of nuclear matter are now well understood. Less well understood is how the complex pattern of nuclear matter that we see around us relates to, and results from, quark-gluon confinement. It is somewhat analogous to the realization that all biology can ultimately be related to the DNA structure of genetic material. However, until the underlying genome structure is revealed through detailed experiments, the connections are difficult, if not impossible, to make and the science remains highly empirical.

Nuclear physics therefore needs a "genome project" to map its quark/gluon structure. This underlies the Electron Laboratory for Europe (ELFE) proposal for continuous electron beams in the 15–30 GeV range. ELFE is promoted by the Nuclear Physics European Collaboration Committee (NuPECC), which is the "parliament" of European nuclear physicists.

This requirement for powerful electron beams has resulted in several studies on both the physics and the machine sides. The first ELFE machine proposal in 1993 was for a "green field" design. A 1997 study at DESY, Hamburg, looked at the possibility of capitalizing on DESY's plans for a new linear electron-positron collider (*CERN Courier* October 1997 p12). The latest machine study, at CERN, aims to exploit the valuable hardware and expertise that will become available when CERN's 27 km LEP electron-positron collider is finally closed.

LEP will begin its 2000 operations in April,



The CERN scheme for an Electron Laboratory for Europe, providing continuous electron beams in the 15–30 GeV range. Superconducting radiofrequency cavities originally supplied for the LEP electron-positron collider would be redeployed in one straight section of a flat racetrack. The linac itself, with the LEP superconducting cavities, would be 1080 m long. The opposite straight section would have six vertically stacked beamlines to handle successive passes of the beam.

but from October the LEP schedule announces "LEP dismantling", so the tunnel can be prepared for the LHC proton collider scheduled to begin operations in 2005.

In 1998 Günther Geschonke and Eberhard Keil at CERN published an idea for an electron machine based on "salvaged" LEP components, particularly its valuable superconducting radiofrequency acceleration cavities. This idea now forms the focus of a conceptual design report, *ELFE at CERN*, which pulls together the underlying physics objectives, requirements for experiments and experimental areas, and the machine itself.

Cryogenics infrastructure, including helium compressors, installed for LEP will enjoy a prolonged life at the LHC and thus will not be available for ELFE.

The outcome of an intense R&D programme (*CERN Courier* December 1997 p8), LEP is now fitted with hundreds of niobium-covered radiofrequency cavities achieving accelerating gradients of 7 MV/m that push its beam energy to 100 GeV and even beyond.

In the ELFE at CERN scheme, these cavities would be redeployed in one straight section of a flat racetrack. The linac itself, with the LEP superconducting cavities, would be 1080 m long, but adding the elements to spread and

combine the beams at each end takes the total length to 1500 m. The opposite straight section would have six vertically stacked beamlines to handle the successive passes of the beam, with a 3.5 GeV energy gain on each of the seven passes through the linac. With the required tight momentum spread in the beam (less than one part per thousand) influencing the bending that could be achieved, the two straight sections would be linked by 300 m diameter arcs. The new ring could be accommodated near CERN's existing North Experimental Area, with experiments in or very near existing halls.

To maximize the scope of the experimental programme, ELFE is foreseen as handling polarized particles. These would be injected at 800 MeV either via a superconducting linac using experience gained from the TESLA international project based at DESY or via racetrack microtrons, as with the MAMI machine at Mainz.

The ELFE at CERN conceptual design report is now seen as definitive and will serve as input to future presentations of the study.

Further reading

H Burkhardt (ed.) *ELFE at CERN, Conceptual Design Report* CERN/NuPECC, CERN 99-10.

Edited by Alison Wright

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

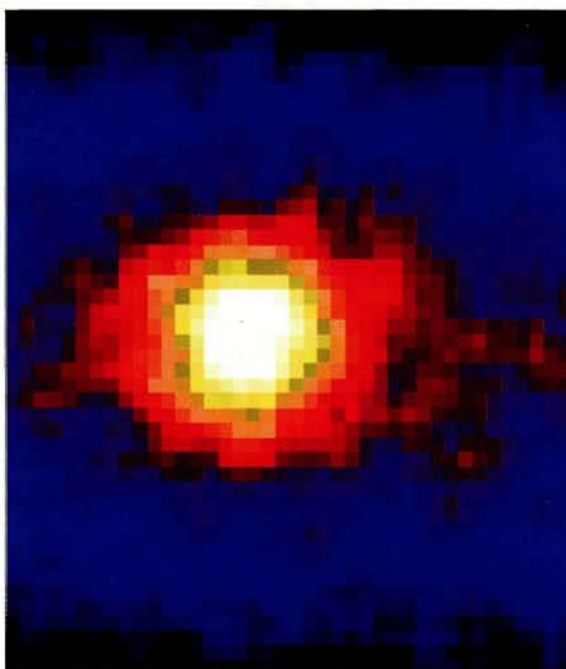
Space weather forecast is fine

Weather forecasting in space is a serious business: bad space weather, associated with solar flares or coronal mass ejections, can cause surges in terrestrial power grids, disrupt telecommunications and put the safety of both astronauts and spacecraft at risk.

Now US scientists have demonstrated an effective forecasting technique using helioseismic holography. They can predict Sun-related disruption more than a week in advance by spotting active regions on the far side of the Sun.

As sunspots absorb and scatter acoustic waves, while the solar interior is transparent to seismic waves, surface acoustic wave disturbances can be mapped back into the interior of the Sun to produce holographic images.

The researchers analysed



Another view of the Sun – the Super-Kamiokande 50 000 ton water Cerenkov detector, 1 km underground in Japan, took this “photograph” of the sun in “neutrino light”. The exposure time was 503.8 days and each pixel represents about 1 degree of the sky. (R Svoboda, Louisiana State.)

“Dopplergrams” (or sound travel time maps) made over two consecutive 24 h periods by the Solar Oscillations Investigation–Michelson Doppler Imager (SOI-MDI) flying onboard the Solar Heliospheric Observatory (SOHO). The maps revealed an active region on the far side of the Sun that was confirmed 10 days later by a surge in magnetic activity in that region, as the sunspot swung into view with the rotation of the Sun. AIP

Hydrocarbons ease fibre-optic links

Electro-optic (EO) modulators that convert electric pulses into optical signals are important components of fibre-optic communication links.

Both high speed and wide bandwidth are already possible, but the “holy grail” of these modulators is a device that would operate at drive voltages of less than 1 V, rather than the current operating voltages of around 5 V. However, because gain is inversely proportional and noise is directly proportional to the drive voltage, subvolt devices could significantly increase the efficiency of fibre-optic communication systems.

US researchers have experimented by adding bulky hydrocarbon chains to the organic molecules (“chromophores”) of the modulating material so as to minimize electrostatic interactions between the molecules. The electro-optic properties of the device were then enhanced such that a drive voltage of only 0.8 V was needed.

How can you make a million?

Many young physicists have moved into high finance to help with sophisticated market simulations. In an unusual example of experimental physics input into high finance, Japanese scientists have unveiled a \$5 electrical circuit that can mimic fluctuations in the yen-dollar exchange rate.

Electrical noise in the circuit is the seed

that generates voltage variations similar to yen-dollar fluctuations. The researchers hope to develop a cheap calculator for currency options (the right to buy currency in the future at a predetermined price, rather than at the existing exchange rate) to outperform the current system, which combines mathematical simulation and pricey computer power. AIP

Double-quantum vortex seen in helium-3

A group of physicists from Finland, France, the Netherlands and Russia have seen a double-quantum vortex in superfluid helium-3. The vortex is typical of the linear defects in quantum systems and analogous to quantized flux lines in superconductors and cosmic strings in relativistic quantum field theories.

For superfluids, Landau, Onsager and Feynman developed the picture of a quantized vortex line with a central core around which the phase of the order parameter winds by $2\pi n$. Usually vortices are singly quantized ($n = 1$),

but in superfluid helium-3, double-quantum vortex lines with $n = 2$ should appear.

The team set a tiny helium-3-filled cylinder spinning about its axis and used NMR in a 9 mT field to spot the lines. In fact, these can be made to appear one by one by increasing the rotation rate in constant steps, where this increment depends on the winding number n .

Their measured value for the incremental rotation rate increase of $6.2 \times 10^{-3} \text{ rads s}^{-1}$ implies $n = 2$ for the most commonly formed vortex line in superfluid helium-3.

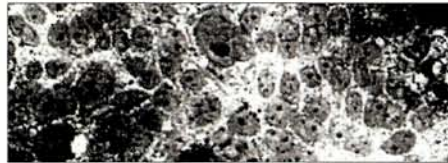
Smart scalpel cuts tissue damage

A "smart scalpel" that will allow surgeons to cut away malignant growth while minimizing damage to healthy tissue may soon be available. Developed by US scientists, the crucial component is a small microcavity laser.

"We can quickly identify a cell population that has abnormal protein content, as do tumour cells, by passing only a few hundred cells – a billionth of a litre – through our device", says Paul Gourley, leader of the research team at the Department of Energy's Sandia lab.

The biocavity laser is a sandwich of gallium aluminium arsenide between layers of gallium arsenide. Energizing the middle layer makes it emit photons, while the others act as mirrors reflecting photons back and forth and amplifying the output in the classical process of a laser – all on the scale of a few nanometres.

A micropump pushes blood cells from the



surgeon's incision through tiny channels on the cavity's surface and the cells are incorporated into the lasing process. Cancer cells contain more protein than normal cells, so their higher refractive index causes a change in the laser light's output frequency. The signal is relayed to

Top: blood cells pumped through this 18 mm diameter biological microcavity laser can be checked for cancer in real time, helping surgeons to cut away malignancies while minimizing the removal of healthy tissue.

Centre: light scattering in the epithelium, the layer of tissue lining organs like the colon or bladder where an estimated 85% of cancers begin, offers a more quantitative, less invasive method for detecting cancer early, say MIT scientists. Measuring the refractive index and spectral content of reflected white light via a fibre-optic probe indicates symptoms such as abnormal crowding of cells or enlargement of cell nuclei. Bottom: map of epithelial tissue from the colon, which shows normal (blue), precancerous (yellow) and cancerous tissue (red).

a nearby laptop, where it is translated into an easy-to-read graph for the surgeon to monitor.

In lab tests the device has distinguished normal human brain cells from malignant ones and can detect other blood abnormalities, such as sickle cell anaemia. AIP

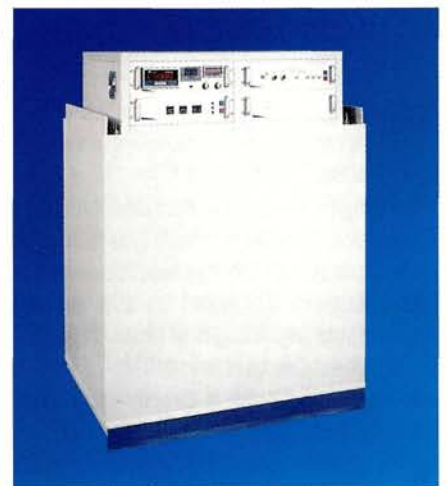
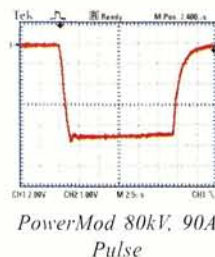
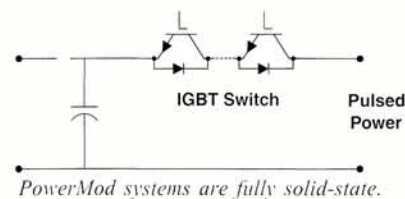
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Gravitational lensing: the light from distant objects is focused by a foreground cluster of galaxies. (NASA/ESA.)

Watch this space for cosmophysics

Space, the ultimate scientific frontier, is being opened up by a new generation of satellite-borne precision experiments, many of which use technology perfected in generations of particle physics studies. A workshop organized by CERN and the European Space Agency looked at the prospects for the experiments and for the underlying science.

Physics was born with ancient feet firmly on the ground, but late in the 19th century the term “astrophysics” crept into use to define the newer quest to understand extra-terrestrial mechanisms as well as terrestrial ones.

At the turn of the millennium a new dictionary term, “cosmophysics”, might have been coined to describe the quest to understand the universe at large as well as its individual components.

In the past 20 years, as the mechanisms of the Big Bang have become increasingly understood, particle physics and cosmology have become inextricably linked. At the same time, new developments in space technology have enabled new experiments, such as

AMS and GLAST, to be carried aloft, high above the stifling blanket of the Earth’s atmosphere. These provide new observations and measurements that have increased our understanding considerably.

As well as the physics involved, these studies call for a range of technological expertise to mount precision experiments under harsh conditions.

This development was underlined in a workshop entitled “Fundamental Physics in Space”, which was organized jointly by CERN and the European Space Agency (ESA), and held at CERN on 5–7 April. Although laboratory and space physics are developing along several parallel avenues, the meeting provided a valuable >

but rare opportunity for laboratory and space physicists to compare notes and discuss topics of common interest.

The workshop, which was initiated by the Board of the Joint Astrophysics Division of the European Physical Society and the European Astronomical Society, followed on from the May 1998 decision by both ESA and CERN to create working groups to study joint activities.

Opening the summary talks at the meeting, CERN director-general Luciano Maiani pointed to the growing overlap between particle and space physics. Recently, both subjects have underlined the important role played by the most invisible aspect of the universe – the vacuum.

ESA director-general Antonio Rodotà recalled the pioneer work carried out in the 1970s that pointed out the need for opening up the physics exploration of space, particularly for precision measurements and the deeper exploration of gravity, which now provide cornerstone missions for the new millennium.

Cosmology is flourishing

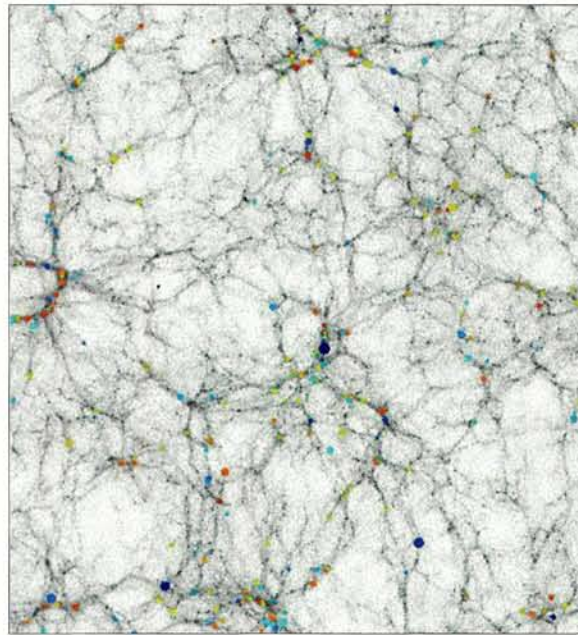
What Chandrasekhar once called “the graveyard of astronomy” is now a flourishing field, commented Lodewijk Woltjer of the St Michel Observatory and former ESO director-general, as he commenced his summary of the cosmology sessions. Indeed, to hear the wealth of science presented and the number of new instruments in the pipeline, it looks like its future is bright.

Type 1A supernovae have long been used as “standard candles” to measure distances in space. A measure of their apparent luminosity gives a measure of their distance. However, the method is prone to many errors and different teams can get very different results. Gustav Tammann of Basle explained how, with new corrections for decline rate and colour, the Hubble constant becomes 59 ± 7 , corresponding to the universe being 17 billion years old. “Photometry with the Hubble Space Telescope is working at the limits of what is possible, the main problem being the background,” he said.

Another cosmological parameter is ω , the ratio of matter in the universe to the critical level needed to halt the expansion of the universe. The inflation model of the Big Bang predicts that ω should be exactly equal to one – that the universe is “flat”.

Woltjer summarized current results that suggest that contributions of both radiating and dark matter to the density of the universe give an ω of around one-third. A non-zero cosmological constant or some new form of energy would be needed to make up the difference.

Sidney Bludman from DESY and Penn State showed how quintessence, or negative pressure, could solve this problem. A conse-



A simulation of bright galaxies (in colour) and dark matter distribution at a redshift of 1. (Durham University and Virgo Consortium.)

quence would be to increase the expansion of the universe with time – an accelerating universe. A non-zero cosmological constant has also been suggested by studies of distant supernovae (June 1999 p13).

This picture was confirmed by Jean-Loup Puget of Orsay in his round-up of observations of the cosmic microwave background radiation. Results from the Boomerang experiment announced earlier this year (March p12) give ω as one (± 0.3) and suggest a non-zero cosmological constant. Puget looked forward to results from ESA's Planck satellite, which is due to be launched in 2007.

“That the universe is expanding forever seems to have a certain philosophical appeal for some people,” said Woltjer. “However, I have never really understood this,

because our fate won't be very much different!”

Imaging dark matter

The most exciting cosmology news was that gravitational lensing has now really come of age. Cosmic shear raised a significant amount of interest. Peter Schneider of Bonn showed how gravitational weak lensing can reveal the invisible. His team has discovered a “dark clump” of 10^{15} solar masses (assuming a redshift of 0.8) with no optical counterpart, which he believes is the first-ever lensing-detected dark matter cluster.

Schneider was waiting for the results of infrared observations of the region. If confirmed, this technique will have enormous implications for cosmology. “The future is very encouraging,” he said. Indeed, he announced another area where gravitational weak lensing is showing results – measuring the effect of lensing across a large field can help to map the dark matter making up so-called galactic halos. Observations by the Sloan Digital Survey have shown no sign of halo truncation at distances of up to 150 kpc. In fact, says Schneider, galaxies probably don't really have halos of dark matter at all; what is seen is just a correlation between the galaxies' positions and the overall large-scale dark matter distribution.

This view is supported by Carlos Frenk of Durham. With the Virgo Consortium, he has carried out simulations of the evolution of matter and dark matter in the universe (October 1999 p13). His modelling shows dark matter evolving in enormous filaments with galaxies forming at high-density nodes.

Woltjer reminded participants that a lot of assumptions are made before carrying out such simulations, in particular regarding the relationship between gas, dust and stellar objects. “We are still a long way from constructing the universe from first principles,” he commented.

Frenk was optimistic about the future. “Enormous progress has

been made in instrumentation over recent years. If the 1980s belonged to the theorists, then the late 1990s most certainly belonged to the experimentalists," he said.

Future telescopes

The next-generation space telescope (NGST), still on the drawing board, should contribute. At redshifts of greater than 5, only 5% of stars have formed. However, "this is a very interesting fraction of stars," said Frenk. He believes that the NGST will detect primeval galaxies at redshifts of up to 10.

Peter Shaver of ESO reviewed the recent progress in detection techniques, in particular for observations of the first galaxies and quasars. The discovery of the Lyman alpha break in the spectrum of high-redshift objects has caused a revolution over the last five years or so, enabling more and more high-redshift galaxies to be recognized. "We are closing in on the reionization epoch," he said. In his opinion, the furthest galaxy discovered to date is at a redshift of 5.74. He believes that claims for galaxies at a redshift of 6.68 are yet to be proven.

With the NGST it will be interesting to look at the evolution of galaxies at high redshift, and also the quasar epoch around redshift 2. NGST will be launched in around 2010. Another useful tool for studying early galaxies, which is to be launched in 2007, is ESA's Far Infrared and Submillimetre Telescope (FIRST), explained Reinhard Genzel of Garching. These space observations will be paralleled by the ALMA ground-based infrared array.

