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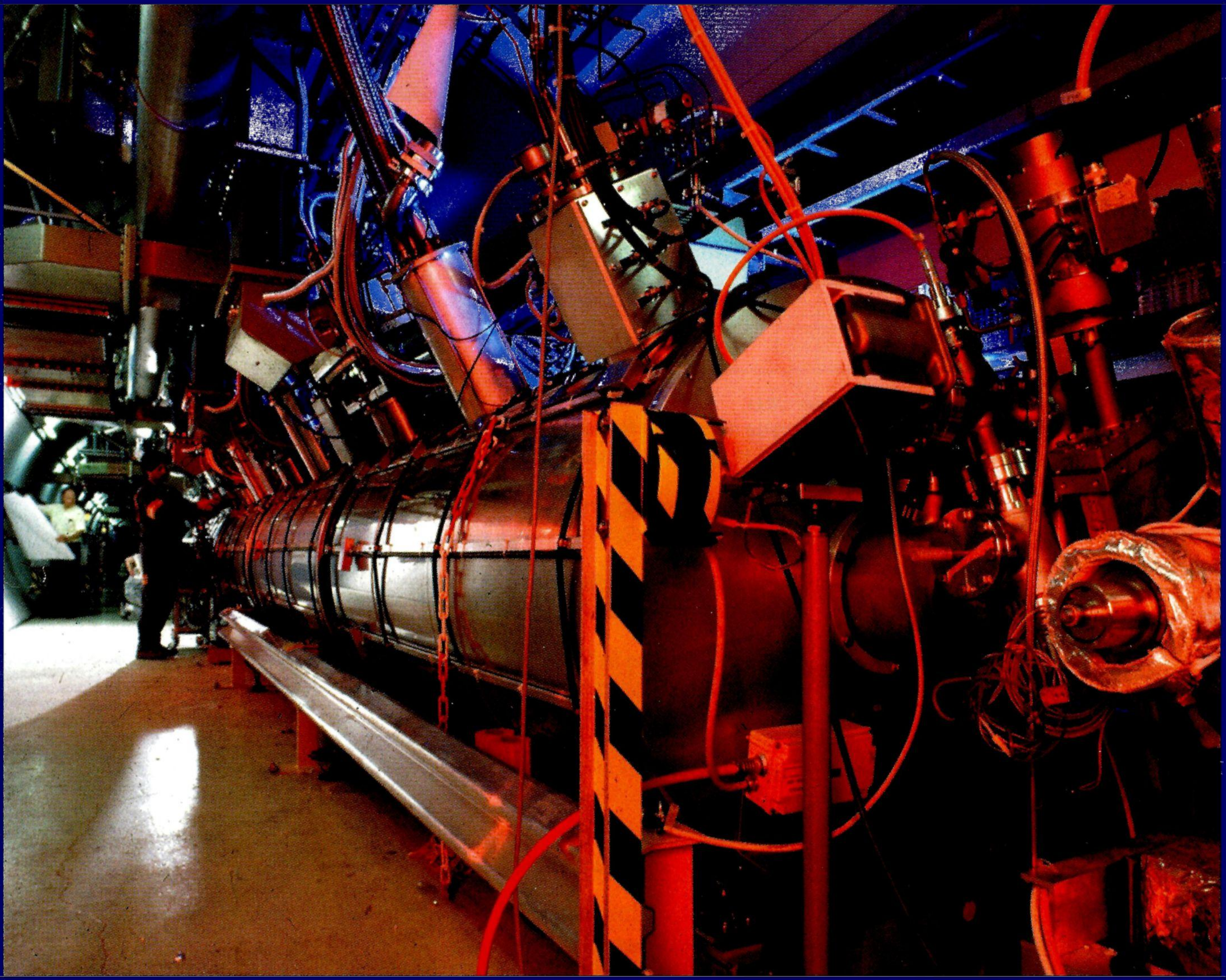
CERN COURIER

VOLUME 39 NUMBER 6 JULY 1999



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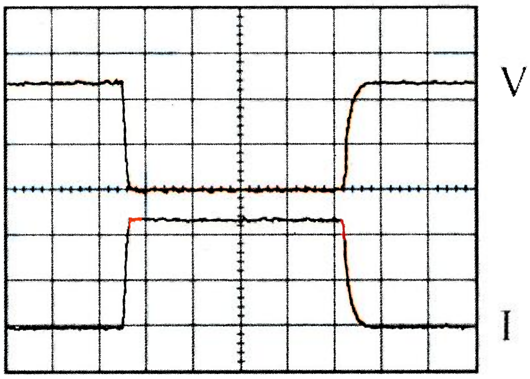

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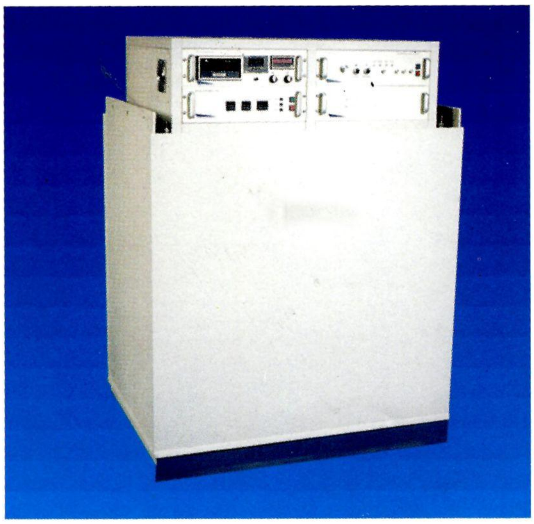

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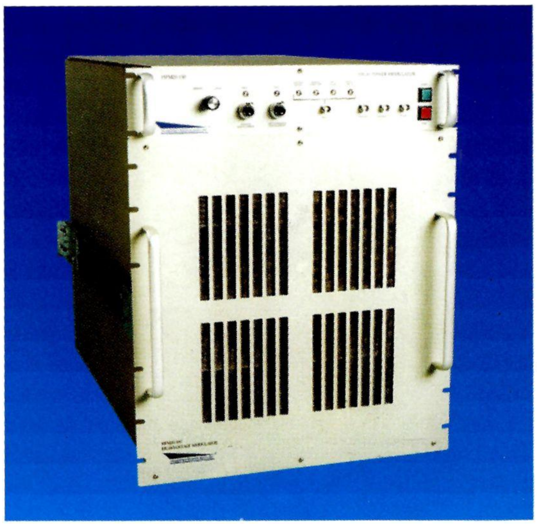

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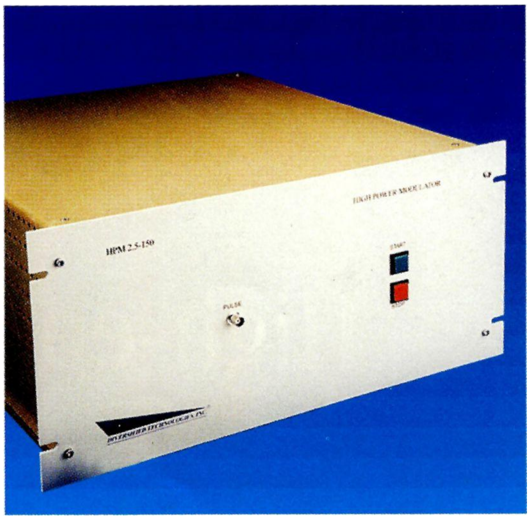

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VOLUME 39 NUMBER 6 JULY 1999

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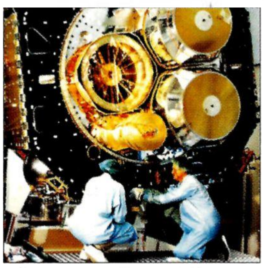
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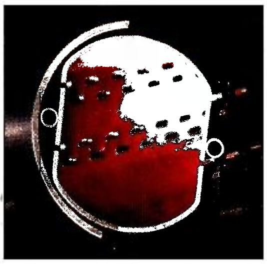
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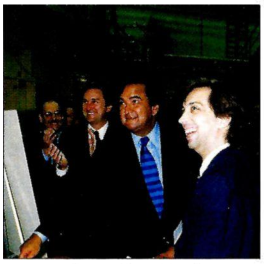
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Features

Cover: One of the modules of superconducting accelerating cavities in CERN's LEP electron–positron collider, which can take LEP's particles to record 100 GeV energies (p5).

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New Fermilab machine dedicated

Fermilab's new 2 mile circumference, 150 GeV main injector (foregound) injects particles into the larger Tevatron.

The world's newest particle accelerator – Fermilab's 150 GeV main injector – officially began its career on 1 June. The US Energy Secretary Bill Richardson, the Speaker of the House of Representatives Dennis Hastert and Illinois Governor George Ryan joined Fermilab staff and visiting scientists in celebrating the on-time, under-budget completion of the $260 million project.

"It has taken seven years to reach this dedication day – a long time," said Fermilab director John Peoples, whose 10 year term in office has spanned the entire project.

The new main injector will, literally, be a major boost for Fermilab's centrepiece machine – the superconducting Tevatron proton synchrotron and proton–antiproton collider.

In 1991 a $2.2 million challenge grant from the state of Illinois enabled Fermilab to take the first steps towards building the new main injectors. Federal funding was approved in October 1991, and construction got under way in 1993.

The main injector team worked together so well that a new storage ring – the antiproton recycler – was added to the accelerator complex without increasing the total project budget or delaying its scheduled completion.

The recycler, which shares the new, 2 mile, circular tunnel with the main injector, uses permanent magnets to retrieve, store and literally recycle antiprotons that would previously have been discarded.

The Tevatron, which began operations in 1983, was previously fed by Fermilab's original main ring, closed in 1997 after 25 years of service. The Tevatron and the main ring shared the same 4 mile circumference tunnel. As the Tevatron injector, the main ring was a bottleneck in the antiproton supply.

LEP hits 100

A "family album" photograph of the final module of superconducting accelerating cavities for CERN's LEP electron–positron collider. These cavities power LEP beams to 100 GeV.

CERN's LEP electron–positron collider walked onto the stage for its 1999 season and, after its customary greeting at the Z resonance (45 GeV per beam), impressed the waiting audience by quickly taking a shot of electrons to a record 100 GeV. This showed how smoothly its complement of 288 superconducting accelerating cavities can pull together, supplying 3.15 GV (3.3 GV without beam).

Soon after, colliding beams were established with 98 GeV electrons and positrons for radiofrequency tests. After these spectacular opening fireworks, high-energy physics got under way with 96 GeV electron and positron beams. Collision rates were high, with luminosities well above 10^{31} $cm^{-2}s^{-1}$, with sizable beam currents and good integrated luminosities (1–2 inverse picobarns per day).

Just 10 years ago, LEP began operations equipped with room temperature copper radiofrequency accelerating cavities, supplying 45 GeV per beam. From 1995, equipped with superconducting cavities, LEP's beam energy was increased to 65 GeV, then to 80.5 GeV in 1996 with more superconducting accelerating power. Last year, LEP ran routinely at 94.5 GeV per beam.

At these new high energies, the LEP experiments are treading on potentially very fertile physics ground and could soon reveal what makes the electroweak theory tick.

Magnetic detector sees cosmic-ray anomalies

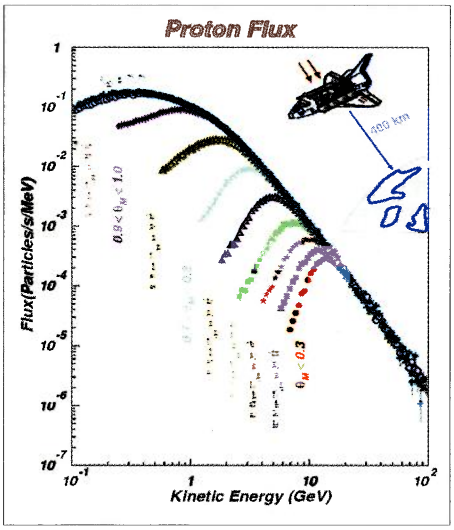


Fig. 1: Expected cosmic-ray proton distribution with latitude at an altitude of 400 km.

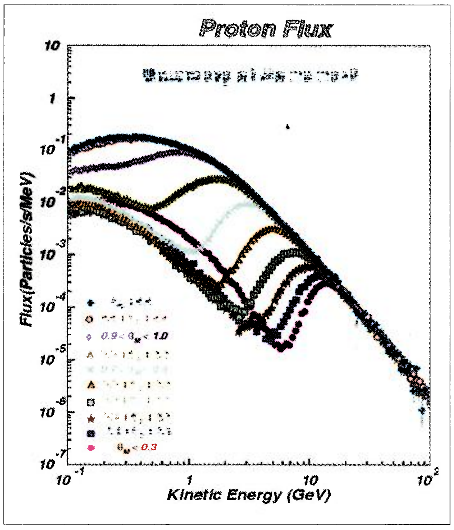


Fig. 2: Cosmic-ray proton distribution measured by the AMS experiment aboard the Space Shuttle at various latitudes.

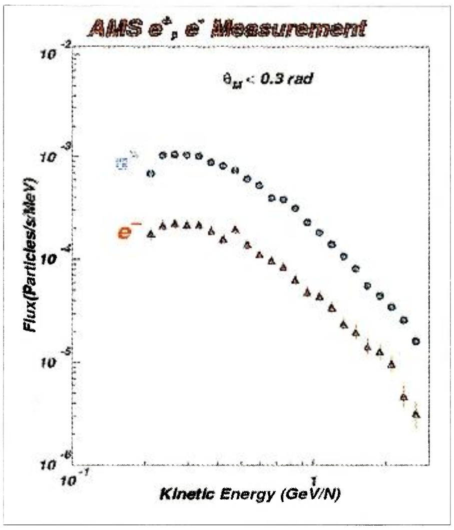


Fig. 3: Antiparticle puzzle. In the equatorial region, AMS sees about four times as many low-energy positrons as it does electrons.

As reported briefly in the June issue (p6), the Alpha Magnetic Spectrometer (AMS) presents several intriguing effects, which include unexpected distributions of cosmic-ray particles, from its 1998 trial Space Shuttle flight.

From 2 to 12 June 1998, AMS was the primary payload of NASA's Space Shuttle Discovery in orbit 400 km above the Earth. This was a shakedown mission prior to deploying AMS on the International Space Station in a few years time.

AMS is a sophisticated magnetic detector of the type normally used in high-energy physics laboratories. During the 10 day voyage, AMS recorded the tracks of millions of cosmic-ray particles. It was the first time that such a sophisticated physics detector had been deployed in space and the first time so much information on cosmic particles had been recorded. The first results from this mission have been eagerly awaited.

The advertised goal of AMS was to search for signs of cosmic antimatter. In a universe created from a Big Bang that must have generated matter and antimatter in equal initial amounts, there should be signs of this primordial antimatter, with antinuclei built of antiprotons and antineutrons. However, our universe appears to be built up entirely of matter and no experiment has ever detected any primordial antimatter. AMS set out to look for antinuclei above the screen of the atmosphere, but a sample of almost 3 million cosmic helium nuclei arriving from outer space did not reveal one helium antinucleus. AMS sees no primordial antimatter, but 3 million nuclei is not many and the search continues. However, AMS did see several other unexpected effects, which show that the behaviour of cosmic rays is much more complicated than had been thought.

In orbit, AMS was able to intercept cosmic rays arriving at different latitudes as the Earth turned. Cosmic-ray protons have a range of energies and the Earth's magnetic field should repel less energetic particles. This terrestrial magnetic repulsion becomes weaker at higher latitudes, and more particles of low energy should be seen nearer the poles, with a magnetic cut-off at each latitude (figure 1). However, AMS finds that, below a certain proton energy for each latitude, there is no magnetic cut-off and the distribution increases strongly instead (figure 2).

When the Space Shuttle flips over, AMS can also collect cosmic particles moving upwards, away from the Earth. Few high-energy, upwards-moving protons are seen, but the spectrum fills up rapidly for lower-energy particles. In a band extending over 4000 km at the Space Shuttle orbit altitude of 400 km, below about 6 GeV AMS saw as many protons moving upwards as downwards. It is as though these particles are confined in a magnetic toroid around the equator.

A similar effect is found with electrons, but here it is interesting to compare the levels of electrons and their antiparticles – positrons. If cosmic-ray electrons and positrons are created in pairs by high-energy gamma rays, there should be as many electrons as there are positrons. However, in the equatorial region AMS sees about four times as many low-energy positrons as it does electrons.

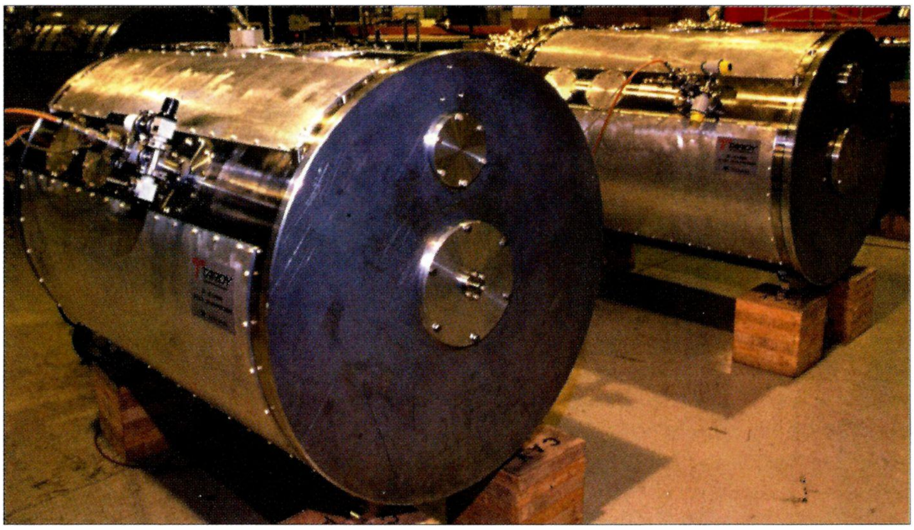
AMS also looked at the distribution of helium nuclei. In a final conundrum, around the equator and at low energies, AMS only sees the helium-3 isotope. Helium-3 is very rare on Earth but was one of the protonuclei formed during the one minute, or so, of the universe's primordial nucleosynthesis.

AMS is a major international collaboration covering Europe, the US, China and Taiwan and is led by Sam Ting of MIT – longtime spokesman of the L3 experiment at CERN's LEP electron–positron collider.

Correction

Last month we unfortunately misspelled the name of Eberhard Keil, who did such a thorough job in coordinating the reports from the 1999 Particle Accelerator Conference.

Accelerating power for the LHC



A protoype cryomodule containing superconducting accelerating cavities for CERN's LHC proton collider.

For CERN's new LHC proton collider, superconducting magnets will not be the only superconducting technology in the 27 km ring.

When the collider was commissioned in 1989, the energy of CERN's LEP electron–positron collider was 50 GeV per beam. After a dedicated period of running around the Z particle resonance, LEP's energy has been increased to 100 GeV per beam.

Behind the success story is the conversion of the machine from conventional radiofrequency to superconducting cavities to feed accelerating power to the circulating beams. Early on, research and development work for LEP showed that cavities made of niobium-coated copper were more effective than those of the more expensive solid niobium. The LHC is set to use this technology from the outset.

The LHC's radiofrequency must be a multiple of 200 MHz, the operating frequency of the upstream SPS synchrotron, to allow rapid transfer of many SPS proton bunches, but not so high as to make for operational incompatibility. Thus it is set at twice that of the SPS.

The radiofrequency scenarios for LEP's electrons and positrons, and the LHC's protons, are very different, even though they both use a 27 km ring. Electrons, being very light particles, lose a lot of energy per turn by synchrotron radiation, which has to be replaced continually by the "accelerating" cavities. Most of LEP's radiofrequency power is transferred to the beam and then dissipated by synchrotron radiation.

Proton beams lose little energy in this way. The main role of the LHC cavities is to keep the many proton bunches tightly bunched to ensure high luminosity at the collision points and to deliver power to the beam during energy ramping. Matching these radiofrequency conditions using conventional copper cavities would lead to unacceptable displacement of the beam crossing points.

