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Volume 40 Number 9 November 2000

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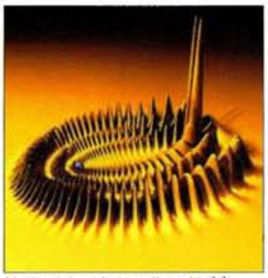
Extension for LEP p5



New molecule predicted p11

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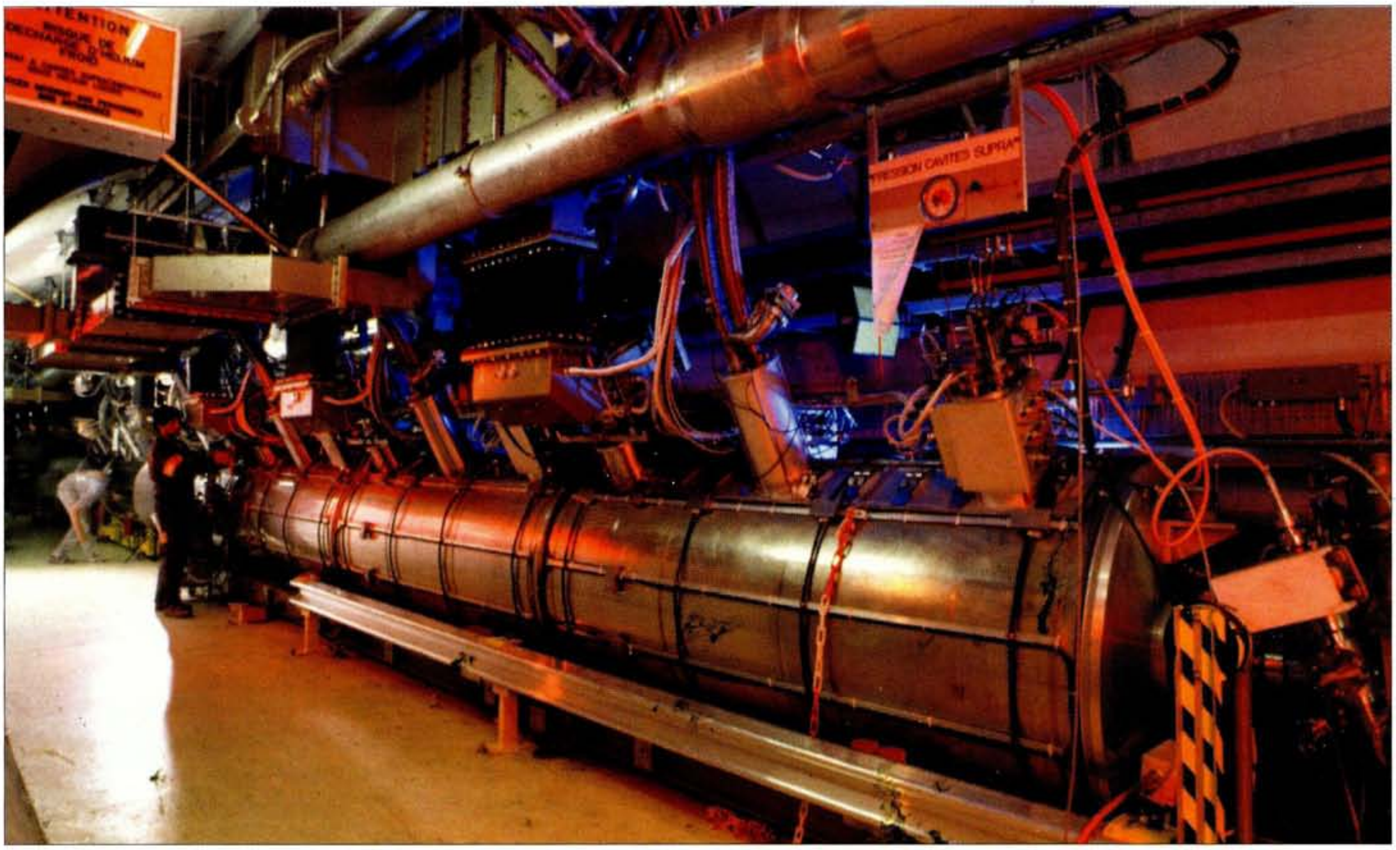
Cover: Combining radio and optical observations gives a better understanding of black holes. (Photo NASA/ESA.) p13.

NEWS

LEP gets a stay of Higgs execution



Equipped with superconducting radiofrequency accelerating cavities, the collision energy of the electron and positron beams in CERN's LEP collider has been pushed as high as 209 GeV.

With possible signs of the elusive Higgs particle on the horizon (October p8), on 14 September CERN decided to extend the life of its flagship LEP electron-positron collider until 2 November 2000.

LEP's 11 year period of physics research was scheduled to finish at the end of September, to allow commencement of serious engineering for the installation of CERN's new Large Hadron Collider (LHC). However, the new Higgs hints from the LEP experiments justify this change of plan. The construction schedule for LHC – expected to begin operations in 2005 – will not be affected by the prolonged LEP operation.

One of LEP's main physics aims has always been to search for the missing link of the Standard Model of particle physics – the Higgs particle, which breaks electroweak symmetry. The Higgs field pervades the whole of space and endows particles with mass.

During LEP's first phase of operations from 1989 until 1995, the collision energy was set at just over 91 GeV (the mass of the Z particle, the neutral carrier of the weak force), and searches showed that the Higgs must be heavier than 65 GeV. From 1996, Higgs searches at LEP continued as successive collision energy increases reached 202 GeV in 1999, showing that the Higgs must be heavier than 108 GeV.

In April the stage was set for a final push. Everything was done to boost the energy of LEP's particle beams as high as possible. Excellent work by CERN teams has allowed LEP to achieve collision energies of up to 209 GeV, well beyond the original design energy.

As experimental data started to accumulate above 206 GeV, a number of events compatible with a Higgs production with mass around 114–115 GeV were reported in the combined results of the four LEP experiments, ALEPH, DELPHI, L3 and OPAL. In these events, a LEP electron-positron pair could produce a back-to-back Z and Higgs particle. However, these signals are difficult to disentangle from more common processes, notably the production of Z and W particle pairs.

The prolongation of the LEP running in October 2000 is the response to this intriguing situation. The extension, the maximum still compatible with the tight LHC construction schedule, should effectively double the experimental data at collision energies above 206 GeV, allowing the candidate Higgs signal at 114 GeV to be tested. Such light Higgs particles would be copiously produced at the LHC.

The decision to extend LEP's experimental programme set the scene for a cliffhanger finish to its career. Many eyes are scrutinizing the latest data.

On 9–11 October, a series of major events at CERN marked the imminent end of the LEP era. Reports of these events will feature in the next issue.

Future plans take shape in Beijing

Aerial view of the Beijing Electron Positron Collider complex at the Chinese Institute of High Energy Physics. The machine and its detector are the subject of a comprehensive upgrade plan.

The lifetime of a modern electron–positron collider seems to span about a decade – witness LEP at CERN, commissioned in 1989 and now being decommissioned. At Beijing, the Beijing Electron Positron Collider (BEPC) was commissioned in 1988 and physicists are now considering the next step.

Beam energy at BEPC ranges from 1 to 2.8 GeV. The Beijing Spectrometer (BES) is the only detector with the major goal focused on tau-charm physics. Since data collection began in 1989, BES has collected large data samples of J/psi, psi', D_s and tau particles.

Many important results have been obtained, including the precision measurement of the tau mass, decay properties of J/psi and psi', and the observation of new decay channels of the $\xi(2230)$. Recently, the cross-section scan between 2 and 5 GeV has provided key input to Standard Model consistency calculations, with significant impact on the prediction of the mass of Higgs.

During the 1999–2000 running period, more than 20 million J/psi hadronic events were collected in five months. Peak luminosity was $5 \times 10^{30}/cm^2/s$ at a collision energy of 3.1 GeV. Many interesting new results will be published soon. As well as providing beams for particle physics, BEPC also provides synchrotron radiation light for many other research areas. Typically, the beam current is 130 mA at 2.2 GeV with a lifetime of 20–30 h.

There has been much discussion about the future of BEPC. There are two possibilities – construction of a new two-ring collider (tau-charm factory) with the luminosity increased by two orders of magnitude, or upgrade of BEPC (BEPC II) with the luminosity increased by one order of magnitude. The feasibility study on the tau-charm factory was carried out in 1995–1996.

Considering the latest developments of high-energy physics experiments and the successful running of B-factories, the best physics window for the future development of BEPC is foreseen as the charm sector, mainly in the J/psi and psi' energy region, including searches for glueballs and quark-gluon ▷

hybrid particles, the study of light hadron spectroscopy, the J/psi family, and charmed and excited baryons. These studies are very important for the development of theoretical understanding.

BEPC has unique advantages for these physics topics, which cannot be covered by B-factories. Since the machine will run mainly on the J/psi and psi′ peaks, where the reaction rates are very high, BEPC II can provide enough statistics. BEPC II could be constructed at reasonable cost within a relatively short time.

Recently the Chinese Academy of Sciences chose the BEPC II option for the future development of BEPC, an upgrade of both the machine and the detector. The upgrade of the detector will improve its resolution to reduce systematic errors and to adapt to the higher event rate.

Achieving higher luminosity means squeezing the colliding beams more tightly together, reducing the bunch length and increasing the beam current. Some key technical modifications are under discussion, such as using a 500 MHz radiofrequency system and superconducting cavities, reducing the impedance of the vacuum chambers, installing a micro-beta quadrupole to further squeeze the beams, and using interlaced pretzel orbits for multiple bunches and bunch trains. The injection rate from the linac must also be increased by a factor of five with the full beam energy.

The upgrade of the BES detector currently foresees new barrel shower counters made of lead-scintillator fibres, new readout electronics, trigger and data acquisition system, new time-of-flight counters, new vertex chambers, etc.

The Chinese government supports the decision of the Chinese Academy of Sciences, and ratified the BEPC II project in principle in July. The Institute of High Energy Physics is working on the detailed BEPC II design, and will submit the proposal, including the budget and schedule, to the government soon.

BEPC was the outcome of close co-operation in the world high-energy physics community. BES is also an international collaboration, including many physicists from the US, the UK, Japan and Korea. Continuing international cooperation on the construction of both the machine and the detector of BEPC II is very important for its success, and Chinese physicists sincerely hope that the international community will continue its tradition.

SOLEIL is set to rise

French window – the LURE synchrotron radiation facility at Orsay, near Paris.

On 11 September, French Minister of Research and Technology Roger-Gerard Schwartzenberg announced the decision to build the SOLEIL third-generation synchrotron radiation source near Paris.

This decision marked the climax of 10 years of effort to convince French scientific and political authorities to replace the DCI and Super-ACO rings at the LURE synchrotron radiation laboratory at Orsay with a modern synchrotron radiation source.

The project study was started and led by LURE between 1990 and 1996, and developed in a 3 year collaboration aimed at producing a 2.5 GeV machine with a circumference of 337 m and very high brightness. The detailed pre-project, costing 70 million French francs ($9 million) including salaries, was completed in June 1999.

Three major obstacles have been overcome in reaching the final decision. First, the reference site of Orme des Merisiers met opposition from proponents of political decentralization from 1992 onwards. Then budgetary restrictions on research quickly led to a successful search for alternative financial sources in different French regions. In this area, LURE made a spectacular breakthrough.

Finally, the categorical no to SOLEIL on 2 August 1999 from the previous Minister of Research in favour of a minority participation in the British project DIAMOND (May p7) began a pitched battle. The massive intervention of the French synchrotron radiation community, with wide support from scientific and political circles, brought the question into the media spotlight.

In March this year, a French parliament scientific and technological evaluation committee mounted a strong counterattack that was taken up by the Académie des Sciences and numerous scientific institutions. The arrival of the new Minister of Research and Technology turned the tide and helped produce the final decision.

In addition, the authorities of the Ile-de-France Region and the Département of the Essonne decided to increase their financial support to 1.2 billion francs ($160 million) out of a total of 2.1 billion francs including salaries, over an 8 year period.

SOLEIL will have 16 straight sections, of which 14 will be for insertions with undulators or wigglers, and must be able to provide room for a maximum of 40 beamlines including those from the dipoles. The photon spectrum must be wide, with performances of particular interest in the 1–11 keV range, but also on either side.

SOLEIL is a project of nationwide importance, but also intends to be European in scope, bringing in researchers from Spain, Belgium and elsewhere, as has always been done at LURE. Several governments, in particular those of Spain and Portugal, are also examining the possibility of participating in SOLEIL. The project incorporates a dozen innovative ideas, including a single mode superconductor which has been designed and built in collaboration with CERN.

First beams should appear in 2005. In this way LURE will continue its long pioneering tradition at the Orsay site.

LHCb's Brazilian CARIOCA

The demands that CERN's forthcoming Large Hadron Collider (LHC) place on detectors have led the LHCb collaboration to look to Latin flair for a solution. A group from the Laboratorio de Particulas Elementares (LAPE) at the Physics Institute of Brazil's Federal University of Rio de Janeiro (UFRJ) has been working with the CERN microelectronics group to develop readout chips for the experiment's muon detectors.

LHCb is a collaboration dedicated to the study of CP violation, the mechanism responsible for the matter–antimatter imbalance in the universe. It will do so by observing the decays of B-mesons, particles containing b-quarks, emerging from high-energy proton–proton collisions in the LHC.