Gravitation

Moving on to another type of radiation altogether, Martin Huber from ESTEC summarized the session on gravitational wave astronomy. Gravity waves are ideal probes of the universe because they interact very weakly and carry huge energies. Their existence has long been confirmed by measurements of the energy loss from binary star systems. However, they have never been detected directly.

Besides the classic resonance detectors, current ground-based detectors include the GEO 600 and TAMA interferometers. The next generation of ground-based detectors, Virgo and Ligo, will improve in accuracy by a factor of 10. "I am confident that we will detect gravity waves within the next decade," said Huber. "However, it will be very difficult to pinpoint the sources."

Most of the sources within the frequency range of the next detectors will be transient. Bernard Schutz of the Einstein Institute, Potsdam explained that the ideal sources are compact, such as black holes, and repeating, such as rotating binary systems. Ground detectors can only observe at frequencies above 1 Hz because the Earth's background noise cannot be screened. Events in this frequency range are rare or weak, such as supernova collapses and



In STEP for checking the equivalence principle – left to right, Thibault Damour of IHES, Bures-sur-Yvette; Mark M Lee of NASA; and Francis Everitt of Stanford.

compact binary spindown.

The future is the ESA cornerstone mission, LISA, which is to be built jointly with NASA. This interferometer in space will observe in the low-frequency window below 1 Hz, where emission occurs from many known strong sources, such as massive black holes and compact binary star systems.

An afternoon gravitation session served as a public presentation of the mission. Karsten Danzmann of Hannover gave a taster of the physics to come. "More than 90% of the universe is dark," he said. "If part of the

dark matter clumps, then gravitational wave detectors may be the only way to see it directly."

Another exciting area is the stochastic gravitational wave background. "Just as the cosmic microwave background radiation shows us the universe when it was 300 000 years old, a gravitational wave background would be a picture of the Big Bang itself – when the universe was perhaps just 10–24 s old," said Danzmann. The planned LISA launch date is in 2010. "It is a completely new field," said Huber. "We should expect the unexpected."

The other session on gravitation showed how space experiments could really test the physics of gravity. In particular, Pierre Touboul of ONERA and Nicholas Lockerbie of Glasgow talked about two new satellite experiments that are planned to test the equivalence principle, or the universality of free fall. The French team is working on *scope*, which is to be launched in around 2003. It hopes to test the equivalence principle to 1 part in 10^{15} – an improvement of three orders of magnitude on current experiments. The ESA/NASA STEP mission could be launched in around 2005 and will test to 1 part in 10^{18} . "String theory gives a natural explanation of why gravity is dynamic without assuming it," said Thibault Damour of IHES, Bures-sur-Yvette. "In theory, not only is space not rigid but there are also coupling constants that imply a violation of the equivalence principle."

Accelerators in the sky

There is apparently no end to the mysteries of the heavens – our lifelong acquaintance with puny, everyday mechanisms makes us ill-equipped to understand the mighty forces at work in the depths of the universe.

New telescopes peering into the depths of space from fresh vantage points reveal sources pumping out energy at unimaginable rates. Many of these, whatever they emit and however they are seen, are poorly understood and can be conveniently grouped under the heading "extreme sources". In his summary, P L Biermann of Bonn said: "the sky contains all this and a lot more".

Jewels in the intense source crown are the mysterious gamma-ray bursts – now an everyday occurrence. Attempts to explain



Left: opening plenary session at the CERN/ESA Workshop on Fundamental Physics in Space. Left to right: ESA director-general Antonio Rodotà, session chairman Roger Bonnet (ESA science director) and CERN director-general Luciano Maiani.



Far left: workshop co-chairmen Martin Huber of ESA (left) and Maurice Jacob of CERN.



Left: Michel Spiro of Saclay summarized the sessions on the potential use of high-energy physics instrumentation in space.

how so much energy can be released focus on extremely relativistic fireballs. Other fireballs – active galactic nuclei, black holes, etc – are also held to be responsible for X- and gamma-ray fireworks.

While electromagnetic radiation points back to its source, cosmic rays, tangled by intergalactic magnetic fields, do not reveal where they come from. The tip of the mystery cosmic-ray iceberg is now 24 cosmic-ray events that, in principle, should never be seen – their energy is beyond that “allowed” by interactions with the all-pervading cosmic microwave background. How can such extreme energies be produced and how can they elude the all-pervading background radiation?

Cosmic rays – once the point of entry for particle physics – are now a new point of departure. The universe has to contain “radio-galaxy hot spots” – cosmic accelerators larger than a typical galaxy, to whirl charged particles to such “astronomical” velocities.

Dark matter

That most of the universe is composed of invisible dark matter is perhaps the ultimate physics paradox. Attempts to uncover dark matter and to resolve this paradox are a major theme in astrophysics research, both theoretical and experimental.

At the CERN/ESA meeting, Alvaro de Rujula of CERN summarized the dark matter sessions, where direct searches for exotic particles, such as axions (“aaxions”, according to de Rujula), have yet to turn up positive evidence. More promising is the area of gravitational lensing. Objects can be invisible but still exert a gravitational pull,

which can disturb visible light in transit.

One specialist area is gravitational microlensing, which is looking for the effects of otherwise invisible objects as they cross the line of sight of a more distant luminous object. Interpreting this mass of results (May p13) is still difficult, but de Rujula suggested that, while dark matter massive astronomical compact halo objects (MACHOs) are out of favour, weakly interacting massive particles (WIMPS) are coming in.

The DAMA (sodium iodide) detector at Gran Sasso (June 1999 p17) has reported an annual signal variation that has been interpreted as possible evidence for galactic WIMP particles. Such a signal is not seen by the Cryogenic Dark Matter Search (CDMS) experiment at Stanford using silicon and germanium sensors.

This part of the programme also covered neutrino astronomy. As well as providing a new window on the universe, neutrino astrophysics has offered evidence for neutrino mixing, and therefore for non-zero neutrino mass. A new understanding of neutrinos would provide fresh light on the basic interactions of nature.

The limited seasonal and diurnal variation in solar neutrino signals provides important limits on neutrino-mixing mechanisms. The big Superkamiokande detector in Japan dominates the world data on extra-terrestrial neutrinos and has now intercepted 17 terrestrial neutrinos fired from the KEK laboratory, some 250 km distant – the first time that terrestrial neutrinos have been tracked over such a long path.

Extra-terrestrial neutrino physics “has a long past and a brilliant

future", ventured de Rujula.

In particle physics the continual demands to handle and analyse increased data rates and to attain greater precision provides a fertile ground for detector innovation. Michel Spiro of Saclay, chairman of CERN's LEP Experiments Committee, summarized the session covering the use and potential use in space experiments of instrumentation developed for high-energy physics.

Innovations in instrumentation

Detectors in space "see" X-ray and gamma radiation before it is absorbed by the atmosphere. Highly sensitive cryogenic X-ray detectors will be a useful new addition to the sensor armoury. The massive R&D programmes for the major experiments at CERN's future LHC collider have already yielded an impressive array of techniques - pixel detectors as "eyes" and scintillators for energy measurement - which could go on to provide useful opportunities. Time projection chambers are another means of providing remarkable images of physics beyond the atmosphere.

As well as the detectors, read-out mechanisms too are developing quickly. Sensors and chips can be dissociated and exploit complementary technologies. Photomultiplier technology has received considerable impetus from experiments studying neutrinos.

The LHC experiments are also blazing new trails in data acquisition and handling (p17) and in semiconductor technology (May p5).

Spiro highlighted several new flagship space-borne experiments exploiting particle physics know-how - the AMS detector for the Space Station and the GLAST telescope, which is due for launch in 2005, while the Supernova Accelerator Probe (SNAP) and Extreme Universe Space Observatory (EUSO) proposals could continue this tradition.

Gert Viertel of ETH Zurich summarized the current instrumentation of space. Here the requirement for very high timing accuracy has driven the development of precise atomic clocks. Pixel detectors already have a distinguished track record of astronomical measurements. Superconducting tunnel junctions (March p22) are poised to begin a new chapter of space research.

Away from the detectors, the highly successful GEANT simulation software developed for particle physics is finding increasing use in astrophysics and astronomy.

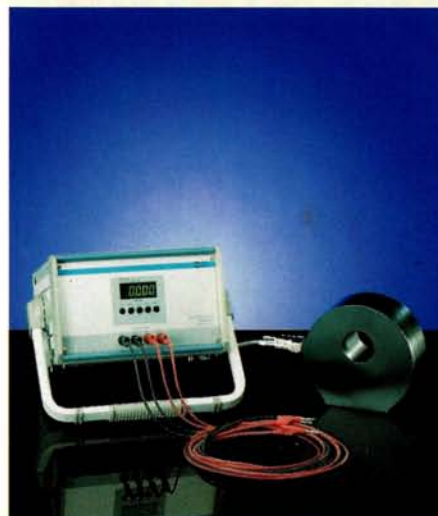
While particle physics is a fertile breeding ground for new detector technology, it is not the only variable in the equation. Space-borne experiments, requiring years of fruitful operation with minimal or no manual maintenance and intervention, have their special requirements.

This new contact between particle physicists and cosmophysicists is already paying dividends on the instrumentation front. CERN's "recognized experiment" status now covers a range of studies that do not use accelerator beams, but ensure that the laboratory remains a focal point of this physics. At the start of the millennium, the rapidly maturing field of cosmophysics is poised to make a major contribution to our knowledge and understanding of the universe.

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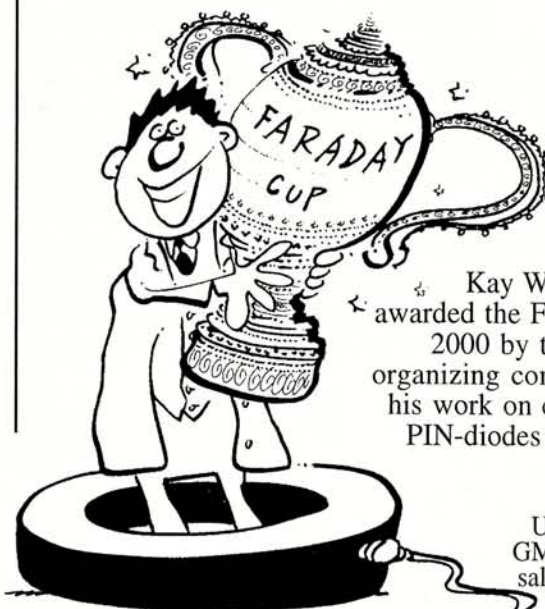


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The grid is set to grapple with large computations

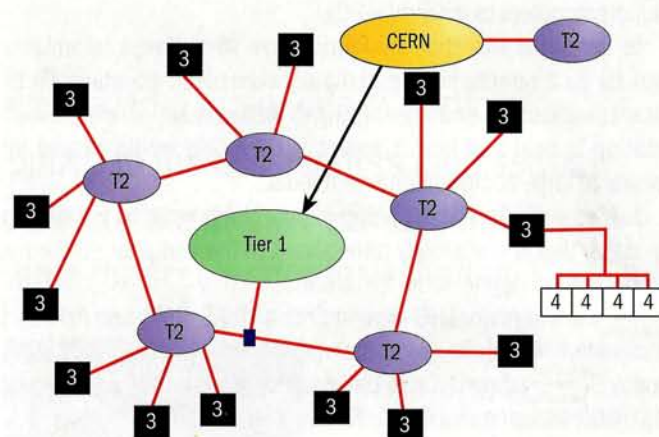
Particle physics has always pushed computing and computing techniques to the limit – witness the World Wide Web developed at CERN. Continuing this tradition, particle physics at CERN will soon provide a crucial testbed for even more powerful network-based information handling systems – the Grid.

When CERN's LHC collider begins operation in 2005, it will be the most powerful machine of its type in the world, providing research facilities for thousands of researchers from all over the globe.

The computing capacity required for analysing the data generated by these big LHC experiments will be several orders of magnitude greater than that used by current experiments at CERN, itself already substantial. Satisfying this vast data-processing appetite will require the integrated use of computing facilities installed at several research centres across Europe, the US and Asia.

During the last two years the Models of Networked Analysis at Regional Centres for LHC Experiments (MONARC) project, supported by a number of institutes participating in the LHC programme, has been developing and evaluating models for LHC computing. MONARC has also developed tools for simulating the behaviour of such models when implemented in a wide-area distributed computing environment.

This requirement arrived on the scene at the same time as a grow-



Grid reference – to prepare for the avalanche of data that will be produced by the experiments at CERN's LHC collider, an initiative to build a prototype computer grid infrastructure for the UK is well advanced. A Tier 1 centre will be based at the UK Rutherford Appleton Laboratory with two or more Tier 2 regional centres elsewhere in the UK. Tier 3 centres will be at university campus level, while Tier 4 would be inside research departments. Similar arrangements will be developed in other countries.

ing awareness that major new projects in science and technology need matching computer support and access to resources worldwide.

In the 1970s and 1980s the Internet grew up as a network of computer networks, each established to service specific communities and each with a heavy commitment to data processing.

In the late 1980s the World Wide Web was invented at CERN to enable particle physicists scattered all over the globe to access information and participate actively in their research

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projects directly from their home institutes. The amazing synergy of the Internet, the boom in personal computing and the growth of the Web grips the whole world in today's dot.com lifestyle.

Internet, Web, what next?

However, the Web is not the end of the line. New thinking for the millennium, summarized in a milestone book entitled *The Grid* by Ian Foster of Argonne and Carl Kesselman of the Information Sciences Institute of the University of Southern California, aims to develop new software ("middleware") to handle *computations* spanning widely distributed computational and information resources - from supercomputers to individual PCs.

In the same way that the World Wide Web makes information stored on a remote site immediately accessible anywhere on the planet without the end user having to worry unduly where the information is held and how it arrives, so the Grid would extend this power to large computational problems.

Just as a grid for electric power supply brings watts to the wallplug in a way that is completely transparent to the end user, so the new data Grid will do the same for information.

Each of the major LHC experiments - ATLAS, CMS and ALICE - is estimated to require computer power equivalent to 40 000 of today's PCs. Adding LHCb to the equation gives a total equivalent of 140 000 PCs, and this is only for day 1 of the LHC.

Within about a year this demand will have grown by 30%. The

demand for data storage is equally impressive, calling for some several thousand terabytes - more information than is contained in the combined telephone directories for the populations of millions of planets. With users across the globe, this represents a new challenge in distributed computing.

For the LHC, each experiment will have its own central computer and data storage facilities at CERN, but these have to be integrated with regional computing centres accessed by the researchers from their home institutes.

CERN serves as Grid testbed

As a milestone en route to this panorama, an interim solution is being developed, with a central facility at CERN complemented by five or six regional centres and several smaller ones, so that computing can ultimately be carried out on a cluster in the user's research department. To see whether this proposed model is on the right track, a testbed is to be implemented using realistic data.

Several nations have launched new Grid-oriented initiatives - in the US by NASA and the National Science Foundation, while in Europe particle physics provides a natural focus for work in, among others, the UK, France, Italy and Holland. Other areas of science, such as Earth observation and bioinformatics, are also on board.

In Europe, European Commission funding is being sought to underwrite this major new effort to propel computing into a new orbit. □

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Accelerators to span the globe

International collaboration has always played a major role in particle physics experiments. Could this also be applied to the accelerators themselves? Here, *Albrecht Wagner*, chairman of the directorate of the DESY Laboratory, Hamburg, looks at an innovative scheme for accelerator task sharing.

During the past 50 years, high-energy accelerators have not only become major research tools for nuclear and particle physics, but also influenced many other fields of science and industry by providing a powerful source of synchrotron radiation and other beams. New accelerator concepts have been the key to both an increased understanding of nature via fundamental research and the growing application of accelerators and accelerator techniques in other fields. It is therefore important to continue to develop new accelerators and to maintain accelerator expertise worldwide.

However, the size and cost of future large accelerators will most likely outstrip the resources of a single region, and building them will require a new approach. One way is via the framework of an international collaboration. A collaboration for a major accelerator facility must meet the following challenges:

- maintain and nurture the scientific culture of the participating laboratories;
- maintain the visibility and vitality of each partner.

Furthermore, all participating countries must be willing to invest and to commit themselves through long-term agreements. The proposed solution is a Global Accelerator Network (GAN).

Gaining through GAN

Scientists and engineers from laboratories and research centres around the world could form a network to integrate their scientific and technical knowledge, ideas and resources, and focus them on



International collaboration on high-energy machines in action: the first piece of hardware for CERN's new LHC collider from the US-LHC collaboration after its arrival at CERN. The US is a major LHC partner. The equipment – a heat-exchanger test unit for the LHC's superfluid helium cooling system – was built by the collaboration at Fermilab.

a common project – a merger of worldwide competence.

The GAN would allow participating institutes to continue important activities at home while being actively engaged in a common project elsewhere. All of the participants could demonstrate a visible level of activity, thus maintaining a vital community of scientists and engineers, and attracting students to the field of accelerator research and development. Last but not least, the network approach could facilitate the thorny problem of site selection for new large accelerator facilities.

The approach is based on the substantial experience gained in the construction and operation of large particle physics experiments at the LHC and LEP (CERN), HERA (DESY) and Fermilab's Tevatron. In these projects, multinational teams, motivated and united by a common research goal, share the responsibilities of a large experiment. In this way, many groups, mostly from universities, become technically and financially responsible for the design, construction, operation and understanding of parts of the detector, which may be small but are nevertheless vital to the success of the experiment. Much of the work would be done at the home institutes.

These experiments have continually grown, with those for CERN's LHC collider being comparable in manpower terms with major laboratories, and in complexity with large accelerators.

On the other hand, most accelerators so far have been built and are operated by only one laboratory. An important exception is the HERA electron-proton collider at DESY, where major accelerator ▷



The HERA electron-proton collider at DESY, showing the superconducting proton ring (top) and the electron ring (below). The major components were designed and built in other countries.



Albrecht Wagner – accelerator task sharing.

components were designed and built in laboratories in other countries. However, once installed, responsibility for their operation and maintenance was handed over to the host laboratory, DESY. The LHC at CERN has evolved along similar lines.

In the GAN framework, new accelerator facilities, as well as experiments and beamlines for synchrotron radiation, would be designed, built and operated by an international collaboration of “partner” laboratories and institutes.

The machine would be built at an existing laboratory – the “host” – to capitalize on available experience, manpower and infrastructure. The host state would have to underwrite a major part of the finance and to make a clear commitment to support the project throughout its duration. (In the case of CERN, the host states are not the principal sponsors of international facilities built on their territory – the organization as a whole is responsible.)

Each partner would take responsibility for certain components of the project, designed, built and tested at home before being delivered to the host site. This responsibility would be maintained even after delivery. Component maintenance, operation and development would be carried out as much as possible from the home institutes, using modern communications technology. For this the partners would need to maintain duplicates of accelerator components for testing, checking and development. In some institutions, “copies” of the accelerator control room could even provide for highly efficient round-the-clock operation. At the host site, a core team, under guidance from all partners, would provide the necessary on-site technical support.

Sharing the cost

With GAN, major capital investment and operation funding would be taken up inside the partner states. Operational costs (mainly electricity), excluding manpower, would be shared by all partners according to a predefined arrangement. Most manpower would remain in the partner institutions, except during periods of installation and overhaul, and during collaboration meetings.

Details of the collaboration and management structures, together with the exact sharing of responsibilities between partners and the host, have yet to be worked out, but examples can surely be found within existing arrangements.

Remote control and diagnostics, allowing off-site partners to participate on site actively, are the key GAN features. While this would be an innovation for accelerators, there already exists substantial experience worldwide in the remote operation of large technical installations.