Superconducting cavities with small losses and large stored energy are the best solution. This leads to a design using single-cell accelerating cavities with large beam tubes, similar to those considered for the new generation of electron–positron colliders.

The LHC will use eight cavities per beam, each capable of delivering 2 MV (an accelerating field of 5 MV/m) at 400 MHz. The cavities will operate at 4.5 K (the LHC magnets will use superfluid helium at 1.8 K). For the LHC they will be grouped in fours in cryomodules, with two cryomodules per beam, and installed in a long, straight section of the machine where the interbeam distance will be increased from the normal 195 to 420 mm. The cavities are being made by spinning and electron-beam welding, with the surface niobium being added by magnetron sputtering.

For LHC cavities, an ingenious mechanical tuner has been designed and successfully tested, to cope with the larger detuning range of the LHC cavities and their increased stiffness (compared with LEP cavities).

The experience gained with LEP couplers, which were once a very critical element of the LEP2 project, has led to the design of state-of-the-art LHC couplers, which link the cavity to the RF power system.

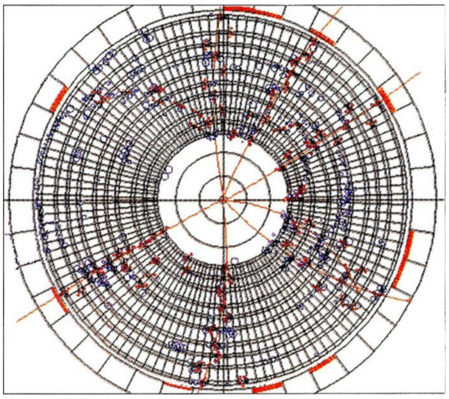
B factory sees first B events

On the morning of 26 May 1999, physicists recorded the first events in the large BaBar detector at the asymmetric B factory at the Stanford Linear Accelerator Center (SLAC). The factory began operating last year and was formally inaugurated on 23 October 1998 (*CERN Courier* December 1998 p5).

The collider was constructed by SLAC, Lawrence Berkeley and Lawrence Livermore National Laboratories with $177 million of US government funds. The BaBar detector was built by scientists and engineers from 73 institutions in the US, Canada, China, France, Germany, the UK, Italy, Norway and Russia. It has cost about $110 million in all, with 40% of the total coming from foreign sources.

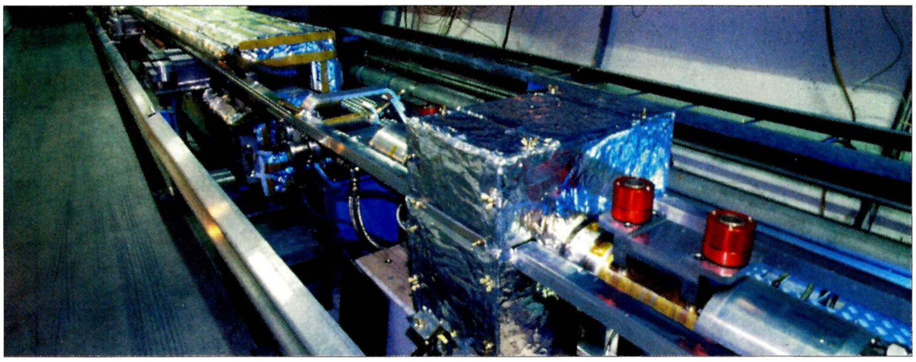
The goal of the detector is to study CP violation in reactions involving B particles, containing the fifth ("beauty", "bottom" or simply "b") quark.

The first published results should be available by next year.

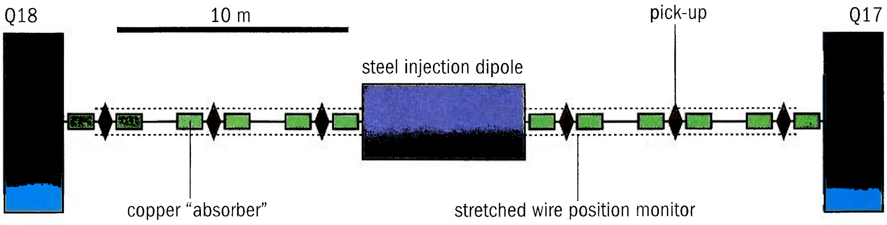


An early event recorded by the BaBar detector at the asymmetric B factory at SLAC.

Precision physics progress



The main magnet (covered with foil to control temperature) of the spectrometer for precision measurements of the beam energy of CERN's LEP electron–positron collider ring.



Schematic of the new spectrometer, showing the surrounding pick-ups to track the path of the beam and the absorbers to soak up synchrotron radiation.

CERN's LEP electron–positron collider has underlined the importance of precision measurements in particle physics. For this work it is vitally important to know the beam energy of this huge machine as accurately as possible.

In 1983, the UA1 and UA2 teams at CERN's proton–antiproton collider saw the Z particle – the electrically neutral carrier of the weak interaction – via a handful of events. By the mid-1990s the four experimental teams at CERN's LEP electron–positron collider had accumulated millions of Zs.

The object of this massive data sample was to establish the consistency of the underlying Standard Model of particle physics. Before the sixth "top" quark was found at Fermilab's Tevatron proton–antiproton collider in 1994, this LEP data provided a valuable indication of where the top quark – then the missing element of the Standard Model – should lie.

With the discovery of the top quark, and the underlying Standard Model of physics in such good shape, the central requirement now is to pin down the parameters of the long-sought Higgs particle, which is responsible for the symmetry breaking at the heart of the Standard Model. Precision measurements could also aid the search for discrepancies signalling new physics effects beyond the Standard Model.

This "precision physics" continued as LEP moved away from its initial target at the Z resonance and moved to higher energies to explore the production of the W, the electrically charged partner of the Z, where a precision fix of the W mass could serve as a valuable benchmark. Before LEP went to higher energies, W mass information came via proton–antiproton collision physics.

The first LEP W mass measurements in 1996 relied on determining the production threshold, but, as LEP energies were increased further, the W mass was determined by the kinematics of the production processes.

This need for precision has driven a continual need to measure the energy of the particle in LEP as accurately as possible, hopefully to within 10–20 MeV, or about 1 part in 10 000.

Thus began a programme to identify and compensate for external factors that could influence the beam energy measurement. Tiny tidal effects in LEP, amplified by the acceleration process, can contribute up to 40 MeV to the beam energy. Gravitational effects, owing to the neighbouring Jura mountains and the level of water in Lake Geneva, have to be allowed for. LEP energy calibration has even become an expensive way of monitoring the passage of French TGV high-speed trains.

The main technique for accurately measuring LEP beam energy has been resonant depolarization, in which the spin alignment of the stored electrons is destroyed. However, this is only precise at lower energies, around 60 GeV per beam. With LEP now approaching 100 GeV per beam, the low energy measurements have to be extrapolated over a long distance, limiting the attainable precision.

To sidestep this, LEP embarked on a project to mount a magnetic spectrometer inside the ring that will measure the beam energy directly via magnetic deviation.

The spectrometer is a steel dipole magnet, mounted in the LEP ring between the standard dipole magnets, with steel laminations in concrete, which are used to guide LEP's particles. Beam position monitors either side of the spectrometer dipole track LEP particles as they enter and leave, the objective being to measure variations in the bending of the particles to an accuracy of 10^{-4}. The adjacent monitors measuring to within 1 μm.

As LEP's particles are bent round the ring, they continually emit a "screech" of synchrotron radiation that can reach levels of almost 1 kW/m. This emission is not dangerous in an uninhabited ring and disappears as soon as the machine is switched off. During operation, however, this radiation can heat up mechanical supports, producing expansions and contractions of the order of microns, which would mask the spectrometer measurements. To avoid this, the monitors are shielded by copper absorbers to soak up the synchrotron radiation. A stretched wire positioning system checks the relative position of the beam position monitors to within a 1 μm.

The system is now installed and recording preliminary data prior to regular operation later this year. The new spectrometer provides a vivid example of precision microengineering and electronic read-out for physics.

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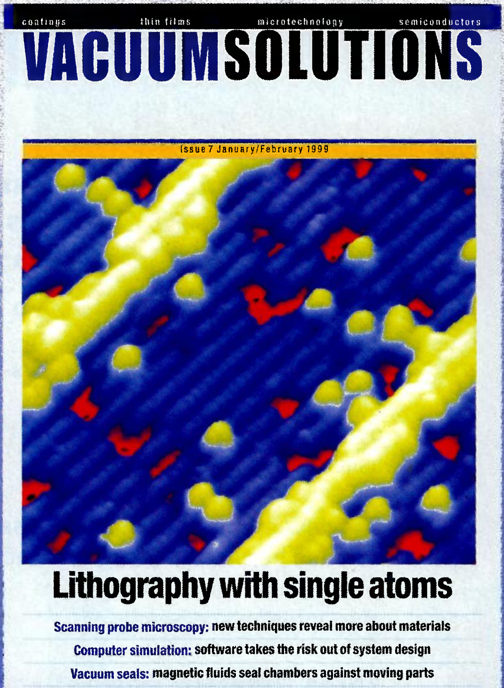
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Issue 7 January/February 1999

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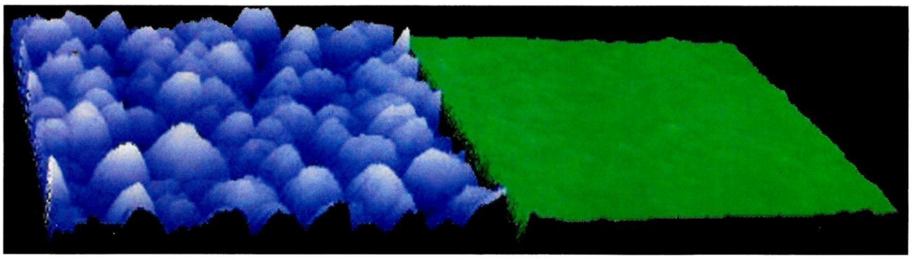
The rough and smooth



Piling atoms on a substrate can produce a rough surface as forces between the atoms cause them to build up in peaks (as left, which shows a 10-atom thick layer of silicon). Understanding this mechanism means that atoms can be manipulated to produce surfaces that are smoother (right).

Scientists at Twente in the Netherlands have demonstrated the effect of "steering" when making thin films of copper atoms on a surface. Long-range attractive forces "steer" incoming atoms towards existing peaks of atoms in the substrate, thereby increasing the roughness of the surface. This effect is even stronger for atoms grazing the surface.

Understanding the causes of roughness will lead to the ability to produce smoother surfaces, but roughness could also be deliberately encouraged to make arrays of surface ridges as templates for magnetic nanowires, for example. *AIP*

Mars has magnetic stripes

New data from NASA's Mars Global Surveyor may indicate that Mars once had plate tectonics similar to those that exist on Earth.

On Earth, as magma flows from ridges between tectonic plates and cools, iron in the magma aligns with the planetary magnetic field. In time, the material spreads out from the ridge, and planetary field reversals cause a pattern of magnetic stripes to be formed.

A team of physicists from France and the US have discovered similar stripes around some ridges and craters on the surface of Mars. The stripes are more strongly magnetized than on Earth (possibly because Mars has a higher concentration of iron in its crust) but are also longer and wider, suggesting that the magma flowed more quickly or that the planetary field flipped less frequently. Some of the younger surface ridges do not have magnetic stripes, which is consistent with tectonics ceasing some 4 billion years ago as the iron-rich core of Mars cooled and froze.

However, other physicists believe the magnetic stripes are too strong to be explained by plate tectonics and are perhaps the result instead of chemical activity.

Chips to be smaller, faster and cheaper?

Collaborative research by Cambridge and Hitachi has produced a new semiconductor memory device.

The phase-state low electron (hole) number drive memory (PLEDM^{TM}) cell allows the instant recording and accessing of massive amounts of information. The cell is smaller than existing devices and consumes very little power. It would make equipment such as computers and mobile phones both lighter and more economical.

Conventional devices employ a transistor and capacitor in the memory cell, but now the newly developed transistor, which is fabricated on silicon dioxide substrates using standard processes, has been stacked onto the gate of a conventional transistor to make a cell of $0.2 \times 0.4\ \mu m$ in area with a read/write time of less than 10 ns.

The new cell is a promising candidate for the multigigabit memory chip that is expected to become available early in the next century. It could replace current data storage devices, such as hard disk drives. *AlphaGalileo*

Early warning

A novel technique that can be used for breast cancer scanning could avoid the need for a biopsy, which is currently used to identify cancerous tissue.

Tumour tissue is about 40 times as conductive as normal tissue. Therefore, cancers can be identified by applying just 1 V across a patient's body. A scanner employing this method has recently been approved for use in the US. *New Scientist*

The age of CAMP

Probably the largest outpouring of lava from the Earth's core took place about 200 million years ago, forming a huge expanse of basalt across the ancient super-continent Pangaea. As tectonic forces tore Pangaea apart, forming the Atlantic Ocean, the basalt of the Central Atlantic Magmatic Province (CAMP) fragmented, and this now lines the Atlantic rim in Europe, Africa and the Americas.

Now geophysicists from Berkeley, Trieste, Padova and Sao Paulo have identified basaltic deposits in northern and central Brazil, extending the known size of CAMP by 2.5 million to around 7 million km^2.

The abundance of the isotopes argon-40 and 39 date the basalt samples to 200 million years ago and the position of the magnetic pole of the samples indicates the same age. Their normal polarity also indicates that CAMP formed within 4–5 million years – very brief by palaeontological standards – because before and after there were long intervals of reversed polarity or frequent polarity reversals.

The measured CAMP age matches the boundary between the Triassic and Jurassic, and the volcanic activity may be linked to mass extinctions at that time. *AIP*

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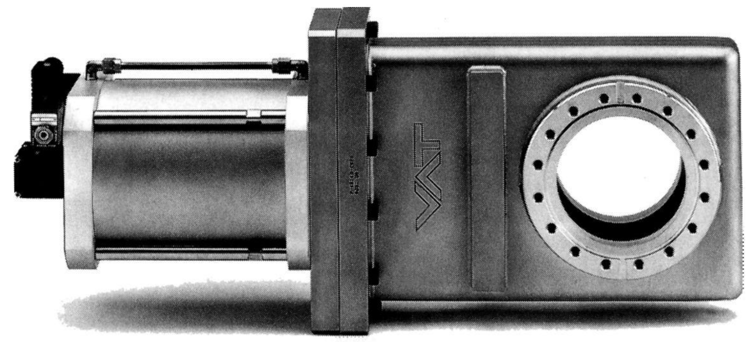

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Edited by Emma Sanders

Astrowatch reports on the meeting of the European Space Agency's governing body with European science ministers in Brussels in May.

Space agency looks to the future

"The decisions taken here in Brussels will set the direction for the agency for the next five years and beyond," said European Space Agency (ESA) director Antonio Rodota, following a meeting of ESA's governing body with European science ministers in May.

The ministers agreed to keep the core budget of €2112 million constant for the next four years and announced a top-up fund called "complementary science funding", which is expected to average around €10 million a year. The remaining 85% of ESA's funding is provided by governments on an "à la carte" basis – the governments subscribe to the schemes that interest them.

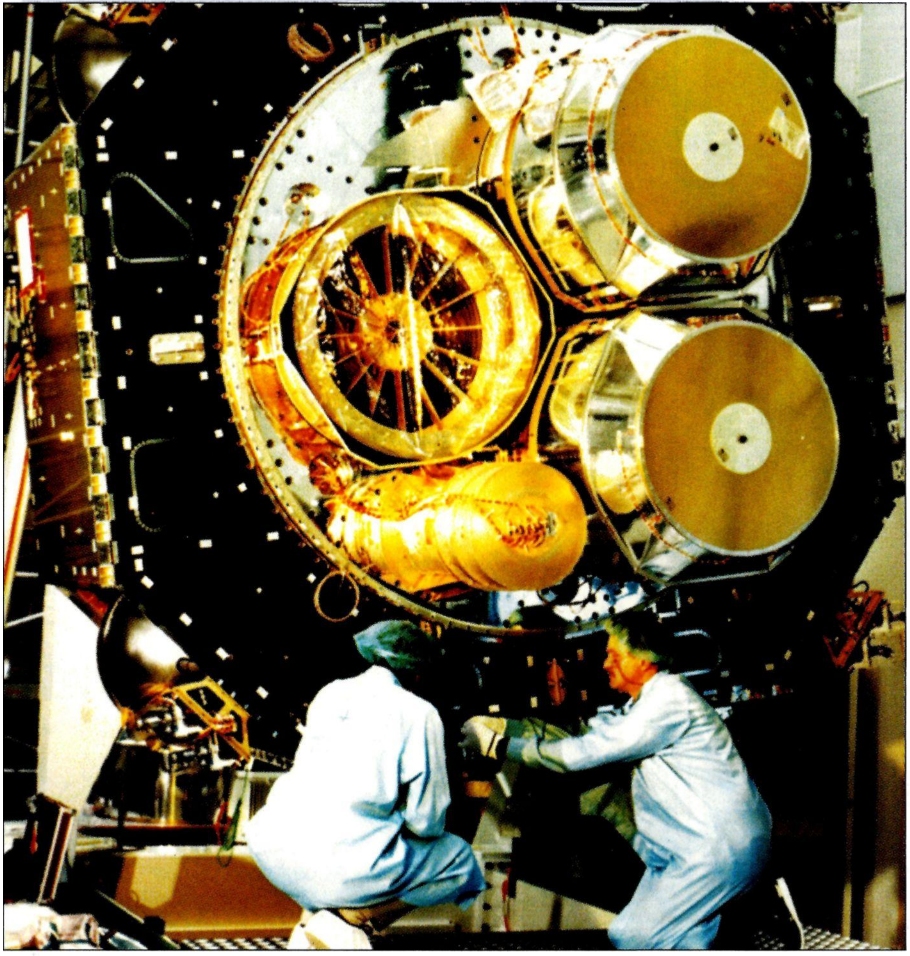
Following the Brussels meeting, ESA's Scientific Policy Committee met in Berne to define the launch schedule of the major science missions up until the year 2007. The schedule comprises:

- 1999: XMM, an X-Ray telescope (see "Picture of the month");
- 2000: Cluster II, to study plasmas in the Earth's magnetosphere (March p9);
- 2001: Integral, a gamma-ray telescope with a ground station in Geneva. (November 1998 p9);
- 2003: Rosetta, a mission to land on the comet Wirtanen, and Mars Express (October 1998 p9);
- 2007: FIRST, a far-infrared telescope, and Planck, a microwave telescope (see "Planck and FIRST given go-ahead" p14).

The space agency's contribution to the International Space Station was also confirmed. However, Hans Balsiger, outgoing chairman of the scientific policy committee, said that he had "hoped to gain more". In particular, he is worried that budget constraints will limit ESA's smaller missions, such as the SMART technology test missions that are planned for 2001.

One thing is certain: European industry will have a significant role to play. The science ministers emphasized the importance of transferring greater responsibility to industry and engaging in a wider range of partnerships.

Picture of the month



Three gold X-ray mirrors have been fitted to ESA's X-ray space observatory (XMM), which is under construction in the Netherlands. XMM stands for X-ray Multi-Mirror, and these mirrors will give the most sensitive picture of the X-ray universe ever. In particular, the telescope will be used to look at emissions from gas circling black holes and from extremely hot objects that formed when the universe was young. An additional telescope will provide complementary observations in visible and ultraviolet light. The satellite is due for launch next January. (European Space Agency.)

Correction: Alert readers will have noticed that May's image, labelled supernova remnant, was in fact a planetary nebula.

Planck and FIRST given go-ahead

The planning of two major astrophysics missions has been approved by ESA's scientific policy committee. The satellites Planck and FIRST will be launched together in 2007.

Planck is a cosmology mission that is designed to test models of the origin and evolution of the early universe by studying the cosmic microwave background radiation.

This radiation was released around 300 000 years after the Big Bang, when the universe had cooled sufficiently for atoms to remain bound together. Originally at a temperature of some 3000 K, it has now cooled to microwave radiation at a mere 3 degrees above absolute zero.

Studying small variations in this background radiation shows how matter was clumped together in the very early universe, revealing the "seeds" of future galaxies. Planck's angular resolution will be two orders of magnitude better than that of NASA's 1990 COBE satellite and its sensitivity will be improved by an order of magnitude.