Since such decays frequently involve muons, the collaboration's muon system is a key element of the detector, both for triggering and measurement purposes. LHCb's muon detector is a combination of resistive plate chamber (RPC) and multi-wire proportional chamber (MWPC) technologies. While RPCs cover the region with a modest particle flux, MWPCs are used in a higher radiation environment, placing stringent demands on the readout electronics.

Some 600 MWPCs with a total of around 125 000 readout channels will make up the LHCb muon system. Efficiency above 99% in a 20 ns time window with rates up to 800 kHz is required, and the readout electronics must also withstand an integrated radiation dose of one megarad over the experiment's lifetime.

Danielle Moraes of the Federal University of Rio de Janeiro at work on the LHCb experiment's CARIOCA chip.

This has led to the choice of quarter-micron CMOS technology, which is known for its radiation hardness when designed according to a particular layout technique, and which has been adopted by all the LHC's experiments. LHCb's particular requirement derives from the fact that the muon system's readout pads cover a large range of sizes, leading to capacitances varying from 10 to 200 pF.

A preliminary chip designed by the CERN–UFRJ group, CARIOCA (CERN And RIO Current Amplifier), was tested at CERN in September. Optimized for an input capacitance of 120 pF, the CARIOCA chip has so far performed well. The time for the signal to peak rises linearly with input capacitance from a pedestal value of 14 ns to 22 ns at 120 pF, while sensitivity remains constant across the full range at around 8 mV/fC. Low noise performance has also been achieved, with 2000 electrons for a detector capacitance of 50 pF. Radiation measurements have yet to be done, but so far the CARIOCA chip's performance is living up to expectations. A second-generation prototype is expected soon, with the goal of optimizing for an input capacitance of 200 pF.

Elsewhere in LHCb, progress is equally positive. Following the collaboration's first technical design report (TDR), which covered the magnet and was submitted in December 1999 and approved in March, two further TDRs were submitted to the LHC Committee in September. These cover the Ring-Imaging Cherenkov counter and calorimeters.

A tender has recently been issued for the magnet, which bucks the trend in particle physics in that it is not superconducting. For LHCb, the ability to switch polarity during a run is vital to reduce systematic errors on sensitive CP-violation measurements, and that is more easily achievable with a warm magnet.

A further seven TDRs are scheduled to be submitted up to mid-2002, covering all of the remaining LHCb sub-detectors. That for the muon system is scheduled for May 2001, with the final TDR covering the experiment's computing needs to take full advantage of Moore's Law. Like all the LHC's experiments, LHCb is relying on computing components whose development timetable matches that of the experiment itself.

ICARUS prepares to fly

Taking shape in the Italian Gran Sasso underground laboratory is a large module for the Imaging Cosmic And Rare Underground Signals (ICARUS) detector.

ICARUS uses the liquid argon time projection chamber idea initially proposed by Carlo Rubbia in 1977 which combines the advantages of visible particle tracks (like a bubble chamber) with the flexibility of fully electronic data acquisition. The drift time of electrons released by ionization drift over long distances can be picked up via an arrangement of readout wires giving simultaneous imaging in different views.

A large continuously active detector could be used to record neutrino interactions from terrestrial beams sent over long distances, from atmospheric and solar neutrinos, or from particles from cosmic and atmospheric sources. Track chambers provided important milestones in neutrino physics history, and the hope is that this tradition will continue with the new technique. In addition the detector could also monitor for proton decay.

From 1991 until 1995, a 3 t prototype chamber at CERN demonstrated proof of the principle. With the ultimate goal of building a 5000 t detector, a stepwise strategy foresaw: ▷

Wiring and photomultiplier mounting for the T600 ICARUS prototype.

Boost for Andean cosmic ray laboratory

The Mount Chacaltaya Cosmic Ray Research Laboratory (5220 m).

New support for the Chacaltaya Cosmic Ray Research Laboratory, on Mount Chacaltaya near La Paz, Bolivia, underlines its relevance for cosmic ray research. At 5220 m above sea level (a barometric pressure of about 540 mbar; just over 0.5 atm), it is the highest continuously functioning research station on the globe, providing a unique opportunity for siting relatively large cosmic ray detectors.

At energies above 10^{14} eV, the flux of primary cosmic rays is so low that direct observation by balloon- or satellite-borne instruments (with areas of only a few square metres) is difficult. For example, the integral primary cosmic ray flux of energies above 10^{16} eV is only one particle per m^2 per year. Consequently the most sensitive indirect studies of cosmic rays with energies of 10^{15} eV (1 PeV) and above suggest the deployment of large-area detector systems at as high a terrestrial elevation as possible, in order to reduce atmospheric shielding.

Although Brazilian and Japanese groups have maintained their research activities at Chacaltaya throughout recent years, the research potential of this site has been under-utilized. In consideration of the unique capabilities of this site, and to stimulate further exploitation of this facility, the Centro Latinoamericano de Fisica (CLAF), at its General Assembly in Leon, Mexico in November 1999, unanimously approved a declaration of support for the installation of new experiments at Chacaltaya.

To coordinate the international, and in particular the Latin American, collaborations for new experiments at the laboratory, CLAF asked its director, Luis Masperi, and deputy director, Joao dos Anjos, to form a special committee together with Carlos Aguirre, president of the Academia Nacional de Ciencias of Bolivia, and P Miranda of the Universidad Mayor de San Andres of La Paz and the director of the Chacaltaya Laboratory.

The laboratory was founded in 1942 by I Escobar, initially as a meteorological station. Soon afterwards, a road was constructed, partly to give access to a ski station opened in 1940 by the Club Andino Boliviano.

The project was championed by an Austrian physicist then in Bolivia, F Hendel (now at Michigan) and R Posnaski. C M G Lattes initiated cosmic ray research on Chacaltaya with the exposure of nuclear emulsions, confirming the strange particle decays discovered at Pic du Midi in France.

The Bolivian Air Shower Joint Experiment (BASJE) collaboration was started in about 1960 by B Rossi (MIT) and K Suga (Japan). Lattes, together with Brazilian colleagues and a Japanese group including Y Fujimoto and S Hasegawa from Waseda, established a long-term program at Chacaltaya, working mainly with nuclear emulsion chambers – stacks of alternating layers of nuclear emulsion and lead.

Other research groups from the US, Japan and Europe were also active there from the 1950s until the 1970s. Notable discoveries included the "Centauro" events and other exotic phenomena not apparent in the lower-energy collisions studied with particle accelerators, and which are still not understood. The current research activities are primarily the BASJE observations, now involving only a Japanese group and the Saitama–Yamanashi–San Andres collaboration.

At 5220 m, the laboratory is only an hour's drive from La Paz airport (on the Alte Plano, at 4200 m) and about two hours from central La Paz (3600 m). As Chacaltaya is 17° south, access is possible throughout the year.

The second half-module for the ICARUS T600 prototype en route to Pavia for initial testing.

- developing the infrastructure needed to build and operate a large detector;
- acquiring the *in situ* safety experience with a still modest liquid argon volume; and
- evaluating a definitive and practical engineering choice for the final phase.

For this, the most efficient and economical approach was to build and test a module of intermediate size outside Gran Sasso before moving it underground for final assembly. The module thus has to be transportable, which limited its size to about 600 t (twin sub-modules of 3.9 × 4.2 m and a length of 19 m).

As well as testing design and logistics, such an intermediate detector would at the same time be an important first step in the ICARUS scientific programme, with a target mass close to that of the Japanese Kamiokande detector, but with the advantages of the new technology. En route to this T600 prototype, a 10 m^3 (15 t) prototype built by Air Liquide was first shipped to INFN Pavia for cryogenic testing and to check operation of the inner wire chamber at liquid argon temperatures before trials *in situ* at Gran Sasso. Track lengths of up to 4 m have been achieved. Assembly and tests of the T600 module are taking place during this year at Pavia prior to initial cooldown. Much longer tracks are hoped for and expected.

T600 modules could be piled up, lego fashion, for the 5000 t detector. Another objective is "ICANOE" (ICARUS for a Neutrino Oscillation Experiment) to intercept the neutrino beam from CERN at Gran Sasso (January p5).

Initially a CERN-Italian venture, ICARUS has grown to also involve groups from the US (UCLA), Switzerland (ETH Zurich), China (Beijing) and Poland.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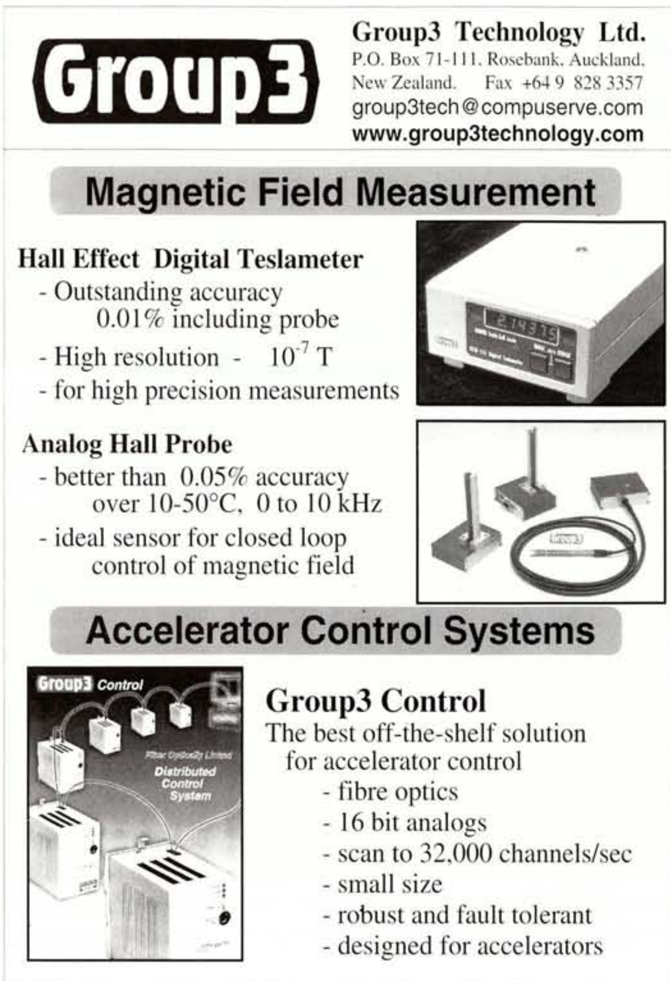
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PHYSICSWATCH

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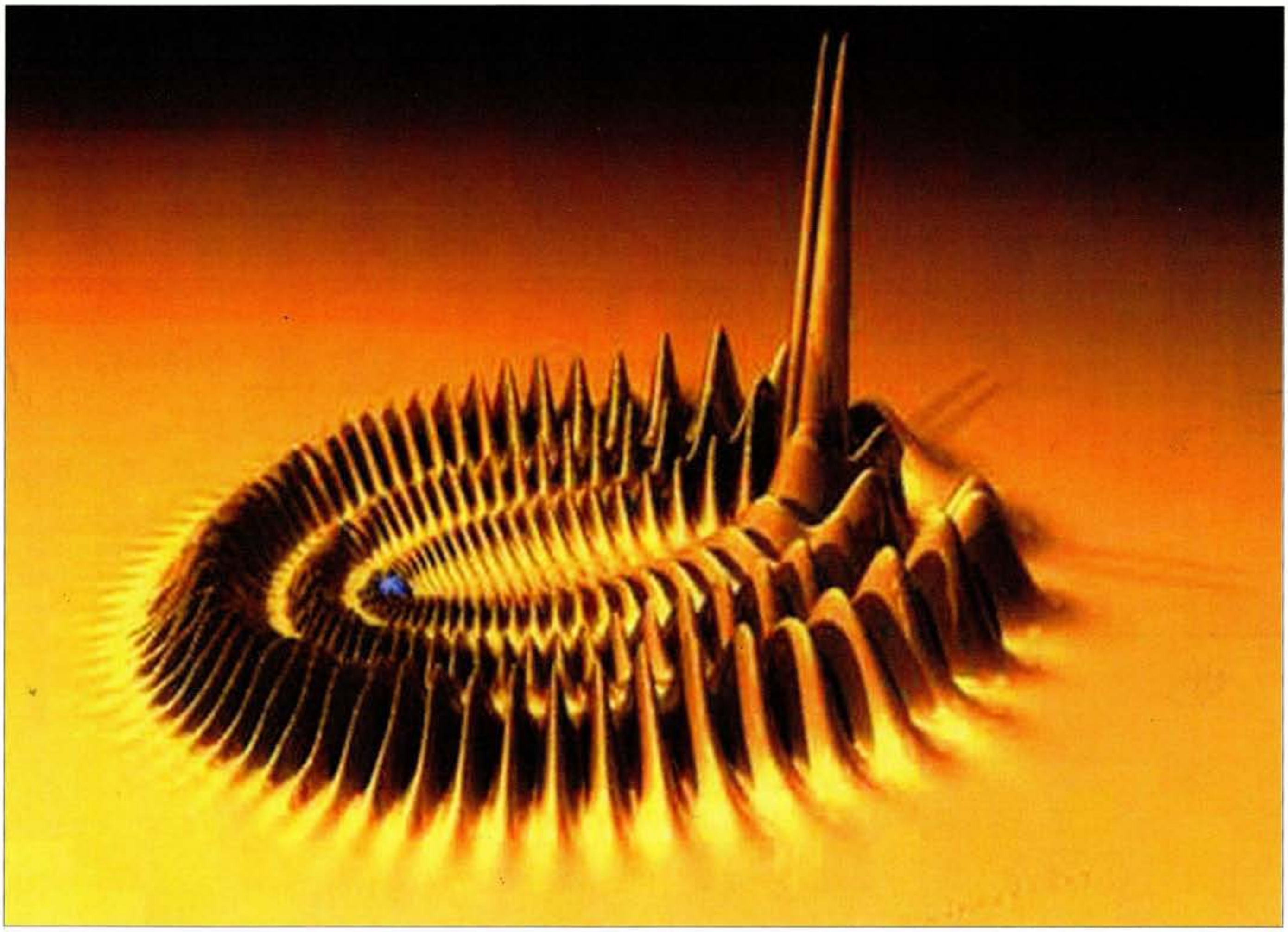
The shape of things to come...