In major particle physics experiments, subdetectors are frequently monitored and run remotely. A synchrotron radiation facility in Hiroshima, Japan, is operated under remote control from Tokyo. Large telescopes for astronomy are operated remotely – experiments on satellites and on distant planets are routinely operated from control centres on Earth. In industry, remote diagnostics and operation have become standard, even in nuclear power plants.

Many technical issues, including hardware- and software-related items, such as multiple control rooms, modular components and spare parts, standardization of systems and software, common data bases, common documentation, optimal communication and adequate protection against unauthorized access, are examined in an initial proposal (Willeke *et al.* 1999).

The financial implications of a GAN now need to be appraised, especially to understand the additional costs resulting from remote operation. Several human aspects are also involved. How can the desired “corporate identity” be attained? How much manpower is needed at the host site and at the partner institutes? What scientific sociology will emerge? Many of these issues resemble those that have already been encountered in large experiments, which will serve as useful role models.

Whatever the challenges, a GAN could provide the framework for the construction and operation of future large accelerators, which would otherwise be impossible to realize. As a first step, the International Committee for Future Accelerators (ICFA) has set up a task force to study the model and its implications.

Further reading

F Willeke *et al.* November 1999. *Proposal for an Inter-Laboratory Task Force on Remote Operation.*

Albrecht Wagner is chairman of the directorate of the DESY Laboratory, Hamburg.

Muons make the grade as microscopic probes

The technique of muon spin rotation has become a major tool for the investigation of structure of all kinds of condensed matter and has even developed its own research communities. A recent major conference highlighted progress to date.



Participants in the 8th International Conference on Muon Spin Rotation, Relaxation and Resonance enjoying the mountain air of Les Diablerets, Switzerland.

Some 40 years since it was first recognized that the positively charged muon could be used as a local microscopic probe of condensed matter, the application of muons in this field has grown from the exotic hobby of some particle physicists in the late 1950s and early 1960s into an established and mature technique.

Polarized positive muons, brought to a stop inside materials, precess in the local magnetic fields. This muon spin rotation (μ SR) method competes with and complements approaches like neutron scattering, Mössbauer spectroscopy, nuclear magnetic resonance (NMR) and electron paramagnetic resonance, to form the arsenal of modern experimental tools in condensed matter research.

With interest continually growing, the μ SR community has become the largest user group at the meson factories of PSI in Switzerland and TRIUMF in Canada, and it now shares equal status with the neutron scatterers at the ISIS facility of the UK's Rutherford Appleton Laboratory.

Continuing in the tradition that was established in 1978 in Switzerland, and followed up in Vancouver (1980), Shimoda (1983),

Uppsala (1986), Oxford (1990), Maui (1993) and Nikko (1996), the 8th International Conference on Muon Spin Rotation, Relaxation and Resonance (μ SR 1999) was held in its country of origin. Close to 180 physicists and physical chemists gathered in the beautiful alpine setting of Les Diablerets to discuss and learn of the latest applications of positive and negative muons in condensed matter research and physical chemistry.

Condensed matter contributions

More than 200 original contributions were presented (orally and in poster form). Each session was opened by one of eight invited plenary speakers from outside the μ SR community, thereby providing a link to the condensed matter community as a whole.

Superconductivity, and in particular high-temperature superconductors and their discovery, were a key feature of a talk given by Nobel laureate KA Müller (Zürich), who emphasized that, rather than pure luck, it was the result of well focused year-long research into material properties and their understanding that led to their

discovery.

Techniques such as NMR, closely related to μ SR, are now being employed to study high- T_c superconductors. These exciting studies were outlined by C P Slichter (Urbana-Champaign).

New results from μ SR studies of non-superconducting materials, such as the cuprate $\text{La}_{1-x}\text{Sr}_x\text{CuO}_4$, revealed a huge isotope effect. This oxygen isotope effect manifests itself by dramatically increasing, by up to 80%, the spin glass transition temperature (phase transition) when oxygen-16 is replaced by oxygen-18, thus pointing to a strong electron-phonon coupling in cuprates that in turn is also expected to govern the cooper-pairing mechanism in superconducting compounds.

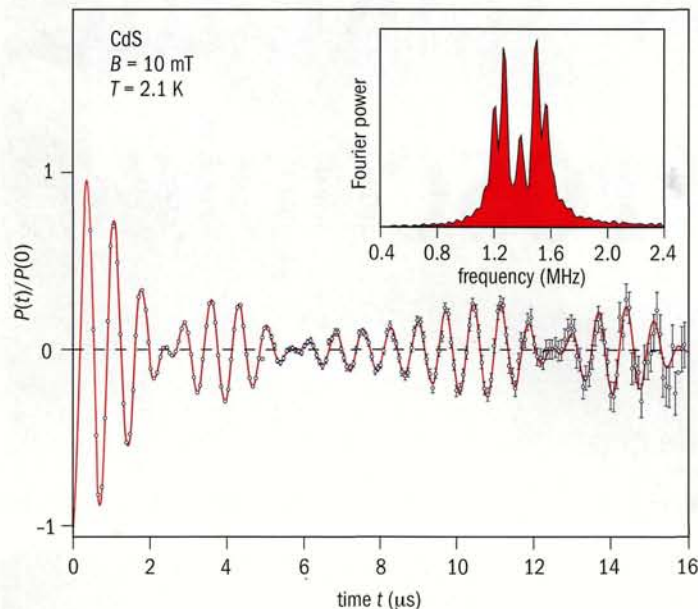
A second new result was the first unambiguous discovery of a spontaneous magnetic field signalling the onset of superconductivity in Sr_2RuO_4 . This result implies that time-reversal invariance is broken, as in the case of a ferromagnet, and that the Cooper pairs are in a different spin state compared with conventional or high- T_c superconductors.

Magnetic moments

Magnetism featured high on the list of popularity, with nearly half of the contributed papers focusing on the subject, undoubtedly reflecting the fact that the positive muon is itself a magnetic probe. X-rays and neutrons are also now used as complementary probes to muons in magnetism, as demonstrated in a talk by G H Lander (EC-JRS-ITE, Karlsruhe).

A new class of magnetic materials – molecular magnets – which are made up of either purely organic or inorganic molecules or a mixture of both, together with molecular clusters and magnetic nanoparticles, are currently under study with muons. Molecular clusters exhibit large spins and their magnetization relaxation may be governed by magnetic quantum tunnelling. A first observation of this, in CrNi_6 and CrMn_6 , was presented at the conference and was seen as a highlight in this field. New opportunities for μ SR in studying such systems were presented by D Gatteschi (Florence).

Another subject of intense study concerns lower-dimensional magnetic systems. Some materials, such as SrCu_2O_3 , have their magnetic moments aligned in parallel running chains, forming a



A classic example of a muon spin rotation precession signal, originating from muonium (a bound state of a positive muon and an electron) in the semiconductor CdS. The Fourier transform of the signal (insert) clearly shows five distinct frequencies, indicating an extremely shallow muonium state and providing first information on a hydrogen-like impurity in the compound. Such a measurement, taken over a period of eight muon lifetimes, was made possible by a new technique implemented at the Swiss PSI laboratory, using the MORE (Muons-On-Request) kicker. This device makes it possible for only single muons to reside in the sample at any one time, practically free from any accidental background. (Data from a group in Coimbra, Portugal.)

ladder-like structure, where the spins combine into non-magnetic spin singlets. By creating couplings between the so-called ladders, or doping these materials with non-magnetic species, one can drive these systems into a long-range magnetically ordered state, and this has indeed been verified. In one example it even appears as if the presence of the muon can break up the spin-singlet pairs.

Probing particles

The muon can also be thought of as a light proton isotope and it has been used as such to study the structural and dynamic features of materials, including the determination of the site of the implanted muon. Muonium, which is a hydrogen-like quasi-atom (μ^+e^-), has been used extensively as a probe in μ SR studies of the behaviour of hydrogen in semiconductors, hydrogen being a common impurity affecting the electronic properties (e.g. the

passivation of donors or acceptors) in these substances. A session devoted to muons in semiconductors was opened with a talk by B Bech-Nielsen (Aarhus) on vacancy-hydrogen defects in silicon.

As far as the role of muons as light proton isotopes in metal hosts is concerned, current investigations are part of the extensive and technologically relevant research on hydrogen-metal systems, as pointed out in a talk by P Vajda (Palaiseau) on hydrogen ordering and magnetic phenomena in metal-hydrogen systems.

Two new highlights in this area, both concerning the quantum nature of muon or muonium diffusion in matter, were reported. The first, which has been found independently by two groups, consisted of the first observation of a local muon tunnelling state seen in two different materials. The second showed that muonium can travel in the form of a Bloch wave, through propagation in a band-like state at very low temperatures (below 10 mK) – something that many had considered impossible.

New results on the formation of muonium in liquids and solids seem to suggest that the formation happens mainly after the thermalization of the implanted muon, followed by capture of a free electron created by ionization near the end of the muon track, also termed as delayed muonium formation. The liberated electrons were found to be located downstream of the stopped muon, indicating that the initial momentum direction is largely conserved during the

Magnetism featured high on the list of popularity, with nearly half of the contributed papers focusing on the subject, undoubtedly reflecting the fact that the positive muon is itself a magnetic probe

slowing-down phase.

The step from muonium formation to muonium chemistry is only a short one. Here the muon can, for example, be used as a polarized spin label in physical chemistry. Muonic radicals (muon-containing molecules, each with an unpaired electron) have also been used to investigate materials, and studies have been made of molecular dynamics and intermolecular electron transfer in systems of biological interest.

A session on instrumentation and techniques, devoted to new ways of using muons, showed that the development of low-energy muon sources in the 10 eV – 20 keV range, and in particular the successful implementation of such a source at PSI together with the first applications, opens up new possibilities for the study of thin films and multilayers.

The complementary use of spin-polarized beta-radioactive nuclei, as produced at ISOLDE (CERN) and soon to be produced at ISAC (TRIUMF), were described by R F Kiefl (Vancouver). Positron spin relaxation, inspired by μ SR, was presented by J Major (Stuttgart).

Future facilities

New developments also bring a push for new facilities. An evening session devoted to further developments and new facilities gave an overview as well as allowing discussion. In particular, plans for muon sources at the Japanese KEK-JAERI accelerator complex (most likely to be realized), the neutron spallation source at Oak Ridge and the second planned spallation target of the Rutherford Appleton Laboratory ISIS facility were presented.

Three devil's advocates – Yuri Kagan (Moscow), John Mydosch (Leiden) and Roderick Wasylshen (Halifax) – provided friendly and sometimes critical feedback throughout the sessions, culminating in their summaries at the end of the meeting.

In recognition of his important role in the development of μ SR at the venerable 184 inch cyclotron at the Lawrence Berkeley Laboratory in around 1970, Kenneth M Crowe was guest of honour. Many groups can trace their roots back to those exciting days in Berkeley.

The conference, under the patronage of the European Physical Society, was organized by A Schenck, conference chairman (ETH-Zürich); E Roduner, chairman of the programme committee (Stuttgart); G Solt, conference secretary (PSI); and a local organizing committee. It was supported by PSI, the Swiss National Fund, ETH-Zürich, the University of Zürich, the European Science Foundation through the FERLIN Programme and industrial and private sponsors.

μ SR 2002 will take place in Richmond, Virginia, with C Stronach (Virginia State) as conference chairman and Y J Uemura (Columbia) as programme committee chairman.

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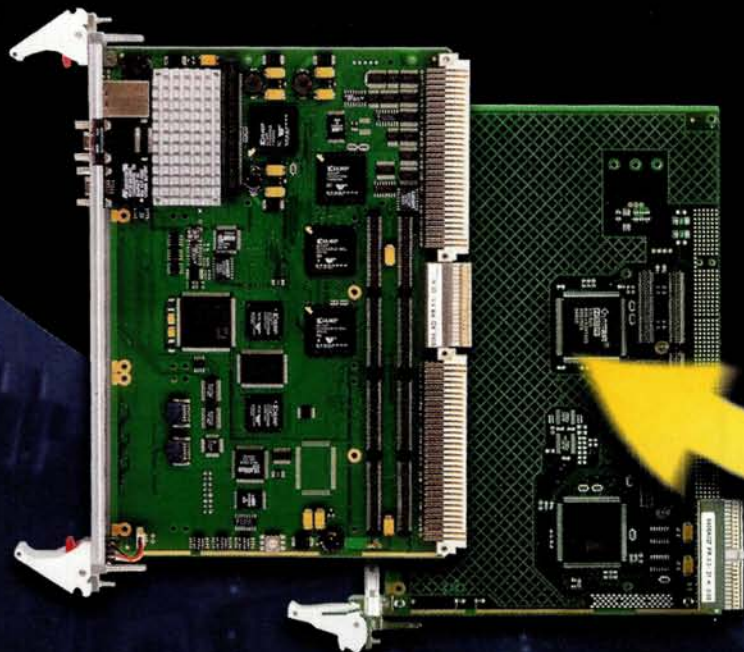
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Opening the door to the quark–gluon plasma

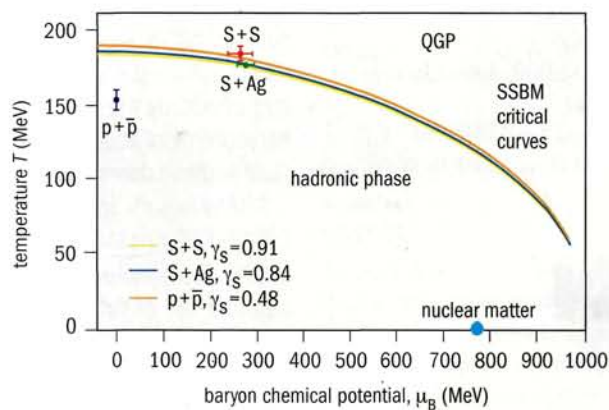
Recent experiments at CERN (April, p13) using high-energy beams of nuclei reported evidence for a quark–gluon plasma. Interpreting such evidence is not straightforward, and this article underlines the physics message.

A nucleus is like oranges stacked in a bag – with discernable “fruit” or nucleons (protons and neutrons) and spaces in between. Crush the bag and the oranges dissolve into juice, which fills the reduced space. A pip that once belonged to a particular orange is now free to move anywhere. In the same way, when a nucleus is crushed, it dissolves into a plasma of quarks and gluons. These, once imprisoned inside a particular nucleon, are free to move inside a much larger volume.

In ordinary nuclear matter a nucleus consists of nucleons with a vacuum between them. Each nucleon has a volume of about 2 fm^3 and contains three valence quarks together with a cloud of gluons – the carriers of the strong nuclear force that binds the quarks in the nucleon and the nucleons in the nucleus.

In physics a phase diagram shows the boundaries between different types of the same substance, such as steam, water and ice, depicting where boiling and freezing occur. Boiling and freezing are very dependent on external conditions, such as pressure and temperature. For nuclear matter the phase diagram shows the boundary between normal nuclear matter, composed of nucleons, and the quark–gluon plasma (QGP).

Normal nuclear matter is situated at temperature zero and a bary-



Phase diagram of nuclear matter, showing the boundary between (below) ordinary nuclear matter composed of nucleons and the quark–gluon plasma (QGP), formed when ordinary nuclear matter is compressed and/or heated. Experiments at CERN have suggested that this plasma can be recreated in the lab.



Looking for changes in nuclear matter – the time-projection chambers of the NA49 heavy ion experiment at CERN.

ochemical potential (a measure of the nucleon density) of about 765 MeV . The nucleon density is about 0.145 fm^{-3} and the energy density is about $0.135 \text{ GeV fm}^{-3}$.

Compressing nuclear matter, so that the nucleons start to interpenetrate and overlap (by at least 3%), makes the intervening vacuum disappear. Each nucleon dissolves and its constituent quarks and gluons are free to move inside a larger volume, which has become very dense by compression. A new state of matter is now formed – the deconfined QGP – with a critical nucleon density and an energy density of greater than 0.72 fm^{-3} and 0.7 GeV fm^{-3} respectively. Liberating quarks at zero temperature therefore requires matter and energy densities at least five times as large as those of normal nuclear matter.

How can this be achieved? The only known way is by compressing and heating nuclear matter, by slamming a very-high-energy beam of nuclei onto fixed-target nuclei, or by bringing two counter-rotating nuclear beams into collision. This was the objective of the heavy-ion fixed-target programme at CERN’s SPS and Brookhaven’s AGS accelerators, and it will also be the aim of the upcoming RHIC and LHC colliders at Brookhaven and CERN respectively.

Theoretical statistical models \triangleright

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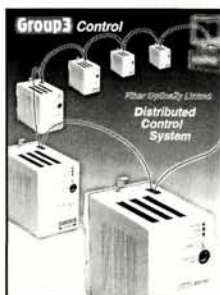


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have been used to analyse and evaluate the data from nucleus-nucleus interactions. Such models produce very satisfactory representation of the experimental data, verifying that the statistical model is applicable. However, little fundamental insight is gained into the actual dynamics of the collision.

The important objective is to ascertain where on the phase diagram the original thermal source (fireball) is situated - in the domain corresponding to a gas of nucleons or in that of the QGP. For this a simple statistical analysis is inadequate. Only if interactions among the multitude of emitted particles are taken into consideration can the description of a possible change of phase into the QGP be envisaged.

Statistical approach

The Statistical Bootstrap Model (SBM), introduced by Rolf Hagedorn at CERN some 35 years ago, is a statistical approach, incorporating at the same time the effects of interactions in a self-consistent way. Recent development and extension of this model, the so-called S (for strangeness) SBM, can define the phase diagram and the limits of nuclear matter, as shown in the diagram (Kapoyannis, Ktorides and Panagiotou, in press). This boundary incorporates the largest possible and physically meaningful value of the critical temperature at zero baryochemical potential ($T_0 = 183$ MeV) so as to have the largest possible nucleon domain and avoid over-optimistic interpretations.

SSBM-based analysis of data from the NA35 experiment at CERN's SPS has shown compelling evidence that head-on collisions of even light-nuclei, such as sulphur-32, at 200 GeV/nucleon have attained the critical conditions, thereby allowing us to probe the deconfined quark state.

The overall situation resulting from the data analysis is depicted in the diagram. It is found that the sulphur-sulphur interaction is situated 76% inside the QGP domain, beyond the nucleon phase, while the proton-antiproton collision, measured in the UA5 experiment at CERN, is well within the nucleon region, as expected.

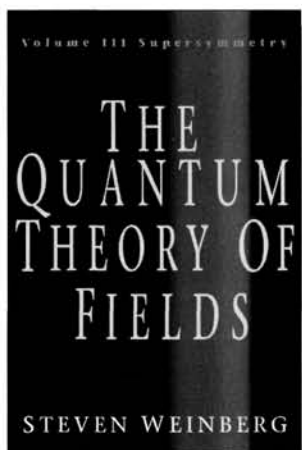
A second indication that the QGP phase has been reached in the sulphur-sulphur collisions is the substantial excess of pion (entropy) production, the explanation for which calls for a contribution of at least 30% from a high-entropy phase, such as that of the QGP.

A third important sign is the achievement of thermal and chemical equilibrium conditions (equilibrium between the different quark species produced) in the initial stage of the nuclear interaction, materializing at a temperature of at least 177 MeV, a baryochemical potential of more than 252 MeV and a strangeness saturation (specifying the relative strange-quark production in chemical equilibrium) of close to unity. Thermal and chemical equilibrium conditions are expected and required for the transition to QGP. Finally, the energy density created in these interactions is at least 2 GeV fm^{-3} - well above the critical value for deconfinement of about 1 GeV fm^{-3} .