FIRST (the Far InfraRed and Submillimetre Telescope) will look for planetary systems and study the evolution of galaxies in the early universe. The satellite's name is appropriate because the instrument will be able to observe certain wavelengths for the first time and will be more powerful than any of its predecessors.

To avoid background noise caused by emission from the instruments, FIRST will be cooled to 2 degrees above absolute zero by liquid helium. The telescope is the successor to ESA's Infrared Space Observatory (ISO).

For more information on ESA's physics missions, see "Fundamental physics in space" by Maurice Jacob (p16), chairman of ESA's Fundamental Physics Advisory Group.

Diamonds in space?

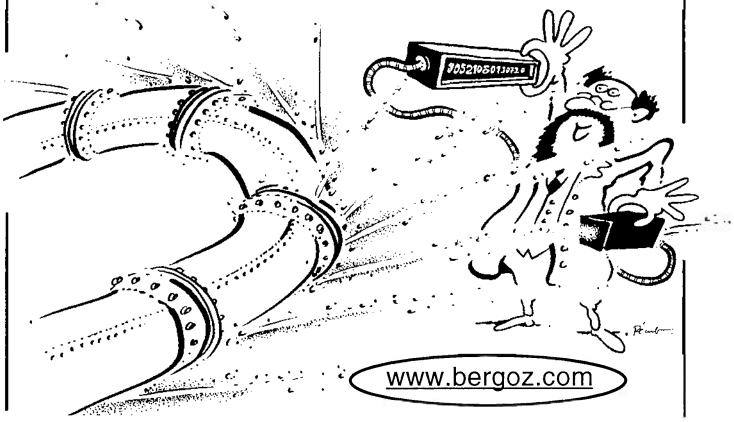
Results from the Infrared Space Observatory (ISO), after three years of data collection, reveal what appear to be diamonds in space.

The analysis of infrared emission from dust surrounding a dying star shows the presence of a carbon compound resembling diamond or buckyballs – football-shaped carbon molecules. Neither has been detected before in space, though their presence was predicted.

The feature originates from a complex carbon-based organic molecule (in gaseous or solid form). This shows that complex organic forms can be made by stars, over short periods (probably a few thousand years). Understanding their chemistry will help our understanding of the origin of life.

The astronomers say that industry may benefit from their discovery. If diamonds are indeed formed in the dust surrounding stars, at relatively low temperatures and pressures, new production methods could be developed.

ISO finished collecting data last year.



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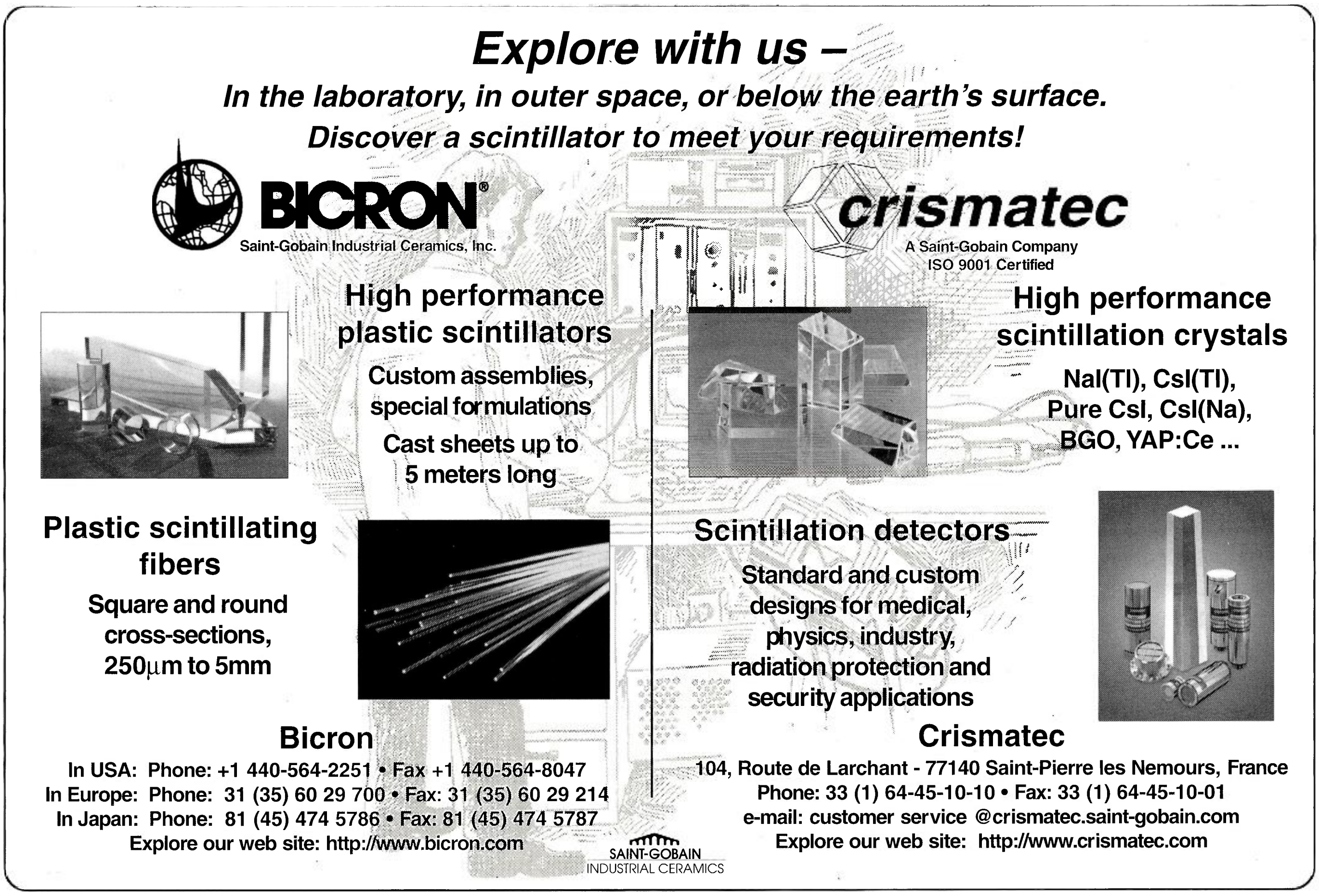

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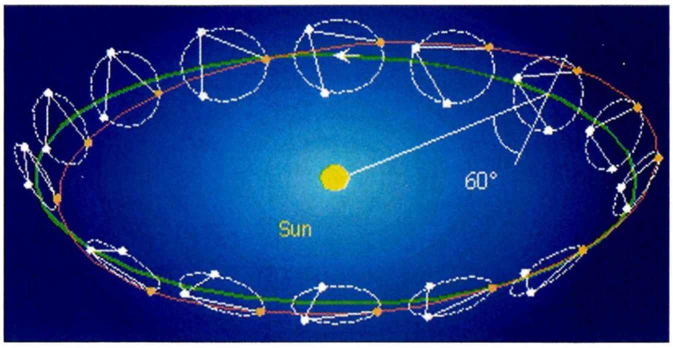
Fundamental physics in space

What better way of launching science in the new millennium than embarking on a programme of fundamental physics research in space? *Maurice Jacob* looks at existing plans and new possibilities.



The European Space Agency's LISA (Laser Interferometer Space Antenna) project is the flagship fundamental physics experiment in space. The LISA mission will consist of three spacecraft that will form an equilateral triangle with a distance of 5 million km between any two spacecraft. Gravitational waves passing through the solar system will generate small changes in the distances between each of the spacecraft. The distance changes can be made very accurately using laser interferometry.

A NASA/JPL conference on Fundamental Physics in Space, held in Washington DC, brought together the chairman and three vice-chairmen of Commission H of the International Committee for Space Research (COSPAR). Left to right: vice-chairman Maurice Jacob (also chairman of ESA's Fundamental Physics Advisory Group and the author of this article), chairman Francis Everitt of Stanford, vice-chairman Guenter Alhers of Santa Barbara (also chairman of NASA's Fundamental Physics Discipline Working Group) and vice-chairman Stefano Vitale of Trento.

Addressing fundamental physics questions in space is far from a new idea. In particular, the fascinating prospects of testing Einstein's theory to an unprecedented accuracy using the quietness of space environment and long observation times have long been considered. However, it was soon realized that flight conditions would have to be controlled to a very high precision.

In Europe, the 1971–1979 Fundamental Physics Panel, chaired by Herman Bondi, fully recognized the great interest of such missions but concluded that they were "projects for the 21st century". We are now at the eve of that century.

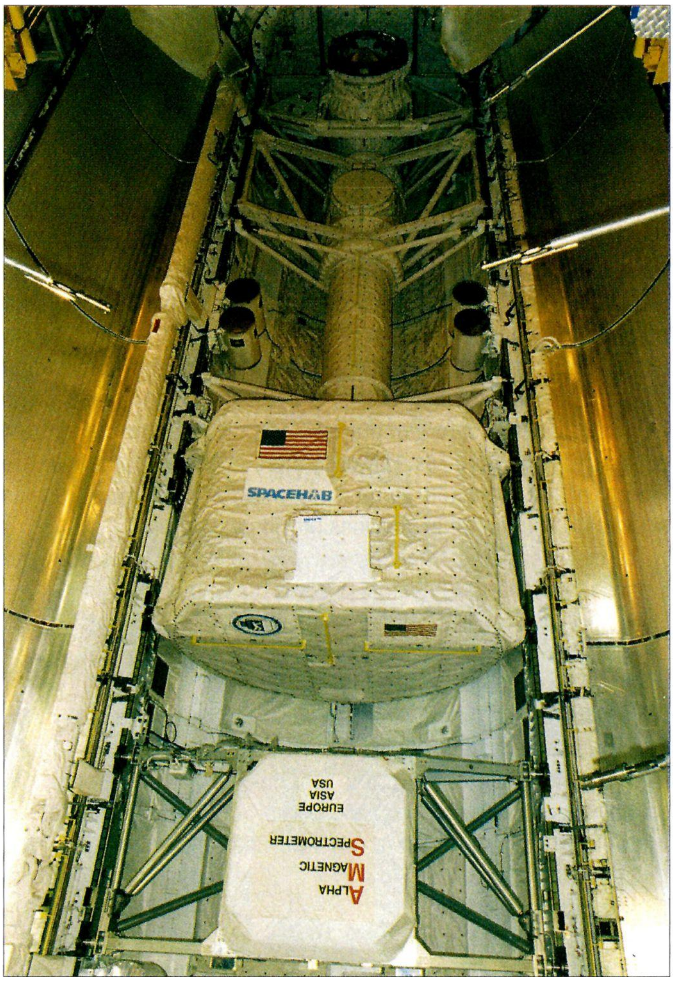
European plans

In 1989 the European Space Agency (ESA) announced a call for mission proposals also open to fundamental physics. By 1993, fundamental physics proposals represented close to one-third of all of those received. ESA dealt with them via ad hoc committees, and in 1994 a major project, Laser Interferometer Space Antenna (LISA), was listed among the key "cornerstone" elements of the Horizons 2000 programme (the ESA equivalent of CERN's LHC programme). Horizons 2000 projects ESA scientific activities up to and beyond the year 2010.

In 1994, ESA created a special Fundamental Physics Advisory Group (FPAG) to complement the established Astronomy Working Group and the Solar System Working Group.

In 1996, COSPAR (the international Committee for Space Research) created a new commission for fundamental physics, Commission H. In 1997 the Alpbach Summer School provided a useful and extensive overview of prospects as seen from Europe. The proceedings (ESA-SP-420) are a reference document for the new community working in that domain. So is the more recent Fundamental Physics Road Map established by NASA.

US fundamental physics in space started with microgravity



The Alpha Magnetic Spectrometer (AMS), the pioneer major particle physics experiment for space, had a shakedown flight aboard the Space Shuttle Discovery *in 1998. It is seen here in the Shuttle's payload bay.*

research associated with manned space flights and, in particular, the study of helium superfluidity, to be complemented by the study of laser-cooled atoms. This was eventually extended to gravity. The important mission Gravity Probe B, testing the frame-dragging effect around the rotating earth, is soon to fly. This domain of research is monitored by NASA's Fundamental Physics Discipline Working Group.

While fundamental physics at ESA did not initially include microgravity, things have developed in that direction with FPAG interest for the ACES mission. With its combination of a laser-cooled caesium clock and an H-maser, this should provide the most precise clock ever (accurate to 10^{-16}). This is now approved for the International Space Station.

Interest developed for Satellite Test of the Equivalence Principle (STEP) to achieve 10^{-18} accuracy (the present ground-based limit is 10^{-12}) with a cryogenic system orbiting the Earth. There was also considerable ESA interest and, if everything goes well, this mission could fly in around 2004 as a NASA-led project with strong ESA participation. In the opposite transatlantic direction, there is now a strong US interest in LISA. An ESA–NASA collaboration on LISA could advance the project by a decade to around 2009.

At present, LISA is the flagship fundamental physics experiment. The LIGO terrestrial search for gravitational waves using laser interferometry aims for phenomenal accuracy and was described by Riccardo DeSalvo in the March issue ("The quest for gravitational waves" p10).

A space experiment is in principle very similar, but could extend over several millions of kilometres and would focus on low frequencies (10^{-2} to 10^{-4} Hz). Ground-based detectors are blind to anything below about 10 Hz because of gravitational noise, and they have to focus on high frequencies (10^{2} to 10^{4} Hz) looking for signals from supernovae and the demise of compact binary stars.

Gravity waves in space

A spaceborne experiment would be sensitive to permanent emission from compact binaries (of the Hulse–Taylor type). Thousands of these (black hole, neutron star and white dwarf binaries) should be detectable in our galaxy. Other viewable phenomena would include the formation, accretion and merging associated with the very massive black holes (1 to 10 million solar masses) known to exist at the centre of most galaxies.

The typical emission frequency of a black hole is inversely proportional to its mass, and very large ones should be within range of LISA anywhere in the universe. Spaceborne experiments could thus study the strong gravity of very compact objects, while ground-based studies will be looking for effects resulting from the Big Bang, cosmic strings, etc. Both terrestrial and spaceborne studies open a new window to astronomy.

Whether or not gravitational waves are soon detected on Earth, they also have to be sought in space. A LISA mission at the end of the next decade would be particularily timely. Three satellites would provide two independent laser interferometers on a heliocentric orbit trailing the earth at 20°. The LISA Pre-Phase A Report (MPQ 233) is a detailed description of the mission, which has now entered industrial study.

However, such a mission relies on technology that has still to be proven in space (exhibiting, for example, very precise accelerometry, drag-free control and very stable laser interferometry). A small dedicated mission is planned in Europe under the codename ELITE and is entering industrial study. However, the most efficient route is probably via an ESA–NASA collaboration, as will also be the case for LISA. This, like other projects, will also benefit from positioning using an electric propulsion engine, which is soon to be tested by an other small ESA mission.

Particle physics and space science

Some particle physicists are following with great interest the development of space projects. This is in particular the case for PLANCK, an ESA Horizons 2000 project, which should improve the COBE results on the cosmic microwave background by two orders of magnitude.

The past two decades have seen increased symbiosis between particle physics, astrophysics and cosmology, and this new field of astroparticle physics is now thriving. Probing the deep structure of matter through very-high-energy laboratory collisions reveals physics such as prevailed in the early universe. Today's laboratory experiments simulate conditions 10^{-10} s after the Big Bang.

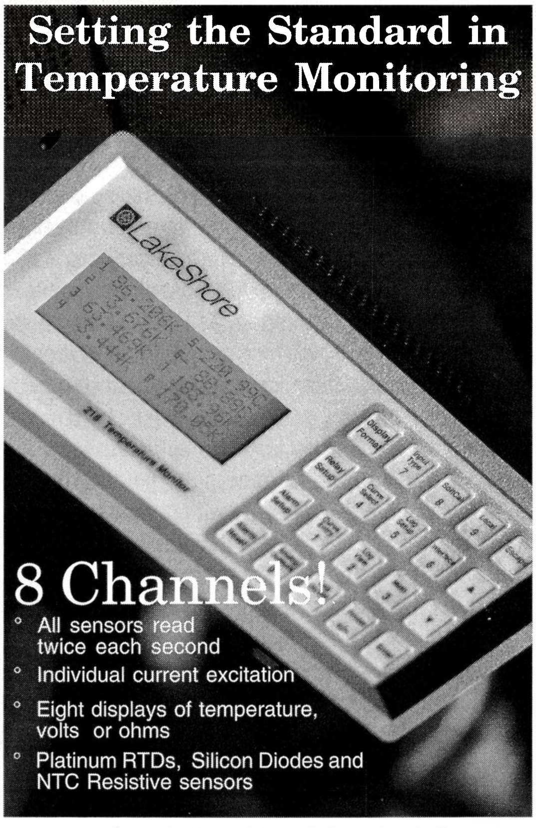
With laboratory energies necessarily limited, the universe provides a fantastic range of extraterrestrial particle accelerators. The cosmic-ray spectrum extends up to 10^{12} GeV, so that a cosmic-ray proton colliding with a stationary nuclear proton gives a collision energy of about 10^6 GeV – about a hundred times that of CERN's LHC collider. However, collecting 100 cosmic-ray events per year at LHC collision energies would require a 10^4 sq. m detector. The LHC will provide 10^8/s.

High-energy physics techniques have been developed for and applied to astrophysics. Examples include detectors of high-energy gamma rays and high-energy neutrinos. This work demands extensive data collection and data handling, in particular for the study of otherwise invisible astronomical objects via gravitational lensing. Other examples include the study of neutrino oscillations and the search for dark matter.

Spaceborne detectors

The pioneer major spaceborne particle physics detector is Alpha Magnetic Spectrometer (AMS), which was designed to search for antimatter in space but which also gives valuable information on the composition and distribution of cosmic rays (June p6). This information is welcome for the analysis of information on atmospheric neutrinos, where there are strong hints for neutrino oscillations.

AMS will be deployed on the International Space Station but has already had a test flight on the Space Shuttle and is preparing for a second. In the US the detector project involves a special collaboration between NASA's space responsibilities and the Department of Energy, traditional paymasters of US particle physics. It relies on a worldwide collaboration of particle physics research centres with a strong European contribution.



More such experiments could appear soon, but their aims should be very specific because of cost. Examples include searches for new forces and probing gravity at small distances. In particular, a mission like STEP should provide checks on the sensitivity that should be attainable in future studies.

Another interesting direction involves searching for heavy stable remnants of the Big Bang, looking in particular for particle–antiparticle annihilations into gamma rays. Candidates are the lightest supersymmetric particles. However, there is little to say about the energy of the expected gamma ray and its intensity. Physicists should look out for other missions providing a ride.

The trail-blazing experiments cover cosmic rays, such as AMS, and X-ray and gamma-ray detectors, such as the Gamma Ray Large Area Space Telescope (GLAST), and particle physicists will enter space research via cross-fertilization between different fields, as has been the case for AMS and GLAST.

I see the future of high-energy physics in space more in terms of physicists than in terms of physics. Know-how developed in particle physics, and in particular for the LHC, is likely to find good use in space research: new tracking chambers, silicon detectors, radiation-hard electronics, bolometers and new photomultipliers. Also, the LHC experiments are likely to trigger a breakthrough in data collection and data handling – 10^{15} bytes per year, a million times the information stored in the human genome. Ingenious particle physicists, at ease with these new techniques, will be eager to apply them in space research.

In this spirit, the Joint Astrophysics Division of the European Physical Society and the European Astronomical Society is organizing a workshop on Fundamental Physics in Space and Related Topics at CERN next year under the joint sponsorship of ESA and CERN.

More collaboration

Researchers always complain about funding for basic research. In the post-cold-war era, governments seem to be saying: "What you do is interesting, but what is the rush? Couldn't you do it more slowly with smaller annual budgets?"

A minimum momentum has to be maintained, otherwise young people would cease to be attracted. More extensive collaborations would ensure new experiments and missions. This is particularily the case for fundamental physics, where the chance to fly a mission depends much on the cost to each partner.

Recent transatlantic contacts have involved compromise, but a door could be opening for extended Europe–US collaboration. ESA has endorsed the principle of such collaborations for fundamental physics. The dawn of a new millennium is a golden opportunity to embark on a new voyage of scientific discovery.