American physicists have predicted a new molecule made of two rubidium atoms whose electron cloud (simulated above) would resemble a trilobite, the marine invertebrate that lived more than 300 million years ago. They claim the molecule could be made from two rubidium atoms inside the ultracold, dense environment of a Bose-Einstein condensate: first, using laser pulses or electromagnetic fields, an electron in one atom must be coaxed into a very high orbit; then the molecule could form as this outermost electron attracts another atom. This unusual molecule would be huge, with the two atoms separated by up to 50 000 Å, compared with the typical atomic size of just 1 Å. The trilobite-shaped electron cloud means the molecule would have a very large permanent electric dipole moment, as much as 1000 times larger than that of any other polar diatomic molecule. *AIP*

Bouncing buckyballs score as transistors

A single molecule of carbon-60 bouncing between gold electrodes is the basis of a new transistor which has been developed by US scientists. The football-shaped carbon-60 molecule is called a fullerene or "buckyball" after architect Buckminster Fuller, and is formed by carbon atoms arranged in 12 pentagons and 20 hexagons.

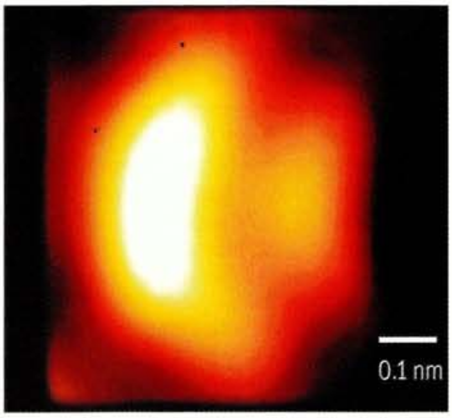
The new transistor works by quantum tunnelling: electrons of the right energy can tunnel across the gap between the electrode and the buckyball to occupy the lowest energy level in the molecule; if the electron has additional energy that is equivalent to the vibration energy of the molecule, it can tunnel onto the molecule and set it in motion. Under the right conditions, the researchers believe one electron at a time can be transferred between the electrodes via the bouncing buckyball. Since the energy of vibration of the molecule is quantized, there is automatically a tight control on the current flowing through the transistor that could be exploited for accurate current measurement.

Atoms under the microscope

Researchers in Augsburg, Germany, have produced unique images of the atom using an atomic force microscope. Using an extremely sensitive instrument, they were able to see the electron clouds inside a silicon atom, and found the predicted distinctive shape.

An atomic force microscope produces images of surfaces by sensing the forces that exist between a sharp tip and a sample. The Augsburg researchers designed a special quartz "tuning fork" to act as the cantilever for the tungsten tip of their microscope in order to improve the resolution of the images. The cantilever oscillates at a particular frequency, but as the tungsten tip moves over the sample, the frequency of oscillation shifts as covalent bonds form between the tip of the microscope and the electrons inside the silicon atom.

The researchers now plan to image the internal structure of a variety of atoms to improve the understanding of the properties of electrons in solids. *Science*



The electron orbitals inside a silicon atom are revealed using atomic force microscopy.

Nuclear decay causes electron excitement

When an excited nucleus decays to a lower state, its energy may in turn excite an orbital electron in a process known as internal conversion. The energy transferred from the nuclear decay is much bigger than the typical binding energy of an electron and the electron can escape from the atom. Now an international team of researchers working at the GANIL accelerator in France have seen the first direct proof of what they call "bound internal conversion" (BIC).

The team fired tellurium ions into a thorium target. In the collisions the tellurium ions lose more electrons and their nuclei become excited. With up to 48 valence electrons missing, those that remain are bound so tightly to the nucleus that their binding energy starts to exceed the energy differences between nuclear excitation states. Then internal conversion of the nuclear decay energy to electron excitation doesn't kick the electron out of the ion – it is just excited to a higher energy state. The researchers saw characteristic X-rays emitted by the ions as the electronic vacancy was subsequently filled. Such photons could be due just to decays of excitations caused in the collisions. However, as the photons arrived after a time delay consistent with the nuclear state lifetime, the researchers believe that this is a definite signature of BIC.

Meanwhile, Japanese researchers have reported observations of the reverse effect – nuclear excitation by electron transition, the latest experiments using synchrotron radiation to excite gold atoms.

This coupling between electronic and nuclear states is suspected to account for the anomalous lifetimes of some nuclear excitations, and may have some bearing on the synthesis of elements inside stars, where highly-ionized atoms are likely to exist. *AIP*

Superconductor is supreme at 77K

A new method boosts the power capacity of superconducting wires at liquid nitrogen temperatures.

Over the past five years, thin films of yttrium barium copper oxide (YBCO) have become the favoured material for superconducting wires. However, the supercurrent passing through the material has always been limited due to boundaries in the films where the crystals are not perfectly aligned. These grain boundaries act like insulating "Josephson junctions" – the current flow is restricted as charge-carrying holes become depleted by interface charging and bending of the electronic band structure at the boundary. Previous experiments have shown that doping the YBCO film with calcium, introducing more holes, does help – but only at temperatures much lower than 77K.

However, a collaboration of Dutch and German physicists has found a way to "overdope" specifically at the grain boundaries. They grew a 25 nm calcium-doped YBCO film over an undoped YBCO film and found that some of the calcium migrated into the grain boundaries, effectively bridging the weak links. Supercurrent flow across the boundary increased by up to a factor of six – and the critical temperature T_c, at which the material becomes superconducting, was also unchanged.

Paul Grant of the US Electric Power Research Institute welcomed these findings, saying that they "could have profound consequences for future developments of high T_c technology". *Nature*

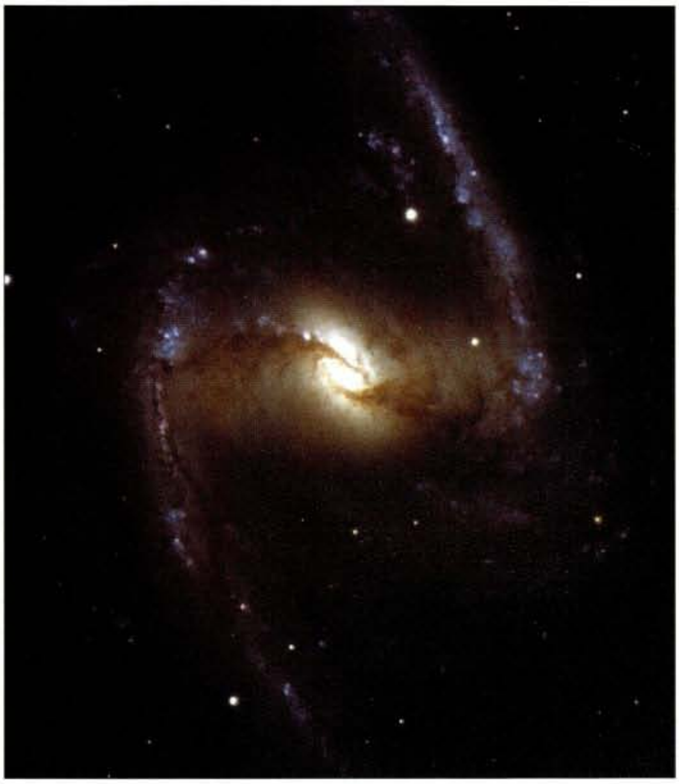
Sonic crystals could prevent noise

Physicists in Hong Kong have come up with a new material for soundproofing. Their "sonic crystals" are made of lead balls, about 1 cm in diameter, coated in silicone rubber and mounted in an epoxy matrix. They say a layer of this material only 2 cm thick could block out everyday noise. The periodic variation of density inside the crystal means certain frequencies of sound can't propagate through it – exactly like the blocking of electromagnetic radiation inside photonic crystals (May p9). The researchers built up disordered composites of the crystals so that local resonant properties could even block long-wavelength environmental noise within a small thickness.

Looking deep into galaxies

Part two of Astrowatch's coverage of the meeting of the International Astronomical Union in Manchester: *Emma Sanders* reports on new studies of active galaxies and the latest innovative instrumentation.

A Hubble Space Telescope image of the region surrounding the black hole in Centaurus A, our nearest active galaxy. (NASA/ESA.)



Bar structures facilitate gas flow, feeding activity at the centre of galaxies. (ESO.)

Today's telescopes allow astronomers to probe deep into the active inner regions of galaxies and see far back in time to the periods of momentous upheaval in the early universe. At this year's International Astronomical Union (IAU) conference in Manchester, attention focused on new high-resolution studies of some of the most energetic objects known to exist.

Around a billion years ago, at a redshift of about 5, the first galaxies started to agglomerate. They were very different from the galaxies we see around us today.

During this period of intense activity, quasars released extraordinary amounts of energy into the interstellar medium, outshining galaxies of hundreds of billions of stars. These quasi-stellar objects are thought to be associated with the growth of big black holes in the inner parts of the first galaxies. Quasar activity is seen to peak at a redshift of around 3 – the same time at which bulges start to form in the centres of spiral galaxies.

Extra-galactic black holes

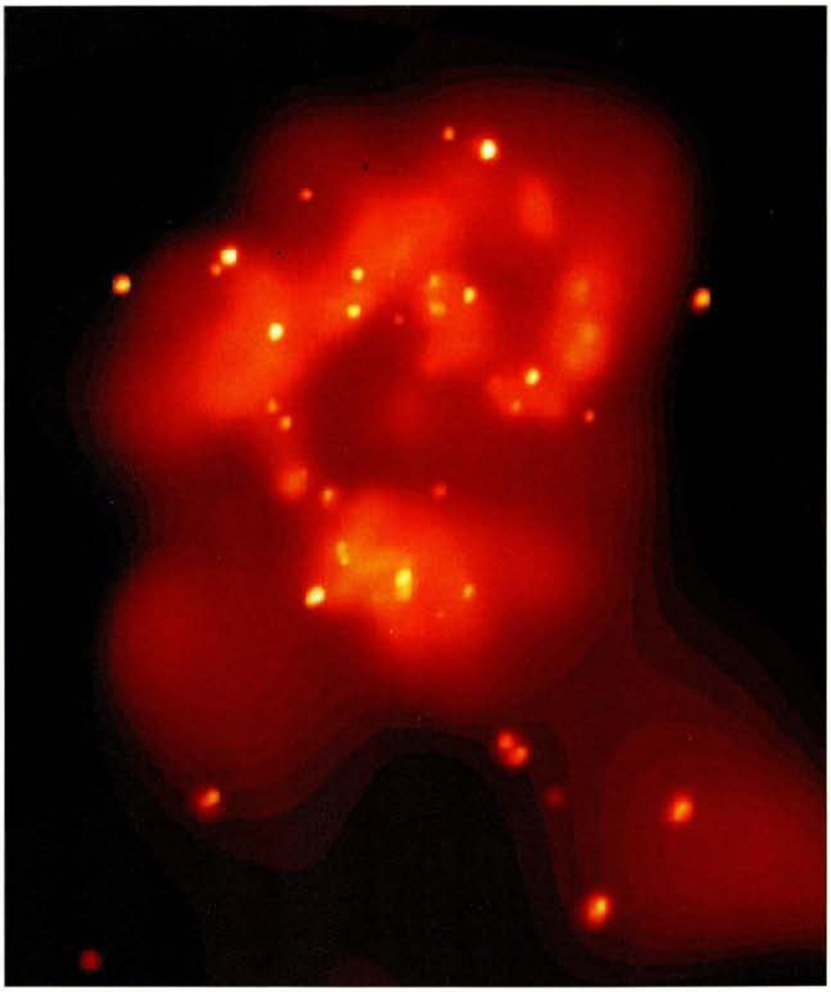
"The most convincing information about black holes comes from water maser emission in the surrounding accretion disks," said Martin Rees of Cambridge. Maser microwave emission also comes from OH and CH_2O (formaldehyde) present in the disk, which is pumped by the far infrared emission. The masing allows astronomers to detect the transverse motion of material orbiting the black hole and to calculate the mass and density of the central region. We now know of 21 such megamasers.

Last May's meeting of the International Telecommunications Union provided good news for astronomers, as proposals were adopted to protect maser wave bands from radio pollution from mobile phone networks (March p11).

Dayton Jones of Caltech presented a radio image of the centre of galaxy NGC6241, ▷

showing two jets projecting outwards from the centre, as is common in such active galaxies. However, Jones has observed a gap in the jets that he believes is caused by absorption from the accretion disk of gas and dust orbiting the central black hole. The gap matches up with an optical image of the accretion disk taken using the Hubble Space Telescope (HST). The fact that different wavelength observations can be matched up in this way is a step forward in the understanding of black holes.

Radio observations of gas movement in the centres of galaxies and spectral line data from the HST suggest that super-massive black holes exist in the centre of every galaxy. "So why aren't more galaxies active?" asked John Conway of the Onsala Space Observatory.



The interacting antennae galaxies X-ray imaged by the Chandra satellite. (NASA.)