These observations, together with several other intriguing clues (*CERN Courier* November 1999 p8), give rather definitive indications that the door to the quark-gluon plasma has been opened by the SPS heavy-ion programme at CERN.

Further reading

A S Kapoyannis, C N Ktorides and A D Panagiotou, in press *European Physical Journal C* (hep-ph/9911306).



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nd the deep blue sea



Virtual reality image of what the 0.1 km² ANTARES observatory will look like in 2003.

The NESTOR project



Artists's impression of the Delta Berenike ballasted floating platform being made for the NESTOR underwater detector. The 60 m triangular platform (hence Delta) is shown with an array of photodetectors. Berenike was the wife of Ptolemy III and Coma Berenikes is a galaxy in the Bootes constellation.

The Greek National NESTOR Institute for Deep Sea Research, Technology and Neutrino Astroparticle Physics has been operating for several years and has its headquarters at Pylos in Navarino Bay, 300 km south of Athens. Nearby is the Hellenic trench, the deepest point in the Mediterranean. At these depths the goal is to deploy 4 km high towers of optical modules. "Floors" of these towers of 34 m in diameter have already been tested (*CERN Courier* October 1997 p17). To support these towers and provide a staging post for the experiment, NESTOR is developing the Delta Berenike ballasted floating platform.

the AMANDA and RICE projects in the Antarctic ice (*CERN Courier* January 1996 p7), the RAND Antarctic scheme, the Lake Baikal detector in Siberia (*CERN Courier* September 1996 p25) and the Greek-led NESTOR project (see box). The Italian NEMO project is evaluating deep-sea sites and carrying out environmental studies off the coasts of Italy and Sicily.

Since 1996 the physicists and engineers of the ANTARES project have assessed the feasibility of a deep-sea telescope. Three years of intense R&D went into understanding the deep-sea environment and solving the technical challenge of deploying a complex and large piece of equipment in the Mediterranean Sea. The collaboration has now begun the construction of a 300 m² detector off the French Mediterranean shore.

ANTARES is now a CERN "Recognized experiment". The collaboration consists of 16 particle physics institutes, 2 marine science institutes and an astronomy institute from France, Italy, the Netherlands, Russia, Spain and the UK.

Neutrinos as cosmic messengers

Until now, apart from a handful of events induced by a nearby supernova in 1987, no neutrino of cosmic origin has been identified. High-energy source candidates like cores or jets of active galactic nuclei, or the extremely violent cosmic events that are thought to be responsible for frequent gamma-ray bursts, are increasingly being observed and becoming better understood, but their activity at high energy remains mysterious: do they produce high-energy cosmic rays or are they simply gamma-ray emitters?

If high-energy protons are accelerated in these sources, they must also emit neutrinos. On the other hand, if these high-energy cosmic accelerators cannot fulfil the role of producing the observed cosmic-ray spectrum, then very-high-energy cosmic rays (and neutrinos) must be created by non-accelerating mechanisms like the decay of Big Bang massive relic particles.

Furthermore, neutrinos could reveal the presence of dark matter in the form of neutralinos, the lightest of the yet undiscovered particles predicted by supersymmetry theories. These would have been formed in the early universe and would accumulate in the cores of stars, galaxies and planets, from where they would "shine" as neutrinos.

Last but not least, as recent history has shown, astrophysics experiments permit the exploration of domains beyond the reach of accelerator experiments: studying the fluxes of atmospheric neutrinos, the Super-Kamiokande and MACRO experiments have been able to test very small values of the mass difference between two types of neutrinos. The observation of the same phenomenon is also possible with large neutrino telescopes using the Earth's diameter as a baseline and at higher energy, thus with very different systematics. It would thus be possible to confirm or rule out the recent evidence for neutrino masses and to measure neutrino oscillation parameters. ▽



A prototype ANTARES detector line safely back on board after underwater tests.

Neutrinos can only be detectable through their interaction with matter. As they interact very weakly, massive targets are necessary. High-energy muons produced via such interactions are electrically charged and very penetrating, with a trajectory that is almost aligned with that of the parent neutrino.

When they traverse a transparent medium such as seawater, these relativistic particles produce a wake of Cerenkov light. The time development of this luminous wake allows physicists to reconstruct the direction of the muon, and thus that of the neutrino, with a precision better than a fraction of a degree, and thus pointing back to the celestial object that emitted the neutrino.

High-energy cosmic rays that bombard the upper atmosphere generate a flux of high-energy muons, which constitute a significant background to other terrestrial measurements, even under several thousand metres of water. Only neutrinos are capable of traversing the Earth, and a chance interaction immediately afterwards produces an upgoing muon beneath the detector. The atmospheric muon background is removed by selecting only these upgoing tracks. Thus the Earth itself is used as a neutrino target as well as providing a shield to filter background muons. The detectors will therefore be looking towards the bottom of the sea.

A cosmic neutrino telescope will consist of a three-dimensional array of light sensors (photomultipliers) covering an effective vol-

ume of the order of a cubic kilometre at a depth of a few thousand metres. In a first stage, a smaller telescope will give the first indications of cosmic neutrino sources and fluxes and will be used to validate the methods of this new type of astronomy.

An initial requirement is to explore the unusual environment and study the design and deployment of a large deep-sea detector. A three-year step-by-step R&D programme was initiated in 1996 to measure the deep seawater properties and find a suitable site.

Another goal was to bring together and master the marine technologies required to deploy, connect and operate large and complex pieces of offshore apparatus in a deep-sea environment. In parallel, studies were carried out to optimize detector performance.

Autonomous instrumented mooring lines were used to study the properties of the seawater – transparency and light scattering, optical background due to natural radioactivity and living organisms, and the bio-fouling of optical surfaces. The results were very encouraging – light can travel over more than 50 m without noticeable alteration. In particular, the small amount of large-angle scattering promises good angular accuracy.

Deep-sea tests

To study mechanical solutions and to test deployment and recovery procedures, an actual size detector line has been built and was immersed and recovered several times during 1998. This line was 350 m high and consisted of 32 optical modules (glass spheres designed to protect the photomultipliers against water pressure). It was also instrumented with acoustic and electronic sensors to measure position to within 10 cm.

In a second stage the line was equipped with eight photomultipliers and deployed at a depth of 1100 m off Marseille in November 1999. It was linked to the shore by a 37 km submarine electro-optical cable. Atmospheric muon data analysis is under way. About one muon every 10 s is recorded and reconstructed. Position monitor analysis indicates an accuracy of a few centimetres on the reconstructed position of individual photomultipliers.

The future telescope will need to connect individual lines to a central node *in situ*. Deep-sea connection tests have therefore been carried out using the *Nautile*, a deep-sea submarine belonging to IFREMER. Connections were successfully made and electrically validated at a depth of 2400 m in December 1998.

With site quality and technical feasibility established, the project is entering a new phase. In three years a detector will be installed consisting of 1000 photodetectors on 13 lines, 400 m high and distributed over a 150 m radius surface. It will be deployed at a depth of 2400 m off Toulon and should provide an effective surface after reconstruction of 0.1 km² for 10 TeV muons, 0.2° angular resolution for muons above 10 TeV, and enable reconstruction of the direction and the energy of neutrino-induced muons over a wide range.

This detector will open a new era of cosmic neutrino astronomy and will also provide practical experience and expertise which will be invaluable for the realization of a future large-scale detector capable of conducting a search for astronomical sources.

Further information is available at "<http://antares.in2p3.fr/>".

François Montanet, CPPM Marseille.

Raising the curtain on antimatter

At first sight, physics and theatre are difficult to mix, but this is no reason not to try. Together, the genius of Dirac, the dilemma of antimatter, an unusual setting and some physical and mental gymnastics make good entertainment.



For that antimatter – Renilde Vanden Broeck (left; CERN press office) with Markus Schmid and Anne Gaud McKee (Miméscope).

This winter *The Delphic Oracle*, by Geneva's Miméscope company in collaboration with CERN, ran for an extended season in the pit that houses the Delphi experiment at CERN's LEP electron-positron collider. Using a matter-antimatter collider as the scene, the play focused on Paul Dirac's mathematical discovery of antimatter symmetry.

Writing the script was a challenge – presenting the ideas of antimatter as entertainment, not as a scientific seminar. Renilde Vanden Broeck of CERN's press office, following a diploma course in Science Communication at the University of London, chose to present the idea behind and the build-up to *The Delphic Oracle* for her course dissertation.

In the following extract, Renilde describes some obstacles encountered on the way to presenting antimatter on stage.

Just two weeks before opening night, Anne Gaud McKee of the Miméscope company and I are walking to CERN's reception area. We are both very excited about the forthcoming play's freshly printed posters and leaflets. She is picking them up to have them distributed all over Geneva. I tell her about the first interviews she will have to do

tonight and that the press is really picking up. She is very excited and suddenly exclaims: "You haven't heard the last yet: we changed the whole script!"

I think am going to faint! "I can't believe it – just two weeks before the first night!" I shout.

Anne explains they had a crisis a couple of days ago. They had mainly been working on four set pieces and hadn't really practised the actual lines that Markus Schmid (who plays Dirac) has to say.

"What was wrong with it?" I demand.

Anne explains that Markus and the others found her script too difficult and dry. So much abstract thinking out loud. What they disliked most of all was that it had become too focused on the science and less on the show. The script wouldn't work with the acrobatics and dance the audience was to see, and that would kill their imagination. These dream scenes are so poetic...and then to revert suddenly to those dry sterile lines. "It would annihilate the whole atmosphere!" Anne objects, and we laugh at the word "annihilate" – after so long, physics terminology is seeping into our everyday speech.

Anne explains that Markus refused to say lines he couldn't feel. "I instinctively sense that he was right, that there was something awfully wrong with my scenario," she continues, "and then suddenly it hit me – after all our discussions they hadn't understood a ▷

key item of the play, the famous Scientific Process! And there was so little time left!"

"It all started when we were rehearsing the cosmos scene," Anne explains. "That scene is all about the infinitely big. Dirac goes to the cosmos to look for antimatter because that is the natural result of his prediction. As much antimatter as matter should have been created by the Big Bang. Thus there should have been antigalaxies, antistars, etc."

Antimatter or no antimatter?

But Dirac comes back from his dream empty-handed with no antimatter. So the cast concluded that antimatter doesn't exist. I told them that this is simply not true. Scientists don't know this yet for sure and are still searching with sophisticated detectors.

"If antimatter is not up there, that doesn't necessarily mean that it is down here instead," I insist. "Maybe there's another reason why nature preferred matter to antimatter. Perhaps Dirac thinks that there is a slight, almost undetectable, difference between the two. Maybe if he could study antimatter closely he could find this asymmetry."

Later, putting these ideas to the cast, Markus objects immediately. "We can't tell all that!" he shouts, "They'll be totally confused!"

"We have to," I insist, "because we can't say that there is no antimatter in space – we don't know that yet, so Dirac thinks that there could be another explanation."

Cast members Claire de Buren and Yasmina Krim agree, but point out "But then the 'particle collision scene' has nothing to do with his initial hypothesis."

"Exactly," I reply. "That scene is there because he questions his first theory and follows another line – abandoning the idea of antimatter in space to instead explain the dominance of matter over antimatter. He thinks, if only I could have a close look at antimatter colliding with matter...that's where the particle collision dream scene comes in.

That is how science works! You follow one road and when you find that it leads nowhere, you go back to the crossroads and choose another route. That's what scientific research is all about," I explain, feeling that they were beginning to see how science really operates.

Anne agrees. "It would be good if we could make people understand that science is not a smooth road to a fixed objective, but full of twists and turns, doubts and questions."

The cast just hadn't seen that science could be so vulnerable and fragile. It was such a relief that they finally understood.

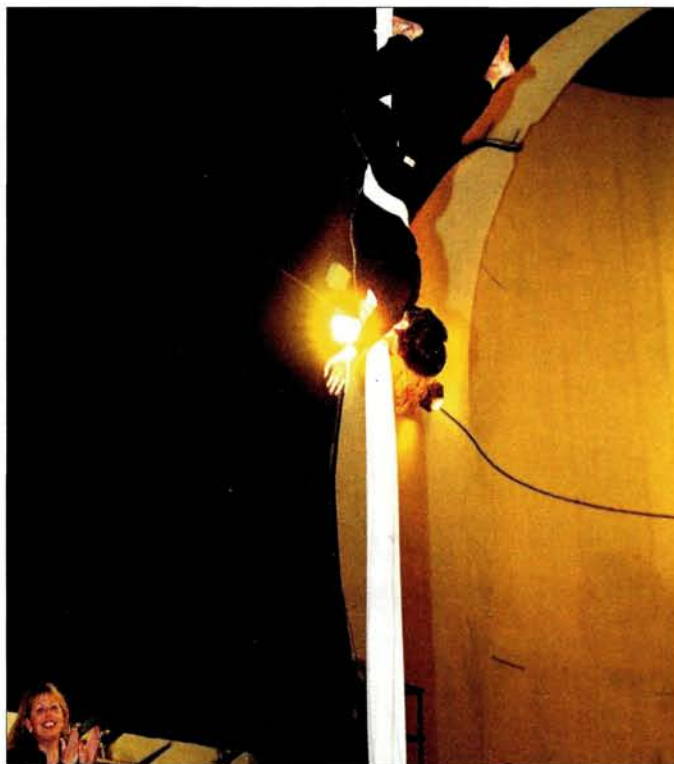
"Better late than never," Anne laughs.

Diary

When the penny drops, they bombard me with questions. Now they understand why CERN has such big machines. I tell them about CERN's new antiproton decelerator and its quest to look for any subtle differences between matter and antimatter.

"We can never explain this in one hour! What are we going to do now?" says a horrified Anne, realizing she still didn't have the right formula to communicate the difficult antimatter message. The next day she starts over, calling in Claire and saying: "Tell me as soon as you don't understand anything."

"It's all so abstract," Claire objects immediately. "You should tie the ideas down to everyday things – Dirac's gestures, for instance. Integrate his thoughts into the normal things that people do."



Rope trick: Yasmina Krim (*Miméscope*) polishes her antimatter act under (or rather above) the eye of Renilde Vanden Broeck.

This leads Anne to hit on a new formula for the script. Suppose Dirac writes letters expressing his feelings? She remembers learning about one important event in Dirac's life, when his research supervisor at Cambridge, R H Fowler, received the draft of a key paper from quantum mechanics pioneer Werner Heisenberg. Fowler passed the paper to Dirac, who later said this was what got him started in quantum mechanics. Suppose there had been a mistake or misunderstanding in Heisenberg's paper which Dirac spotted? Pure fiction, but that was the hook for the final script.

So Anne begins to write for Dirac: "My dear and respected colleague and friend, this night I stayed up until four o'clock in the morning, and could it be because of the exhaustion, that I have finally managed to solve the equation that you sent me two weeks ago."

The fictitious letters make the difficult Dirac come alive on stage. While he goes about his everyday life, his mind struggles with strange equations and is bewildered by their implications. Reluctant to go against the scientific tide, he says: "No physicist has ever seen a positive electron...I hope you will not take me for a madman."

From such bold predictions came antimatter.

Renilde Vanden Broeck, CERN.

The *Miméscope* company

Cast: Claire de Buren, Anne Gaud McKee, Yasmina Krim, Markus Schmid

Scenario: Anne Gaud McKee

Choreography: Markus Schmid

Music: Christian Denisart

MIT–Bates celebrates 25 years

In 1967, helped by Massachusetts congressman William H Bates, who was then on the US Joint Committee on Atomic Energy, MIT acquired a site for a new electron accelerator, which is still going strong. A recent symposium, held at MIT, marked 25 years of physics operation.

Some accelerators come and go; others come to stay. One of the stalwarts is the MIT–Bates electron linear accelerator. A symposium at MIT last November marked the 25th anniversary of the first publishable data on high-resolution electron scattering and photonuclear reactions at this remarkable machine.

Representatives from the Bates community and from universities and sister laboratories where electronuclear research is being undertaken took part. Speakers summarized where the field stands now, how it got there and where it might lead.

Talks from experimentalists covered the current state-of-the-art research at Bates and other laboratories, while theorists focused on some of the issues that arise in electroweak studies of nuclear and hadronic structure. The symposium aimed to underline the relationships between nuclear structure and electrons, the structure of few-body nuclei, few-body nuclei/nucleon structure, hadronic structure and parity-violating electron scattering.

From the excitement conveyed in the talks, it is clear that each of these areas is receiving a lot of attention at all of the active laboratories and that the near future will continue to reflect intense activity. A notable feature at Bates has been the central position of the users, many of whom were present at the symposium, and in particular the enthusiasm and talent of generations of graduate students.

The decisive roles played by technological developments in the evolution of this field, and in particular at Bates, were highlighted.

In the earliest days, the development of dispersion-matching and energy-loss spectroscopy produced spectroscopic data with



The Out of Plane Spectrometer (OOPS) – a major new addition at MIT–Bates.

resolutions of better than 10^{-4} using the entire accelerator beam, the spectrum of which was spread over 10^{-2} . In this era a group from the University of Massachusetts designed and built a magnetic chicane that extended the angular range to 180° , giving better access to magnetic transitions in complex nuclei.

Shortly after the pioneering experiments at SLAC in 1978 on parity violation in deep inelastic scattering, a Yale group proposed a similar experiment at Bates for which they designed and built a polarized electron injector. This ultimately produced a polarized electron beam of $60 \mu\text{A}$ and measured a parity-violating asymmetry in elastic scattering from carbon-12 of less than 1 ppm.

The success of spin physics

A succession of experiments using polarized electrons have followed, so that today most of the experimental programme uses spin-oriented electrons. Of note in the past few years have been the very successful data-taking runs on parity-violating electron scattering from hydrogen and deuterium (SAMPLE; *CERN Courier* April 2000 p6), the goal of which has been to determine the magnetic strangeness content of the nucleon.

Spin physics in general has been a growing theme at Bates. Quasielastic scattering from polarized helium-3 has been carried out on targets based on spin exchange with optically pumped rubidium (Harvard and Michigan) and/or optically pumped helium-3 with metastability exchange (Caltech).

Spin transfer and induced polarization have been studied in ▷



Participants at a symposium to mark a quarter of a century of productive physics at the MIT-Bates electron linear accelerator.

hydrogen and deuterium using either a proton polarimeter (Virginia, William & Mary, MIT) or a neutron polarimeter (Kent State). Tensor recoil polarization in elastic scattering off deuterons used polarimeters designed and built at Argonne, Alberta and Saclay.

These developments have been complemented by a challenging target development programme. Notable cryogenic targets were about 50l of tritium for elastic and quasielastic scattering (MIT and Saskatchewan), 50 bar of helium-3 at 24 K (Massachusetts) and a 40 cm liquid-hydrogen target dissipating 500 W of beam power (Caltech). Many of these projects have had implications that are

continuing not only at Bates and other medium-energy labs but also at SLAC, DESY (HERMES) and the Jefferson Laboratory.

Bates and the Out of Plane Spectrometer (OOPS) collaboration (Illinois, MIT, Arizona and Athens) have recently completed the construction of an array of four proton spectrometers that can be moved with great precision out of plane, which, when combined with polarized electrons, will provide access to electronuclear response functions that are otherwise difficult or impossible to obtain.