Former CERN theoretical physicist **Maurice Jacob** *is now chairman of ESA's Fundamental Physics Advisory Group and vice-chairman of COSPAR's Commission H.*

How Martin Luther King almost came to Fermilab

At his 80th birthday event at Fermilab, former laboratory deputy director, Ned Goldwasser, recalled Fermilab's early days, when human rights were as important as protons.

US National Accelerator Laboratory director Robert Wilson (left) with deputy director Ned Goldwasser in a model of the laboratory's future accelerator. In 1974 the laboratory was renamed the Fermi National Accelerator Laboratory, which is commonly abbreviated to Fermilab. At a recent Fermilab event marking his 80th birthday, Goldwasser recalled the heavy political overtones of the decision to site the laboratory in Illinois.

Present at the beginnings of a great adventure in high-energy physics, former laboratory deputy director Ned Goldwasser will not forget the long hot summers of the mid-1960s: a formative time for Fermi National Accelerator Laboratory and an era when turmoil raged from coast to coast in the US.

There were major fires and riots in Watts (Los Angeles), Detroit, Washington DC (where the National Guard had tanks in the streets) and the South Bronx and Bedford-Stuyvesant areas of New York City.

Before a building had been raised on the 6800 acre laboratory site in March 1967, newly named director Robert R Wilson telephoned Goldwasser, then at Illinois, asking him to come on board the project.

Goldwasser, who had served on the committee that recommended potential sites for the new laboratory to the US Atomic Energy Commission, took the job and agreed to visit Wilson at Cornell. When they met, they spoke not only about relationships in particle physics but also about relationships among people.

At The Early Days of Fermilab, a mini-symposium honouring his 80th birthday, Goldwasser recalled: "We spent a large fraction of that meeting discussing our independent but similar notions that the opportunity of building a lab at that time, with what was happening in the country, was an opportunity that shouldn't be missed.

"We wanted to demonstrate that such a project could be started and run in a manner sensitive to some of the racial problems the country was suffering from. Cities were burning. There were large-scale protests against discrimination. Bob felt, and I agreed, that we could and should do something to address those problems."

Beam or bust

The first speaker at the symposium was Norman Ramsey, 1989 Nobel Prizewinner for his invention of the separated oscillatory fields method and its use in the hydrogen maser and other atomic clocks. Ramsey was the first president of the Universities Research Association, the consortium that manages Fermilab for the US Department of Energy.

Bill Fowler, currently associate project manager for Fermilab's Main Injector, joined Fermilab in 1970 to construct the 15 ft hydrogen bubble chamber. He later served as Wilson's deputy project leader in developing the Tevatron. Fowler summed up the feeling of the lab's early days as: "Co-operation – we had it at that time."

However, those early days are also characterized by the crisis management, "beam or bust" outlook described by Rich Orr, who

King's English

With the threat of demonstrations to block construction work at the new US National Accelerator Laboratory (to become Fermilab) on 22 June 1967, director Robert Wilson sent a telegram to 1964 Nobel Peace Prizewinner Martin Luther King.

Dr Martin Luther King, Southern Christian Leadership
Conference, 334 Auburn Avenue N.E., Atlanta, Georgia.
with copy to: Southern Christian Leadership Conference,
336 East 47th Street, Chicago, Illinois.

"We scientists now designing the 200 BeV accelerator to be located in Weston strongly support the struggle for open housing in Illinois. Science has always progressed only through the free contribution of people of all races and creeds. This is not less true today in America, and the full success of this laboratory will depend on achieving conditions in Illinois which allow any scientist, regardless of race or creed, to participate in this important project – a project which will contribute to a truly great intellectual and cultural heritage in Illinois. We join you in wanting to attain these great ends."

Robert Rathbun Wilson, Director,
National Accelerator Laboratory

served the lab in many capacities over 20 years. Orr lauded Wilson and Goldwasser as being "responsible for how Fermilab became Fermilab, as opposed to what it set out to become".

In those early days, buildings were put up before funds were authorized. "We try to start before we've been approved so we know we can finish," joked current director John Peoples.

Even in the winter of the Cold War, researchers were welcomed from the Soviet Union. Physics experiments transcended international politics. "Experiments were open to users from all areas," said Yoshio Yamaguchi, a former president of the International Union of Pure and Applied Physics. "I'm very glad that high-energy physics started such a wonderful idea."

Goldwasser remembers a Soviet VIP visit. The new lab's goal was to have beams circulating around the entire Main Ring. "We worked all night, but we didn't get it," Goldwasser said. "The whole Soviet entourage was there and we said we were sorry, but we weren't able to get it done. Later, the Soviet commissioner told Bob Wilson such an admission had been very stupid. 'In the Soviet Union,' he said, 'we have learned that it doesn't matter. They don't know if it's a full turn or not. We just tell them we made a full turn and that's just as good.' "

Civil rights

Those early days were full of hope for the future of physics. However, with the cities burning, the civil rights struggle and national politics were uppermost in people's minds.

"My feeling," Goldwasser said, "is that President Lyndon Johnson made the decision at least in some measure as a trade-off with Illinois Senator Everett Dirksen."

Democrat Johnson, who became President in 1963 following the assassination of John F Kennedy, set great store by passing civil rights legislation to heal the country. He also held a longstanding interest in Big Science from his years as vice-president. NASA had been his particular area of responsibility, and the Johnson Space Flight Center, in his native state of Texas, is named in his honour.

"The Federal Open Housing Bill [to desegregate housing officially] was before Congress," said Goldwasser. "Everyone knew that the vote in the Senate would be very close. What surprised everyone was that [Republican] Dirksen, who had a long record of strong positions against anything in the nature of open housing, withheld his vote to the end, then he cast in favour of the bill, to break a tie."

Although open housing became the law of the land, its implementation was not immediate everywhere. The Revd Martin Luther King, angry that at the state level Illinois soundly rejected a similar bill, threatened to lead demonstrations blocking the construction of the laboratory in Illinois. The subject of racial tensions dominated the first official meeting of the National Accelerator Laboratory on 15 June 1967 at the design offices in Oak Brook.

Affirmative action

Goldwasser recalled: "Bob asked me to take on the job of going into Chicago and meeting with the leaders of minority groups in an effort to persuade them that we intended to have a very active programme for what would now be called affirmative action. There was no such thing in those days, but we told them we expected to find employment for minority people and we expected to try to recruit many of them from among the inner-city gangs in Chicago.

"Those were some of my interesting days. I met with leaders of the Urban League and the National Association for the Advancement of Colored People, but I also met with leaders of the Black Panthers, as well as with gangs in Chicago. I told them what our intentions were and asked them to give us ideas about how we might proceed."

Soon the informal affirmative action programme managed to take a major step forward when Ken Williams joined the lab from one of the local hospitals. He headed the lab's affirmative action efforts for many years.

"The first thing he did was a great relief to me," said Goldwasser. "He took over the responsibility of going into the city and meeting with the gangs. In those meetings he interviewed individual gang members, trying to evaluate who was really serious about getting out of gang life and getting a real job in the outside world. I felt he had unerring taste and judgement in the people he chose."

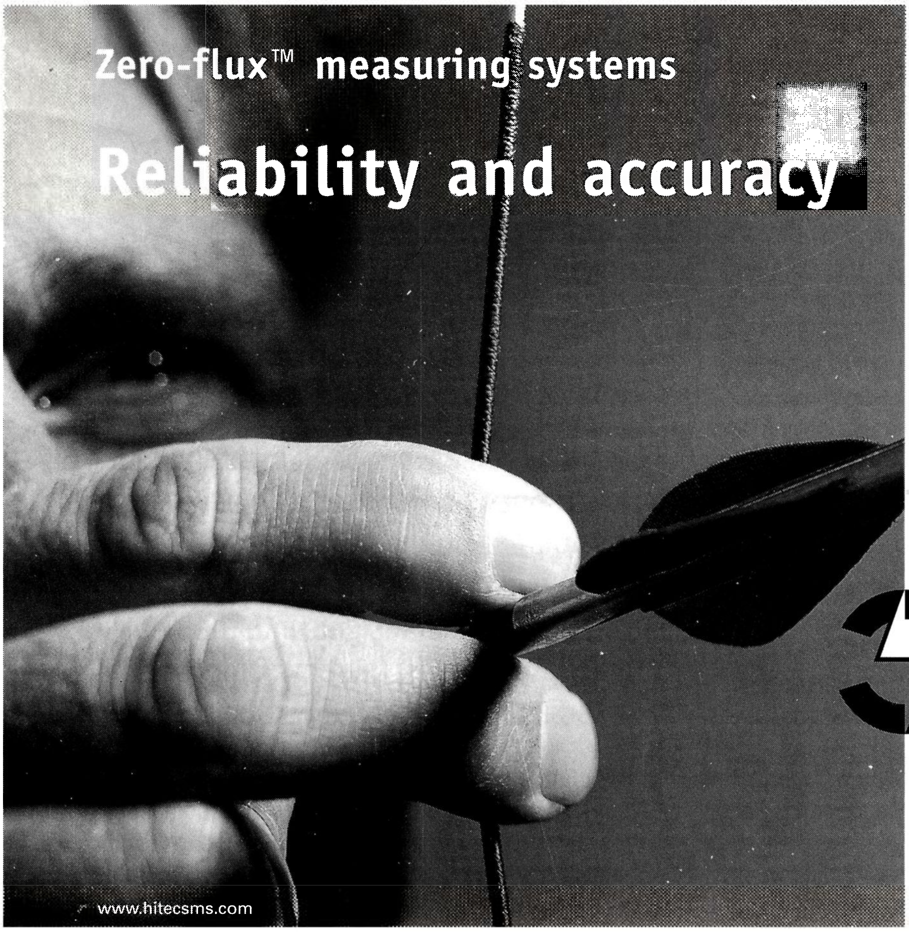
The lab and community leaders cobbled together a programme taking kids out of city gangs and sending them to a six-month technical training programme. Those who stayed the course would return to the lab with jobs as technicians. Training was at Oak Ridge, and spending six months in Tennessee in the 1960s might have seemed daunting to young black men from Chicago, but it worked. "Around the time I left the lab [in 1978], I think we were about 90% successful in retaining those trainees. And most of the people who left had gone on to better jobs. Ken Williams made an enormous contribution to the laboratory," Goldwasser said.

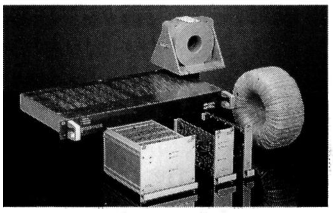
Robert Wilson leads a 1967 Fermilab staff meeting in temporary accommodation in Oak Brook, Illinois.

Within the first year of the lab's operation, Wilson and Goldwasser had also issued a policy statement on human rights. Goldwasser read from its final paragraph: "Our support of the rights of the members of minority groups in our laboratory and in its environs is inextricably intertwined with our goal of creating a new centre of technical and scientific excellence."

Against a background of racial turmoil, the human rights focus of Goldwasser, Robert Wilson and all of those involved at the start of what was to become Fermilab demonstrated clearly their commitment to principles beyond science.

Mike Perricone, *Fermilab.*





Muon ring could act as a neutrino factory

Neutrinos have always been in the particle physics spotlight. However, with new machine ideas opening up the possibility of intense neutrino sources, this area of research could go on to reveal further insights into the weakly interacting particles, thereby complementing the detailed knowledge of the quark sector.

With CERN's LHC collider now committed to beginning its experimental programme in the year 2005, and with research and development work well advanced for a new generation of linear electron–positron colliders, a totally new avenue of particle physics machines that is currently being enthusiastically explored is that involving muon colliders.

Muons, which are heavy relatives of the electron, come in postively and negatively charged versions with properties that are broadly similar to those of electrons. These oppositely charged beams could be made to collide with each other to produce a wealth of particles.

As a result of their being more than 200 times as heavy as electrons, muons that are bent by a magnetic guide field lose much less energy than electrons and could be housed in far smaller rings. Several generations of muon colliders could be accommodated on existing laboratory sites. Initial thinking towards muon colliders was outlined by Fermilab's Steve Geer in the December 1997 issue ("Muon colliders move nearer" p1).

Neutrinos from muons

One interesting possibility en route to a full muon collider scenario with two muon beams is to employ a single circulating muon beam. As they decay, the stored muons would provide an intense source of neutrinos with properties that are very different those of conventional synthetic neutrino beams.

The first step would be an intense 2 GeV drive beam of protons from a linear accelerator to produce pions at a secondary target. These pions decay into muons, captured in an intermediate storage ring. The muons would then be accelerated in a booster synchrotron up to 20 GeV or higher.

At rest, a muon lives on average for approximately 2.2 μs. Without the intervention of relativity, even a high-energy muon would travel only around 600 m before it decayed. Under these conditions, few cosmic-ray muons would reach the Earth's surface and muon storage would not be possible. However, the lifetimes of fast-moving muons are stretched by relativity, thus, the faster muons travel, the longer they appear to live. High-energy cosmic-ray muons easily reach the Earth, and high-energy muons could be stored.

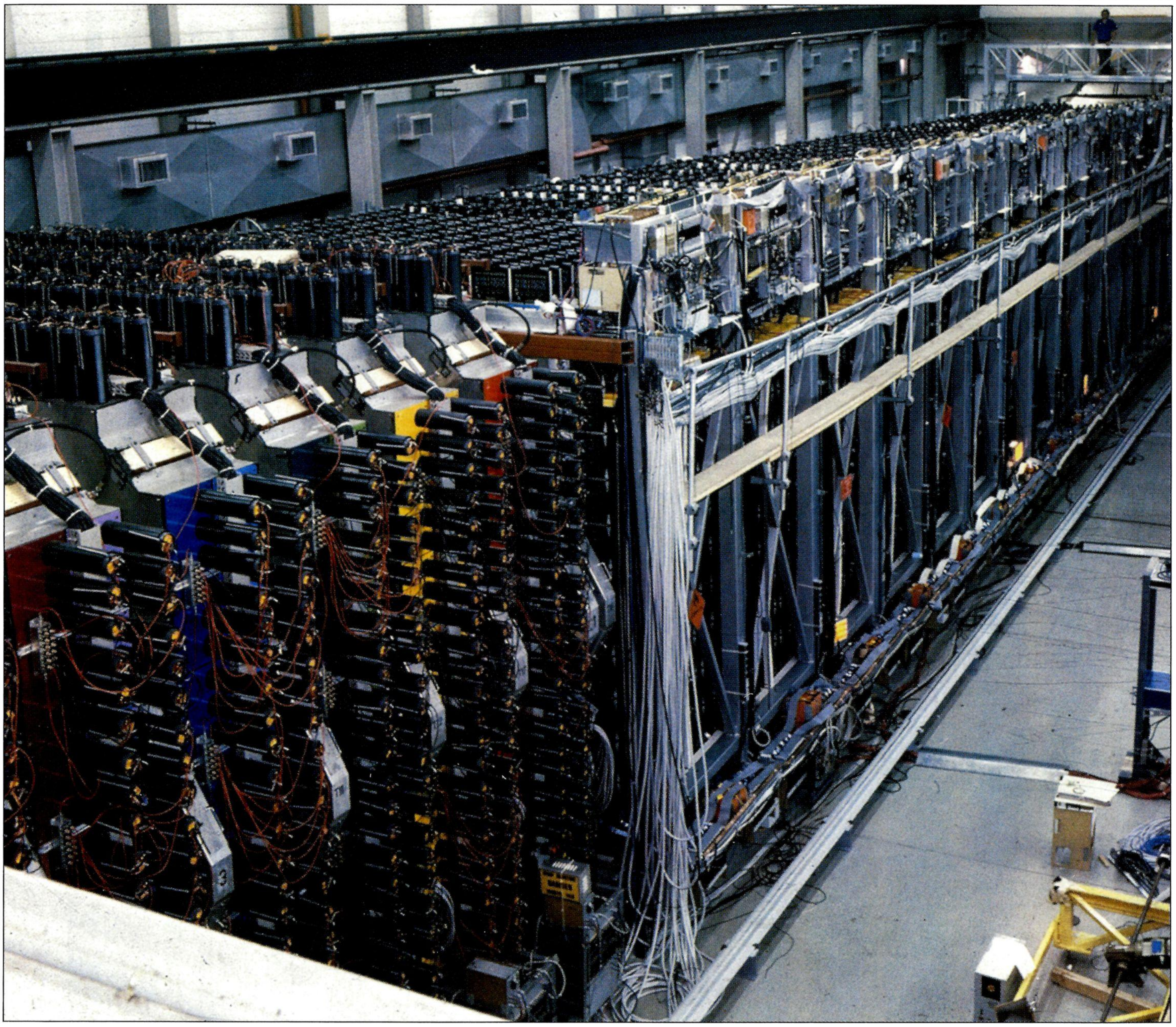
However, for this to occur it is essential for the muons to be accelerated quickly, therby endowing them with an increased lifetime as rapidly as possible. The muon storage "ring" would have 300 m straight sections in which most of the stored muons would decay into electrons, neutrinos and antineutrinos.

Negatively charged muons decay into electrons and equal numbers of muon-type neutrinos and electron-type antineutrinos, while positively charged muons decay into positrons and equal numbers of muon-type antineutrinos and electron-type neutrinos.

Energy spectra

The energy spectrum of the produced neutrinos depends only on the muon energy and their spin orientation. That of the muon–neutrinos peaks towards the upper end of the spectrum, towards the energy of the muons, while the electron–neutrinos are softer. Decay electrons would be swept away by the storage ring bending magnets.In addition to having a clear energy spectrum, the flux of neutrinos produced in this way can be calculated from the muon population of the storage ring. The intense neutrino fluxes available via this route warrants the label "neutrino factories".

Neutrinos at accelerator laboratories are traditionally produced via the decay of kaons or pions. The neutrino detector has to be some distance from the production target to allow the pions and kaons sufficient time to decay, and the accompanying muons have to be screened off. A pure neutrino beam is only established some



Traditionally, neutrino physics has been a large-scale operation, needing big detectors to intercept the dispersed particles. The CHARM II detector at CERN extended over a distance of 40 m. Neutrino detectors at muon storage rings would be more compact.

distance away, so that neutrino physics has always been a large-scale operation, requiring large detectors to intercept the dispersed particles.

However, with muon storage rings, the electrons from muon decay could easily be screened off, providing a pure neutrino beam very close to the intense source. New-look compact neutrino detectors could be mounted using state-of-the-art detector technologies to pinpoint the neutrino interactions and thereby open up a new era of neutrino physics.