With advances in interferometry instrumentation and techniques, studies of active galactic nuclei (AGN) have dramatically improved over recent years. Roeland Van der Marel of the Space Telescope Science Institute stressed the importance of bar structures in spiral galaxies that encourage gas to flow into the centre, feeding star formation. He believes that many AGN are hidden by dust and will only be revealed as observations at other wavelengths improve. "With X-ray imaging now advancing, it will be interesting to see how much obscure AGN activity is actually going on," he said.

Sagittarius A*

The nearest black hole is in the centre of our galaxy, the Milky Way. It lies in a region of high activity known as Sagittarius A*. Recording the movements of the stars in orbit around Sagittarius A* shows that the central black hole is 3 million times heavier than the Sun.

In the summary of the session on galaxies and their components at high-angular resolution, Peter Wilkinson of Jodrell Bank looked at what future telescopes will reveal. The Large Binocular Telescope being built by Italy, the US and Canada should record the orbits of individual stars close enough to measure whether general relativistic effects come into play. Does the black hole act as a point source mass (relativistic) or as a distributed mass (non-relativistic)? Using today's Very Long Baseline Interferometry (VLBI) radio observations, we can see Sagittarius A* down to 15 times the effective size of the black hole (Schwartzchild radius). "By the end of the decade, sub-millimetre VLBI will be able to image the event horizon of the black hole," said Wilkinson.

New X-ray observations

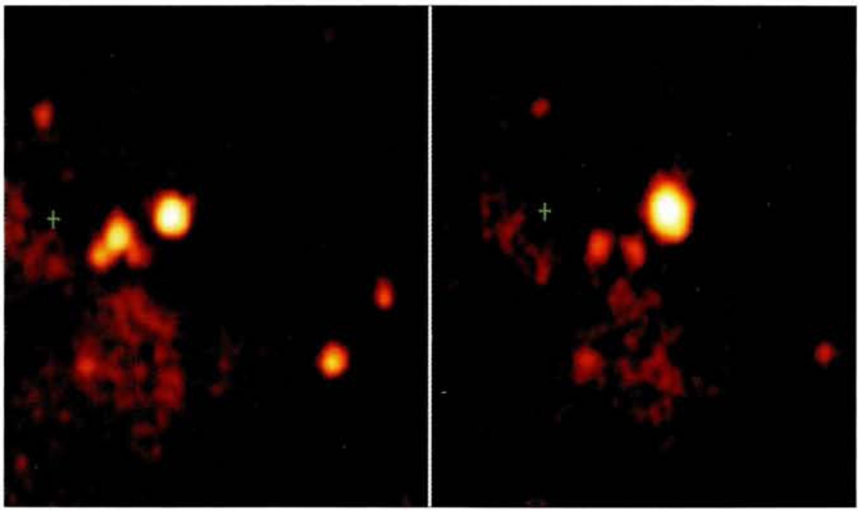
"What is new at this conference is that for the first time we have comparable resolution between radio and X-ray," said Rees. Indeed, with the launch of two new X-ray satellites, astronomers are spoilt for choice (April p11).

Astronomy in Manchester

Manchester University, founded in 1851, was a fitting venue for this year's IAU conference. For nearly 50 years, the university's Jodrell Bank Observatory has been at the forefront of radio astronomy. The site is now headquarters for the MERLIN radio telescope network which pioneered high-resolution studies of galaxies. The network has a resolution of at least 50 milliarcseconds, better than the HST.

The Lovell radio telescope at Jodrell Bank.

The linchpin of MERLIN, the 76 m steerable Lovell radio telescope, named after Jodrell Bank's founder Sir Bernard Lovell, is undergoing a £2 million upgrade which is due to be completed by the end of 2002. This will allow the telescope to operate in a higher frequency range and will more than double its sensitivity.


Two Chandra images of the centre of M82, taken 3 months apart. (NASA.)

In Manchester, X-ray images from NASA's Chandra satellite stole the show. The new results were presented by Guiseppina Fabbiano of the Smithsonian Astrophysical Observatory. "For the first time, we have sub-arcsecond resolution in conjunction with spectral resolution," she said.

X-rays are emitted by the hottest, most energetic regions of the universe. Fabbiano gave a run-down of the impressive range of observations now possible, including new estimates of the baryonic content of the universe, measures of the elemental composition of stars from supernova remnants, and a new perspective on the evolution of galaxies.

Observations of the antennae galaxies, colliding galaxies with streams of material emanating from their core, reveal huge bubbles of hot gas at X-ray wavelengths, and provide an example of conditions when our universe was young and galaxies were forming. "This is just the beginning," said Fabbiano.

Starburst galaxies

Andrea Prestwich of Chandra showed new X-ray images of starburst galaxies. M82 is particularly bright in the X-ray region, emitting a total of 10^{42} ergs/s. What was previously detected as X-ray background emission can now be resolved into point sources. Alan Pedlar of Jodrell Bank told the conference how radio images of the supernovae in M82 can be used for studies of the star formation rate and as a probe of the interstellar medium (February 1999 p9).

Much interest was generated by attempts to match up the X-ray sources with radio counterparts. The strongest X-ray source has no radio counterpart. The flickering of the source and its high luminosity are strong evidence that the X-rays are produced by matter accreting onto a black hole with a mass more than 500 times that of the Sun (see above).

Future instrumentation

Richard Schilizzi, director of the European VLBI network and chair of the symposium on galaxies and their components at high-angular resolution, told *CERN Courier* that his aim had been to bring together people from different wavelength ranges who work on the same things but who are perhaps not fully aware of what the others are doing. "It's been a real showcase of the latest experiments," he said. He was particularly enthusiastic about the many presentations on new instrumentation: "There are plans right across the spectrum, it really is fantastic."

During the meeting, astronomers from Europe, the US, Asia and Australia signed an agreement to plan a huge new radio telescope, the Square Kilometre Array. Construction is scheduled to begin in 2010 and the finished telescope should give milli-arcsecond resolution, with a collecting area 50–100 times larger than existing radio interferometers.

In infrared, ALMA (Atacama Large Millimeter Array) will bring equivalent resolution, with 64 12 m diameter antennae to be built over a 10 km area in Chile.

"What was completely new to me was the presentation on X-ray interferometry," said Schilizzi. "Gamma ray was a real eye-opener too – that Bragg diffraction crystals could give milli-arcsecond resolution at gamma-ray wavelengths."

At the start of a new millennium, astronomy is poised for a big leap forward in instrumentation across the whole electromagnetic spectrum. The future lies in combined multi-wavelength observations, which are set to provide new perspectives on the many fundamental questions waiting to be answered: How much mass is there in the universe? What is dark matter? How did large-scale structure form? How did galaxies form? Are there any pockets of antimatter left in the universe? What physical processes are behind the prodigious amounts of energy released in gamma-ray bursts? Does this have anything to do with high-energy cosmic rays? It's an exciting time to be working in the field. □

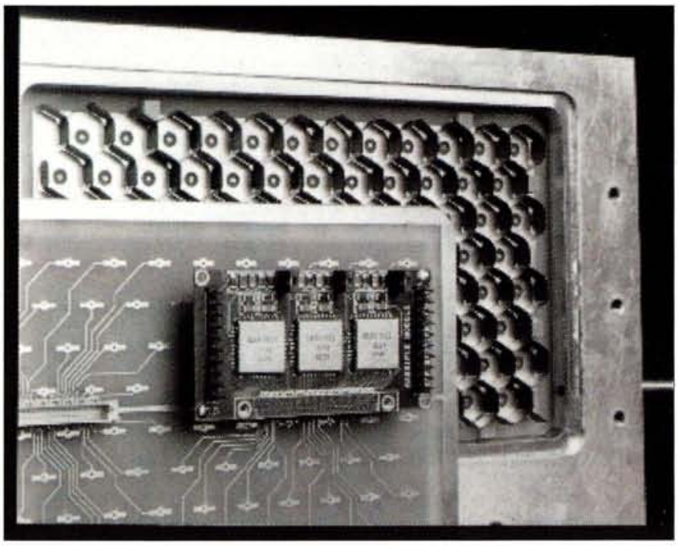
Astroparticle physics

"Astronomers are looking to establish new collaborations with research labs such as CERN and Fermilab," the new president of the IAU Franco Pacini told *CERN Courier*. Pacini is a great believer in the importance of increasing the ties between particle physics and astronomy. He points to many key areas of research that will benefit from combined efforts. "Neutrino experiments are getting bigger and bigger," he said. "Many physicists are already involved in gamma-ray astronomy." The two communities should share knowledge of new advances in detector technology, and the organization of large experiments.

Research into fundamental cosmological values and the formation and evolution of stars will also benefit from new collaborations. "Dark matter was discovered by astronomers," Pacini added. "Now, to find out what it is, is up to the physicists." The IAU is setting up a working group on particle astrophysics within its division on high-energy astrophysics. He promised that by the next IAU meeting, in Sydney in 2003, the working group will be in place and more joint projects will be underway.

ALICE through the phase transition

Russian members of the ALICE collaboration with the first completed coil for the experiment's muon spectrometer magnet.



Components of a prototype honeycomb chamber for ALICE's photon multiplicity detector.

While proton-proton collisions will be the principal diet of CERN's LHC machine, heavy-ion collisions will also be on the menu. The ALICE experiment will be ready and waiting.

The ALICE collaboration of some 900 physicists is preparing a detector to study lead-ion collisions at CERN's Large Hadron Collider (LHC) starting in 2005. By observing the results of such collisions, ALICE will continue CERN's pioneering investigations through the phase transition from ordinary nuclear matter to the state of matter as it is believed to have existed when the universe was just a few microseconds old.

The ALICE detector is being built around the existing magnet of the L3 detector, which is currently taking its last data at the Large Electron Positron collider (LEP), CERN's current flagship accelerator. ALICE has the same Russian-doll structure as most collider detectors, but with the addition of a dedicated spectrometer at one end. This will have the job of reconstructing the particles produced in lead-lead collisions that decay into muons.

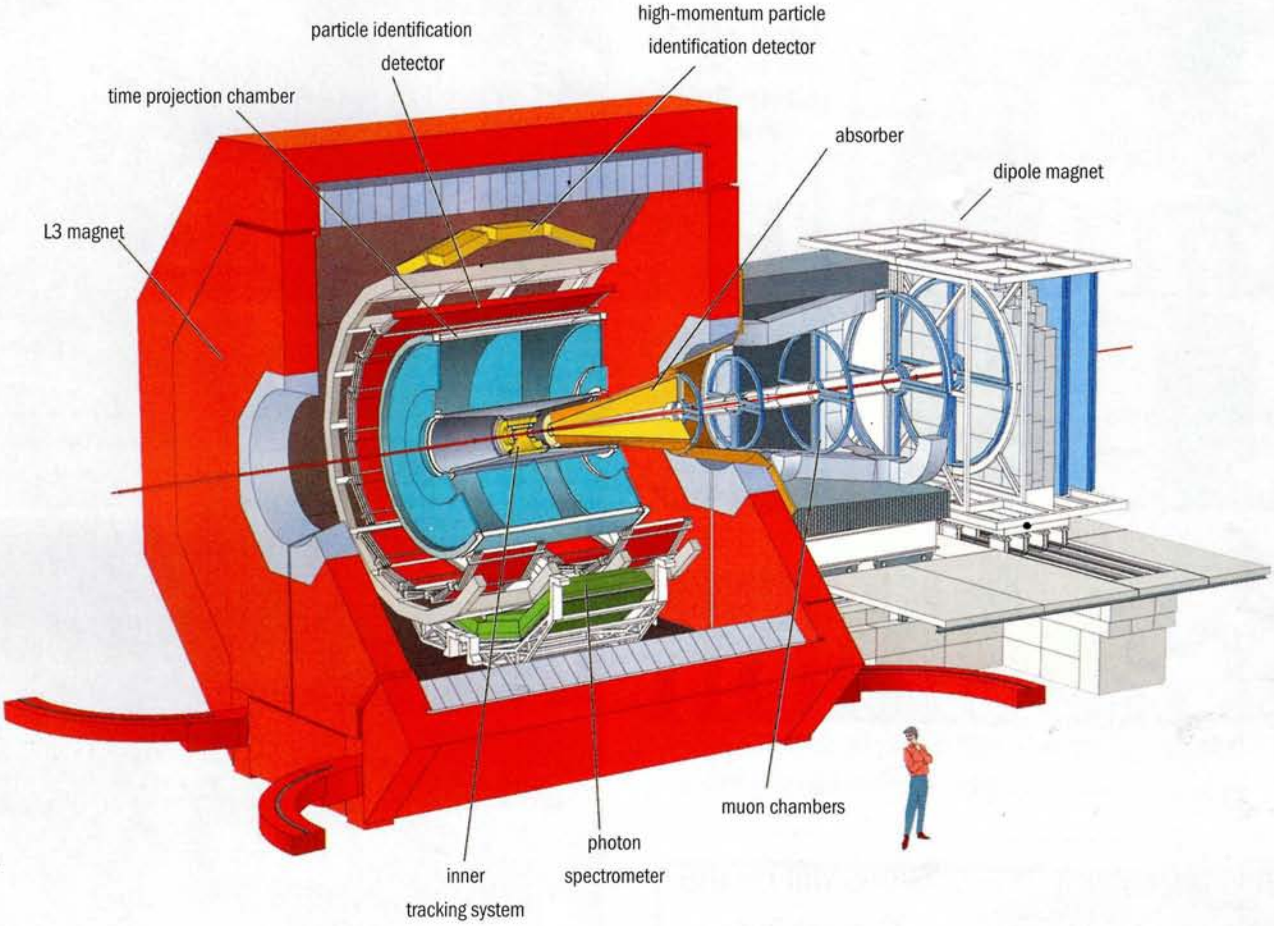
The overall design of the muon spectrometer was finalized in 1999, and was the subject of one of the collaboration's technical design reports (TDRs) – the documents that mark the transition from R&D to production phases for all the LHC's experiments. A full-scale prototype of the muon spectrometer's momentum-analysing dipole magnet was completed in April. The spectrometer's sensitive elements, 10 multi-wire proportional chambers with a total of around a million read-out channels, have been the subject of test-beam studies this summer.