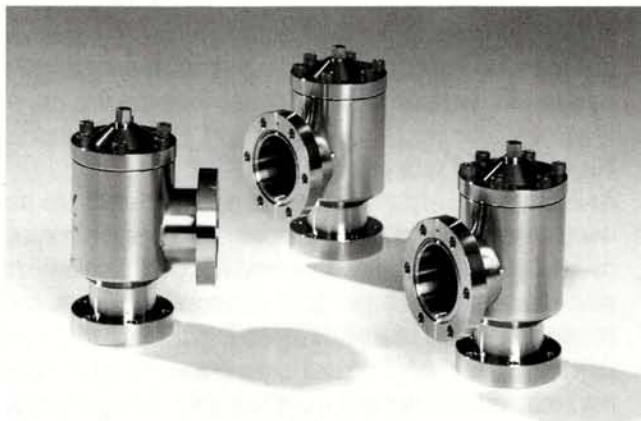
Commissioning and data-taking starts this spring and a time-stretcher ring will be used for part of this run to deliver high-duty factor extracted beams. In addition, looking to the near future and new initiatives, the lab is actively constructing a large acceptance detector (BLAST) to be used with polarized internal targets in the electron storage ring. Commissioning is expected in 2001 and the community is anticipating an exciting programme of nuclear/hadronic structure studies with electrons at Bates.

These and other technical developments provide a powerful handle on the electronuclear S matrix. Experimental work has just begun on a selection of the more promising observables, and some important new results were presented at the symposium, with many more expected in the near future.

The symposium proceedings will soon be published by the American Institute of Physics.

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Breakthroughs for radioactive beams

New ideas for radioactive beam experiments, ranging from nuclear physics to low-temperature physics and supernovae, were on the agenda at a CERN workshop in March. *Juha Äystö reports.*

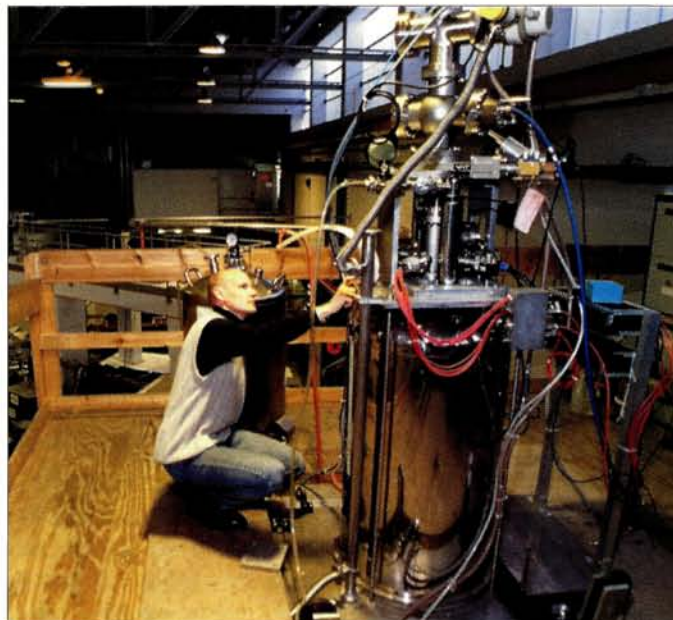
Scientific achievements at CERN's ISOLDE radioactive beam facility, following its move to the laboratory's PS booster in 1992, were the subject of a weekend meeting at CERN in March. About 100 physicists from around the world discussed the range of ISOLDE research, from exotic nuclei far from stability to nuclear astrophysics, and from fundamental symmetries to solid-state physics and biomedical applications.

The opening presentations covered the technology of radioactive beam production. Orsay's Michel de Saint-Simon and Helge Ravn of CERN each reviewed a high-resolution isotope separator designed to provide good isobar separation and consequently contaminant-free beams of proton-rich or neutron-

rich isotopes for experiments starting this year. Jyväskylä's Arto Nieminen then explained how the cooling and bunching of low-energy radioactive ion beams has been achieved using gas-filled radiofrequency quadrupoles, both at ISOLDE and at his home university. This offers a new way of improving beam quality for future experiments.

REX-ISOLDE

One of the most exciting new developments for the near future is REX-ISOLDE, a post-accelerator for the ISOLDE facility that will accelerate radioactive ions up to 2.2 MeV/nucleon. Dieter Habs of Munich, spokesperson of the first experiment at REX-ISOLDE, presented the physics outlook. REX-ISOLDE's most novel and challeng-



The ISOLTRAP mass-measuring device recently, via the measurement of the mass of argon-33, demonstrated its ability to measure masses of very short-lived nuclei to a relative precision of 10^{-7} .

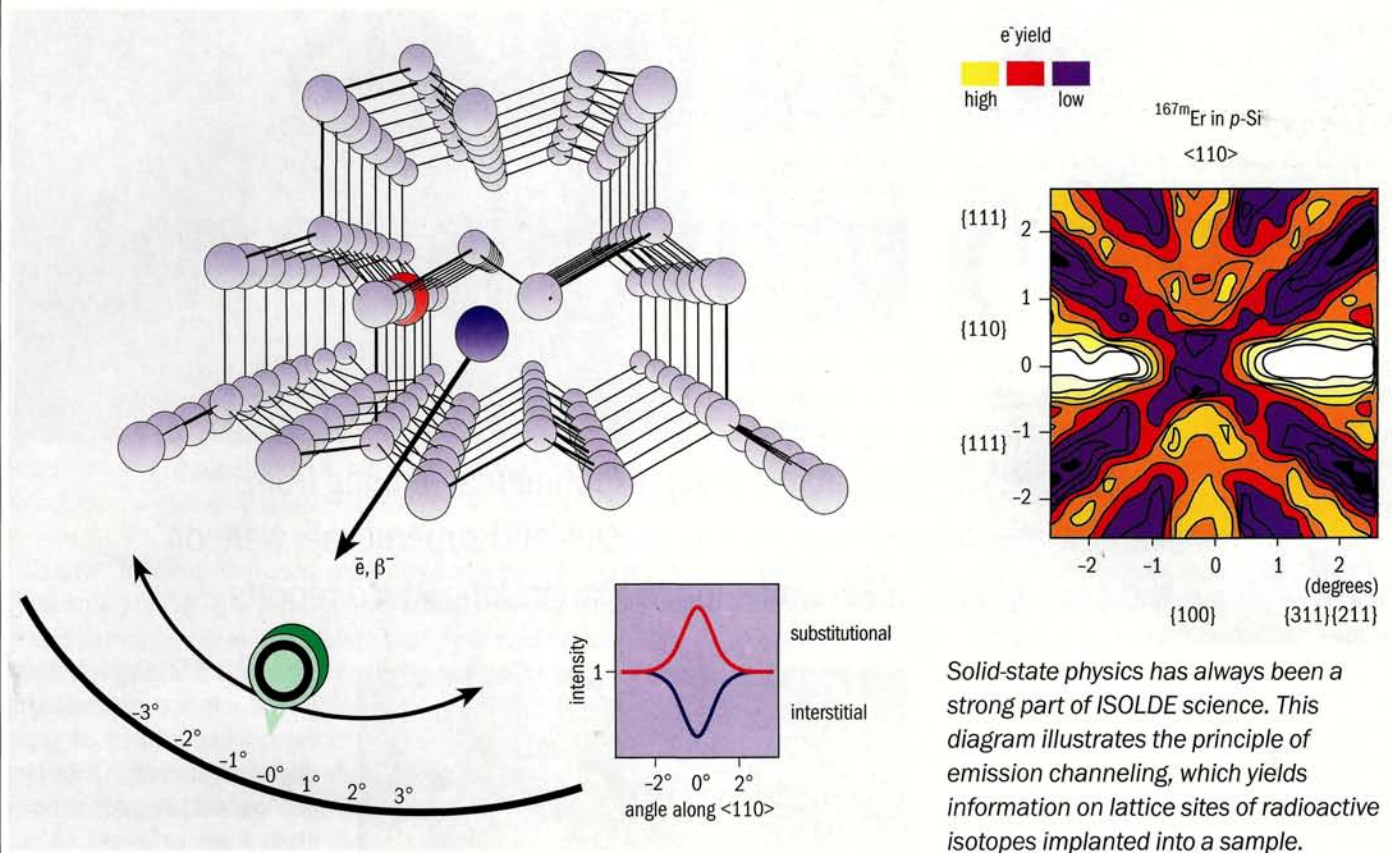
ing aspect is "charge breeding". This is achieved in two stages: the required isobars are separated and bunched in a Penning trap (REXTRAP), before being ejected into an electron-beam ion source (EBIS) for charge-state breeding. The first tests at REXTRAP and EBIS have already demonstrated the expected performance with more than 20% transmission and excellent overall stability. Commissioning experiments are scheduled to begin in the autumn of this year.

Theoretical aspects

The technical aspects having been concluded, the workshop then moved on to research topics, with theoretical overviews from Alfredo Poves of Madrid and Paul-Gerhard Reinhard of Erlangen. Among the topics for

investigation are core nuclear physics issues such as neutron halo systems whereby a nucleus consists of a central core with one or more loosely bound neutrons orbiting, and mapping the so-called neutron dripline of neutron rich nuclei at the limit of stability. In astrophysics, for example, ISOLDE's potential in elucidating the rapid neutron capture (r-process) and rapid proton capture (rp-process) paths of nucleosynthesis was emphasized.

Turning to experimental nuclear structure, Karsten Riisager of Aarhus summarized the current understanding of neutron halos, where many experiments on neutron-rich lithium and beryllium ions at ISOLDE have contributed significantly. He also outlined future opportunities at REX-ISOLDE for looking beyond the driplines



Solid-state physics has always been a strong part of ISOLDE science. This diagram illustrates the principle of emission channeling, which yields information on lattice sites of radioactive isotopes implanted into a sample.

using low-energy nuclear reactions, extending work already done at ISOLDE. On the proton-rich side of the valley of stability, experiments employing beta-delayed multiparticle decays have probed highly unbound states of light nuclei. On the neutron-rich side, recent decay studies of very neutron-rich sodium and aluminium isotopes, reported by Jyväskylä's Saara Nummela, have resulted in new evidence for shell inversion at $N = 21$ and suggested the disappearance of the "magicity" of the neutron number $N = 20$, which was known for a long time as a good magic number in the valley of stability. This reordering of the nuclear shell structure is believed to result from the strong modification of effective nucleon interactions in nuclei very far from the valley of stability.

The physics of ground-state properties of exotic nuclei was also the subject of much attention. Munich's Georg Bollen reported on recent progress on mass measurements by the ISOLTRAP and MISTRAL experiments, where a new era in high precision is dawning. Frank Herfurth of CERN described new data on the mass of the short-lived argon-33 isotope with a precision of 10^{-7} , exceeding all previous measurements. Rainer Neugart of Mainz gave an extensive review of a highly successful ISOLDE programme investigating ground-state properties of nuclei



Saara Nummela of Jyväskylä discusses recent data from an ISOLDE experiment on exotic neutron-rich sodium, magnesium and aluminium isotopes in relation to the disappearance of the magic neutron number 20 far from the valley of stability.

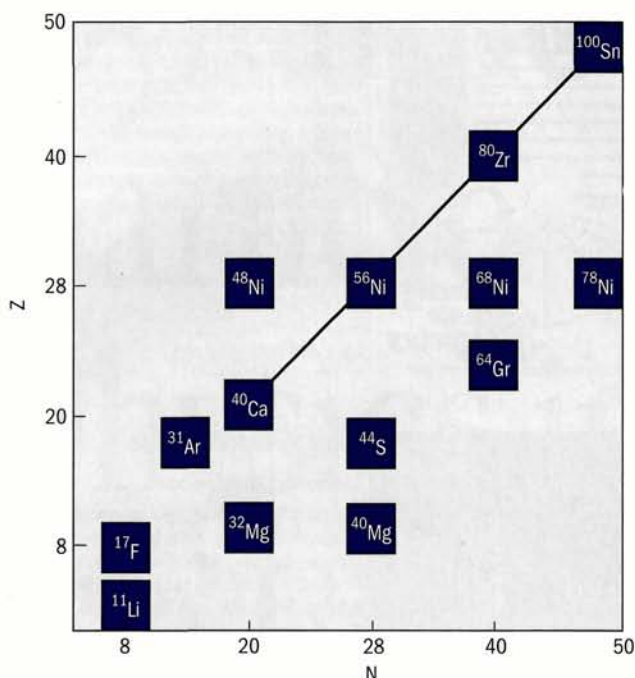
obtained by optical laser spectroscopy. He cited as an example a recent experiment that has provided information on moments and charge radii of neon isotopes from the proton-halo nucleus neon-17 up to the highly neutron-rich neon-28.

Nathal Severijns of Leuven gave a lively presentation covering fundamental physics beyond the Standard Model. After discussing ongoing work at the low-temperature nuclear orientation facility at ISOLDE (NICOLE), which allows the angular dependence of radioactive decay to be measured, he turned his attention to future opportunities for studying scalar contributions in the weak interaction by employing a special ion trap measuring technique that is under development at Leuven and ISOLDE.

Solid-state physics at ISOLDE was reviewed by Manfred Deicher of Konstanz. Experiments at ISOLDE can be classified into three groups: those exploiting the emission angle of radiation from implanted radioactive isotopes; hyperfine interaction spectroscopy; and labelling with radioactive isotopes. One advantage of the emission-channeling method is that suitable isotopes of nearly all chemical elements exist. This has already proved useful for a large number of semiconductors. Information on the lattice sites of copper and erbium in silicon, for example,

One of the most exciting new developments for the near future is REX-ISOLDE, a post-accelerator for the ISOLDE facility that will accelerate radioactive ions up to 2.2 MeV/nucleon

NUCLEAR BEAMS



The star nuclei of today and tomorrow were highlighted by Alfredo Poves. Many of these exotic nuclei have been studied extensively at ISOLDE and some are a major challenge for tomorrow's ISOLDE and REX-ISOLDE.

have been measured, providing a view into their structural and dynamical properties. High T_c superconductors of the mercury family have also been investigated with a hyperfine spectroscopy technique. The oxygen content in the charge reservoir layer was found to determine the critical temperature.

Isotopes aid identification

In the 1990s the availability of many different radioactive isotopes as pure ion beams at ISOLDE triggered a new era involving methods used for investigating optical and electronic properties of solids, especially in the field of semiconductor physics. Extremely sensitive spectroscopic techniques, like deep level transient spectroscopy, photoluminescence and the Hall effect, gain a new quality by using radioactive isotopes: owing to their decay, the chemical origin of an observed electronic and optical behavior of a specific defect or dopant can be identified unambiguously. Solid-state physicists are now looking forward to the implantation of their probes deeper into the crystals with the help of REX-ISOLDE. This will open up new possibilities for studying certain materials in greater depth than before, and of adding new materials such as ferroelectrics to ISOLDE's repertoire.

This workshop revealed a rich spectrum of science at CERN's veteran nuclear physics facility. New ideas in combination with ongoing effort in target and ion-source development promise a rich future for ISOLDE.

Juha Äystö is chairman of the Nuclear Physics European Collaboration Committee, an expert committee of the European Science Foundation.

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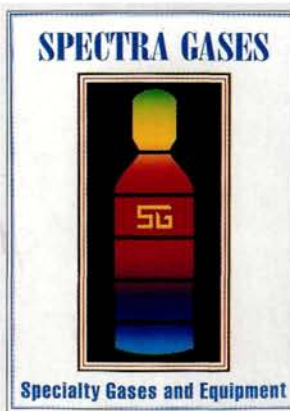
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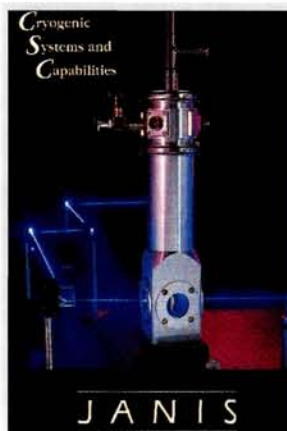
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Dynamic particle physics in the UK

The European Committee for Future Accelerators, which met in London in March, was impressed by the vitality of particle physics in the UK.

Continuing its eternal round of visits to CERN member states, the European Committee for Future Accelerators (ECFA) met in London in March, with a side trip to the Rutherford Appleton Laboratory.

The particle physics effort in the UK, with a strong focus on CERN but with many active projects elsewhere, is very dynamic. Despite this success, specialists are not complacent and take care not to be wrong-footed by new developments.

ECFA delegates were happy to hear UK Minister of Science and Space Lord Sainsbury praise the role that their committee has played in coordinating European strategies and in ensuring the coherence of the community.

"Particle physics contributes much more than world-leading science," he maintained. "European particle physics laboratories are a hot-bed of cutting-edge technology in many other areas. Everyone knows the story of the World Wide Web and has watched, almost in amazement, the explosive growth of the Internet and e-commerce. For example, in the UK, the Web is currently used by more than 34% of the population. This is now having a profound impact on science, commerce and increasingly on our daily lives."

His main message to particle physicists was to ensure that their new technologies are not only recognized but also transferred for wider industrial and commercial application.

UK funding was described by John Garvey (Birmingham). UK par-



Surveying the UK scene at the ECFA meeting: left to right, CERN director-general Luciano Maiani, UK Minister of Science and Space Lord Sainsbury, and meeting organizer David Miller of University College London (Cecilia Jarlskog.)



At the London ECFA meeting, Christine Sutton (left) described the national particle physics outreach programme, while Anna Burrage, working with the H1 collaboration at DESY, added a PhD student's insight.

particle physics and astronomy are jointly funded by the Particle Physics and Astronomy Research Council (PPARC) with support through studentships, through direct funding to the university groups – especially research associateships and technical manpower – and through funds for constructing and running experiments. Funding decisions are peer-reviewed by a panel drawn mostly from the university groups, and the projects are administered by the Rutherford Appleton Laboratory (RAL).

Some 16 experimental physics university groups have 166 academic staff, about 200 PhD students (spread over 3–4 years), 190 research associates and fellows, and about 90 technical and computing support staff. The 17 university theory groups have 72 academic staff, more than 100 students and 84 research associates and fellows (including both PPARC- and non-PPARC-funded positions).

RAL has an additional 60 people directly involved in the particle physics programme (which is entirely PPARC-funded) and about 100 full-time-equivalent specialists providing technical support.

Experiment programme

Neville Harnew (Oxford) surveyed the UK experimental particle physics programme, with supplementary comments from RAL director Ken Peach, who is the manager of the UK particle physics programme. UK physicists are active in a number of ongoing

experiments, both in Europe and the US, and are busy preparing for several future projects. Their major future involvement will be in ATLAS, CMS and ALICE at CERN's LHC. They are also preparing for LHCb and the Fermilab neutrino experiment MINOS, both of which are close to being approved for PPARC funding.

Activities away from accelerators include the measurement of the neutron electric dipole moment at ILL, Grenoble, the measurement of solar neutrinos at the SNO Sudbury Neutrino Observatory in Canada and searching for dark matter at the Boulby mine, UK.

In addition, some far-sighted UK physicists are busy with R&D for linear colliders and for a neutrino and muon factory (*CERN Courier* April 2000 p17). The UK would like to have a neutrino factory at RAL, possibly associated with an upgraded spallation neutron source.

The range of experiments with UK involvement is broad, and enthusiasm and optimism exude everywhere.

Technology and the Central Laboratories

PPARC has a technology panel chaired by Phil Allport (Liverpool), who described UK innovations in instrumentation and the long-term technology plan. A key concept is "data deluge". Particle physics is driving sensor technologies that have applications across many disciplines, and UK academics, in collaboration with industry, are involved in common programmes.