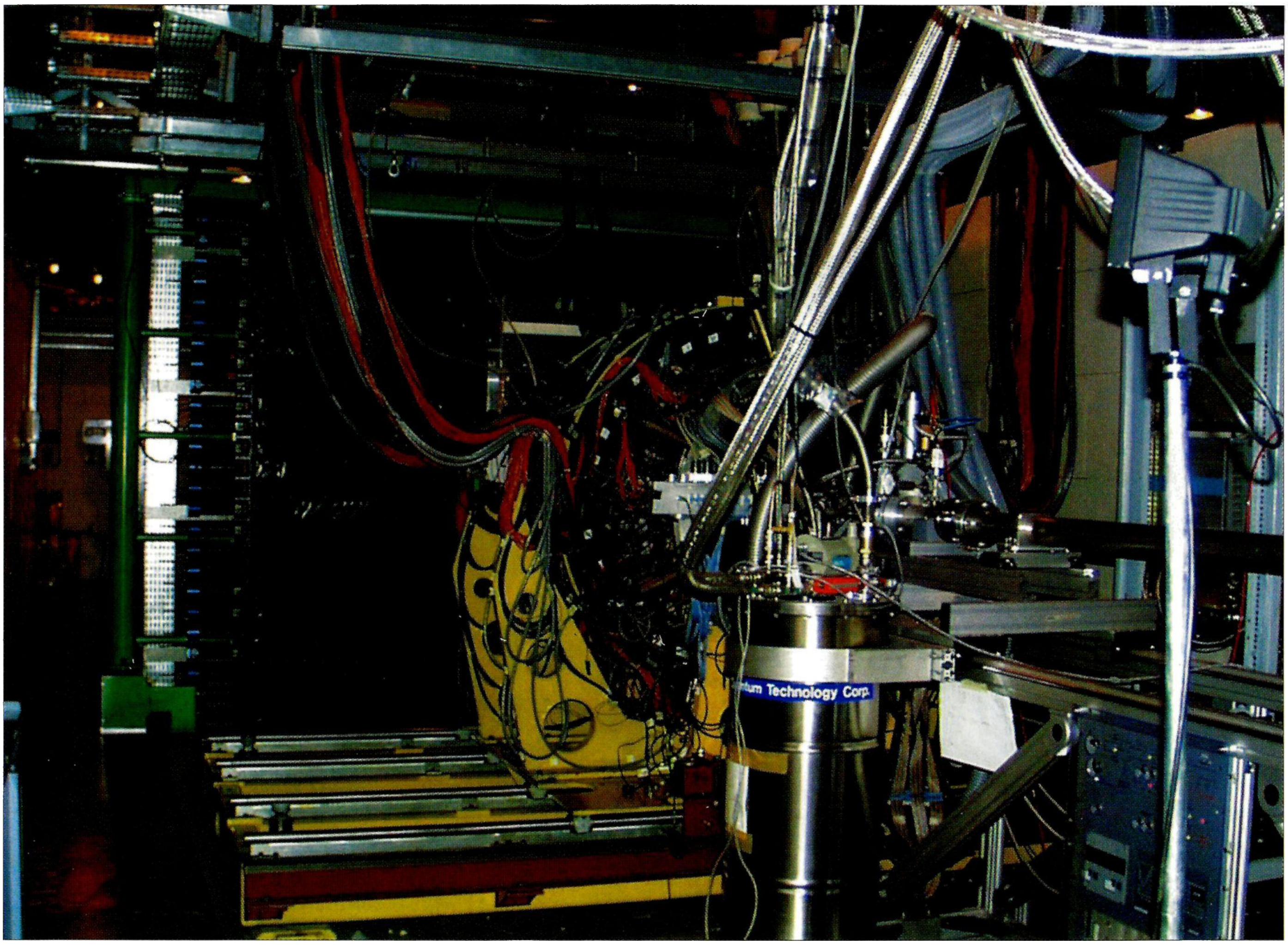
Oscillating neutrinos

Classically, neutrinos were supposed to be massless and came in three immutable kinds – electron, muon and tau – according to their particle allegiance. However, experiments studying neutrinos coming the Sun and from collisions of cosmic rays in the atmosphere have led physicists to believe that neutrinos are not immutable or massless. Other hints for neutrino oscillations come from an experiment at Los Alamos.

Endowed with tiny masses, neutrinos can transform into each other in flight, so that what leaves the Sun as an electron-neutrino could become a muon-neutrino as it flies through space, or what leaves an accelerator facility as a muon-neutrino could transform into a tau-neutrino.

Such effects are subtle, and measurements of the neutrino masses and mixing parameters are difficult. However, the intense fluxes provided by neutrino factories would provide optimal conditions, particularly compared with existing (and planned) sources of accelerator neutrinos. □

The Graal of particle



A particle physics experiment in the midst of synchrotron radiation, with a general view of the Graal apparatus at the European Synchrotron Radiation Facility, Grenoble. The photon beam (obtained by scattering the ESRF electron beam off a laser beam) enters from the right in the steel tube. The vertical cylinder houses the cryogenic cooler for the liquid-hydrogen target. At the centre, with the red and black cables, is the BGO ball on its yellow support. Behind are the planar wire chambers and scintillator walls.

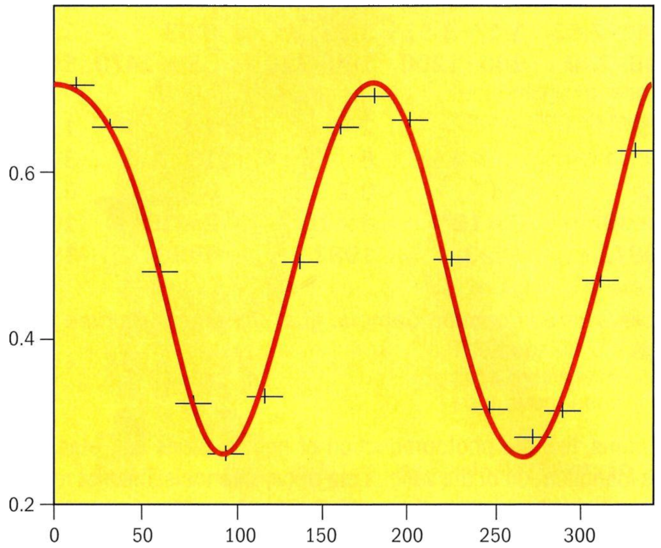
"One very powerful way of experimentally investigating the strongly interacting particles (hadrons) is to look at them, to probe them with a known particle; in particular the photon (no other is known as well). This permits a much finer control of viariables, and probably decreases the theoretical complexity of the interactions," wrote Richard Feynman (1992 *Photon–Hadron Interactions*, Addison Wesley).

Synchrotron radiation, which is an example of one type of photon, is produced when charged particles are bent in a magnetic field. This radiation is used over a range of science as a microstructure probe. The European Synchrotron Radiation Facility (ESRF) in Grenoble, France, is devoted to producing synchrotron radiation for the study of atomic, molecular and more complex organic and inorganic systems. The radiation is produced by a beam of 6.04 GeV electrons circulating in a storage ring. The electrons radiate synchrotron radiation in the bending magnets of the ring lattice and in magnetic insertion devices – wigglers and undulators – that shake the beam.

However, the new Graal experiment at the ESRF generates radiation in another way to probe nuclear and nucleon structure. Graal has been realized by a French-Italian-Russian collaboration with primary financial support from INFN in Italy and IN2P3 in France through several Italian laboratories and universities (Laboratori

physics

A new particle physics experiment uses a very different setting – the European Synchrotron Radiation Facility electron ring in Grenoble.



Azimuthal asymmetry for the photoproduction of eta mesons. The beam polarisation asymmetry can be derived directly from these data.

Nazionali di Frascati, Laboratori Nazionali del Sud, and the universities of Catania, Genova, Roma II and Torino), two French Institutes (Institut des Sciences Nucleaires and Institut de Physique Nucleaire) and the Institute for Nuclear Research of the Russian Academy of Science.

Undulators are normally composed of physical magnets, but Graal uses a micro-undulator in the ESRF straight section D7,which is a beam of ultraviolet laser light moving against the electron beam. The electrons scatter the laser photons, transferring energy to them and producing narrowly collimated gamma rays.

At the ESRF, a laser beam in the near-ultraviolet produces gamma rays with a maximum energy of 1.47 GeV, a maximum linear polarization of 98% and an intensity of a few millions of photons per second. In this way, Graal extends the ESRF resolving power to nuclear and that of nucleon structure down to a spatial resolution of 0.2 fm (0.2×10^{-13} cm).

The first advantage of this technique over normal electron bremsstrahlung synchrotron radiation is the almost flat energy spectrum. Polarization is the second advantage: photons scattered in the electron direction maintain their polarization. Therefore, at the higher end of the spectrum, the polarization is very close to that of the laser light. Rotating or changing the polarization of the gamma rays is easily accomplished by rotating or changing the polarization of the laser light.

A gamma beam of a useful intensity for studying photonuclear reactions was first produced at Frascati using the Adone storage ring. After this success, several more such beams were produced (table I). A beam with a maximum energy of 2.4 GeV is now under construction at Spring8 in Japan.

Graal's main goal is the study of photonuclear reactions in the intermediate energy region, where the nucleons cannot be treated as elementary particles and their internal degrees of freedom cannot be ignored, but away from the asymptotic freedom of quarks and gluons. In this region, many excited baryon states are clearly visible and many others await careful exploration

As highlighted by Feynman's quotation, photons are an interesting probe of hadronic structure because the interaction is given by the product of the electromagnetic vector potential and the hadronic current. The former is well known from quantum electrodynamics, and the relative weakness of electromagnetic coupling makes second-order effects small, thus models of photonuclear reactions are possible. Moreover, the possibility of using linearly and circularly polarized gamma rays makes several single- and double-polarization observables experimentally accessible, providing strong constraints on theoretical models. A linearly polarized photon beam introduces a fixed direction for the electric field, so that the reaction yield is no longer cylindrically symmetric with respect to the beam direction.

In a circularly polarized beam, the photons have well defined helicity and their spins are aligned parallel or antiparallel to their momentum. Parity conservation in photoreactions dictates the overall form of the interaction. The asymmetry in the weak decay of the (strange) lambda provides information on lambda polarization, so it is possible to measure the correlation between the gamma and lambda polarizations in the photoproduction of strange particles.

Ultraviolet photon beam

In Graal, an argon-ion laser provides a beam of ultraviolet photons. A three-lens zoom focuses them at the centre of the laser–electron interaction region. Two precisely adjustable mirrors align the laser light with the electron beam 35 m away to within 3 μrad. A retardation plate rotates the plane of linear polarization of the beam. The ultraviolet enters the storage ring vacuum system through a quartz window and is subsequently reflected through 90° by a beryllium mirror coated with aluminium. This mirror lines up the laser beam with the electron beam. (Beryllium minimizes the absorption of backscattered gamma rays that travel in the opposite direction to the ultraviolet.)

Electrons that have transferred part of their energy to a photon, move with the electron bunch along the straight section but, owing to their lower energy, veer away in the next dipole and become separated from the unscattered electrons by a few centimetres. Measuring the distance between a scattered electron and the electron beam is a measure of its energy loss and therefore of the gamma energy.

Physics with photon beams

Project name	Ladon *	Taladon†	ROKK-1‡	ROKK-2	ROKK-1M	LEGS§	Graal||	LEPS¶
Location	Frascati		Novosibirsk			Brookhaven	Grenoble	Harima
Storage ring	Adone	Adone	VEPP-4	VEPP-3	VEPP-4M	NSLS	ESRF	SPring-8
Energy defining method	collimation	internal tagging	tagging	tagging	tagging	external tagging	internal tagging	internal tagging
Electron energy (GeV)	1.5	1.5	1.8–5.5	0.35–2.0	1.4–5.3	2.5	6.04	8
Photon energy (eV)	2.45	2.45	2.34–2.41	2.41–2.53	1.17–3.51	3.53	3.53	3.5
Gamma-ray energy (MeV)	5–80	35–80 variable	100–960 simultaneous	140–220	100–1200	180–320	550–1470	500–2400
Energy resolution (%)	1.4–10	5	–	1.5	–	2	1.1	1.25
FWHM (MeV)	0.07–8	4–2	1.5–2	4	–	6	16	30
Electron current (A)	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1
Gamma intensity (s^{-1})	10^5	5×10^5	2×10^5	2×10^6	2×10^6	4×10^6	2×10^6	107
Date of operation	1978	1989	1982	1987	1993	1987	1996	1999

**Laser ADONe, †TAgged LADON, ‡ROKK is a russian abbreviation for Backscattered Compton Gamma, §Laser Electron Gamma Source, ||GRenoble Anneau Accelerateur Laser. ¶Laser-Electron Photons at SPring-8.*

The detection of the scattered electron and the measurement of its precise position are done with the tagging detector, which comprises plastic scintillators and silicon microstrips. The microstrips give the position of the electron and the scintillators give its precise timing. The electron timing correlates an event in the hadronic detector with the corresponding electron, thus providing the energy of the gamma ray that produced it. It also provides a precise starting signal for measuring the time of flight (TOF) of photoproduced particles. The jitter of the TOF start pulse, provided by the scintillators, is reduced to 120 ps, effectively synchronizing this pulse with the phase of the accelerating radiofrequency of the ring. This is possible because the electrons travel in short bunches separated by 2.8 ns.

The Graal hadronic detector covers the entire solid angle except for two small entry and exit holes along the beam axis. The detector is made of three parts. In the central part, between 25° and 155°, the emerging particles pass through two cylindrical wire chambers and a barrel of 32 thin plastic scintillators, then enter a calorimeter made of 480 BGO crystals, each 24 cm long, and arranged, like an orange, in 32 sectors of 15 crystals each.

Particles emitted at angles of less than 25° go through two plane wire chambers and three plastic scintillator walls. The first two thin walls are used to measure the specific ionization of the particles. Then a thick wall, with alternating layers of plastic scintillator and lead, measures the total charged particle energy and detects neutrons and gamma rays. All three walls provide a measurement of the position and time of flight of the particles.

Particles emitted backwards encounter two plastic scintillator discs separated by lead. Each disc has a small central hole for the passage of the beam and is viewed by 12 photomultipliers to reconstruct the position and timing of a particle. The responses of the two discs allow charged particles and gamma rays to be differentiated.

The main features of the Graal detector are high efficiency, good energy resolution for gamma-ray detection and complete angular coverage. The detector is well suited to events producing several photons, like the photoproduction of neutral pions and etas, and the identification of the various eta decay channels. The first results to emerge are extensive measurements of the beam polarization asymmetries for the photoproduction of positive and neutral pions and etas. The two-photon and three-neutral-pion (giving six photons) decay channels of the eta have been detected simultaneously.

Polarization asymmetries, derived experimentally from the ratio of successive measurements with the same apparatus, are immune to otherwise common systematic experimental errors, such as the knowledge of the solid angle, the efficiency of the apparatus, the measurement of the dose and the size of the target. From a theoretical point of view, polarization asymmetries are given by the interference of different amplitudes and are therefore more sensitive to small, hitherto unobserved, contributions – if b is much less than a, then ab is more sensitive to b than is $a^2 + b^2$.

Event discrimination

Another advantage of full solid-angle apparatus, with a high overall efficiency for the detection of gamma rays, is its ability to discriminate rare events, where only one or a few photons are produced, from the more frequent events containing many gammas.

One example is Compton scattering, which is about 50 times as rare as neutral pion photoproduction and can be difficult to single out using only kinematics. However, Compton scattering has only one photon in the final state, while neutral pion photoproduction has two. Another example is the rare decay of the eta into a neutral pion, which has four photons in the final state compared with the frequent decay into three neutral pions, which has six.

Graal is now in full operation. It can collect data for more than six months per year – a large fraction of the time that the ESRF ring is available to the experimenters. A 10 mK dilution refrigerator and a 16 T magnet are now being delivered for the construction of a polarized target. With polarized targets, double-polarization experiments will be possible in all channels. ☐

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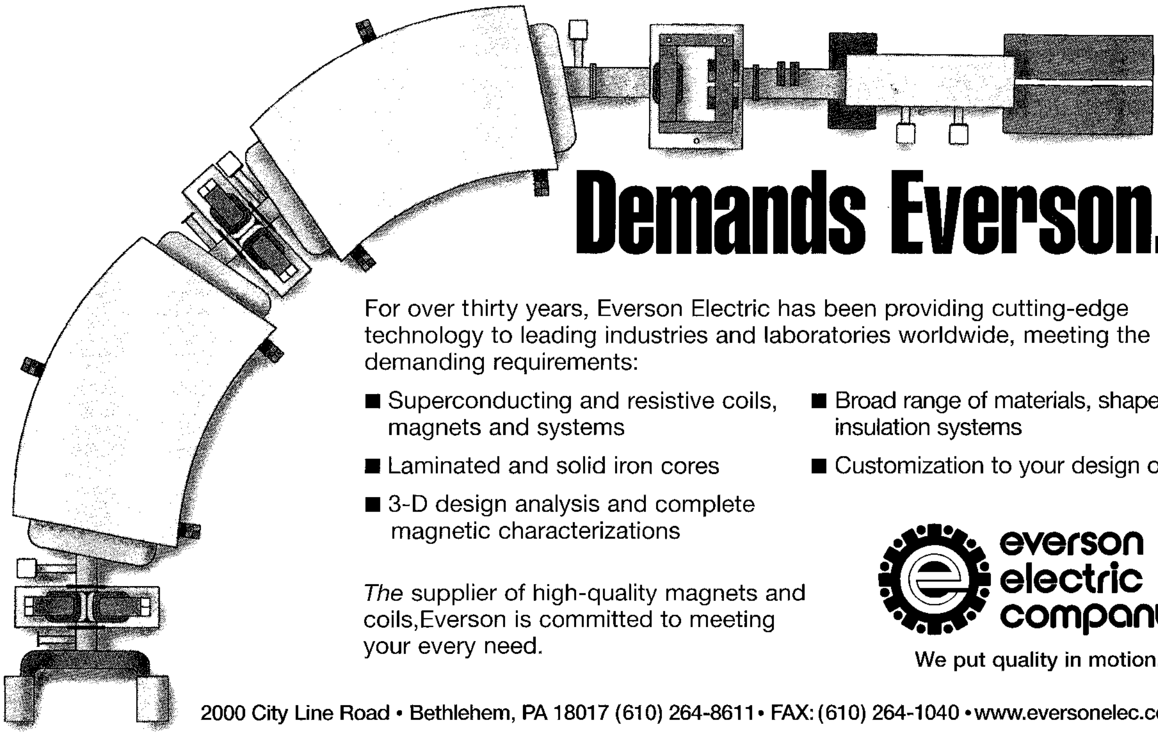

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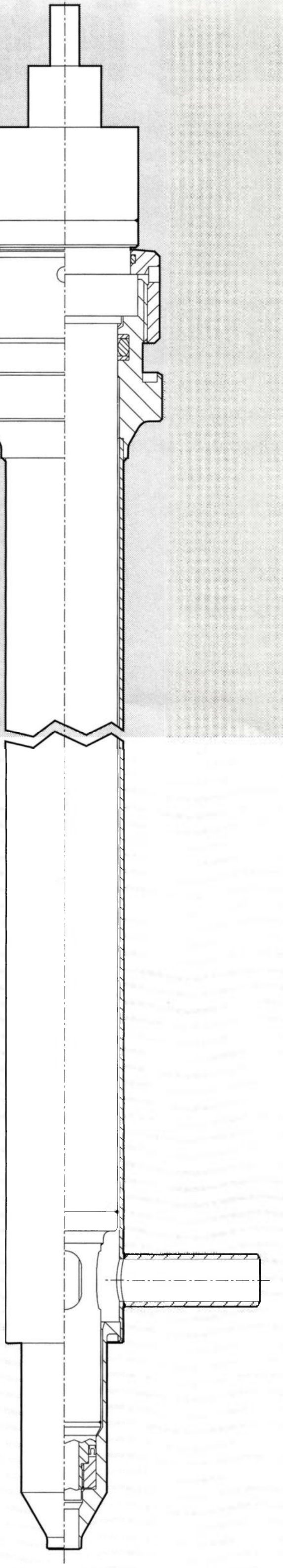

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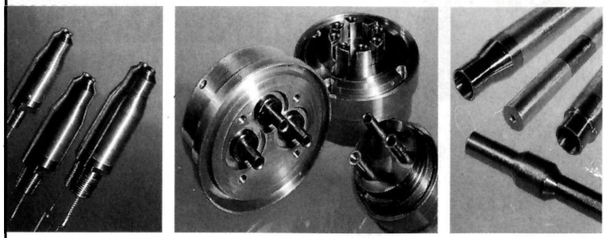

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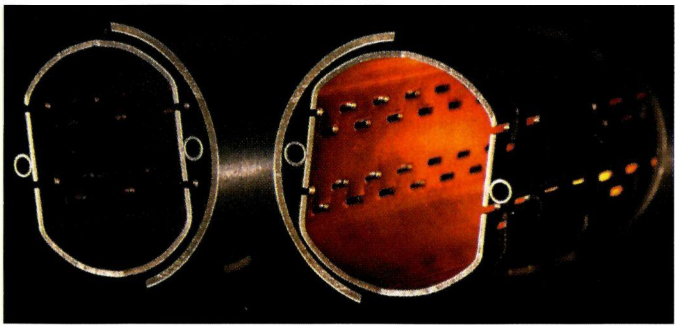
Electron clouds with copper linings

Energy loss through synchrotron radiation is the bane of circular high-energy electron accelerators, which is one reason why CERN's next accelerator, the Large Hadron Collider will be accelerating protons. Nevertheless, synchrotron radiation at the Large Hadron Collider still has to be considered carefully.