Particle tracking

Another of ALICE's TDRs concerns the experiment's inner tracking system (ITS). This is the innermost layer of the detector, responsible for tracking emerging particles where their density will be at its highest.

ALICE physicists have been working with colleagues from fellow LHC experiment LHCb to develop silicon pixel chips for the inner two layers of the ITS. The result is a chip with 50×425 μm cells; a prototype detector based on this chip is being tested this year. The ITS has six layers, all using silicon technology, and about 10 million digital and 2 million analogue readout channels to digest the huge number of particles produced in LHC lead-ion collisions. The collaboration has opted for a hybrid ITS structure combining sensors, electronics and mechanical support. Beam tests so far have indicated that the ITS should achieve position resolution better than 20 μm.

Surrounding the ITS is the core of the ALICE detector – its time projection chamber (TPC). The TPC is a gas-filled detector with ▷



Schematic of ALICE. The detector is 25 m wide, has a diameter of 15 m and weighs 10 000 t.

an electric field applied across it. Electrons liberated by ionization of the gas caused by a passing charged particle drift in the electric field and are detected at the end of the chamber. By measuring the arrival time of these electrons, the TPC reconstructs the path of the original charged particles. Several of the TPC's most crucial elements have been extensively tested over recent years, and its largest element – a gas-filled cylinder made of composite structures similar to those used in space applications – will enter the production phase early next year.

The TPC in turn will be inside a transition radiation detector (TRD) that will be used to identify electrons and positrons. Several physical processes of interest to lead-ion physics give rise to electron–positron pairs. These include pairs directly produced in the initial stages of the collision or pairs produced as the result of the decays of heavier particles. The TRD, in conjunction with the ITS and TPC, will be able to identify the sources of electron pairs. It will work by measuring the radiation emitted when charged particles cross the boundary between two media with different refractive indices.

Special detectors

Unlike a conventional "Russian doll" collider detector, several of ALICE's subdetectors will cover only a part of the full solid angle surrounding the collisions. Among these are the experiment's high-momentum particle identification system (HMPID), its photon spectrometer (PHOS) and four detectors designed to measure particles emerging very close to the beam direction – the zero-degree calorimeters (ZDCs), the CASTOR small-angle calorimeter, the photon multiplicity detector (PMD), and a forward-charged particle multiplicity detector (FMD).

A prototype HMPID was put through its paces in 1998 using particles produced when a 350 GeV pion beam from the SPS proton synchrotron struck a beryllium target. This allowed the collaboration to test both the detector's performance and the pattern-recognition programs that will identify individual particles. That prototype was then shipped to Brookhaven in the US where it is now operational in the STAR detector at the laboratory's Relativistic Heavy Ion Collider. ALICE, meanwhile, has started construction of its full-scale HMPID detector.

The PHOS will be made of lead tungstate crystals and will sample emerging photons over a limited area. This means that a relatively modest number of 18 000 crystals is needed. These will be supplied from production plants in China and Russia. For comparison, the LHC's CMS experiment, whose electromagnetic calorimeter is based on the same crystals, will require around 80 000. By summer 2000, ALICE crystal production was getting under way with several hundred crystals having been produced in Russia.

One of the small-angle detector systems will serve primarily for triggering purposes – telling the electronics when an interesting collision has taken place. The ZDCs will be placed about 100 m away on

The ITS has six layers, all using silicon technology, and about 10 million digital and 2 million analogue readout channels to digest the huge number of particles produced in LHC lead-ion collisions.

each side of the main ALICE detector to measure the energy carried by particles emerging very close to the beam direction.

The CASTOR calorimeter will be placed about 16 m away from the interaction point on the opposite side to the muon spectrometer. It will have a sandwich structure of quartz fibre planes separated by tungsten plates. CASTOR's job will be to search for exotic particles.

The FMD will consist of a number of discs, each divided into sensitive pads, placed at varying distances from the interaction point so as to cover the largest possible area. It will count the number of charged particles in the forward region and provide information for the experiment's trigger.

The PMD will be embedded within the main detector, attached to the magnet return yoke at 5.8 m from the interaction point opposite the muon spectrometer. It will be used primarily with the FMD to measure the ratio of photons to charged particles emerging on an event-by-event basis. This will give ALICE physicists information about event shapes and fluctuations in the forward region. The PMD has a honeycomb geometry, the cells of which are 8 mm deep with a surface of about 1 cm^2. Copper walls separate the cells in order to prevent signals from blowing up by confining low-energy electrons to a single cell. A 96-cell prototype has been successfully tested in beams at CERN.

Time of flight

Another critical measurement for ALICE is the time of flight of emerging particles. Conventional time-of-flight detectors use fast scintillator detectors with coarse granularity. For ALICE, where a very fine granularity is required, this would have presented a very costly option and several alternatives were studied.

The one that the collaboration has adopted is multigap resistive plate chambers (MRPCs). These consist of a series of gas-filled gaps separated by high-resistivity plates. A strong electric field across the gaps gives rise to electron avalanches when charged particles pass through the chambers. The design of ALICE's MRPCs involves optimizing the gap size – a small gap gives a faster response but a large gap gives a stronger signal. Multiple gaps allow for a smaller gap size since the signal can be integrated over several gaps. Extensive tests in 1999 with varying gap size and using different material for the resistive plates gave very encouraging results with time resolution better than 80 ps at more than 95% efficiency – easily competitive with classical scintillator detectors. Further tests aimed at finalizing the detector design are under way.

The ALICE collaboration is currently putting the finishing touches to its last few TDRs. With these completed, the entire detector blueprint will be in place and the collaboration expects its detector to be in full-scale production by the end of the year – right on schedule to be ready for the LHC's first lead-ion collisions in 2005. □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No smoking guns under the Sun

A range of different experiments have studied in detail the neutrinos emitted by the Sun. What does this complex picture now tell us? *Arnon Dar* reviews the latest wisdom.

The Sun is a typical main sequence star that generates its energy via the fusion of hydrogen into helium in two chains of nuclear reactions: the so-called pp chain and the CNO chain. If the nucleon number, electric charge, lepton flavour and energy are conserved and the Sun is in a steady state, then the total solar neutrino flux is fixed, to a good approximation, by the solar luminosity (approximately 65 billion neutrinos/cm^2/s at Earth), independent of the specific nuclear reactions that power the Sun and produce neutrinos by beta decay or the electron capture of reaction products.

The neutrinos from the dominant pp chain are produced by the beta decay of proton pairs (pp), boron-8 and lithium-4, and by electron capture by pp pairs and beryllium-7. Their spectra can be measured directly in the laboratory or calculated from the standard theory of electroweak interactions.

To a very good approximation, they are independent of the conditions in the Sun. Only their relative contributions depend on the detailed chemical composition, temperature and density distributions in the Sun. Solar neutrino experiments can therefore test both the standard theory of stellar evolution and neutrino properties over a long distance, much larger than the diameter of Earth.

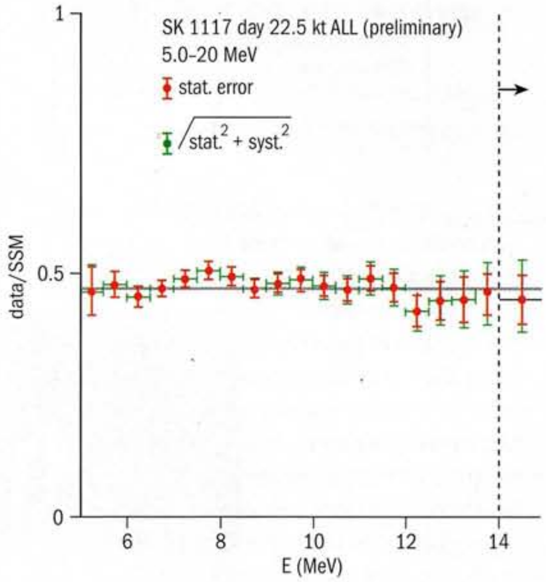


Fig. 1. The ratio between the observed number of electrons that were scattered by solar neutrinos in Superkamiokande during 1117 days and the expected number from the standard solar model (SSM), as a function of electron energy. The expected number from Bahcall's standard solar model was corrected by the new laboratory measurements of the energy spectrum of boron-8 neutrinos by Ortiz et al. *(Notre Dame/Berkeley collaboration) and by the new theoretical calculation of the cross-section for neutrino production in proton capture by helium-3 by Marcucci* et al. *The ratio looks constant, but is not equal to 1. The reason for this discrepancy is still unknown.*

By the turn of the last century, solar neutrinos had been detected by radiochemical methods in three underground solar neutrino experiments in the US (Homestake) and Europe (SAGE and GALLEX) and in real time by the water Cherenkov techniques in two experiments in Japan (Kamiokande and Superkamiokande). These studies have confirmed that the Sun is powered by the fusion of hydrogen into helium – a milestone achievement in physics.

However, the combined results also suggested that the solar neutrino fluxes differ significantly from that expected from the standard solar models. This discrepancy has become known as the solar neutrino problem (SNP).

Neutrino oscillations

Many scientists have argued that this discrepancy is due to neutrino properties beyond the minimal standard electroweak model. In 1968, Gribov and Pontecorvo suggested that "oscillations" of electron neutrinos to other neutrino flavours may reduce the solar electron neutrino flux at the Earth. Later, Mikheyev and Smirnov elaborated on work by Wolfenstein on the propagation of neutrinos in matter and found that matter amplification of these oscillations in the Sun can provide an elegant solution (the so-called MSW solution) to the SNP.

The widespread belief in this solution of the SNP was strengthened by the accumulating data from the deep underground experiments on the atmospheric neutrino anomaly (fewer muons than expected) and, most recently, also from the first terrestrial long distance neutrino experiment, K2K, which were reported by Kenzo Nakamura from the KEK laboratory at Neutrino 2000 – the 19th international conference on neutrino physics and astrophysics which was held this summer in Sudbury, ▷

Canada (October p31).

Both the atmospheric neutrino anomaly and the K2K results can be explained by the hypothesis of nearly maximal strength oscillations of muon neutrinos to tau neutrinos if their squared masses differ by some 3×10^{-3} eV^2. However, conclusive solar neutrino evidence for electron neutrino properties beyond the standard electroweak model can be provided only by detecting at least one of the following signals:

- neutrinos other than electron-type visible by neutral current interactions;
- spectral distortion of the fundamental beta-decay spectra;
- a neutrino flux different from that expected from the solar luminosity;
- modulations of the solar neutrino flux, such as a day-night or summer-winter difference, other than that expected from the seasonal variation in the Earth's distance from the Sun.

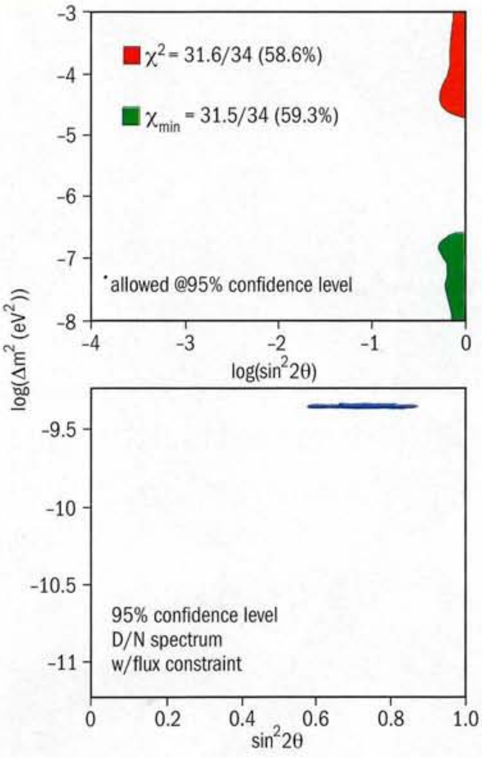


Fig. 2. The region of electron neutrino mixing parameters (squared mass difference and mixing angle) with muon or tau neutrinos which still allow an oscillation solution (exclusion has less than 95% confidence level) to the SNP. Only large mixing angle oscillation solutions have not been ruled out by the solar neutrino experiments. Mixing of the electron neutrino with sterile neutrinos (which do not have standard electroweak interactions) is also ruled out by the observations (at 95% confidence level) as a solution to the SNP.

Looking for smoking guns

It was hoped that these "smoking gun signals" would be found before Neutrino 2000 with the two currently operating solar neutrino telescopes: the 50 kt Superkamiokande underground light-water Cherenkov detector that has been collecting data on the boron-8 solar neutrino flux, its spectrum, and seasonal and day-night possible variations, with a lower energy threshold and lower background; and the 1 kt Sudbury Neutrino Observatory (SNO) heavy-water detector in a 2 km deep Canadian mine that started taking data half a year ago and is expected to detect the conversion of solar electron neutrinos to mu or tau neutrinos through their dissociation of the deuterium into a proton and a neutron in the heavy water.