The GRID project, where UK has taken a leading role, was described by Steve Lloyd (Queen Mary and Westfield College,

London), who discussed plans for a UK regional centre for all four major LHC experiments and the resource implications.

The vital role of the Central Laboratories of the Research Councils (CLRC) was reviewed by chief executive designate Gordon Walker. The CLRC, an independent non-departmental public body of the Department of Trade and Industry, comprises the Rutherford Appleton and Daresbury laboratories. These provide science and technology support, operate a number of large facilities for UK users, provide advanced engineering and computing resources, and have their own research programmes.

Facilities include Daresbury's SRS synchrotron radiation source and the RAL ISIS spallation neutron source. ISIS is the scene of the KARMEN neutrino experiment, with strong German participation, which is looking for evidence of the phenomenon of neutrino oscillations. The new Diamond synchrotron radiation source, with support from France and the Wellcome Foundation (*CERN Courier* May 2000 p7), is to be built at RAL.

Peter Sharpe of RAL surveyed advanced resources for microelectronics, where miniaturization is ever smaller. The present micro-electronic linewidth of 0.25 μm is expected to decrease five-fold in the next 10 years. RAL and some of the university groups are very much involved in this development, which is expected to be important not only for physics but also in many other fields.

Important decisions are being taken about the future of the CLRC, and ECFA was invited to participate in the debate. In a round-table discussion moderated by ECFA chairman Lorenzo Foà, laboratory directors Luciano Maiani (CERN), Albrecht Wagner (DESY) and Paolo Laurelli (Frascati) explained their view of the role of a national laboratory. PPARC chief executive Ian Halliday examined how its RAL relations might develop.

Richard Kenway (Edinburgh) described the continual evolution of UK particle physics theory and restructuring for the 21st century, partly due to developments in computers and networks. A new proposal involves setting up a national Institute for Particle Physics Phenomenology, and a site decision is imminent.

Anna Burrage, a PhD student working with the H1 collaboration at DESY, alleged that British particle physics PhD students are required to be highly self-motivated and to complete original research at the highest international level.

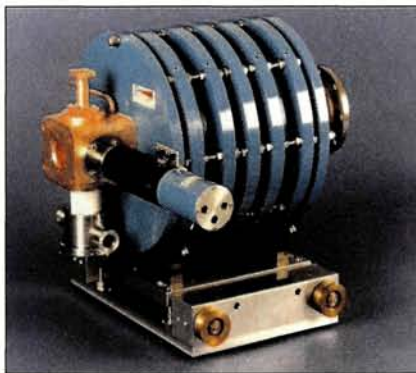
A supervisory support framework provides academic and technical day-to-day assistance. Students acquire a range of "transferable skills", such as computer literacy and communications, which are highly valued by employers.

However, there are problems: students have great difficulty in finishing in three years of funding, and frequently finish their PhD deeper in the red. Burrage pointed out that PPARC is now introducing measures to ensure timely PhD completion, and it will be interesting to see how this develops.

Christine Sutton (Oxford) described PPARC-supported outreach activities in particle physics. These dynamic efforts point the way for similar developments elsewhere. As well as giving information on particle physics in the UK and elsewhere, the Web site at "<http://hepweb.rl.ac.uk/ppuk/>" also features a memorable "Picture of the Week".

The ECFA meeting was organized by David Miller from University College, London, and his UK colleagues. □

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2000

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26 - 30 June 2000

The 7th European Particle Accelerator Conference will take place at the Austria Center, Vienna, from 26 to 30 June 2000. Previous conferences took place in Rome, Nice, Berlin, London, Sitges and Stockholm, with approximately 800 delegates participating each time. Lively poster sessions, an important industrial exhibition and a session organized with representatives of the industry in mind, complete the overall programme of the conference.

EPAC 2000 is a Europhysics Conference, organized by the Elected Board of the EPS Interdivisional Group on Accelerators. The Organizing Committee is chaired by Dr. S. Myers, CERN, Geneva. The Scientific Programme Committee is chaired by Dr. J.-L. Laclare, CEA, Paris. The Local Organizing Committee is chaired by Professor M. Regler, Institute of High Energy Physics of the Austrian Academy of Sciences, Vienna.

All information concerning the conference is published at the conference website at

<http://www.cern.ch/epac/Vienna/General.html>

Registration is possible via mail, fax, e-mail, and the WWW.



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Associate Scientist

• Beams Division •

The Beams Division of Fermi National Accelerator Laboratory (Fermilab) has an excellent opportunity for an Associate Scientist. The successful candidate will be focused on applications of accelerator physics required by the Fermilab research program but will have some opportunity for self-directed research. The beam physics applications include contributing to machine operation, improvements or diagnostics. The candidate will be expected to perform beam studies, coupled with advanced accelerator calculations aimed at improving machine performance and versatility.

The Associate Scientist position carries an initial three-year appointment with a possible extension and consideration for a regular position on the Fermilab scientific staff. A Ph.D. in Physics (or equivalent) is required and two or three years of relevant postdoctoral experience. Excellent communication skills and leadership potential are also required.

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Fermilab

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The Faculty of Science (mathematisch-naturwissenschaftliche Fakultät) of the University of Zurich

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The new professor will participate in the teaching of theoretical physics at all levels and supervise diploma and PhD students.

Candidates with a recognised scientific record in theoretical astrophysics or cosmology are asked to send their curriculum vitae, list of publications, and a summary of their research interests to the Dean of the Faculty of Science (Mathematisch-naturwissenschaftliche Fakultät), Prof. Dr. K. Brassel, University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich by June 30, 2000.

Please visit our website at
<http://www-theorie.physik.unizh.ch>.



The University encourages female candidates to apply with a view towards increasing the proportion of female professors

Postdoctoral Research Position The Johns Hopkins University

A postdoctoral research position is available immediately with the HEP Group at the Johns Hopkins University. It involves participation in the hardware and software of the CMS detector for the LHC, concentrating on the pixel detector system including development and testing of pixel sensors and optical links, and associated software. Faculty members involved in this project are C.Y. Chien, B. Barnett, and M. Swartz. Detector, electronics and software experience will be required. This position will be based in Baltimore in the next few years.

Applicants should send a CV, bibliography, a statement of research interests, and three letters of reference to: **Prof. Chih-Yung Chien, or Prof. Morris Swartz, Department of Physics and Astronomy, Johns Hopkins University, 3400 North Charles St., Baltimore, MD 21218, USA.**

(TEL: 1-410-516-7359, FAX: 1-410-516-8664, E-mail: chien@jhu.edu)

Review of applications will begin in April 2000, and will continue until the position is filled.

THE UNIVERSITY OF MINNESOTA

Experimental HEP Group has several open postdoctoral positions.

The Minnesota HEP group has major responsibilities in CMS in both the ECAL and HCAL. We are also responsible for data acquisition and physics analysis on the BNL g-2 experiment that will measure the contribution of W and Z to the anomalous magnetic moment of the muon and set stringent limits on the Standard Model.

As part of our program in precision constants, we are preparing an approved experiment to directly measure the muon neutrino mass in the g-2 ring, measuring the muon lifetime to 2 ps at PSI, and in the proposal stages of a dedicated muon electric dipole moment measurement.

**Professor Priscilla Cushman (prisca@mnhep.hep.umn.edu)
Dept. of Physics and Astronomy, University of Minnesota,
116 Church St. SE, Minneapolis, MN 55455, USA**

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Thomas Jefferson National Accelerator Facility

MECHANICAL PROJECT ENGINEER

(Position #AR3223)

Jefferson Lab, located in Newport News, VA, is a world-class scientific laboratory centered around a high-intensity, continuous wave electron beam, which provides a unique capability for nuclear physics research. The lab is managed for the Department of Energy by the Southeastern Universities Research Association. We are located near Colonial Williamsburg, the Chesapeake Bay and the resort area of Virginia Beach.

Currently we have an excellent opportunity for a Mechanical Project Engineer. The candidate will provide mechanical engineering support for the Accelerator Division, serving as a project engineer on a variety of assigned tasks. He/she will take concepts from physicists and other engineers and turn them into working designs. The incumbent must be able to work independently on involved projects and be able to solve complex problems where there are limited precedents available. He/she may work with one or two designers on individual designs or be responsible for leading a group of several engineers and designers on larger projects. He/she will be responsible for the design, procurement, and fabrication of parts, installation, and commissioning, and all documentation needed to support and maintain said designs. Possible engineering duties may be in vacuum, pressure vessel, cryogenic, magnet, support structures, and water system designs as well as heat transfer and vibration analysis.

The minimum qualifications for this position are a BS or MS in Engineering with fifteen years of design experience related to particle accelerators. Familiarity with multiple aspects of accelerator design and theory, including injector design, ultra high vacuum, cryogenics, accelerator diagnostics, magnets, alignment, and superconducting radio frequency cavities and cryostat design is a must. The candidate must also be an expert in one or more of the following: injector design, ultra high vacuum, accelerator diagnostics, materials, welding, and superconducting radio frequency cavities and cryostat design. Supervisory and/or project management experience is also required. The incumbent must have a demonstrated ability to do independent research and proven analytical skills. Good communications skills and the ability to interact constructively with physicists, engineers, designers, technicians and procurement personnel are required.

The starting annual salary range will be \$68,600-\$108,400. For a higher classification, the salary range is \$83,100-\$131,300. For prompt consideration, please send resume and salary history to: Jefferson Lab, Attn: Employment Manager, 12000 Jefferson Ave., Newport News, VA 23606. Please specify position number and job title when applying. Further information and complete descriptions of this and other positions can be found by visiting our web site at <http://www.jlab.org/jobline.html> or by calling our jobline at 757-269-7359.

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RESEARCH ASSOCIATE POSITION

Experimental High Energy Physics Carnegie Mellon University

The Department of Physics at Carnegie Mellon University invites applications for a postdoctoral Research Associate position in experimental high energy physics. We are looking for an outstanding individual interested in hadron collider physics at the Fermilab Tevatron. For more information regarding this position please contact Professor Manfred Paulini (paulini@cmphys.phys.cmu.edu) and Professor James Russ (russ@cmphys.phys.cmu.edu). Applicants should submit a curriculum vitae and arrange to have three letters of recommendation sent directly to Professor Manfred Paulini and Professor James Russ, Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA. The vitae and recommendations can be sent either by normal or electronic mail. The position is available until filled. We will begin to consider applications on June 30, 2000.

Carnegie Mellon is an equal opportunity/affirmative action employer.

Universität Bielefeld

Professorship (C-4) in Theoretical Physics

The Department of Physics invites applications for a professorship of Theoretical Physics (succession H. Satz) in the field of Elementary Particle Theory. The appointment will be made for September 1, 2001.

Candidates should have a record of successful research on the basic physical questions of the field. They should complement the Bielefeld research program in this field and be willing to cooperate with the existing groups (quantum field theory, lattice field theory, statistical aspects of particle physics).

The successful applicant will participate in the general teaching duties of the department, in particular in theoretical physics. It is therefore expected that candidates have the necessary interest and pedagogic skill for this.

Prerequisites are a doctorate in physics and "Habilitation" of sufficient proof of scientific achievements.

The University of Bielefeld aims to increase the fraction of women on its staff and therefore invites in particular applications from qualified women; in case of equal qualifications, they will be given preference.

Applications should be sent until August 31, 2000, to

Dekan der Fakultät für Physik,
Universität Bielefeld, Postfach 100131,
D-33501 Bielefeld, Germany.



DESY is a physics research laboratory with 1400 employees and more than 3000 guest scientists from Germany and abroad. The scientific programme includes research in particle physics and synchrotron radiation.

DESY invites applications for the position of an

Experimental Physicist

The candidate should be highly qualified to take a leading role in the research program of the ZEUS experiment at the electron-proton storage ring HERA. The person should take considerable responsibility in physics analysis, participate in the operation and upgrade of the detector and participate in shaping the future research program of the laboratory.

Applicants should have a Ph.D. in physics, several years of experience in experimental particle physics, and should be active in research in this field. They should have an established record in data analysis and in hardware and software for particle physics detectors. Excellent communication skills and the ability to lead larger collaborative efforts are essential.

The appointment is to a permanent position with a salary according to federal tariffs (BAT 1b).

Applicants with a physical handicap will be given preference over other candidates when they have equal qualifications. Women especially are encouraged to apply.

Letters of application including curriculum vitae, list of publications and the names of three referees should be sent before July, 24th 2000, Code-No. 42/00, to

DESY, Personalabteilung
Notkestraße 85, D-22607 Hamburg
Tel. 040/89984488

UNIVERSITY OF COPENHAGEN NIELS BOHR INSTITUTE FOR ASTRONOMY, PHYSICS, AND GEOPHYSICS

Postdoctoral position in Experimental Particle Physics

A postdoctoral position is available from September 1, 2000 with the Experimental Particle Physics group at the Niels Bohr Institute, University of Copenhagen. The position is for two years with a possibility of prolongation, however, not exceeding five years.

The particle physics group is located at the Niels Bohr Institute, University of Copenhagen, 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 preparation, the second level trigger and the GRID involvement.

The candidate will be based in Copenhagen. The candidate must have documented experimental research at an international level and have documented abilities in the construction of complex experiments. The position also demands participation in the university teaching program.

Salary is set by agreement between the Ministry of Finance and AC (The Danish Confederation of Professional Associations). The annual salary depends on seniority, and the scale ends at a yearly salary of DKK 313.808 after contributions to the pension scheme and including a seniority independent yearly increment of DKK 39.746.

Deadline for applications is July 31, 2000, at noon.

Further information can be obtained from: **professors John Renner Hansen (renner@nbi.dk) and Jørn Dines Hansen (dines@nbi.dk)**

Applications should be sent to:

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

LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

C3-PROFESSUR FÜR THEORETISCHE PHYSIK

The Faculty of Physics has an immediate vacancy for a Professor (C3) for Theoretical Physics

Candidates with a recognized research record in particle physics phenomenology (preferred fields: dynamics of electroweak interactions and mass generation, symmetries, QCD) are invited to apply for this position. The future professor will be in charge of research and teaching. Collaboration with the other research groups of the department is required, especially with the existing research group in experimental high energy physics.

The qualification requirements are: Ph.D. in physics and habilitation (or an equivalent qualification), less than 52 years of age at the moment of nomination.

Applications (with a curriculum vitae, copies of certificates and a list of publications) should be sent by 30 June 2000 to

**Dekanat der Fakultät für Physik,
Ludwig-Maximilians-Universität München,
Schellingstr. 4, 80799 München**

Opportunities in Information Technology at CERN



The Information Technology Division of CERN is responsible for providing the general computing infrastructure of the laboratory, as well as services oriented towards the needs of the physics and engineering communities. The Division currently has a number of vacancies for support and development work in the following areas:

- Database management systems, related tools and applications;
- Internet applications; the Windows environment; related tools and applications including for the physics community;
- Computing and networking infrastructure of the laboratory, including services for desktops, the provision of high throughput computing clusters for physics data analysis, and mass storage management.

Depending on the area of assignment, the activities involved will include tasks such as software development and maintenance, selection of hardware and software products, operation of services, interactions with the user community and outside laboratories, supervision of service contracts.

Qualifications Required: a university degree or equivalent in computer science, physics, or a related field and up to 5 years' experience in Information Technology. Knowledge and practical experience in one or more of the following technologies: Relational and/or Object database management systems, Internet applications and technologies, systems management using Unix, Windows NT or Windows 2000, object-oriented programming, preferably in C++ or Java, network management, large-scale data management, development of High Energy Physics applications.

For more information see 'Staff Employment' at <http://cern.ch/jobs>

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RESEARCH ASSOCIATE

Rutherford Appleton Laboratory, Oxfordshire

The Particle Physics Department of CLRC (Rutherford Appleton Laboratory) has two vacancies for real-time programmers. Both of these posts are in technically challenging projects and demand a high degree of initiative and innovation. The new posts offer the opportunity to be involved in a major particle physics experiment currently under construction, and would be suitable either for a real-time programmer or for a particle physicist with a strong interest in real-time computing. Both posts will be based at RAL, but working closely with physicists, programmers and engineers from RAL and UK universities, in collaboration with staff from overseas institutes. A willingness to travel and an ability to communicate effectively and to operate in a large multinational collaboration are essential.

Post 1 (VN1929) is to develop trigger software for the ATLAS experiment being built for the Large Hadron Collider in CERN. ATLAS plans a three-level trigger system, and the RAL group is contributing to the first two levels. Level-1 requires fast purpose-built processors, while Level-2 mainly uses commodity processors and networks but with some custom hardware and software to meet the challenging real-time requirements. The person appointed will work on software associated with these two trigger levels.

Post 2 (VN1928) is to develop data acquisition software for the MINOS long-baseline neutrino oscillation experiment. The experiment consists of massive calorimeters at Fermilab and the Soudan mine. The RAL Particle Physics group, in collaboration with the RAL electronics division, has responsibility for production of the data acquisition system. The person appointed will join the team designing and implementing the real-time system programmes that gather and manipulate the data.

Further information on the ATLAS post is available from Dr F. Wickens Tel +44 1235 445737 fj.wickens@rl.ac.uk or Dr C.N.P. Gee Tel +44 1235 446244 c.n.p.gee@rl.ac.uk, and on the MINOS post from Dr. Peter Litchfield (+44) 01235 446265, e-mail p.litchfield@rl.ac.uk. Information on the experiments and RAL Particle Physics department is available on the World Wide Web at <http://hepweb.rl.ac.uk>

Both posts are for fixed term periods (Post 1 - 3 Years and Post 2 - 4 Years). The salary range is between £18620 and £26600. Progression within the salary range is dependent upon performance. A non-contributory pension scheme and a generous leave allowance are also offered. Application forms can be obtained from: Recruitment Office, Human Resources Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) or email recruit@rl.ac.uk quoting reference VN1929 or VN1928. More information about CLRC is available from CLRC's World Wide Web pages at <http://www.cclrc.ac.uk>. All applications must be returned by 22 June 2000.

The CCLRC is committed to Equal Opportunities and to achieving the Investors In People standard. A no smoking policy is in operation.



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**RESEARCH ASSOCIATE POSITION
HIGH ENERGY PHYSICS
THE OHIO STATE UNIVERSITY**

The experimental high energy physics group at The Ohio State University invites applications for two postdoctoral research associate positions, one with our CLEO program, the other with ATLAS. In the CLEO program, we are involved in both the ongoing data analysis effort in heavy flavor physics and the CLEO III upgrade program where we have major responsibilities for the silicon vertex detector and the data acquisition system. For the ATLAS program, we are involved in the design and prototyping of the optical electronics and packaging for the pixel detector.

Interested candidates should send a letter of application, vitae, list of publications, and three letters of recommendation to: **Professor R. Kass, The Ohio State University, Department of Physics, 174 W. 18th Ave, Columbus, Ohio 43210-1106, or e-mail: kass@ohstpy.mps.ohio-state.edu.**

The Ohio State University is an equal opportunity employer and we actively encourage applications from women and minority candidates.