Prototype beam pipes for CERN's LHC collider, showing the inner beam screen to shield the surrounding superconducting magnets from synchrotron radiation emitted by the beams.

As a beam of charged particles is bent in a magnetic field, the particles lose energy by synchrotron radiation. The amount of energy lost is far greater for light particles than for heavy ones. Protons, the particles to be accelerated in CERN's forthcoming Large Hadron Collider (LHC), are some 2000 times as heavy as the electrons and positrons of the laboratory's current LEP accelerator, thus they lose far less of their energy to synchrotron radiation.

However, although the proportion of energy lost at the LHC will be much less than at LEP, the number of photons emitted by beam particles will, surprisingly, be much greater. Moreover, these photons will give rise to a number of undesirable effects that must be carefully controlled in a cryogenic vacuum environment. They will stimulate the release of gas molecules trapped in the walls of the LHC's vacuum chamber, they will cause the emission of electrons (photoemission), that in turn may liberate secondary electrons, and these will cause heating.

Beam screen solution

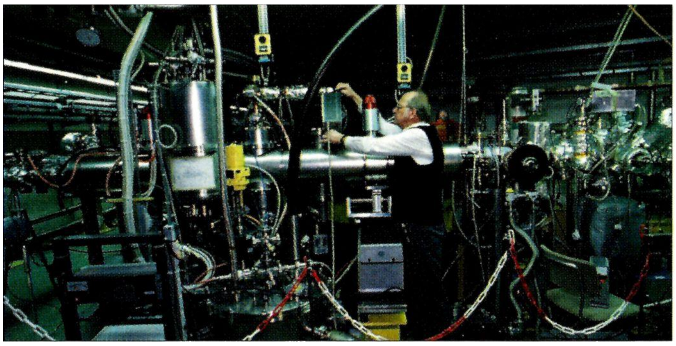
A partial solution will come in the form of beam screens that are designed to prevent the LHC's bending magnets from overheating and losing their superconductivity. These metallic tubes lining the LHC vacuum chamber will be held in the 5–20 K range, whereas the magnets will operate at just 1.9 K. The beam screens will carry away heat generated by so-called image currents, induced by the charge of the beams, as well as by the synchrotron radiation.

However, the story doesn't end there. Within the LHC's bending magnets, synchrotron radiation will tend to strike the outside wall of the beam screen along a very tight band. Electrons liberated by this radiation will immediately be turned back by the magnetic field and reabsorbed. The only problem this will cause is heating of the beam screen, which is easily dealt with.

However, if a photon is reflected and strikes the roof or floor of the beam screen, liberating electrons there, these electrons will be accelerated in a spiralling path by the positive charge of the passing proton bunch towards the opposite wall (bottom or top) of the beam screen, where they may release more electrons. These in turn will be attracted by the following proton bunch and may be accelerated back to the top or bottom, releasing more electrons in a potential runaway situation. This is called multipacting, a phenomenon that is familiar to designers of accelerating cavities.

> When an electron cloud has formed close to the walls of the beam screen, it inhibits further electron emission. Keeping this cloud manageable, however, is a fine art.

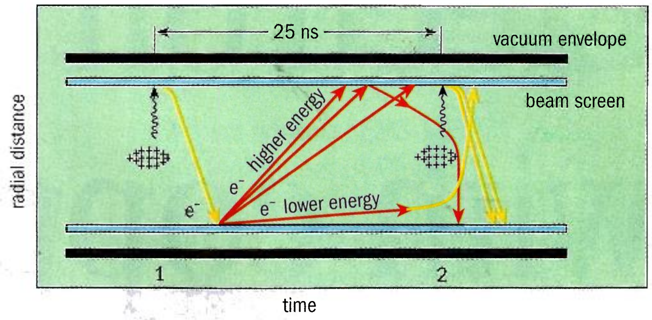
With the LHC, however, multipacting will not be quite the problem it may at first seem. The process is self-damping to a certain extent because, when an electron cloud has formed close to the walls of the beam screen, it inhibits further electron emission. Keeping this cloud manageable, however, is a fine art. Calculations suggest that, as long as the maxi-



Screening the beam. Conrad Grunhagel makes adjustments to the COLDEX experiment.

mum number of secondary electrons produced per primary electron is less than 1.3, then runaway will not occur.

Unfortunately, the current beam screens give a coefficient of around 2.4, so work is under way to finetune the design. Some improvement will occur naturally as the beam screens become conditioned by exposure to synchrotron radiation. But to reach the levels required at the LHC demands an in-depth understanding of factors such as the reflectivity of the emitted photons, the primary and secondary electron yields and the amount of gas release stimulated by electrons and photons.



One possible consequence of synchrotron radiation being emitted in an LHC bending arc. A photon (black) emitted from a proton bunch (1, black crosses) liberates an electron (yellow) from the beam screen. This strikes the opposite wall, where it causes heating and liberates low-energy secondary electrons (red), which drift back across the vacuum. Secondary electrons above a certain energy reach the beam screen before the arrival of the following proton bunch (2). Some are absorbed, and some are reflected and accelerated by this following bunch across the vacuum until they strike the beam screen. Meanwhile, lower-energy secondary electrons are also accelerated by this following bunch so that they too strike the beam screen. The following bunch emits synchrotron radiation, which may give rise to a similar effect or cause gas molecules trapped on the beam screen to be released.

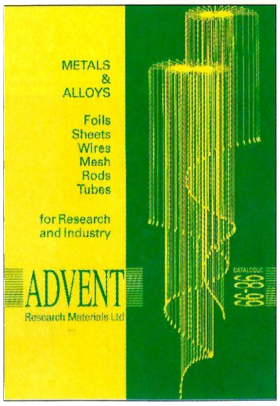
In 1996 a group of researchers in CERN's LHC division began a study of these quantities using both synchrotron radiation from the Electron Positron Accumulator (normally used to collect particles for LEP) and a laboratory electron source. The group's goal is to optimize the design of the beam screens by seeing how different manufacturing techniques influence their behaviour on exposure to synchrotron radiation. The current design is a 50 µm layer of copper, chosen for its low electrical resistivity, covering a rigid structure of high manganese steel, chosen for its low magnetic susceptibility. Low resistivity is important in allowing the image currents induced by the LHC's protons to move as freely as possible to keep resistive heating to a minimum.

Three beam-screen models have been tested at room temperature: a mirror-like copper laminate, electroplated copper and a sawtooth form. The results from the tests suggest that there may be some advantages with the sawtooth design, but further investigations are necessary to be sure that there are no unforeseen drawbacks with it.

The next step is to study beam screen behaviour at cryogenic temperatures. Last year the group began COLDEX (cold experiment). This was designed to measure synchrotron radiation-induced gas release, but it is ideal for all the other measurements as well. When LEP shuts down in November, the COLDEX apparatus will be inserted into the EPA ring to investigate how LHC beam screens operate with positively charged beams passing through them. The results should help to ensure that the LHC's electron clouds have, if not a silver lining, at least a copper one.

James Gillies, *CERN.*

FREE LITERATURE



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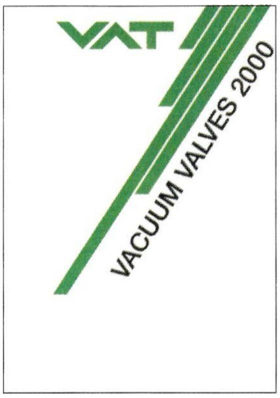

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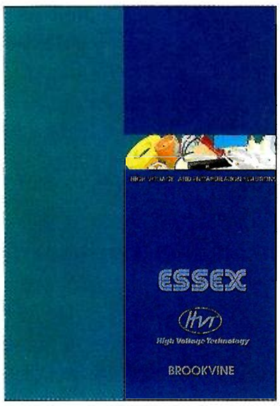

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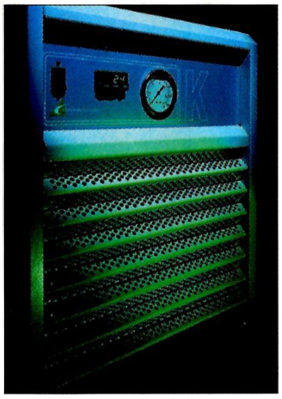

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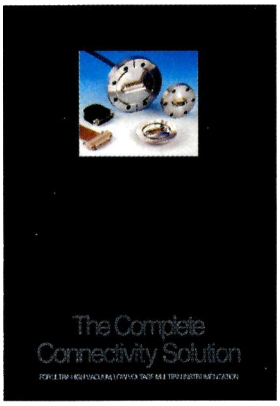

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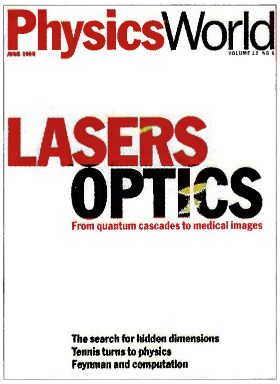

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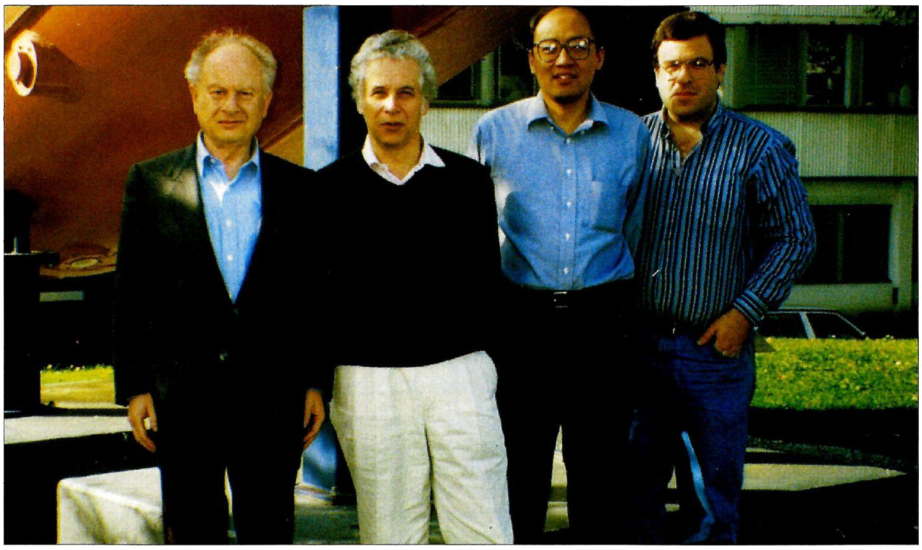
Pomeranchuk prize



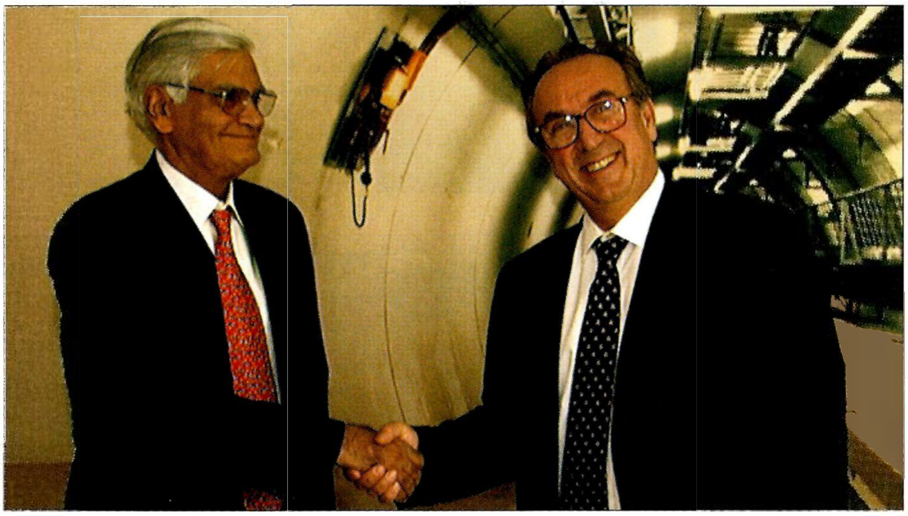
Four "generations" of theoretical physicists: (left to right) Sergio Fubini was the research supervisor of Gabriele Veneziano, who was the research supervisor of Henry Tye, who was the research supervisor of Keith Dienes. Gabriele Veneziano of CERN shares this year's Pomeranchuk prize. (Maurice Jacob.)

The prestigious Pomeranchuk prize, which is administered by Moscow's Institute for Theoretical and Experimental Physics (ITEP), is awarded this year to Karen Avetovich Ter-Martirosyan (ITEP, Moscow) and Gabriele Veneziano (CERN).

Prof. Ter-Martirosyan receives the prize for his pivotal contribution to quantum mechanics and quantum field theory. Born in 1922, he was a pupil of L D Landau and a close collaborator of I Ya Pomeranchuk. Among Ter-Martirosyan's students have been V N Gribov, A A Anselm, A M Polyakov, A A Migdal, A B Zamolodchikov and A B Kaidalov. He is an author of more than 250 articles and the book *Theory of Gauge Interactions of Elementary Particles* (1984) with M B Voloshin. His papers include "Theory of coulomb exitation of nuclei" (1952), "Theory of three body systems" (1956), "Development of the Regge pole theory for high energy scattering and theory of Regge cuts" (with V N Gribov and I Ya Pomeranchuk (1964-1976), and "QCD inspired model of quark-gluon strings" (with A B Kaidalov).

The prize is awarded to Gabriele Veneziano for his outstanding contributions to quantum field theory and the theory of strings. Born in 1942, he has been a staff member at CERN since 1977. His famous 1968 construction of a hadron amplitude satisfying the requirements of crossing symmetry and analyticity triggered the development of dual theory of strong interactions and string theory. His 1974 elaboration of large N expansion in dual models and QCD remains a cornerstone in strong interaction theory. His major contributions also include "Jet calculus in QCD", "Analysis of symmetry violation in QCD and its phenomenological consequences", "the Di Vecchia-Veneziano and Veneziano-Witten relations", "Construction of the effective supersymmetric action and formulation of the nonperturbative aspects of SUSY theory", and latterly "String cosmology".

Nominations for next year's Pomeranchuk prize should be send to pomeron@heron.itep.ru no later than 1 February 2000. Further information is available at http://face.itep.ru/pomeranchuk.html.



Chairman of the Pakistan Atomic Energy Commission Ishfaq Ahmad (left) visited CERN on 7 May to discuss the participation of Pakistan in the collaboration for the CMS experiment at the LHC collider. He met CERN director general Luciano Maiani (right) and agreed to an increase in the Pakistani contribution to CMS.

New chairmen appointed to DESY committees

Ministerialdirigent (assistant secretary) Hermann Schunck from the Federal Ministry for Education and Research (BMBF) becomes the new head of DESY Administrative Council. He replaces MinDirig Hans C.

Eschelbacher has been the head of the council for five years and is now president of CERN Council.

Ralph Eichler from Villingen becomes the new head of the Scientific Council, replacing Dietrich Wegener, who has been in office for three years.

Thies Behnke becomes the new head of the Scientific Committee, replacing Wilhelm Bialowons, who has held the position for a year.

LETTERS

CERN Courier welcomes feedback but reserves the right to edit letters. Please e-mail "cern.courier@cern.ch".

Free electron lasers

With reference to the *CERN Courier* article entitled "Expo 2000", which was published in the May issue (p11), I should like to mention two points.

The self-amplified, spontaneous emission, free electron laser (SASE-FEL) concept originated in the early 1980s (Derbenev *et al.*, 1982; Bonifacio *et al.* 1984). The first detailed proposal and study to use this concept for an X-ray FEL goes back to 1985 (Murphy and Pellegrini 1985).

During the past two years, several groups at UCLA, SLAC/SSRL, Brookhaven and Los Alamos have performed experiments proving this concept (Hogan *et al.* 1998; Babzien *et al.* 1998; Nguyen *et al.* 1998).

The most comprehensive experiment has been carried out by a UCLA–Los Alamos–SSRL group that has measured the FEL photon statistics and a gain of 3×10^5 over the spontaneous undulator radiation (Hogan *et al.* 1998). Both sets of experimental results are in excellent agreement with the theoretical predictions.

These results, and the strong interest in the unique properties of the radiation generated by an X-ray SASE-FEL, are the foundation for the Linac Coherent Light Source project at SLAC (LCLS Design Study Report 1998). The Basic Energy Science Division of the US Department of Energy recently endorsed a research and development programme of the LCLS for the period 1999–2002, with a view to start construction in the financial year 2003.

Claudio Pellegrini, Department of Physics, UCLA

Y Derbenev, A Kondratenko and E Saldin 1982 *Nucl. Instr. and Meth. Phys. Res.* **A193** 415.
R Bonifacio, C Pellegrini and L Narducci 1984 *Opt. Comm.* **50** 373.
J Murphy and C Pellegrini 1985 *Nucl. Instr. and Meth. Phys. Res.* A237 159.
J Murphy and C Pellegrini 1985 *J. Opt. Soc. America* **B2** 259.
M Hogan *et al.* 1998 *Phys. Rev. Lett.* **80** 292.
M Babzien *et al.* 1998 *Phys. Rev.* **E57** 6093.
D Nguyen *et al.* 1998 *Phys. Rev. Lett.* **81** 810.
M Hogan *et al.* 1998 *Phys. Rev. Lett.* **81** 4867.
1998 LCLS Design Study Report SLAC-R-521.

DESY replies:

We thank you for informing us of the UCLA, SLAC/SSRL, Brookhaven SLAC and Los Alamos achievements concerning the SASE-FEL, which we did not intend to underestimate in any way.

The "EXPO 2000" article in the May issue of *CERN Courier* was meant to be a presentation of DESY's next major public relations project, the EXPO 2000 exhibition, entitled "Light for the New Millennium", to a broad audience. This was a very welcome opportunity provided for us by *CERN Courier*. It was not intended as a scientific publication and we thought that this would be obvious from both its style and content.

Indeed, we consider that the task of introducing the public to the fascination of science is of major importance, and it is not always easy in such an article to give credit to all relevant research work. That is why the SASE-FEL principle was mentioned only rather briefly, and in a way that could indeed have been interpreted as if it were solely a DESY development. This was not our intention, however, and we apologize if it has been construed in such a way.

This year's goal at DESY is the proof-of-principle of a SASE-FEL at a wavelength of less than 100 nm – more than two orders of magnitude in wavelength less than the result published by the UCLA/Los Alamos/SSRL group last year. The FEL pilot facility, on display at EXPO 2000, is under construction at DESY.

From 2003 it will deliver radiation at a wavelength of 6 nm for the international user community, which will make it the first SASE-FEL facility to go into research operation.

Petra Folkerts, Project Leader DESY-EXPO.

MEETINGS

An international summer school entitled **Experimental Physics Of Gravitational Waves** will be held in Urbino, Italy, on 6–18 September. Supported by the Institute of Physics, Urbino University and INFN Florence Section, it is aimed at graduate and postdoctoral students. Details and self-registration are available at "http://www.uniurb.it/Phys/School/index.html" or "http://www.uniurb.it/Phys/School/index.html", or contact Flavio Vetrano at Urbino University, e-mail "vetrano@fis.uniurb.it", tel. +39 07224892.

The annual **DESY Theory Workshop**, to be held this year on 29 September – 1 October, has the theme vews from the Universe and will cover neutrino masses and oscillations, baryon and lepton number violation, the cosmological constant, and the structure in the universe. The speakers will include many distinguished names from all over the world.

Parallel sessions are mainly reserved for young researchers. Contributions should be sent before 1 August, together with registration. Limited financial support for young physicists is possible.

Registration via Mrs S Günther, DESY-Theorie, Postfach, D-22603 Hamburg, Germany, fax +49 40 8998 2777.

Information is available from C Wetterich, Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, D-69120 Heidelberg, Germany or "http://www.desy.de/desy-th/workshop.99/".

XI ISVHECRI, the **XI International Symposium of Very High Energy Cosmic Ray Interactions**, will be held in Campinas in Brazil on 17–21 July 2000. It will celebrate the centennial of Gleb Wataghin. Details are available at "http://www.unicamp.br/~isvhcri".