However, no such signals have been detected. At Neutrino 2000, Yoichiro Suzuki from the Kamioka Observatory presented data from 1117 days running of Superkamiokande which show no day-night effect, no spectral distortion of the boron-8 solar neutrino spectrum, and the expected variation due to the annual variation in the distance between the Earth and the Sun.

In fact, the use of a new and more precise laboratory measurement of the neutrino spectrum from boron-8 beta decay and a new estimate of the cross-section for proton capture on helium-3 yield an excellent agreement between the expected and observed Superkamiokande solar neutrino spectra as seen in figure 1.

When combined with the other solar neutrino experiments, the Superkamiokande data rule out, with 95% confidence, the small mixing angle MSW solution and a "sterile" neutrino oscillation solution to the SNP. It leaves only a small region in the mass-mixing exclusion plot with a large mixing angle as a possible simple oscillation solution to the SNP as can be seen from figure 2. Fortunately, this solution will be tested in the near future in a terrestrial experiment – KamLAND, a long base-line neutrino oscillations experiment in Kamioka using nuclear reactor neutrinos (April 1999 p22), and with new solar neutrino experiments such as BOREXINO (October 1998 p12).

What if?

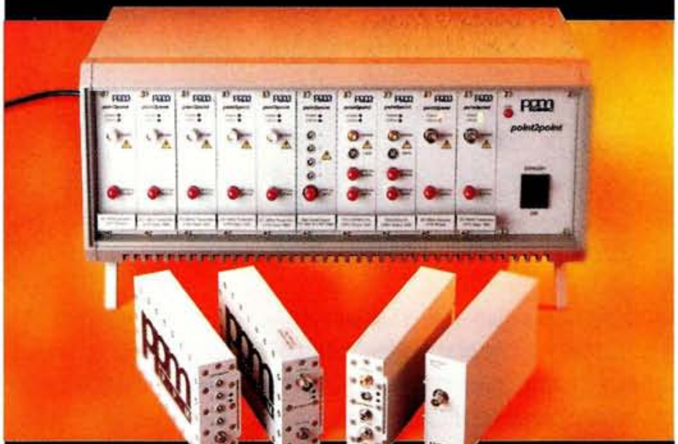
But what if the large mixing angle oscillation solution to the SNP will also be ruled out by KamLAND and BOREXINO, and SNO will not detect conversion of solar electron neutrinos into mu or tau neutrinos? At Neutrino 2000, E Belloti, spokesman of the Gallium Neutrino Observatory (GNO), and V Gavrin, spokesman of SAGE, reported updated results for the solar neutrino capture rate in gallium. Their measured rates, some 78 ± 7 standard solar neutrino units (SNU), are above the minimal signal expected from the observed solar luminosity, if solar neutrinos do not oscillate.

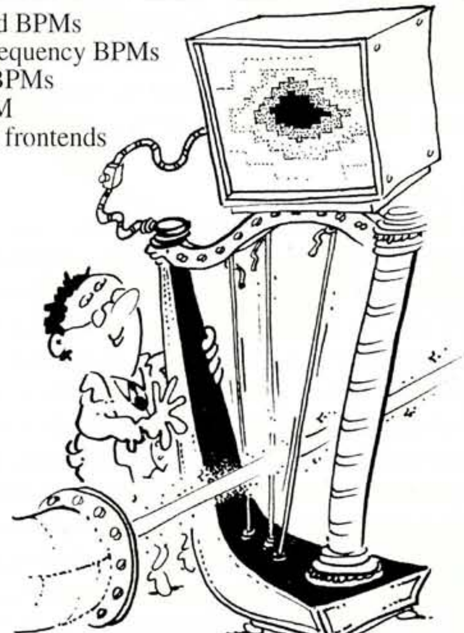
These results seem to leave only a little room for solar neutrinos from electron capture by beryllium-7 in the Sun. This is also suggested by the results from the pioneering chlorine experiment of Ray Davis at Homestake, the counting rate of which, 2.56 ± 0.23 SNU, is consistent with the solar neutrino flux (2.37×10^{10} cm^2/s) measured by Superkamiokande, but leaves very little room for beryllium-7 neutrinos.

However, this conclusion heavily relies on the accuracy of the theoretically-deduced cross-sections for neutrino capture in gallium and chlorine. If the results of GALLEX and SAGE are calibrated with their chromium source experiments, they leave more space for beryllium-7 solar neutrinos, perhaps sufficient to accommodate a solar electron-capture rate in beryllium-7 consistent with the solar proton-capture rate in beryllium-7 that produces the observed boron-8 solar neutrino flux in Superkamiokande.

A direct calibration experiment for the chlorine detector was described by Ken Lande at Neutrino 2000. Improved calibration experiments are also under consideration by the GNO and SAGE collaborations. Altogether, it will still require long, challenging and innovative experiments to give a complete spectroscopy of the elusive solar neutrinos and pin down the origin of the SNP.

Arnon Dar, *Technion, Haifa.*





Focusing an antimat

An experiment at the Stanford Linear Accelerator Center has recently focused positron beams by means of a plasma lens. This is the first time this process has been observed.

In colliding beam physics, the luminosity (collision rate) of a machine determines the yields of interesting high-energy events. Future linear colliders could significantly benefit if the colliding beams were additionally focused to a smaller transverse size beyond that which is possible with conventional or superconducting magnetic beam transport elements.

The theory of a self-focusing plasma lens was first proposed in 1987 by Pisin Chen who also leads the current experiment at the Stanford Linear Accelerator Center (SLAC). If such lenses were, for example, located at the interaction point of a collider, they could focus both the electron and positron beams, thereby reducing beam spot size and increasing the luminosity, perhaps by one order of magnitude or more.

The Experiment E-150 Plasma Lens Collaboration was formed to investigate this process and study the feasibility of its application at proposed future linear colliders like the Next Linear Collider. The collaboration contains members from four laboratories and three universities (see the complete list at the end of this article).

Gas

The process started with a positron beam from the SLAC PEP-II positron source. This was sent through a damping ring and then accelerated to 28.5 GeV in the SLAC linac with a bunch intensity of $1\text{–}2 \times 10^{10}$. The beam was delivered to the Final Focus Test Beam Facility (FFTB) at a rate of 1 or 10 Hz. At the focal point of the FFTB transport, a special plasma chamber contains a 3 mm diameter pulsed gas nozzle (see diagram) through which either hydrogen or nitrogen gas is "puffed" into the ultrahigh vacuum system at plenum gas pressures up to 75 atm with a discharge time of 800 μs. The gas is pumped off by a Roots-type pump. On either side of the central chamber are differential pumping sections semi-isolated from each other by thin titanium windows with small (2–5 mm diameter) apertures for the positron beams to pass through. These sections are evacuated by turbomolecular pumps and allow operation of the plasma lens with ultrahigh vacuum systems on either side.

The plasma lens was generated by ionizing the gas using a pulsed YAG laser operating at 10 Hz in the infrared region (wavelength 1064 nm) and delivering a pulse energy of 1.5 J. The relativistic positron beam exhibits effects from both its charge and its current.

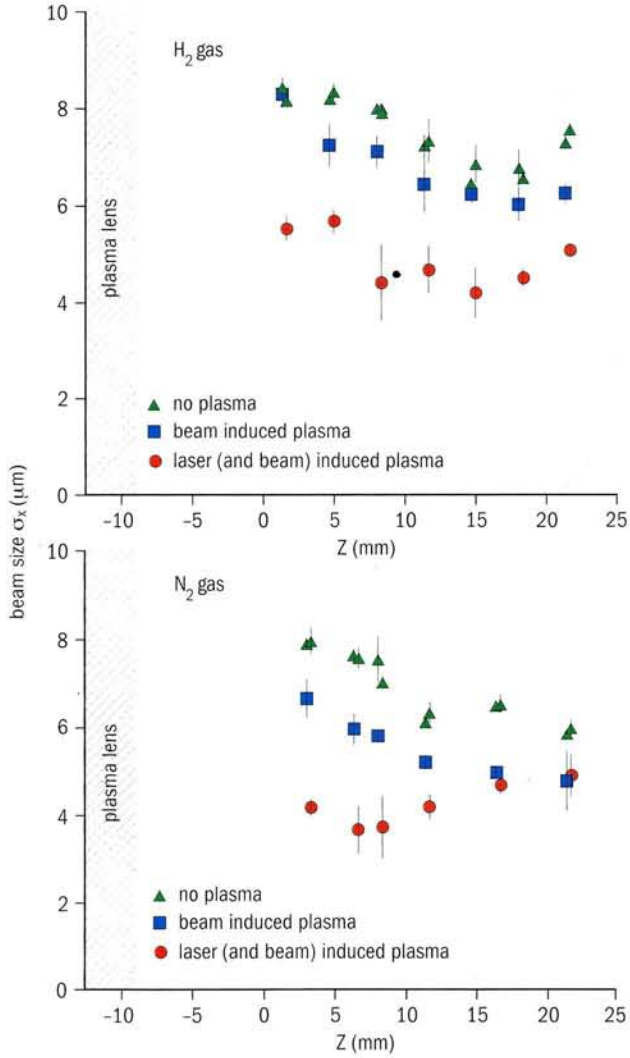


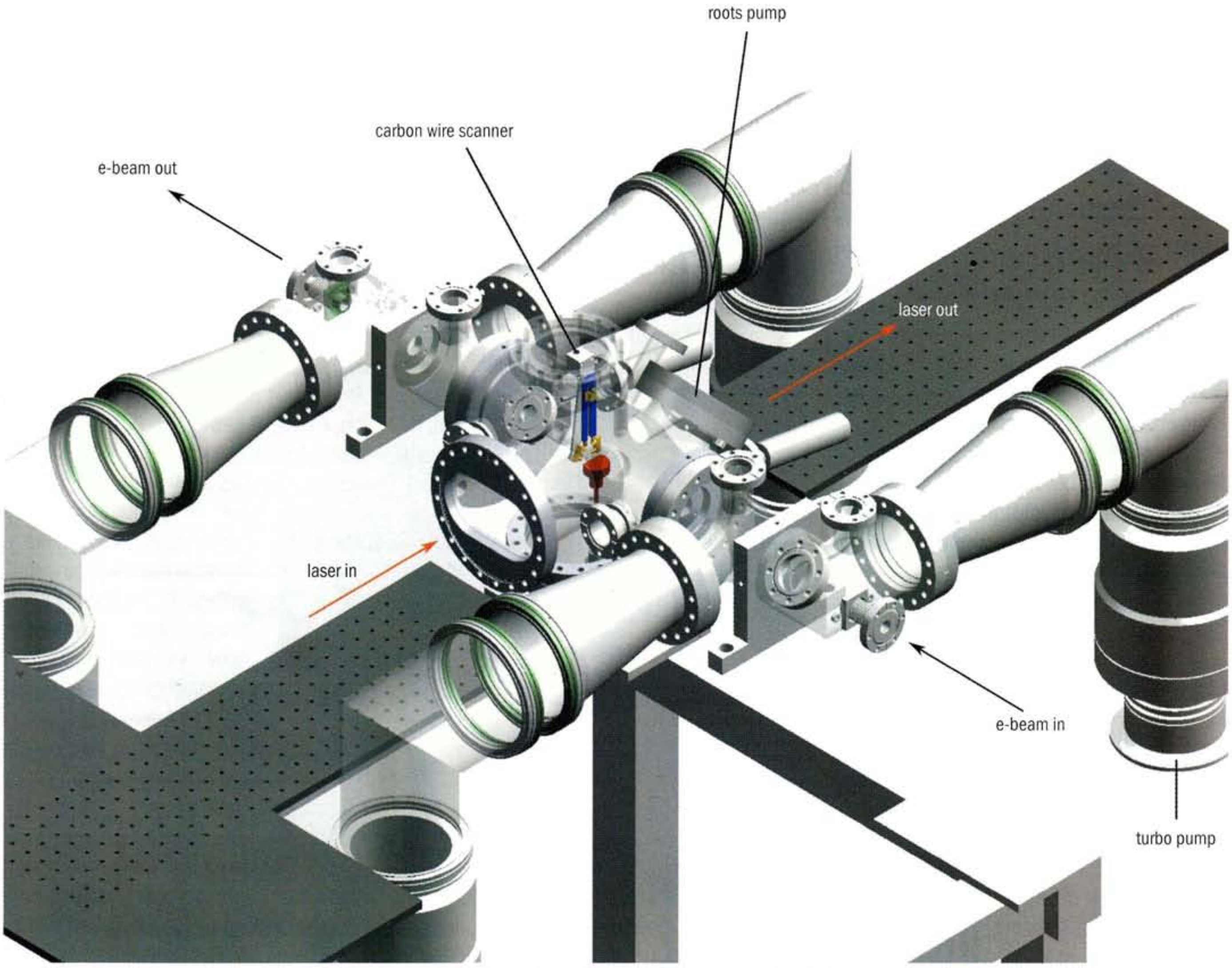
Fig. 1. Plasma focusing of positron beams.

For a beam propagating in a vacuum, the Lorentz force induced by the collective electric and magnetic fields is nearly cancelled, which is why a high-energy beam can travel over kilometres without much increase in spread (emittance).

Plasma response

Upon entering an initially quiescent plasma, the plasma response to the intruding charge and current is such that the plasma electrons are attracted into the positron beam so as to neutralize the space charge of the beam and thereby cancel its radial electric field, which tends to self-repel the positrons. However, if the beam radius is much smaller than the natural plasma wavelength, the neutralization of the intruding beam current by the plasma return current is

ter beam with matter



Focusing a positron beam – plasma is generated by ionizing the gas using a pulsed YAG laser.

ineffective. This leaves the azimuthal magnetic field unbalanced, and this field focuses the beam.