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2000 MRS FALL MEETING SYMPOSIA

Cluster 1: Nano-Microstructured Materials

- A: Nanotubes and Related Materials
- B: Structure and Mechanical Properties of Nanophase Materials—Theory and Computer Simulations vs Experiment
- C: Anisotropic Nanoparticles—Synthesis, Characterization, and Applications
- D: Nanolithographic and Lithographic Methods for Nanofabrication—From Ultralarge-Scale Integration to Photonics to Molecular Electronics
- E: Microphotonics—Materials, Physics, and Applications
- F: Nano- and Microcrystalline Semiconductor Materials and Structures

Cluster 2: Semiconductors

- G: GaN and Related Alloys
- H: Silicon Carbide—Materials, Processing, and Devices
- I: Semiconductor Spintronics—Physics, Materials, and Applications
- J: Semiconductor Quantum Dots

Cluster 3: Metals

- K: Quasicrystals
- L: Supercooled Liquid, Bulk Glassy, and Nanocrystalline States of Alloys
- M: Thermal Barrier Coatings
- N: High-Temperature Ordered Intermetallic Alloys IX

Cluster 4: Materials Processing and Analysis

- O: Ion Beam Synthesis and Processing of Advanced Materials
- P: Growth, Evolution, and Properties of Surfaces, Thin Films, and Self-Organized Structures
- Q: Fundamentals of Nanofabrication and Nanotechnology II
- R: Microstructural Processes in Irradiated Materials
- S: Applied Magnetic Field Effects on Materials Behavior
- T: Dynamics in Small Confining Systems VI
- U: Ultrafast Nonlinear Optical Phenomena
- V: Low-Vacuum SEM/SEEM in Materials Science: Wet SEM—The Liquid Frontier of Microscopy

Cluster 5: Defects, Mechanics, and Length Scales

- W: The Limits of Strength in Theory and Practice
- Y: Influences of Interface and Dislocation Behavior on Microstructure Evolution
- Z: Multiscale Materials Modeling
- AA: Structure-Property Relationships of Oxide Surfaces and Interfaces

Cluster 6: Device and Functional Materials

- BB: Characterization and Modeling of Domain Microstructures in Materials
- CC: Ferroelectric Thin Films IX
- DD: Materials Issues for Tunable RF and Microwave Devices II
- EE: Materials Science of Microelectromechanical System (MEMS) Devices III

Cluster 7: Inorganic Materials

- FF: Materials Science of High-Performance Concrete
- GG: Solid-State Chemistry of Inorganic Materials
- HH: Advanced Catalytic Materials - 2000
- II: High-Temperature Superconductors—Crystal Chemistry, Processing, and Properties

Cluster 8: Organic and Biomaterials

- JJ: Organic Electronic and Photonic Materials and Devices
- KK: Filled and Nanocomposite Polymer Materials
- LL: Orthopedic/Dental Biomaterials
- MM: Cardiovascular Biomaterials
- NN: Biomaterials for Drug Delivery
- OO: Neurologic Biomaterials

Cluster 9: General

- X: Frontiers of Materials Research

2000 MRS FALL MEETING ACTIVITIES

SYMPOSIUM TUTORIAL PROGRAM

Available only to meeting registrants, the tutorials will concentrate on new, rapidly breaking areas of research.

EXHIBIT

Over 225 international exhibitors will display a full spectrum of equipment, instrumentation, products, software, publications, and services.

PUBLICATIONS DESK

A full display of over 630 books, plus videotapes and electronic databases, will be available at the MRS Publications Desk.

SYMPOSIUM ASSISTANT OPPORTUNITIES

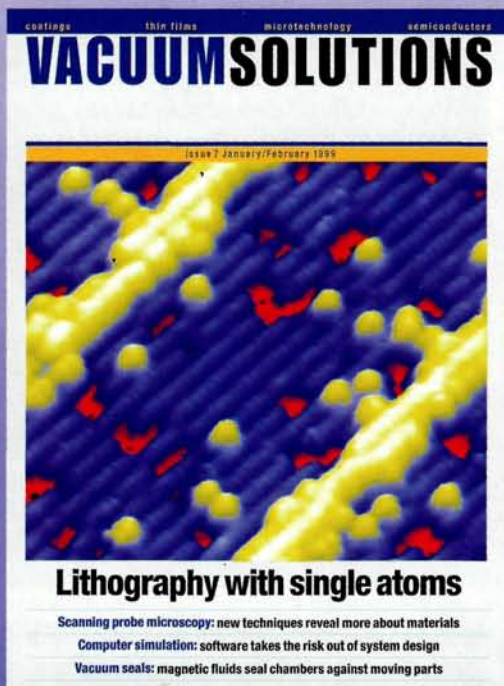
Graduate students planning to attend the 2000 MRS Fall Meeting may apply for a Symposium Assistant (audio-visual aide) position.

EMPLOYMENT CENTER

An Employment Center for MRS members and meeting attendees will be open Tuesday through Thursday.

The 2000 MRS Fall Meeting will serve as a key forum for discussion of interdisciplinary leading-edge materials research from around the world. Various meeting formats—oral, poster, round-table, forum and workshop sessions—are offered to maximize participation.

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PEOPLE

AWARDS



Albert Einstein gold medal winner – Riazuddin, director of the National Centre for Physics, Pakistan.

Cambridge astrophysicist **Donald Lynden-Bell** has received the US National Academy of Sciences' John J Carty award for the Advancement of Science for his outstanding theoretical work.

Valentine Teledgi and **Edward Witten** have been elected foreign members of the Paris Academy of Sciences. This distinguished body only rarely elects foreign members.

Distinguished theorist and popular science writer **Lawrence Krauss** of Case Western Reserve received the American Association for the Advancement of Science's Public Understanding of Science and Technology award "for his ability to maintain an active scientific career while at the same time writing several accessible books about physics for the general public".

On the occasion of the 13th International Khwarizmi award, organized by the Iranian Research Organization for Science and Technology, **Riazuddin**, director of the National Centre for Physics, Quaid-i-Azam University, Islamabad, Pakistan, received a UNESCO Albert Einstein gold medal.

The prestigious Thibaud prize, awarded by the Society of Arts and Sciences of Lyon, has been given this year to **Marc Dejardin** of Saclay, **Olivier Drapier** of Lyon/Claude Bernard and **Jean Yves Ollitrault** of Saclay.

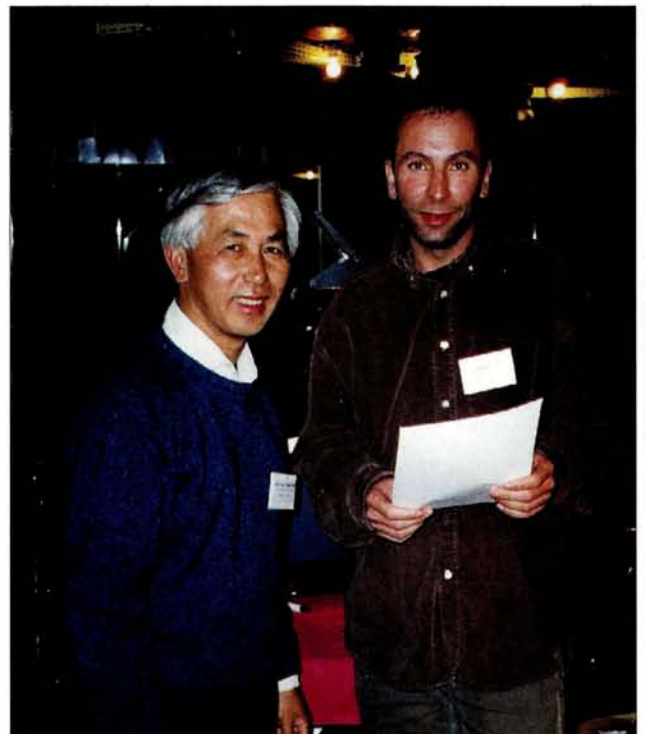
A symposium at the Canadian TRIUMF laboratory, Vancouver, marked the 65th birthday of TRIUMF director Alan Astbury, a prominent figure on the international particle physics scene and formerly co-spokesman, with Carlo Rubbia, of the UA1 experiment at CERN's proton-antiproton collider. Speakers included (back row, left to right) **Richard Taylor** (SLAC), **John McDonald** (Alberta), (second row) **Jean-Michel Poutissou** (TRIUMF), **Jules Deutsch** (Louvain), **Alan Astbury**, **Randy Sobie** (Victoria), **Rob Kiefl** (TRIUMF), (front row) **Richard Keeler** (Victoria), **Michel Lefebvre** (Victoria), **Bill Scott** (Rutherford Appleton) and **Carlo Rubbia** (ENEA, Rome).



An international symposium, Evolution Equations and Large Order Estimates in QCD, was held on 30 April – 4 May at the St Petersburg Nuclear Physics Institute (PNPI), Gatchina, Russia, to mark the 60th birthday of **Lev Nikolaevich Lipatov**, renowned Russian scientist, associate fellow of the Russian Academy of Sciences and head of the PNPI Theory Division. He is well known for his pioneering investigations into high-energy asymptotics for QED and QCD, in particular the Gribov-Lipatov-Altarelli-Parisi-Dokshitzer and Balitsky-Fadin-Kuraev-Lipatov evolution equations and large-order expansions in quantum field theory.



The 35th session of the traditional annual "Rencontres de Moriond" for physics was held this spring at Les Arcs in the French Alps. In parallel was the 30th session of the "Méribel" meetings for biologists. Seen here are Moriond organizer **Jean Tran Thanh Vanh** (left) and Méribel organizer **Pierre Sonigo**. The events shared a talk by Maurice Jacob of CERN on the new insights into nuclear matter coming from the study of nuclear collisions at CERN (*CERN Courier* April 2000 p13).





The opening at CERN of an exhibition marking the bicentenary of Alessandro Volta's pioneer electric pile. CERN was the first venue for the English language version of the exhibition, which was created by the Centro di Cultura Scientifica Alessandro Volta.



Rudiger Voss of CERN leads the round-table discussion at the 2nd Workshop on Electronic Publishing in Physics, which was held at CERN on 31 March. Physics in general and particle physics in particular have been a major driving force in this fast-developing sector.

Big Bang journey in Berlin

The "Reise zum Urknall" (Journey to the Big Bang) event took place in April at the Urania Centre in Berlin. The event formed part of the German national 2000 "Das Jahr der Physik" (The Year of Physics) programme and concentrated on particle and nuclear physics.

For more information about "Das Jahr der Physik", visit the Web site at "<http://www.physik-2000.de/>".



Left: the Urania Centre (Berlin), venue for the Journey to the Big Bang event in April. Right: part of the CERN exhibition at the event.

MEETINGS

Physics for the 21st Century, an International Conference of University Professors for the Great Jubilee of the Catholic Church, will take place at the University of Rome "Tor Vergata" on 6-10 September. The goal of the conference is to review and discuss the most important results obtained in recent years in the various fields of physics, as well as looking at trends for the new century. There is an impressive line-up of invited speakers, and Jubilee events will include a Papal Audience, Penitential Celebrations in the various Basilicas and High Mass with the Pope in St Peters Square. Registration is via the conference Web site at "<http://www.roma2.infn.it/phys21>".

More information is available from Liù Caten, Dipartimento di Fisica, Università di Roma "Tor Vergata", Via della Ricerca Scientifica 1, I-00133 Roma; tel. +39 06 72594301; fax +39 06 2023507; e-mail "catena@roma2.infn.it".

The EuroConference on Frontiers in Particle Astrophysics and Cosmology will be the sixth in a series of meetings on Frontiers in Astroparticle Physics and Cosmology initiated in Valencia in 1991. This year's meeting is organized by the Astroparticle and High Energy Physics Group of IFIC/CSIC University of Valencia jointly with the Astroparticle Physics Group of the Max-Planck-Institut für Physik and is for the first time included in the EURESCO programme. It will be held on 30 September - 5 October in San Feliu de Guixols, Spain. Grants are available for young scientists from EC countries and associated states. Contact Dr Josip Hendekovic or Ms Sally Lewis; tel. +33 388 76 71 35; fax +33 388 36 69 87; e-mail "slewis@esf.org"; or visit "<http://www.esf.org/euresco/00/pc00142a.htm>".

The Zuoz Summer School on the Phenomenology of Gauge Interactions will be held on 13-15 August in Zuoz, Engadin, Switzerland. Topics include QCD theory and

experiment, electroweak theory and experiment, QCD vacuum and non-perturbative effects, hadron spectroscopy, lattice gauge theory, gravity and gauge interactions. For more information visit the Web site at "<http://www.hep.psi.ch/zuoz2000.html>" or e-mail "zuoz@psi.ch".

A Summer School on Theoretical Physics - Escuela de Fisica will take place at Zacatecas Autonomous University, Zacatecas, Mexico, on 31 July - 5 August. Contact Dr V V Dvoeglazov, Escuela de Fisica, Universidad Autonoma de Zacatecas, Apartado Postal C-580, Zacatecas 98068 Zac, Mexico; tel. +52 4 9241314; fax 52 4 9240286; e-mail "valeri@ahobon.reduaz.mx" or visit "<http://ahobon.reduaz.mx/~valeri/school.htm>".

The International Nuclear Physics Conference will be hosted by the Lawrence Berkeley National Laboratory on 30 July - 3 August, 2001. Visit "<http://www.lbl.gov/~inpc2001/>" for more information.

Thaddeus Francis Kycia 1933–99

Thaddeus (Ted) Francis Kycia, the prominent particle physics experimenter, died on 22 December 1999 in Port Jefferson, New York, due to complications of lymphoma. Born in Montreal, he received his BSc (1954) and MSc (1955) from McGill University. His PhD at Berkeley in 1959 was for a study of kaon–proton scattering at the Bevatron.

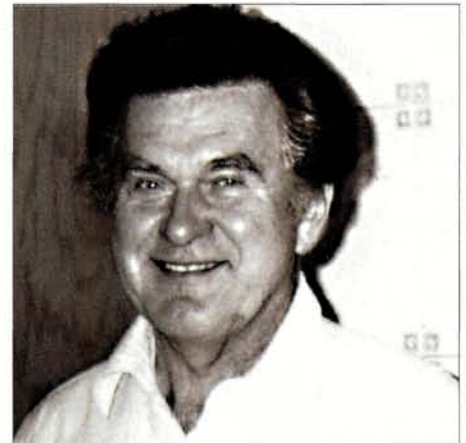
After joining Brookhaven in 1959, Kycia spent the remainder of his career there, becoming a senior physicist and group leader. In the early 1960s he participated in some of the earliest measurements of hyperon magnetic moments. Among other innovations in this work was the deployment of a superconducting magnet in the first measurement of the cascade minus magnetic moment. In the 1960s he led a series of hadron–nucleon total cross-section measurements at the AGS, pushing this deceptively simple technique to ever-increasing precision. In the process he discovered many new pion–nucleon and kaon–nucleus resonances. The final measurements of this series were carried out at the newly operating Fermilab, where, achieving a precision of about one part in a thousand, Kycia showed that all hadron–nucleon total cross-sections had the same behaviour: as the incident energy increases, the cross-sections fall, reach a minimum and then rise.

This is still not completely understood.

In the late 1960s Kycia embarked on landmark studies of rare kaon decays. At the end of the 1970s he led a series of clarifying experiments to check predictions of various new particles and/or claims of discoveries, and in the mid-1980s he returned to rare kaon decays as one of the initiators of AGS Experiment 787, the search for the decay of a charged kaon into a pion and two neutrinos. This process is highly sensitive to the otherwise elusive coupling of the top to the down quark, as well as to many varieties of possible new interactions. Kycia's vision for that experiment was to design a detector capable of detecting this process at the Standard Model level, which at the time of the proposal was some four orders of magnitude beyond what had been achieved. After many years this decay mode was discovered by E787, opening up a new window into short-distance physics. This work continues.

At the time of his death, Kycia was working on a new experiment to make a precise measurement of the Cabibbo angle, one of the fundamental parameters of the Standard Model.

Kycia was a leader in the design of Cerenkov counters, especially with gas radiators, for particle identification. He built



Thaddeus Francis Kycia 1933–99.

several of these, impressing his colleagues with their performance, but unfortunately rarely describing them in print. At Fermilab, one of his counters cleanly separated pions and kaons at 340 GeV; a few years later, others made modifications and achieved pion–kaon separation at 530 GeV. This is a record that is unlikely to be exceeded at any time in the foreseeable future.

Ted Kycia's expertise was in the design, planning and execution of particle physics experiments, and he had an impressive record of obtaining correct and accurate results. We and many of our colleagues learned much through working with him.

Roy Rubinstein, Fermilab, and Kelvin Li and Laurence Littenberg, Brookhaven.

Hugh Menown 1926–2000

Hugh Menown, MBE, who died in March aged 73, made a remarkable contribution to accelerator technology by developing multigap thyristors to switch the fast magnet systems in high-energy particle accelerators. He worked for the English Electric Valve Company (EEV; now Marconi Applied Technologies) for nearly 50 years.

Menown was born and brought up on a farm in Northern Ireland, and after completing an MSc at Queen's University Belfast he joined EEV in 1951 to work on hydrogen thyristors. In the late 1960s he visited CERN and started a long and fruitful association with engineers there who were designing kicker magnets. At various times Menown worked with David Fiander, Willem Middelkoop, Paul Faugas, Gerhard Schröder and many others on kicker switches for the

various CERN accelerators.

Following successes at CERN, most of the other particle accelerator laboratories in Europe, the US and the Far East also adopted EEV thyristors for kicker switching. Among Menown's further innovations were double-cathode and hollow anode thyristors, each capable of switching bidirectional current and further increasing the versatility of kicker magnet systems.

EEV received two Queen's Awards for Technology for thyristors, in 1973 and again in 1984, and Menown was awarded the MBE in 1982. He was appointed visiting professor at St Andrews University in 1986 and received the GEC Nelson gold medal for achievement in 1987.

Hugh Menown's individual style and unique personality will be remembered with great



Hugh Menown 1926–2000.

fondness by his friends and colleagues at CERN as well as at many other particle accelerator establishments in Europe and the US.
Peter Maggs.

BOOKSHELF

Quintessence, the Mystery of the Missing Mass in the Universe by Lawrence Krauss, Basic Books, 04650337402.

Cosmology has a lot going for it at the moment. Unprecedented amounts of data characterizing the universe at almost every possible energy and lengthscale make it one of the richest scientific fields around. Theorists scramble to explain all of the disparate results, while experimentalists and observers push the limits of what, only a few years ago, was not thought possible. In the middle of all this activity, Lawrence Krauss's book *Quintessence* (a re-edition of his 1989 *Fifth Essence*) arrives to assess what is going on.

There is a growing trend in astrophysical and particle cosmology to believe (or at least sell the idea) that cosmology is "solved". Again and again researchers in the field say something like: "things are finally falling into place", so that we now have a standard model for structure formation. Often this represents a very theoretical and prejudiced view in selecting which data to believe.

Krauss himself embraces the latest high-redshift supernova results and consequent evidence for a cosmological constant as a confirmation of the "new standard cosmological model" that he developed with collaborators in the mid-1980s. He is not alone in doing this, but such an attitude seriously compromises the evolution of the field.

It is the glaring inconsistencies and the conceptually inexplicable fixes that we should be trying to tackle. For example, we assume that the universe is homogeneous (and we know that the cosmic microwave background is very smooth), but when we look at the distribution of luminous matter it is strongly clustered as far as we can see; we believe that galaxies follow the underlying distribution of mass, but when we try to compare catalogues of different galaxies we end up having to invoke biasing mechanisms to make them all consistent.

My view is that cosmology is opening up and complexifying, not closing down and focusing on an existing component theory. Having declared my prejudices when starting this book, the truth is that I enjoyed it a lot. Although Krauss does try to oversell the inflationary cosmology and the derived cold dark matter scenario, this theme does not dominate the narrative. He does a great job of explaining the existence of dark matter, critically assessing the different pieces of



Lawrence Krauss – mystery of missing mass.

experimental evidence and ensuring that he can relate these results with understandable physical principles. Particularly impressive is his description of the cosmic virial theorem (relating the kinematics of systems of gravitating bodies with the overall underlying mass) and his careful attempts to explain freezeout and relic abundances.