US Department of Energy secretary Bill Richardson (second from right) inaugurates the OOPS Out-of-Plane Spectrometer at the MIT-Bates Linear Accelerator Center. Also enjoying the event are (left to right) Dan Tieger of Bates, congressman John Tierney (Massachusetts 6th Congessional District) and Adam Sarty of Florida State. OOPS is scheduled to begin a lengthy period of data taking next year.

Bianca Monteleoni-Conforto 1937–1999

With great sadness we learned on 18 May that Bianca Monteleoni-Conforto had left us.

Bianca first came to CERN in 1962 after working in Rome on antiproton interactions in emulsions. The 81 cm bubble chamber had been exposed to the first CERN antiproton beams and Bianca plunged into the analysis of a low-energy scattering experiment, displaying from the outset her personal qualities – a preference for solid work, producing numbers and facts. Her perseverance overcame all obstacles, and she took pride in the eventual result. Her enthusiasm led others to collaborate, at which point she would step back, except when it was vital to intervene.

The wide-ranging antiproton study, extending to kaon production, laid the ground for subsequent LEAR studies. Kaon interactions retained Bianca's interest in Chicago, where she spent two years, and later at the UK Rutherford Laboratory. Back in Rome, she turned to CERN's SPS and neutrino physics, for the beam dump experiment, which brought the first observation of charm production in hadronic interactions. She continued heavy flavour studies in a photoproduction experiment with the Omega spectrometer, later joining the Crystal Ball experiment at DESY.

In 1980 Bianca moved to a research position in Florence, where she displayed her qualities for organizing and for driving a team of young researchers, and embarked on the construction of the Muon Filter for the L3 experiment at CERN's LEP.

Increasingly involved in INFN activities (she became a director in Florence in 1987) and teaching (19 theses supervised), Bianca continually followed new developments. She and her group joined the LVD experiment at Gran Sasso, and pushed the NESTOR underwater neutrino experiment in Pylos, Greece. Her work thus covered a variety of experimental particle physics and even astrophysics.

Bianca was respected and loved by all of us. Besides her standing as a scientist, she had great human qualities, open to the beauty of physics as well as music and arts. It was not only good to work with her, but also to walk in Rome or hear an opera with her, to feel, in life as in physics, her solidity and fidelity, and to share her humour. We will miss her greatly.

Friends of Bianca.

Bianca Monteleoni-Conforto (1937–1999) beside a module for the NESTOR underwater experiment at Pylos, Greece.

Rostislav Mikhailovich Ryndin 1929–99

Leading Russian theoretical physicist Rostislav Mikhailovich Ryndin passed away on 23 March after a protracted illness.

Born in Leningrad in 1929 into the family of a university lecturer, R M (Slava to his numerous friends), like all of his contemporaries, he spent his early life in difficult times. He remained in Leningrad throughout the worst of the siege until September 1942, his father dying of starvation in his arms. Later he endured evacuee hardships and could hardly stand following severe typhoid.

Returning to Leningrad, he graduated in 1952 and started work in Novo-Ivan'kovo (now Dubna), in the Hydrotechnical Laboratory, at that time top secret before becoming the Institute for Nuclear Problems, and then later the Joint Institute for Nuclear Research.

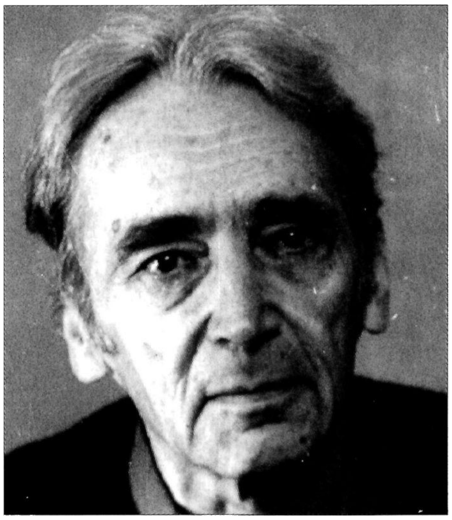
Ryndin had a deep understanding and wide knowledge of physics, particularly the physics of spin. His initial interests at Dubna were in nucleon and pion scattering. For a complete reconstruction of scattering amplitudes, he and his coauthors made a deep study of polarization effects. This classic work, which formed the basis for his PhD (1958), is still applied and referred to. Then he investigated the detailed relations between polarization effects and interaction symmetries, becoming a doctor of science in 1966.

He was able to visit CERN for the first time as early as 1956. During a year at CERN in 1959–1960, he collaborated with a US visitor of Russian origin, Boris Jacobsohn, on parity tests for particles. At CERN he gained a fine reputation, retaining numerous contacts till the end of his life.

In 1970, by now world renowned, he moved to the Theory Group of the Leningrad Physico-Technical Institute, subsequently the Theory Division of the Leningrad (now Petersburg) Nuclear Physics Institute. There his best-known publications were on atomic parity violation, followed by investigations of possible macroscopic parity-violating effects in media or wave guides. His final work focused on the motion of spinning particles in electromagnetic fields producing so-called topological effects.

Ryndin was very attentive to young physicists and gave frequent lectures at schools. From a family of intellectuals, he was an intellectual in the best sense of the word, with wide interests, and he had the rare gift of becoming an acknowledged authority and opinion leader in his various spheres of interest. He did not hesitate from being critical.

He was influential in shaping the image of the Theory Division of PNPI. His death is a hard loss for his family, his friends and his collaborators, and the whole physics community, particularly in Russia and at CERN.



Rostislav Mikhailovich Ryndin 1929-99

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Der Schwerpunkt liegt insgesamt auf der Projektarbeit in den oben genannten Bereichen und der Entwicklung neuer automatisierter Lösungen auf der Grundlage modernster Technologien. Die internationale Zusammenarbeit ist analog zu den Forschungsprojekten des Labors von entscheidener Bedeutung. Aufgaben und Umfeld bieten damit beste Voraussetzungen für die eigene fachliche Weiterentwicklung.

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Schwerbehinderte werden bei gleicher Eignung bevorzugt berücksichtigt. DESY fördert die berufliche Entwicklung von Frauen und ist deshalb an deren Bewerbungen interessiert. Interessierte Wissenschaftler(innen) senden ihre vollständigen Bewerbungsunterlagen sowie Namen und Adressen von 3 Gutachtern an die

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California Institute of Technology

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Knowledge and Experience: University degree or equivalent in computer science, physics or a related discipline and several years of experience in scientific computing is required. Knowledge of software engineering standards, Demonstrated talents in object-oriented analysis, design and coding using C++ in a Unix environment. The successful candidate will have excellent communication skills, and be used to working effectively in a team of similarly motivated individuals.

At least initially, the successful applicant will be based at CERN. The salary will be competitive and at a level commensurate with the successful candidates experience and qualifications. Princeton University is an Affirmative Action, Equal Opportunity Employer.

Applications, including a CV and the names of three professional referees, should be forwarded to

Dr. David Stickland, EP Division, CERN, CH1211, Geneva 23, Switzerland. Email: David.Stickland@cern.ch

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Kansas State University

Postdoctoral Position in High Energy Physics

An experimental postdoctoral position is immediately available in the High Energy Physics group at Kansas State University in Manhattan, Kansas. Our group is involved in construction and commissioning of the Silicon vertex detector for the D0 experiment at Fermilab and in the development of pattern recognition algorithms. It is anticipated that the successful candidate will play a leading role in one of these projects and, eventually, become fully involved in analysis of the Run II data. The K-State High Energy group, consisting of five faculty and two post-docs, also plays a major role in Fermilab E815, a precision neutrino neutral current measurement in its data analysis phase. **Applicants should have strong software and analysis skills and a Ph.D. in particle physics, and be willing to live at Fermilab. Interested parties should send a resume, list of publications, and three letters of recommendation to: Prof. Regina Demina, Dept. of Physics, 116 Cardwell Hall, Kansas State University, Manhattan, KS 66506-2601, E-mail: regina@phys.ksu.edu** The application deadline is September 1, 1999, but the deadline may be extended beyond this date until the position is filled.

Kansas State University is an affirmative action equal opportunity employer andactively seeks diversity among its employees.

UNIVERSITY OF CALIFORNIA, SAN DIEGO

POSTDOCTORAL RESEARCH POSITION IN Experimental High Energy Physics

The Department of Physics at the University of California, San Diego, invites applications from outstanding candidates for a Postdoctoral Research position in experimental High Energy Physics. UCSD is a member of the BABAR experiment at the PEP II B Factory at SLAC. The goal of BABAR and PEP II is to explore CP violation in B decays as a precision test of the Standard Model. The successful applicant will participate in the initial program of data taking and physics analysis with the BABAR detector. In particular, the UCSD group is contributing to the ongoing operation of the Drift Chamber, as well as to tracking, vertexing, and reconstruction software development. Candidates with interest and experience in these areas and in data analysis are particularly encouraged to apply. A Ph.D. in particle physics or a related field is required. Experience in C++ would be an asset. Applicants should send a copy of their curriculum vitae, including a statement of physics interests, and arrange for three letters of recommendation to be sent to:

Professor David MacFarlane
University of California, 0319
9500 Gilman Drive
La Jolla, CA 92093-0319
e-mail: dbmacfarlane@ucsd.edu

phone: +1 (858) 822-1452 fax: +1 (858) 534-0173

The nominal deadline for the receipt of the application is September 1, 1999, although the search will continue until the position is filled.

POSTDOCTORAL FELLOW PHYSICIST

The ATLAS Group at the **Lawrence Berkeley National Laboratory (LBNL)** has an immediate opening for a postdoctoral candidate in experimental High Energy Physics. The LBNL group is part of the ATLAS Collaboration, building one of the two large experiments at the CERN Large Hadron Collider. The LBNL group is engaged in the design and construction of the ATLAS silicon strip and pixel trackers.

You will participate initially in the design and fabrication of the pixel tracker systems and take a major role in the acquisition and analysis of laboratory and test beam data for prototypes of the pixel system. Requires Ph.D in Physics within the last two years. Experience in the area of silicon detector or integrated circuit electronics systems is preferred.

This is a two-year term appointment. The salary is $3,530-$4,170/month. Applicants should submit a letter of application, curriculum vitae, list of publications, and three letters of reference to: **Lawrence Berkeley National Laboratory Physics Division, Personnel Administrator, Job# PHY10051/JCERN, Mail Stop 50-4037, Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, CA 94720, U.S.A.** E-mail inquiries to: **scdougherty@lbl.gov. FAX: (510) 486-4848.** Berkeley Lab is an affirmative action/equal opportunity employer committed to the development of a diverse workforce.

BERKELEY LAB

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science serving society

Deputy Group Leader for Accelerator Development and Maintenance

Summary: Serve as a member of the LANSCE-2 management team by providing technical leadership. The group conducts beam dynamics studies and has a program of beam development activities related to the Proton Storage Ring, beam lines, and H-injectors. Participate in team- building, performance appraisals, salary management, planning and budgeting. Assume a proactive role in the group's ES&H effort.

Required Skills: Demonstrated excellence in technical and project leadership. Excellent management and interpersonal skills. Proven ability to work harmoniously and effectively with scientists, engineers and technicians. Track record of success in the development or operation of an accelerator complex or a similar facility. Strong record of technical accomplishments and experience in one or more of the following: particle beam physics, beam diagnostics, dc and pulsed magnets, ion sources and injectors, materials and radiation effects, pulsed power, high-voltage systems, and accelerator engineering. Excellent verbal/written communication skills.

Desired Skills: Experience in theory or practical aspects of circular accelerators or storage rings. Experience in project management or formal maintenance management. Success as a mentor and in conflict resolution.

Education: Ph.D. in Physics, M.S. or Ph.D. in Engineering, or an equivalent combination of education and experience.

For full text of this job, see http://www.lanl.gov/external/opportunities and search for job number **994920**.

For consideration, please send your resume referencing **"CERN994920"** to jobs@lanl.gov (no attachments, please) or mail to: **Human Resources Division, Los Alamos National Laboratory, "CERN994920," Mail Stop P286, Los Alamos, NM 87545.**

Los Alamos
NATIONAL LABORATORY
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www.lanl.gov AA/EOE

Postdoctoral Position in Experimental Particle Physics

Swiss Federal Institute of Technology Zurich (ETH/Z)

A postdoctoral position is available with the particle physics group at the Swiss Federal Institute of Technology in Zurich (ETH/Z) to participate in the ICARUS underground experiment at the Gran Sasso Laboratory, Italy and in the CMS experiment at LHC.

The goal of the underground ICARUS experiment is to study solar and atmospheric neutrinos and proton decay using a large scale liquid Argon TPC. The detector could also be ideal to study neutrino oscillations with accelerator produced neutrinos from CERN.

The group is involved with the CMS TriDAS project. One of the main challenges at LHC will be detect very rare events. The first level triggers will be processed and reduced online by a powerful online filter-farm.

These research topics will provide opportunities for the candidate to be involved in all aspects of an experiment – construction, hardware, software and physics analysis.

We are interested in candidates, holding a Ph.D. in physics, with diverse experience in experimental particle physics, who perform efficiently and creatively in detector hardware and data analysis work. The candidate will spend about 70% of his/her time doing research and will have a 30% involvement with academic requirements helping diploma and PhD students. He/she will hold a fixed term contract of three years renewable to six years. Interested candidates should send a curriculum vitae and arrange to have at least three letters of recommendation sent to:

Prof. Andre Rubbia, Institute for Particle Physics ETH Hönggerberg / HPK F23, Swiss Federal Institute of Technology, CH-8093 Zurich (Switzerland)

DESY announces several

"DESY-Fellowships"

for young scientists in experimental particle physics to participate in the research mainly with the HERA collider experiments H1 and ZEUS, with the fixed target experiments HERA-B and HERMES and in R & D work for TESLA.

New fellows are selected twice a year in April and October.

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

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

Interested persons, who have recently completed their Ph.D. and are under 32 year of age, should submit an application consisting of a curriculum vitae, copies of university degrees and a publication list; and should arrange to have three letters of recommendation sent directly to:

DESY, Personalabteilung, Notkestr. 85, D-22607 Hamburg
by 30 September,1999 Code-Number 61/99

Applications are particularly welcomed from qualified women and people with disabilities as they are currently under represented within the workforce. Women are especially encouraged to apply.

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

TENURE TRACK FACULTY POSITION
Experimental High Energy Physics
Carnegie Mellon University

The Department of Physics at Carnegie Mellon University invites applications for a junior tenure track faculty position in the area of experimental particle physics. The present program consists of experiment 781 at Fermilab, R&D for the BTeV detector at Fermilab, the L3 experiment at CERN, and the CLEO III experiment at Cornell. We are also engaged in work in the CMS collaboration for the LHC.

Applicants for the position should have postdoctoral experience and demonstrated ability in both instrumentation and analysis. The successful candidate is expected to assume a leadership role in his/her experimental involvement during the coming decade. Applicants should also be committed to excellence in graduate and undergraduate education.

The position is nominally available for September, 2000, but an earlier starting time might be arranged. Applications and three (3) letters of recommendation should be sent before October 15, 1999, to:

High Energy Search Committee
ATTN: Prof. James Russ
Department of Physics
Carnegie Mellon University
Pittsburgh, PA 15213, USA
(e-mail: russ@cmphys.phys.cmu.edu)

Reply may be by email, followed by paper copy.

Carnegie Mellon is an equal opportunity/affirmative action employer

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The Institute of Physics, University of Zürich, CH-8057 Zürich, Switzerland is looking for a candidate to fill the position of a

Senior Assistant/Lecturer

by September 1/1999 or later.

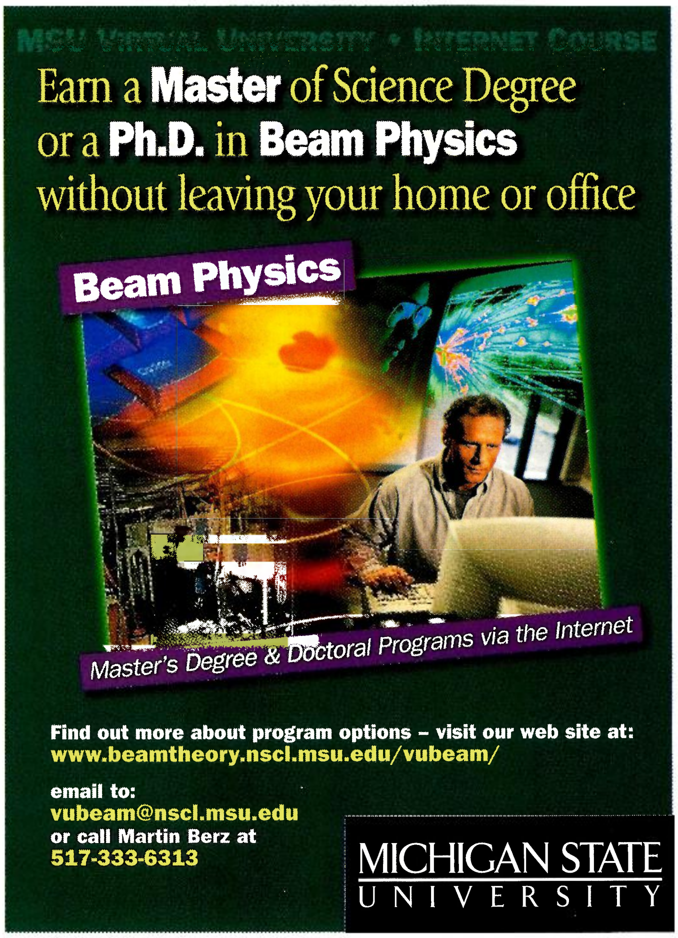
The teaching duties of this person involve the complete responsibility for the laboratories and accompanying lectures on the use of computers in planning and carrying out experiments in sciences. These lectures are part of the program "Computational Sciences and Computer Use for Scientists" of the Faculty of Mathematics and Sciences of the University of Zürich.

Apart from the teaching, the position entails the responsibility for the maintenance of the cluster of workstations available at the institute and running under the LINUX operating system, the administration of the computer budgets, the coordination of hardware acquisitions and consulting to the physicists responsible for the computers in the different research groups.

Candidates preferentially should have a Ph.D. in experimental physics, and advanced experience in data acquisition and analysis. Participation in the research of one of the groups in the institute (particle physics, surface physics, biophysics and solid state physics) is desired. At a later time an unlimited contract is possible.

Though initial knowledge of German is not required, applicants should eventually be able to teach in German, too.
Applications should be addressed until August 1/1999 to

Prof. Dr.R. Engfer, Institutsdirektor,
Physik-Institut der Universität,
Wintershurerstr. 190, CH-8057 Zürich, Schweiz.
Tel: 0041-1-6355720, Email: engfer@physik.unizh.ch



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email to:
vubeam@nscl.msu.edu
or call Martin Berz at
517-333-6313

ELECTRONIC ENGINEERS

The National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory is one of the premier research facilities in the world. Over 2300 scientists from over 470 universities, corporations and laboratories around the world use its unique facilities for research in medicine, pharmaceuticals, plastics, semiconductors, and basic science. The NSLS is seeking qualified candidates for the following positions:

Electronic Engineer

An MSEE degree or higher with experience in beam instrumentation equipment to work in the diagnostic section of the NSLS is required. Experience in beam position monitor systems utilizing feedback techniques to control the electron beam orbit is preferred. Knowledge of digital techniques and processing wide dynamic range, low signal-to-noise ratio signals is very desirable. Job Code: NS7848.

Power Electronics Engineer

A BSEE degree or higher with five years' experience in the design and analysis of high power multi-phase converters; multi-kilowatt systems background is preferred. Knowledge of power transformer configurations, power factor correction, and National Electric code requirements are desirable. The work will be in the power systems group of the NSLS responsible for the maintenance and upgrade of highly regulated power supplies, as well as the building power systems infrastructure. Job Code: NS8433.

Brookhaven offers a stimulating work environment and a comprehensive benefits package. For consideration, please forward your resume, indicating Job Code, to: Nancy L. Sobrito, Brookhaven National Laboratory, Bldg 185-HR, Upton, NY 11973 – USA; or email: Sobrito@bnl.gov. For more information about BNL please visit our website at: www.bnl.gov. BNL is an equal opportunity employer committed to workforce diversity.