The plasma lens concept also works for electron beams. In that case, the plasma electrons are expelled from the beam volume. The result is a near uniform focusing of the beam due to the less mobile ions – the beam is "pinched".

In the FFTB experiment, typical plasma densities were of the order of $10^{18}/\text{cm}^3$, corresponding to a plasma wavelength of about 30 μm. This is indeed much larger than the incoming beam radius, which is about 5 μm.

The focusing strength of such a lens is equivalent to that of focusing magnets like quadrupoles with gradients of the order of 10^6 T/m. For comparison, a conventional small aperture (1 cm diameter) iron core quadrupole can maximally be excited to about 250 T/m.

The focusing effect of the plasma lens was measured using proven wire scanner technology developed for the SLC and FFTB. The wires are 4 μm and 7 μm carbon fibres. The scanner is located just downbeam of the plasma lens and is adjustable to allow mapping of the transverse beam size and pinpointing the longitudinal location of the beam waist.

Measuring the beam

The bremsstrahlung photons emitted by the positron scattering off the wires are detected in a Cherenkov cell-type detector located 33 m downbeam of the lens. The variation in photon yield as the beam "dithers" across the wire provides a measure of the ▷

For a beam propagating in a vacuum, the Lorentz force induced by the collective electric and magnetic fields is nearly cancelled, which is why a high-energy beam can travel over kilometres without much increase in spread (emittance).

transverse beam profile from which the beam size can be determined.

A second, independent method to measure the strength of the plasma lens is a segmented synchrotron radiation monitor some 35 m downbeam of the lens. The harder the beam is focused, the higher the energy of the emitted synchrotron radiation. As the plasma focusing effect is transient, the monitoring of this synchrotron radiation provides an "on-line" measurement of the plasma focusing gradient. Such a plasma focusing induced synchrotron radiation signal was also observed for the first time. The energy was determined to be a few mega-electron-volts, which confirms the gradients derived from the plasma density.

Smaller beams

Figure 1 shows a typical set of scans for hydrogen and nitrogen (Z is in the direction of the momentum vector of the beam), illustrating the beam's convergence toward a waist.

The plasma lens concept also works if there is no pre-ionization by the laser, a process called self or impact ionization. Here, the head of the positron bunch ionizes the gas and the remainder of the bunch is focused. The head of the bunch is not focused, so the efficiency in spot size reduction is lower than for laser pre-ionization. For the latter, the beam size was approximately halved for nitrogen. The reduction in the orthogonal dimension was comparable, so that the reduction in spot size was approximately a factor of four. The maximum possible spot size decrease is much higher, but in the SLAC experiment, the beam current had to be lowered and the incoming beam size enlarged so the fragile carbon fibres in the wire scanner would not melt in the very-high-energy density of the focused beam.

Earlier, the experimental setup was used to focus a 30 GeV electron beam using the self-ionization method. The collaboration is excited about potential future applications of the plasma lens concept and is presently repeating this electron focusing experiment using also laser pre-ionization.

The members of the collaboration, by institution, are: Fermilab (C Crawford and R Noble); KEK-Japan (K Nakajima); Lawrence Livermore (H Baldis and P Bolton); SLAC (P Chen, W Craddock, F-J Decker, C Field, R Iverson, F King, R Kirby, J Ng, P Raimondi and D Walz); Hiroshima University, Japan (A Ogata), UCLA (D Cline, Y Fukui and V Kumar); University of Tennessee (A Weidemann).

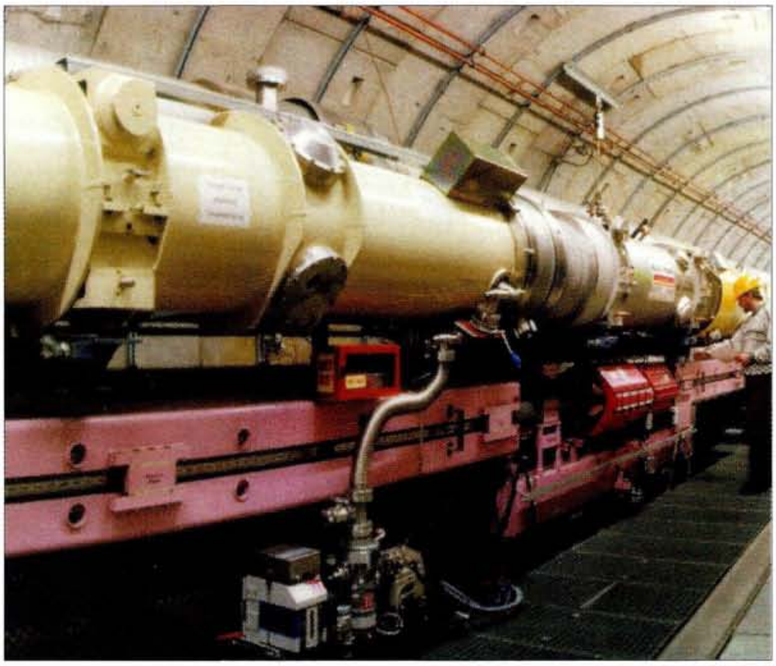
Pisin Chen *and* **Dieter Walz**, *SLAC.*

More collisions ahead for HERA

The unique HERA electron-proton collider at DESY, Hamburg, achieved record performance in 2000 before being shut down for nine months of "lumi upgrade".

For the machine crew at the DESY laboratory, Hamburg, the result of the 2000 run of the HERA electron-proton collider is something to be proud of. As the ever-rising curves of the accelerator's luminosity show, the performance of DESY's 6.3 km flagship accelerator has been increasing steadily ever since it was commissioned in 1992 – an evolution that reached its peak with this year's particle physics run.

A total of only 18 days were spent on maintenance work and machine studies since the beginning of the run on 17 January. The rest of the time, HERA was operated around the clock with the same efficiency as in 1999, with almost all the accelerator parameters achieving or exceeding their original design values.



Luminous upgrade – the HERA electron–proton collider at the DESY laboratory, Hamburg. The superconducting proton ring is mounted above the electron ring.

In particular, HERA reached the peak value of 67 pb^{-1} integrated luminosity (luminosity is a measure of the "impact rate" of the electrons and protons circulating inside the storage ring facility and the particle collisions delivered to the experiments), thereby nearly doubling its performance when compared to the design specification of 35 pb^{-1}.

From 4 September, HERA is enjoying a well-deserved nine-month break: activities in the tunnel are buzzing to get the accelerator back with a luminous 150 pb^{-1} per year next summer.

Getting the machine to reach its planned luminosity target by 1997 – five years after commissioning – had already required a range of improvements. In particular, HERA and its preaccelerator PETRA were fitted with new control systems, which considerably improved the quality of the proton beam.

Electron compatibility

However, a few nagging problems persisted. Operating HERA with electrons proved especially problematic. At just two hours, the lifetime of the particle beam was unexpectedly short, probably due to positively ionized impurities disturbing the beam. To get round this problem, it was decided to switch to positron operation in 1994. In general, the lifetime of the beam has proved to be much better when running with positrons (by a factor of up to two). The energy of the HERA electrons (or positrons) is 27.5 GeV.

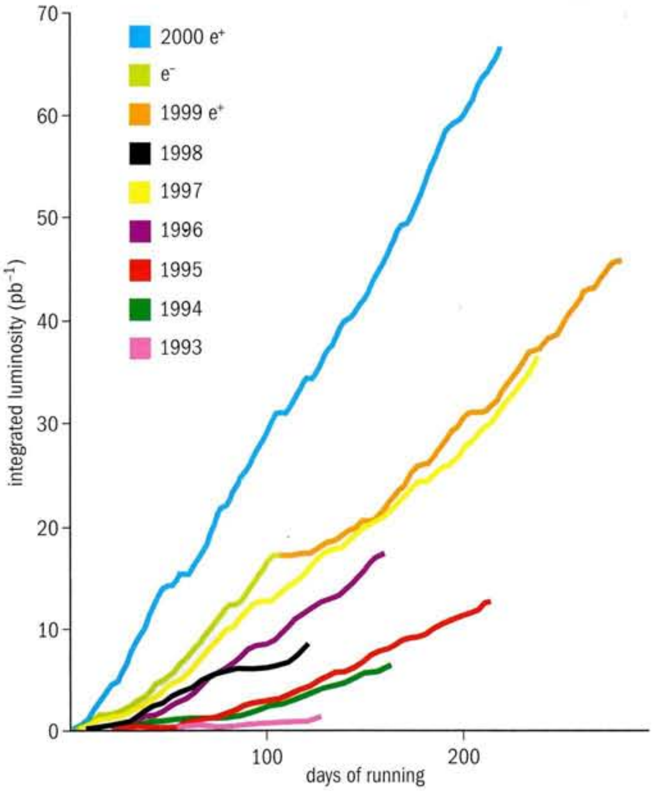
The problem of making HERA "electron compatible" was reduced during the 1997/1998 winter shutdown by changing the vacuum pumps of the electron storage ring. The original ion getter pumps were replaced by passive non-evaporating getter (NEG) pumps – adsorption pumps without high voltage that do not accelerate dust particles into the beam vacuum. At the same time, additional measures were carried out to improve the reliability and efficiency of the machine: for example, an additional radiofrequency power reserve improved the operational stability; complete reorganization of HERA's control system extended its functionality and improved operating ▷

efficiency; the radiofrequency couplers for the superconducting cavities of the electron ring were reconstructed; and the old, often reused main power supply of the superconducting ring was replaced. These extensive modifications paid off. HERA's particle collision rate with electrons was just as high in 1999 as the rate obtained with positrons two years before.

Higher energy protons

The increase of the proton energy from 820 to 920 GeV was carried out without problems as well, despite its pushing the superconducting magnet system closer to its limits. What's more, HERA provided the fixed target experiment HERMES with a stable supply of longitudinally spin-polarized electrons, with polarization of the beam routinely lying between 50 and 60% (and peak values reaching 65%).

This year also saw the full integration into operations of the fourth HERA experiment HERA-B, a fixed target experiment using the proton beam of the accelerator. HERA's increase in efficiency was thus achieved, although both particle beams are used in parallel by the collider experiments H1 and ZEUS and two fixed-target experiments.



Physics profits – integrated luminosity of DESY's HERA electron–proton collider for the period from May 1992 until the end of this year's run displays its increasing performance. Although the 1998 operational year suffered teething problems following significant modification work during the 1997/1998 winter break, HERA performed exceptionally well in 1999 and 2000 before being shut down for nine months of "lumi upgrade".

More luminous

HERA's exceptional performance this year was the crowning touch before extensive work to improve luminosity began in September. The goal is to increase the luminosity four- to five-fold in order to provide experimental access to extremely rare processes.

To achieve this, it will be necessary to reduce the cross-sections of the particle beams at the north and south interaction points to a third of their current area, that is from 21 mm^2 to 7 mm^2. This is quite a challenge, as it also entails a complete rearrangement of the interaction zones.

In particular, it will be necessary to move the low-beta quadrupoles closer to the collision points. The first low-beta quadrupoles will be fitted right into the H1 and ZEUS detectors. These quadrupoles also provide the fields which merge and separate the protons and electrons before and after the collisions respectively.

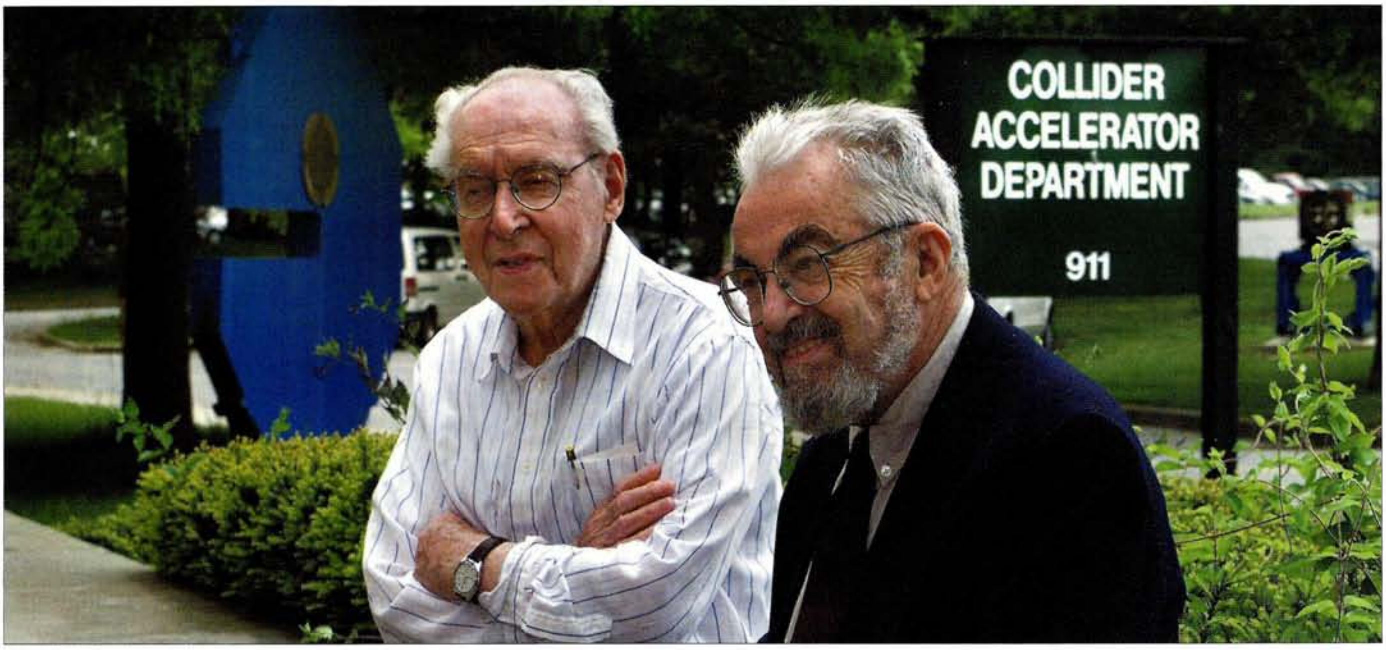
The powerful synchrotron radiation due to the magnetic beam separation will be absorbed downstream, far away from the detectors. Several unconventional components had to be designed to handle this synchrotron radiation problem, including extremely small superconducting magnets that will be integrated into the H1 and ZEUS detectors, as well as keyhole-shaped vacuum chambers, which will be built into the machine at the end of 2000.