Many of the fundamental concepts needed in contemporary cosmology are outlined in the book and I see it as a great source of explanations for a wider audience. It was inevitable that this book would be revised. When Krauss wrote *The Fifth Essence* at the end of the 1980s, it was at the end of a decade of fruitless searches for cosmological relics (he relates the story of the "Cabrera Monopole", which was never properly explained away).

The search for dark matter in the universe really took off in the 1990s, with bolometric and scintillation direct detection experiments being set up all over the world, the microlensing searches producing arguable evidence for clumped baryonic dark matter in our halo and the new weak lensing experiments mapping out the dark mass in clusters. Krauss systematically goes through these different technological advances, explaining why they happened and what scientific returns to expect. I particularly liked his description of the use of bolometric detectors in direct detection experiments, and his clear explanation of the phonon/ionization method used by the CDMS experiments at Berkeley. It conveys the beauty of experimental physics – how clever ideas and masterful work can really transcend physical limitations. Krauss has also done a reasonable job of avoiding the sociological folklore of characters and egos. He succumbs very rarely, the most notable

occasion being in his description of his work on WIMP detection and axions (and he likes Glashow's quips).

The bottom line is that Lawrence Krauss has been able to give us a glimpse of an open, fascinating problem in physics that is far from being solved: the existence and essence of dark matter. The book can be read by the layperson but is also useful for scientists and non-specialists in cosmology.

Pedro G Ferreira, Oxford.

Supersymmetry – Unveiling the Ultimate Laws of Nature by Gordon Kane, Helix/Perseus, 0 7382 0203 7, 224 pages, hbk \$26.

Gordon Kane's opus offers the general reader an introduction to supersymmetry. In a brief foreword, Ed Witten describes the search for supersymmetry as "one of the great dramas in present-day physics", and Kane invites the reader to join him in a "leisurely walk" towards a grasp of this theory.

The author is certainly a well qualified guide. The book contains no technical passages inaccessible to the ordinary reader and there are few equations. A number of more arcane concepts relegated to short appendices will be of benefit to the physicist. The ascent is gradual, with many pauses for breath to enjoy the view, and in the final chapters the reader can be assured of acclimatization to the rarefied atmosphere of superstring theory, M-theory and what Kane terms "primary" theory.

From the outset the author distinguishes between well established areas of knowledge, such as the Standard Model, and what he refers to as speculative Research in Progress, as in the case of supersymmetry (SUSY). Similarly, he divides the answers provided by theories into "how" things happen and, on a higher level, "why" they happen.

The foundation of the Standard Model is clearly presented – the forces, the particles and the fields, as well as their governing theoretical principles. The reader is initiated into a straightforward use of Feynman diagrams to understand the processes that occur. The role of spin is underlined, as well as the difference between fermions and bosons, which supersymmetry will by definition associate as "mirrors" of each other. The "how" of the Higgs mechanism in the Standard Model is covered, with details consigned to an appendix.

Kane makes full use of the notion of

organizing effective theories by distance scales. A theory valid up to a certain scale is improved, at smaller distances, by its successor, answering the “why” where its predecessor merely addressed the “how”.

An effective theory needs a number of parameters (masses, coupling intensities, etc) that it cannot predict. This will be as true for supersymmetry as it is for the Standard Model, despite the progress that it will bring. Beyond these levels would be a theory not requiring such external props, which Kane calls the “primary theory”. Could this already be in our sights with M-theory? If not, how many more stages are there?

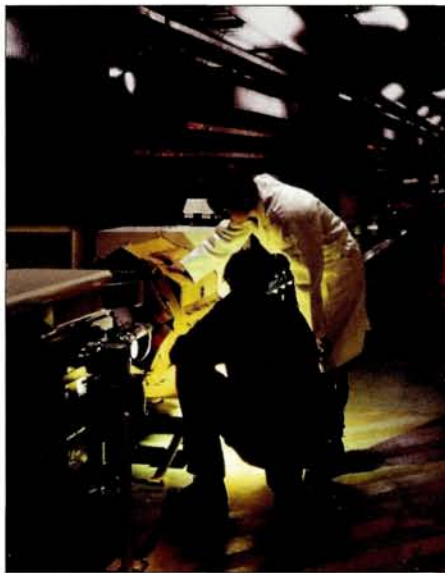
Kane provides a straightforward and pertinent description of supersymmetry, underlining the importance of the new answers that it will bring. Supersymmetry explains the “why” of the Higgs mechanism, predicting that the top quark must be heavy, which has already been verified experimentally.

Supersymmetry explains why the mass scales between that of observed particles and the distant Planck scale are stable, a serious stumbling block for the Standard Model. It offers possible unification of the various forces observed at very high energy. It also proposes an ideal candidate to explain the “hidden mass” of the universe. It is clearly a broken symmetry because the anticipated partners of known particles have yet to be observed. One of the main goals of existing accelerators (such as LEP and the Tevatron), and subsequently of the LHC, is to flush out these hidden supersymmetric partner particles.

Naturally the author looks at the most predictive aspect of SUSY phenomenology. Although our understanding of the mass of superparticles is still hazy, current theory in its minimal version predicts at least one Higgs boson, and very light, according to Kane lighter than one-and-a-half times the mass of the Z.

The search for the Higgs boson is naturally the main objective of current experiments. If the theory is right, Kane predicts that the first SUSY signals should be found soon, with a bit of luck even at LEP and probably at Fermilab’s Tevatron.

Finally, Kane unflinchingly tackles the most fundamental questions in an overview of current attempts to formulate a primary theory – superstrings and their synthesis in M-theory. Having attained this vantage point, the reader will discover that the evident beauties



Higgs hunting, supersymmetric or otherwise – CERN’s LEP electron-positron collider.

of the landscape are overshadowed by further mountain ranges whose peaks are still wreathed in clouds.

Kane also speculates on the future of particle physics and cosmology. Convinced that epistemological scepticism regarding the practical limits of knowledge is not founded on solid arguments, and that the funding for such research should be recognized as a good investment, he hopes that we will achieve a true understanding of the physical universe. He shows that the progress of theories, by increasingly correlating parameters previously considered as independent, will enable us to see the world as less and less accidental and improbable, and will gradually eliminate the temptation to have recourse to anthropic principles.

Particle physics and cosmology research could then be wound up, not because we will have failed to attain the primary theory, but because we will have succeeded in constructing it. One may not share the author’s faith, but his optimism is reassuring.

Kane hopes that the book will remain useful even after the discovery of supersymmetry. Whether and whenever that discovery is made, this instructive, cogent and well written text can in any case be highly recommended. *Daniel Treille, CERN.*

Journeys Beyond the Standard Model by Pierre Ramond, Perseus, 0738201162.

Judging by this book, Pierre Ramond must be somebody who spends more time packing

his suitcases than travelling. He must therefore be a very well prepared and careful traveller. Two-thirds of *Journeys Beyond the Standard Model* is devoted to the Standard Model of fundamental particle interactions. However, those first seven chapters contain much more than an introduction. The Standard Model is presented using a modern point of view – the one usually taken by researchers working to extend the theory to a more fundamental level.

The lessons of the first part of the book are of paramount importance in the construction of theories beyond the Standard Model. For instance, emphasis is given to an effective-theory approach, in which higher-dimensional operators are understood as the low-energy manifestation of a fundamental theory emerging at very short distances. The discussion of the approximate symmetries of the fermionic sector (baryon, lepton and flavour symmetries) and Higgs sector (custodial symmetry) not only provides a deeper understanding of the Standard Model structure but clarifies the basic problems encountered in its extensions.

The book requires a previous knowledge of field theory. Nevertheless, the first chapter contains a brief recollection of important results of the spinorial representations of the Lorentz group, of gauge fields with and without spontaneous symmetry breaking, and of group theory. The discussion of group theory, although short, is very lucid and instructive for particle physicists interested in theories beyond the Standard Model. It is written in “Dynkinese”, the group-theoretical language based on Dynkin diagrams. In the Standard Model the group structure is rather simple and the group-theoretical language is a matter of taste. However, research in Grand Unified theories uses Dynkinese, because keeping track of tensorial indices in large group representations is often totally impracticable.

After some history of the Standard Model, its Lagrangian is presented in its full glory. We learn about its astonishing simplicity in terms of principles and its impressive experimental confirmation. One emerges with the conviction that the Standard Model is one of the greatest intellectual achievements of mankind. The discussion in Ramond’s book is clear and complete – one of the best ever published. The study of the electroweak vacuum is presented with a careful treatment of gauge fixing in theories with spontaneously broken and unbroken gauge symmetry. The book also

contains many detailed examples of calculations of Standard Model processes (tree-level decays, loop corrections to electroweak observables and strangeness-changing kaon processes).

A full chapter is devoted to the chiral Lagrangian and its applications at a depth that is unusual for introductory books on the Standard Model. The author is thus able to introduce many concepts (construction of effective theories for strong interactions, non-trivial vacuum structure of gauge theories and anomalous global symmetries) frequently used in attempts to formulate theories beyond the Standard Model. Many applications of these concepts are found in the chapter on axions towards the end of the book.

While the presentation of the Standard Model in Ramond's book is systematic and of extremely high quality, the discussion of theories beyond the Standard Model is more episodic. Indeed, as suggested by the title of the book, Ramond is offering some journeys into the vast territory of new physics; he makes no claim to discuss the complete subject thoroughly.

The first journey describes possible theoretical explanations for neutrino masses, and the experimental evidence for neutrino oscillations in solar and atmospheric neutrino experiments. In the second journey the author investigates axion properties and derives their effective interactions with matter and radiation. The third journey presents the minimal supersymmetric extension of the Standard Model.

All three chapters are successful introductions to their respective subjects. More advanced readers may remain dissatisfied with the space allotted to these topics – especially for supersymmetry, a subject by now too vast to be covered in any depth by a single chapter of a book.

Anybody who wants to start a journey beyond the physics of the Standard Model will find this book a wonderful travelling companion. It provides a clear and insightful description of the structure of the Standard Model and gives the necessary tools to approach the frontier research in the domain of new physics.

Ramond's book is also very timely, because research in particle physics is now moving from the period of consolidation and confirmation of the Standard Model to a period in which both theoretical speculations and experimental activity will focus on

understanding deep questions that lie beyond the Standard Model's predictability, such as the mechanism of electroweak breaking, the origin of masses and the unification of forces.

Imaginative physicists have produced many possible "ultimate" theories to extend the Standard Model. What are now needed are data to test these hypotheses and guide the

speculations. There will be much to gain by the unprecedented investigation of nature at distances of less than 10^{-19} m. Considerable understanding of the fundamental principles of physical laws can be revealed by undertaking the journeys described in Pierre Ramond's book, provided that the traveller invests in the Standard Model groundwork excellently sur- ▷

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Gian Francesco Giudice, Theoretical Physics Division, CERN.

Introduction to High Energy Physics by Donald H Perkins (4th edition), Cambridge University Press 0 521 62196 8, £30/\$49.95.

Does Donald Perkins' classic *Introduction to High Energy Physics* need another review? When the first edition appeared in 1972, it quickly established itself as one of the most authoritative and successful textbooks on particle physics. However, the latest revision appeared in 1987 – before the advent of physics at LEP, the SLC, the Tevatron and HERA – and was beginning to show its age.

Donald Perkins' distinguished career as an experimental particle physicist has been intimately connected with physics at CERN, where he has been a prime mover of many landmark experiments on neutrino scattering with bubble chambers. He has served as chairman of the Scientific Policy Committee and as UK delegate to the CERN Council. After retiring from his chair at Oxford, he has found the time to tackle a new edition.

The result is worth the wait: this is not just a straightforward update, it is a major rewrite, and the most comprehensive revision so far. It goes without saying that the book covers all significant developments of the past 15 years. Equally important, it has been reorganized thoroughly, such that the discussion is now firmly embedded in the classification of particles and forces of the Standard Model. A welcome addition are two new chapters that treat "Physics beyond the Standard Model" and "Particle physics and cosmology" in much more detail than previous editions and present the relevance of particle physics in a wider scientific context.

Notwithstanding the revised and more logical organization, the fourth edition does not sacrifice any of the qualities that have made previous versions so popular with students and lecturers alike. It focuses on phenomenological concepts rather than theoretical rigour, prefers illustrative examples and intuitive approaches to completeness and abstraction, and emphasizes the historical dimension to illustrate that particle physics is, more than ever, a fast-moving field.

To retain the same page count as previous editions, some material had to be omitted: this is less regrettable for the chapter on

"Hadron-hadron interactions" than for most of the appendices, which provided much handy reference material. Useful additions to the supplementary material are a glossary, a historical account of "Milestones in particle physics" and a bibliography.

The latter is somewhat of a mixed success – while being a good guide to many classic books and papers, it omits many excellent, recent review articles that could take the novice reader to the forefront of current research in greater detail than is possible in a textbook. However, these are minor flaws when compared with the outstanding qualities of a book that once again is well poised to introduce generations of future researchers to the fascination of particle physics.

Rüdiger Voss, CERN.

Gauge Theory of Elementary Particle Physics: Problems and Solutions by Ta-Pei Cheng and Ling-Fong Li, Oxford University Press 0 19 850621 X, £23.95.

Designed as a companion volume to *Gauge Theory of Elementary Particle Physics* by the same authors, this 300-page collection of problems over the full range of field theory applications has very helpful solutions and further explanations.

The Theory of Quantum Liquids by Philippe Nozières and David Pines, Perseus Advanced Book Classics 0738202290, pbk \$49.

Long available as two volumes (*Normal Fermi Liquids* and *Superfluid Bose Liquids*), these reliable classics are now available as a combined volume in paperback.

Unifying themes in Complex Systems edited by Yaneer Bar-Yam, Perseus, 07738200492, hbk \$60.

These are the proceedings of the International Conference on Complex Systems, in the New England Complex Systems Institute Series on Complexity.

Principles of Applied Mathematics: Transformation and Approximation by James P Keener (updated and revised), Perseus 0 7382 0129 4, \$60.

The new edition of this successful book includes material on wavelet analysis, multi-grid methods and homogenization theory, and the introduction of popular software tools. The exercises have been extended, and hints and solutions are now provided.

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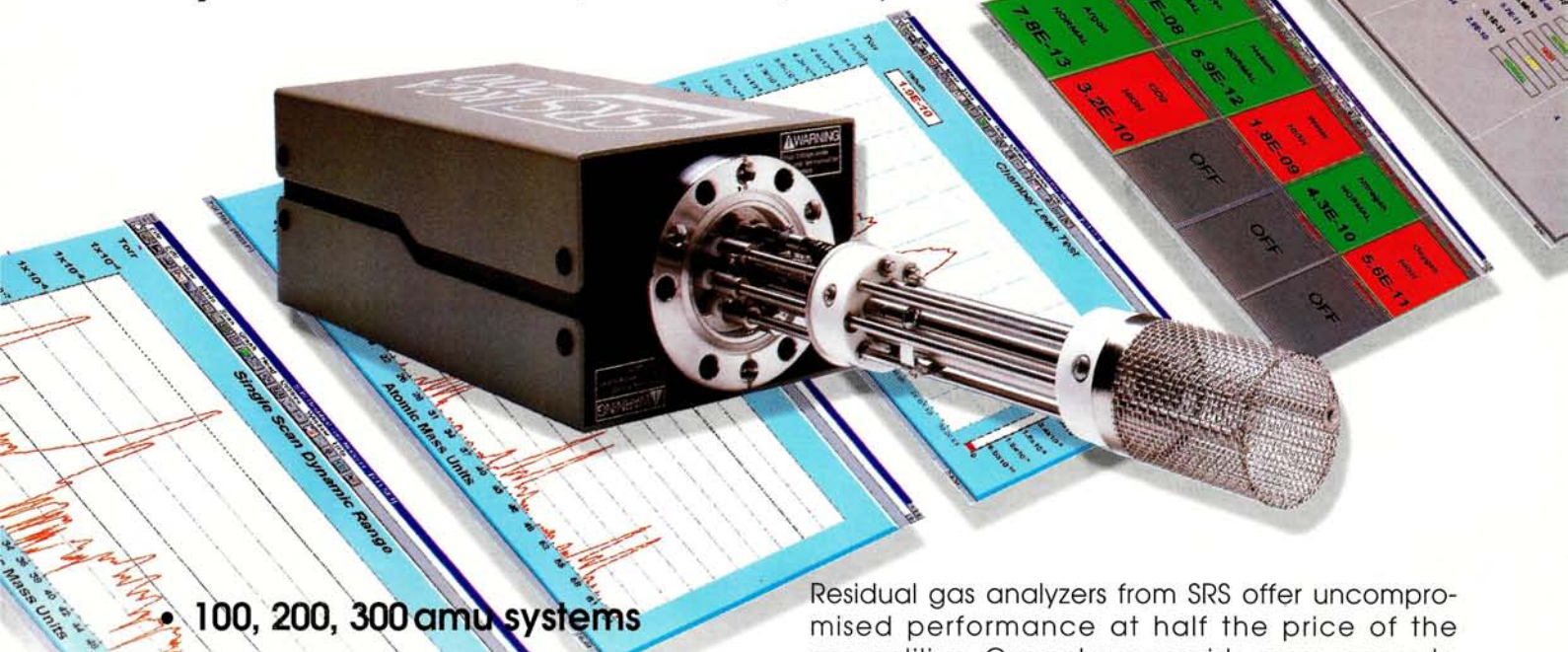
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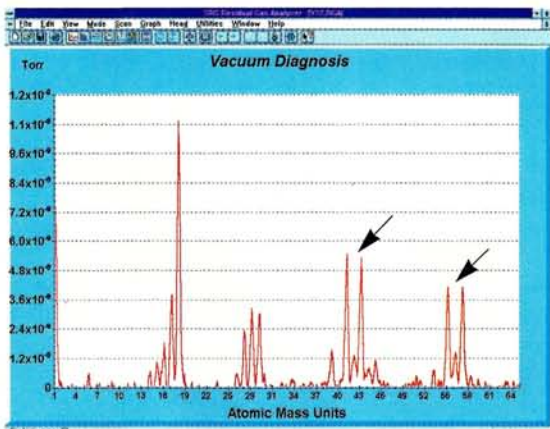
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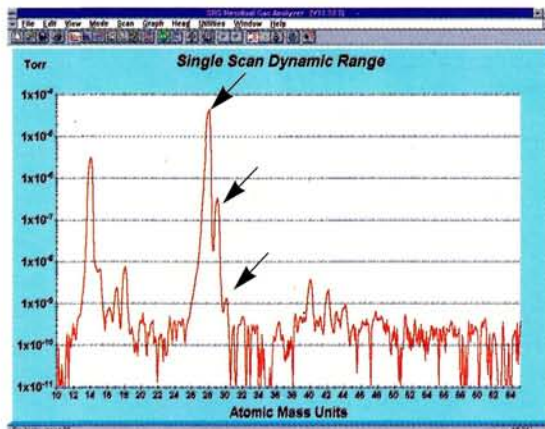


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- Optional Electron Multiplier

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The RGA is an invaluable vacuum diagnostic tool. Shown above is the mass spectrum of a vacuum chamber contaminated with oil.



With dynamic range that spans 6 orders of magnitude, three isotopes of Nitrogen (¹⁴N₂, ¹⁴N ¹⁵N, ¹⁵N₂) are clearly detected in a single scan.



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