BROOKHAVEN NATIONAL LABORATORY
www.bnl.gov

Post-grad and post-doc TMR network applications are invited for post-doc and post-grad positions.

Topic: Cryogenic Detectors development and applications: Beta and X-ray Spectroscopy, Investigation on Beta Environmental Fine structure.

Applicant must have an E.U. citizenship (not Italian). Info and Applications:
Prof. Sandro Vitale Dipartimento di Fisica - Universita di Genova and INFN Genova
Via Dodecaneso 33 - 16146 Genova ITALY
e-mail vitale@ge.infn.it. tel +39 010 3536229 fax +39 010 313358

Further details can be obtained directly on request.

Applications should be received no later than July 30

URGENT RECRUITMENT?

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

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

RWTH
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AACHEN

In der Mathematisch-Naturwissenschaftlichen Fakultät / Fachbereich I ist eine

Universitätsprofessur (C4 BBesG) für Experimentalphysik

zu besetzen.

Das Fach Experimentalphysik ist in Forschung und Lehre zu vertreten, insbesondere im Bereich "Experimentelle Elementarteilchenphysik".

Die Zusammenarbeit mit bestehenden Gruppen der experimentellen Elementarteilchenphysik und Gruppen der theoretischen Physik ist erwünscht.

Zu den Aufgaben in der Lehre gehört die Ausbildung in den Diplom- und Lehramtsstudiengängen der Physik sowie die Beteiligung an der Ausbildung von Studierenden in den übrigen Natur- und den Ingenieurwissenschaften.

Einstellungsvoraussetzungen sind Habilitation oder gleichwertige wissenschaftliche Leistungen sowie pädagogische Fähigkeiten.

Die Bewerbung von Schwerbehinderten ist erwünscht.

Die RWTH Aachen strebt eine Erhöhung des Anteils der Frauen in der Forschung und Lehre an. Bewerberinnen und Bewerber werden gebeten, sich mit den üblichen Unterlagen (Lebenslauf, Darstellung des wissenschaftlichen bzw. beruflichen Werdeganges, Schriftenverzeichnis) bis zum **20. August 1999 an den Dekan der Mathematisch-Naturwissenschaftlichen Fakultät / Fachbereich I RWTH Aachen 52056 Aachen** zu wenden.

Postdoctoral Position in Experimental Particle Physics at Yale University

There is a postdoctoral position available at Yale University with the experimental particle physics group. The successful applicant would have the opportunity to work on Opal,SLD (B-mixing), detector development for a future linear collider and the study of lensed quasars (QUEST). The CCD camera for QUEST is currently being upgraded and there are plans to build prototypes of a central tracking system for the future linear collider detector. Therefore, good hardware as well as good analytical abilities are sought. There are also opportunities to initiate new projects.

We are accepting applications now. For further details please contact Homer Neal at homer.neal@yale.edu or Charlie Baltay at Charles.Baltay@yale.edu.

Applications, with curriculum vitae and three letters of recommendation should be sent to: Prof. Homer Neal, Physics Department, Yale University, P.O. Box 208121 New Haven, CT 06520-8121, USA

Yale University is an equal opportunity employer.

NUI MAYNOOTH
Ollscoil na hÉireann Má Nuad

National University of Ireland, Maynooth

RESEARCH FELLOWSHIP IN EXPERIMENTAL COSMOLOGY

A post-doctoral post is available to work on the optical design of the HFI instrument on the ESA PLANCK SURVEYOR.

The mission goal is to map the faint anisotropies of the Cosmic Microwave Background providing a unique data source for cosmology.

The work will involve computational modelling of the instrument using physical optics and electromagnetics.

The post is available from October 1999 for two years with a salary of c.a. IR£20,000 p.a., depending on experience.

Candidates should send a detailed CV, together with the names of two referees to: Dr. J. A. Murphy, Department of Experimental Physics, National University of Ireland, Maynooth, Co. Kildare. Ireland.
For further information e-mail: anthony.murphy@may.ie, or visit our web site: http://www.may.ie/academic/physics

University of Toronto

Departments of Mathematics and Physics

Tenure Track Faculty Position in Theoretical Particle Physics

The Departments of Mathematics and Physics invite applications to a tenured or tenure-stream professorial joint appointment with an expected starting date of January 1, 2000. This is one of several openings in theoretical astrophysics and particle physics.

We seek candidates with a Ph.D in Mathematics and/or Physics with proven or potential excellence in research. Our goal is to hire a mathematical physicist with interests in string theory who will promote interactions among the two departments and the Canadian Institute for Theoretical Astrophysics. We intend to nominate the successful candidate for a CIAR Fellowship in the Canadian Institute for Advanced Research Cosmology and Gravity Program. We invite prospective candidates to visit our home pages at :www.{math,physics, cita}.utoronto.ca and www.ciar.ca. The rank of the appointment and salary will be commensurate with qualifications and experience.

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

Professor Pekka K. Sinervo
Chair
Department of Physics
University of Toronto
60 St. George Street
Toronto, Ontario, Canada
M5S IA7

The deadline for the receipt of applications and letters of recommendation is 15 July 1999.

Although first consideration will be given to citizens and permanent residents of Canada, we strongly encourage all qualified candidates to apply. The University of Toronto is committed to employment equity and encourages applications from all qualified individuals including women, members of visible minorities, aboriginal persons, and persons with disabilities.

University of Toronto

Department of Physics

Tenure Track Faculty Position in Theoretical Particle Physics

The Department of Physics plans to make a tenure track appointment to the rank of Assistant Professor with a starting date on 1 January 2000. This is one of several new positions at the University of Toronto that will strengthen theoretical physics, including an advertised position in string theory.

For this position, we seek candidates with a Ph.D. in Physics and proven or potential excellence in both research and teaching whose interests are in theoretical particle physics. We invite prospective candidates to visit our home page at www.physics.utoronto.ca. The salary will be commensurate with qualifications and experience.

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

Professor Pekka Sinervo
Chair
Department of Physics
University of Toronto
Toronto, Ontario, Canada
M5S 1A7

The deadline for the receipt of applications and letters of recommendation is 15 July 1999.

Although first consideration will be given to citizens and permanent residents of Canada, we strongly encourage all qualified candidates to apply. The University of Toronto is committed to employment equity and encourages applications from all qualified individuals including women, members of visible minorities, aboriginal persons, and persons with disabilities.

Are you looking for..

- Bio/Medical Physicists
- Radiologists
- Electrical Engineers
- Software Developers
- Technical Editors
- Electrical Engineers
- Cosmologists
- Subatomic, Nuclear, Particle, Astro, High, Medium and Low Energy Physicists.

For further information and professional recruitment advice contact

Chris Thomas.
Tel: +44 (0)117 930 1031
Fax: +44 (0)117 930 1178
E-mail:
chris.thomas@ioppublishing.co.uk

POSTDOCTORAL RESEARCH ASSOCIATE POSITION

Academia Sinica invites applications for a postdoctoral research associate position to participate in the Alpha Magnetic Spectrometer (AMS) experiment. The initial appointment is two years with possibility of renewal up to 4 years.

Academia Sinica is the highest level of research organization in Taiwan, Republic of China. The Institute of Physics is involved in the data acquisition system and the Ring Imaging Cherenkov Counter. The physics topics include proton and positron flux measurements.

The successful applicant is expected to stay at CERN for extended period of time and play a major role in the development of DAQ for the next flight. Applicants should send their Curriculum Vitae, a publication list, and arrange to have three letters of reference sent to:

Dr. Ping Yeh
Institute of Physics, Academia Sinica
128, Sec. 2, Academia Rd.
Nankang 11529, Taipei, Taiwan, R.O.C.
or by e-mail directed to: pyeh@sinica.edu.tw.

POSTDOCTORAL RESEARCH ASSOCIATE

Experimental High Energy Physics, University of Toronto

Applications are invited for a position as part of the University of Toronto group working in Hamburg on the ZEUS experiment at DESY. Members of our group participate in a wide range of physics analysis efforts on ZEUS and are responsible for the ZEUS Third Level Trigger. Applicants should send a letter stating their research interests, along with a resume and three letters of reference to: **Prof. John Martin, Department of Physics, 60 St. George Street, Toronto, Ontario, M5S 1A7, CANADA. For further information please contact Prof. John Martin at martin@physics.utoronto.ca**

Anyone interested is encourage to apply, but in accordance with Canadian immigration regulations, this advertisement is directed in the first instance to Canadian citizens or permanent residents. The University of Toronto strongly encourages applications by women and members of minority and aboriginal groups.

U.S DEPARTMENT OF ENERGY
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OFFICE OF HIGH ENERGY AND NUCLEAR PHYSICS
HIGH ENERGY PHYSICS DIVISION
GS-14: $68,570 - $89,142 per annum
GS-15: $80,658 - $104,851 per annum
PN-99-SC-76-22-045

The U.S. Department of energy is seeking applicants for the position of Physicist within the High Energy Physics Division, Office of High Energy and Nuclear Physics, in the Office of Science. The incumbent will serve as the Program Manager for experimental high energy physics activities relating to an advanced detector research and development program. The incumbent will be responsible for establishing goals and objectives as well as providing leadership and direction for this program with national and international scope and impact. Assesses resource needs and develops policies and plans based on review and evaluation of scientific priorities, and defends needs of projects. Prepares, justifies, and supports the advanced detector research and development and related university experimental physics portion of the high energy physics budget. Develops and recommends strategies, plans, milestones, and schedules for assigned program activities. Establishes the need for, organizes and supervises studies, workshops, symposia, and conferences to facilitate the interchange and transfer of scientific and technical information to a wide community of scientists and engineers. A thorough knowledge and understanding of high energy physics, as well as extensive background and experience based on training and substantial research experience in the field, are necessary.

Please refer to Vacancy Announcement PN-99-SC-76-22-045 (reference http://www.hep.net/doe-hep/home.html) for specific instructions on how to apply for this position. Applicants must comply with the instructions that are in the vacancy announcement in order to be eligible for consideration. Announcements can be faxed to you by calling 202-586-1705 or mailed to you by calling 301-903-1577.

Applications must be postmarked no later than September 7, 1999, and should be sent to the U.S. Department of Energy, MA-352, Room F-125, 19901 Germantown Road, Germantown, MD 20874-1290 (ATTN: Sheila Hopkins).

The Department is an equal opportunity employer.

NATIONAL INSTITUTE FOR NUCLEAR PHYSICS

I.N.F.N.

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

THEORETICAL PHYSICS (N. 10)

EXPERIMENTAL PHYSICS (N. 20)

The I.N.F.N. Fellowship Programme 1999-2000 offers thirty positions for non Italian citizens for research activity in theoretical or experimental physics.

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

Each fellowship is granted for one year (which may start during the period from September to November 2000), and may be extended for a second year.

The annual gross salary is 42.000.000 Italian Lire, plus travel expenses for round trip transportation from the home fellows to the I.N.F.N. Section or Laboratory. Lunch tickets are provided for work days.

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

Applications must be sent to I.N.F.N. no later than *September 30, 1999.*

Candidates will be informed by the end of January 2000 about the decisions taken by I.N.F.N.'s committee.

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

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

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

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

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

NATIONAL INSTITUTE FOR NUCLEAR PHYSICS
THE PRESIDENT
(Prof. Enzo Iarocci)

NEW PRODUCTS

Compact radiation detector supports portable applications

eV PRODUCTS, which is a specialist in the production and supply of CdZnTe-based, room-temperature-operation, radiation detectors, has launched the SPEAR (Single Point Extended Area Radiation) detector.

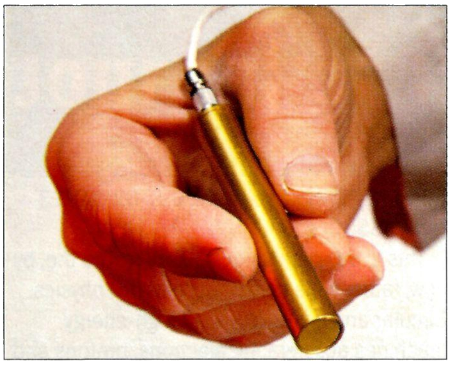
The device is a complete probe, comprising a $5 \times 5 \times 5\,\mathrm{mm}^3$ CdZnTe detector crystal and a low-noise hybrid preamplifier in a compact housing. It comes with a connecting cable, allowing the unit to be used immediately.

The new CAPture technology embodied in the SPEAR detector allows improved charge-collection efficiency, and thus photo-peak efficiency, along with reduced tailing and an improved peak-to-valley ratio for easier identification and quantification.

These improvements are all made without the use of complicated electronic systems and are ideally suited for portable applications, where weight, power consumption and size are important factors.

Available from stock, the SPEAR detectors require a 12 V DC power supply, ground and bias (typically 500–750 V), and it will interface with any standard spectroscopy or counting system.

Contact Chris Bickel, eV PRODUCTS, 373 Saxonburg Blvd, Saxonburg, PA 16056, tel. 724 352 5288, fax 724 352 4435, internet “www.evproducts.com”.



The SPEAR detector from eV PRODUCTS is a complete probe, comprising a $5 \times 5 \times 5\,\mathrm{mm}^3$ CdZnTe detector crystal and low-noise hybrid preamplifier in a compact housing.

VME 64 extensions approved

VITA, the VMEbus International Trade Association, has announced the approval of the VITA 23, *VME64 Extensions for Physics and Other Applications* by the American National Standards Institute ANSI.

The document has been produced to supplement the VMEbus specifications, particularly the VME64 specification (ANSI/VITA 1-1994) and the VME64 Extensions (ANSI 1.1-1997), and to provide for the needs both of the physics community and users with similar requirements.

Issues that are addressed within the standard include grounding, high-frequency signalling, geographical addressing, user-defined input/output pins, efficient block transfer protocols and design guides.

The *VME 64 Extensions for Physics and Other Applications* (ANSI/VITA 23-1998) standard is available for a price of £32 plus delivery. It, and the many other current VITA reference works and standards, can be obtained from VITA Europe, 1 West Street, Titchfield, Hampshire PO14 4DH, UK, tel. +44 1329 841272, fax +44 1329 512063, e-mail “grace@gghnet.demon.co.uk”.

Multiphysics simulation software boasts upgrade

Numerical Objects AS of Oslo has released version 3.0 of its Diffpack Multi Physics Simulation Framework.

Key features include powerful functionality and enhanced software extensibility. This release also introduces a new level of user documentation with a suite of training applications, and it is topped by a new Diffpack 3.0 textbook from Springer-Verlag.

Also new is a high level of support for finite difference methods and mixed finite element methods. The graphical user interface on Windows is extended with an array of new features, and lightweight application-specific interfaces can now be generated in Unix.

Powerful extensions to the software architecture makes it possible to integrate seamlessly user-defined modules, as well as various Diffpack Toolboxes that will be released in the near future.

Diffpack 3.0 is available on Win32 as well as the Linux, DEC, IBM, SGI, HP and Sun Unix platforms. A test version of the software, documentation and application examples are available for download from Numerical Objects' Web site, which is accessible at “http://www.nobjects.com”.

BOOKSHELF

The MATHEMATICA Book, Version 4, by Stephen Wolfram, Wolfram Research, Cambridge University Press 0521 643147 (£35/$49.95). Mathematica is one of the most important programs for algebraic (in contrast to numeric) calculations. It is an indispensable tool in particular for theoretical particle physicists, who use it, for example, for computing Feynman diagrams and analysing the geometry of superstring compactifications. It is also extremely useful for graphical representations of data.

One of the most convenient features is the notebook interface, which allows WYSIWYG formula editing and evaluating. The electronic notebooks are highly editable and programmable, plus they allow for hyperlinks, can contain any graphics and are easily cross-platform transportable.

Wolfram Research has now announced release 4.0 of the popular program. It offers a series of improvements, like enhancements of built-in functions, algorithms, graphic format handling, document publishing, and improvements in speed and efficiency as well as in the notebook interface. While all of these features are very welcome, the difference between the previous version, Mathematica 3.0, is nowhere near as significant as the that between Mathematica 3.0 and 2.2. One hopes that this upgrade provides a thorough fix of all of the new bugs that appeared in Mathematica 3.0. Further information is available at "http://www.wri.com".

Wolfgang Lerche.

Accelerator Physics by S Y Lee (Indiana University), World Scientific 981 02 3710 3 (pbk US$32/£22).

This is a general, introductory text to the, by now, rather wide field of accelerator physics. Circular and linear, low- and high-energy machines accelerating electrons, protons and ions are covered. Synchrotron motion, basic collective effects and synchrotron radiation are described as well.

The book can be strongly recommended for students specializing in accelerator physics, in particular those who appreciate a detailed, formal description of beam optics design and who are likely to use tracking or optics design programs. It should also be useful as a source of reference material for the specialist.

Readers interested in self-study and engineers working on aspects connected with accelerators will probably find the book rather formal, specialized and difficult to read.

Progress in accelerators was, and still is, to a large extent stimulated by the needs of nuclear and particle physicists for higher energies, intensities, luminosities, etc. There is relatively little on these subjects. The beam-beam effect is mentioned only briefly and there is no discussion of the definition, knowledge and optimization of beam parameters of interest to users of accelerators.

The 490 pages contain an impressive amount of material and many formulae. Additional details are often given as exercises for the student.

Helmut Burkhardt.

Introduction to Superstrings and M-Theory (2nd edn) by Michio Kaku, Springer (Graduate Texts in Contemporary Physics) 0 387 98589 1 (hbk $49.95).

This edition of Kaku's book, first published in 1988, ensures the continued availability of a valuable introduction to this field, already heralded in some quarters as the physics of the 21st century. Kaku is professor of theoretical physics at the City College of the City University of New York. A prolific and respected writer of popular science ("Visions: how science will revolutionize the 21st century and beyond"; "Hyperspace: a scientific odyssey through parallel universes, time warps and the tenth dimension"; "Beyond Einstein: the cosmic quest for the theory of the universe" (with Jennifer Trainer)), he is also the author of *Quantum Field Theory: a Modern Introduction*, and hosts a successful weekly radio science programme.

Perseus reissues

This year sees some reissues in Perseus's useful Advanced Book Classics series by prestigious authors. (The series was previously published by Addison Wesley.)

Superconductivity of Metals and Alloys by P G de Gennes 0 7382 0101 4 (pbk $35) copyright 1966.

From the author's introductory course at Orsay, this text explains the basic knowledge of superconductivity for both experimentalists and theoreticians. These notes begin with an elementary discussion of magnetic properties of Type I and II superconductors. The microscopic theory is then built up in the Bogoliubov language of self-consistent fields. This book provides the classic, fundamental basis for any work in superconductivity.

Theory of Superconductivity by J Robert Schrieffer 0 7382 0120-0 (pbk $35) copyright 1983.

This is considered to be one of the best introductory treatments of superconductivity and has been reprinted because of its enduring value. Based on lectures at the University of Pennsylvania, the fundamentals of the microscopic theory of superconductivity are stressed as a means of providing a framework for detailed applications of microscopic theory to specific problems. It also serves as a foundation for more recent developments.

Mathematical Methods of Physics by H W Wyld 0 7382 0125 2 (pbk $45) copyright 1976.

With supplementary material, such as graphs and equations, this text creates a strong, solid anchor for first-year students.

Conceptual Foundations of Quantum Mechanics by Bernard d'Espagnat 0 7382 0104 9 (pbk $35) copyright 1971.

This volume offers a clear and comprehensive account of the fundamental physical implications of the quantum formalism, which deals with non-separability, hidden variable theories, measurement theories and several related problems. Mathematical arguments are presented with an emphasis on simple but adequately representative cases. The conclusion incorporates a description of a set of relationships and concepts that could compose a legitimate view of the world.

Elementary Excitations in Solids by David Pines 0 7382 0115 4 (pbk $35) copyright 1963.

Based on an advanced course in the theory of solids at Illinois in 1961, this continues to fill the need to communicate the present view of a solid as a system of interacting particles that, under suitable circumstances, behaves like a collection of nearly independent elementary excitations. The author frequently refers to experimental data. Both the basic theory and the applications largely deal with the behaviour of "simple" metals, such as the alkali metals, rather than the more complicated transition metals and the rare-earths. Problems are included in most chapters.

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