Thanks to these major improvements, HERA will be in excellent shape to take on the challenges of the new millennium when it restarts with five times its old luminosity in the summer of 2001.

Ilka Flegel *and* **Ferdinand Willeke**, *DESY.*

Four decades in the proton stronghold

Some 40 years after it was commissioned, and as well as continuing to provide particles to its own physics programme, Brookhaven's Alternating Gradient Synchrotron has a new future as the injector for the Relativistic Heavy Ion Collider (October p5). *Liz Seubert* looks back at the invention of alternating gradient (strong) focusing, which made the AGS and a new generation of machines possible.



Distinguished scientists: former Brookhaven director Maurice Goldhaber (left) with strong focusing pioneer Ernest Courant.

"If you can't do two things together, you just do one after the other – that's all there is to it!" Ernest Courant, Brookhaven distinguished scientist emeritus, was describing how he came to think of the strong-focusing principle that he, together with M Stanley Livingston and Hartland Snyder, co-discovered in 1952.

Also known as alternating gradient focusing, this principle was a breakthrough in accelerator design. At Brookhaven it resulted in the construction of the successful Alternating Gradient Synchrotron (AGS), which achieved its design energy on 29 July 1960.

In previous circular accelerators, such as Brookhaven's Cosmotron, particles had been guided round the ring by a magnetic field made by outward-facing magnets. The magnets bent the particles' trajectories and at the same time weakly focused them both horizontally and vertically. The particles' energy could only be increased by enlarging the ring with wider magnets, requiring far more steel – at great cost – to make the larger number of magnets.

However, Courant and his colleagues calculated that energy could be increased dramatically with much smaller magnets if the particles were strongly focused first vertically then horizontally.

They achieved this by arranging the magnets so that their field gradients faced alternately inward and then outward around the ring. (It turned out that this idea had been proposed earlier by Nick Christofilos in Greece, but his innovation had gone unrecognized and was then forgotten. Later he was invited to Brookhaven.) ▷

Strong-focusing accelerators

At the end of 1999, CERN celebrated the 40th anniversary of its Proton Synchrotron. This machine and the Brookhaven AGS were the world's pioneer proton strong focusing accelerators. That both of them are also the hub of complex and ongoing beam networks testifies to the importance of the invention of the strong focusing technique. Other machines that opted for the comfort of the then conventional weak focusing are now history.

In 1952, even before CERN had formally been created, the declared goal of the proposed European laboratory was to build a scaled-up version of Brookhaven's 3 GeV Cosmotron, then nearing completion. In 1952 a group of European pioneers visited Brookhaven to see Cosmotron preparations. The visit prompted the Brookhaven accelerator experts to organize a brainstorming session. The outcome was alternating gradient (strong) focusing. On his return, Odd Dahl boldly insisted that the new European machine should go for the untried focusing technique. CERN went for it, and the European machine was even commissioned several months before that at Brookhaven. The CERN machine's 40th anniversary was featured in the December 1999 issue of *CERN Courier* (p15).

The practicality of the principle was demonstrated in 1954 by Cornell University's 1.3 GeV electron accelerator, and in 1959, well before the AGS was finished, by CERN's 24 GeV Proton Synchrotron.

CERN makes a scoop

On 17 May 1960 a 50 MeV beam completed one turn round the AGS ring. In July that year the 30 GeV design energy was reached and even surpassed. "But," Courant recalled, "although we were all very excited by how quickly things were going, we were a little disappointed that we'd been scooped by CERN."

One reason why Brookhaven had fallen behind was because it had built an electron analogue before starting construction of the AGS, Courant says. The analogue was designed to explore what is called the "transition energy" – a potentially serious problem with the synchronization behaviour. The analogue could also give information on nonlinear resonances that might affect the orbit stability of the particles as they circled the AGS ring.

"These resonances were not a big problem, but it was good to know what was happening," said Courant . "Using the analogue, we found that the transition problem could be overcome. We also found out a lot about higher-order resonances that we hadn't expected, and we confirmed that we could go forward with the design as planned. So the delay was worth it."

Dedicated staff

In a statement made in July 1960 as the AGS began operation, Leland Haworth, Brookhaven director at the time, congratulated Ken Green, John Blewett and the entire staff of the Accelerator Development Department for their work. He offered special congratulations to Courant, Snyder and Livingston, "whose brilliant concept of strong focusing has once more proved its great utility".

Taking over as Brookhaven director on 1 July 1961 was Maurice Goldhaber, now distinguished scientist emeritus. From 6 to 12 September the laboratory hosted the 1961 International Conference on High Energy Accelerators. Immediately following the conference, the AGS dedication ceremony was held. Goldhaber had just returned from a celebration in Manchester for the 50th anniversary of the discovery of the nucleus by Ernest Rutherford.

On the return flight, Goldhaber wrote the talk that he was to give at the AGS dedication: "Why high-energy physics?". Unsurprisingly, Goldhaber's words on the science lying ahead at the AGS are relevant today in the new age of the AGS's mighty spin-off partner, the Relativistic Heavy Ion Collider.

In his talk, Goldhaber described experimentalists, eager to work on the new machine "on the border between light and dark, where no complete set of guiding principles is as yet established. Today, the border between light and dark has moved to questions of nuclear structure, of the structure of elementary particles, and of the forces between them," he also noted. "Research with these machines is a great adventure; it leads us nearer to the heart of the particles of which we all are built. To think of something more exciting is difficult."

Liz Seubert, *Brookhaven.*
This article originally appeared in the 4 August issue of the Brookhaven Bulletin.

RECRUITMENT

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Institute of High Energy Physics, Beijing

Professor Positions

The Institute of High Energy Physics (IHEP), Chinese Academy of Sciences, is the research center of high energy physics in China, The major upgrade of Beijing Electron-Position Collider (BEPC II) has been approved with the luminosity increased by a factor of 10 and rebuilding of Beijing Spectrometer (BES III). IHEP invites applicants from outstanding candidates for full professor positions in the fields of

1. Experimental particle physics (BES experiment, non-accelerator physics experiments, electronics system, computing and network system for high energy physics experiment);
2. Theoretical physics (particle physics, nuclear physics and field theory);
3. Accelerator technology (accelerator physics and technologies for BEPC II and high intensity proton accelerator)
4. Radiation technology (synchrotron radiation technology and applications, nuclear analysis and applications, free electron laser).

The appointments will initially be three years with a possibility of an extension up to tenure. For details, please refer to www.ihep.ac.cn. Applicants should contact Mr. Hou Rucheng before December 15, 2000. His mail address is as follows:

Mr. Hou Rucheng
Institute of High Energy Physics
Beijing 100039 P. R. China
Tel: 0086-10-68219643 Fax: 0086-10-68213374
E-mail: hourc@mail.ihep.ac.cn

University of Zurich, Switzerland

The Faculty of Science invites applications for a
Full Professorship in Theoretical Elementary Particle Physics

The new professor is expected to pursue vigorous research and to teach theoretical physics at all levels. She or he will find a very stimulating environment including major experimental activities at the University, the ETH and PSI with strong involvements in HERA, LHC and Neutrino physics.

Candidates with a recognized scientific record in theoretical elementary particle physics are asked to sent their curriculum vitae, list of publications and a summary of their research interests to the Dean of the Faculty of Science (Mathematisch-naturwissenschaftliche Fakultaet), Prof. K. Brassel, University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich, by November 30, 2000.

For more information, contact Prof. D. Wyler (wyler@physik.unizh.ch).

Please visit our website at **http://www-theorle.physik.unizh.ch**.

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

APPLICATIONS PHYSICIST

The Beams Division of Fermi National Accelerator Laboratory (Fermilab) has an excellent opportunity for an Applications Physicist. The successful candidate will be expected to focus on ion source research and development. Duties will include hands-on experimental activities, calculations and simulations for negative-hydrogen ion source and low-energy beam transport improvements for the Fermilab Linac program.

This position carries an initial three-year appointment with a possible extension and consideration for a regular position on the Fermilab scientific staff. A person with a Ph.D. in physics is preferred. Candidates should have demonstrated competence in a laboratory environment working with electrical, mechanical, vacuum, and high voltage systems. Experience with sources, linear accelerators or accelerator RF systems is a definite plus. Appointment at a more advanced level may be possible for a candidate with appropriate qualifications.

Located 40 miles west of downtown Chicago, on a campus-like setting. Fermilab provides competitive salaries and exceptional benefits, including medical/dental/life insurance, tuition reimbursement, fitness center, on-site daycare, and access to our 6,800 acre nature preserve. Applicants are requested to forward their curriculum vitae and a list of at least three references to Dr. John Marriner, Fermi National Accelerator Laboratory, P.O. Box 500, M.S. 306, Batavia, Illinois 60510-0500 U.S.A.

Fermilab

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Faculty Position in Theoretical Particle Physics

Cornell University

The Department of Physics at Cornell University invites applications for a tenure track Assistant Professor appointment in theoretical particle physics, to begin in Fall 2001 or later.

Outstanding applicants at a more senior level may also be considered. We are seeking highly qualified candidates committed to a career in research and teaching. We especially encourage applications from candidates with an active interest in the interface of string theory, gravity, brane physics, and field theory. However, outstanding candidates in any area of theoretical particle physics will also be seriously considered.

Applicants should send their curriculum vitae, publications list, a brief description of their research interests and arrange for three letters of reference to be sent to Professor Henry Tye, Search Committee Chair, Newman Laboratory of Nuclear Studies, CornellUniversity, Ithaca, NY 14853.

To receive the fullest consideration, applications should be received by January 1, 2001.

Cornell University is an equal opportunity, affirmative action employer.

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 of 1 July 2001. This position complements two recent appointments in string theory in the University of Toronto Physics and Mathematics Departments, anticipated new appointments in condensed matter theory, and recent appointments in cosmological and high energy astrophysics at the adjacent Canadian Institute for Theoretical Astrophysics.

For this position, we seek candidates with a Ph.D. in Physics and strong 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 Henry van Driel, Chair
Department of Physics
University of Toronto
Toronto, Ontario, Canada M5S 1A7

The deadline for the receipt of applications and letters of recommendation is 2 January 2001.

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.

The Physics Division of the Illinois Institute of Technology (IIT) seeks applicants for a tenure-track position at the Assistant or Associate Professor level in Accelerator Physics. This position will be available in January, 2001. (In addition, several postdoctoral, staff, and graduate student positions are immediately available.) The successful candidate for the tenure-track position will become a member of IIT's Center for Accelerator and Particle Physics (CAPP) and will be encouraged to interact with the CAPP faculty and will be encouraged to interact with staff at Fermilab, located approximately 60 km west of IIT. Competitive salaries and startup packages are available. Applicants should submit a curriculum vitae, a statement of research interests, and at least three letters of recommendation to:

Prof. T. I. Morrison
Chair, Physics Search Committee
Physics Division
IIT
3101 South Dearborn
Chicago, IL 60616 USA

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Colorado

University of Colorado at Boulder

Tenure Track Faculty Positions

The Department of Physics of the University of Colorado at Boulder invites applications for two tenure track faculty positions to start September 2001. The successful applicants will be expected to direct active reserach programs and to teach effectively and creatively at both the undergraduate and graduate levels. The positions are approved to be filled at the Assistant Professor level. Applicants should submit a current curriculum vitae, a summary of current and proposed research, and arrange to have at least three letters of reference sent directly to the chair of the appropriate search committee. Additional information can be obtained at **physics.colorado.edu/jobs.html**.

Experimental Nuclear Physics
Candidates with research interests in all areas of nuclear and hadronic physics are welcome. The focus of the present research program at CU-Boulder is on high-energy scattering of leptons and light hadrons from nucleons and nuclei in experiments at DESY (Hermes), Fermilab and Jefferson Lab. Attn: Chair, Nuclear Physics Search Committee, Department of Physics-CB 390, University of Colorado at Boulder, CO, 80309-0390.

Experimental Particle Physics
Candidates with research interests in all areas of this field are welcome. Possible areas of research include, but are not limited to fixed target physics, collider physics at all energies, and particle astrophysics. The current faculty in the Experimental Particle Physics group are studying CP violation physics (KTeV and BABAR), and the physics of heavy quarks (Focus, BTeV). The group is also actively involved in NLC studies. Attn: Chair, Particle Physics Search Committee, Department of Physics-CB 390, University of Colorado at Boulder, CO 80309-0390.

Completed applications and the letters of recommendation for either position should arrive by 5 January 2001, but applications will continue to be reviewed until the position is filled. *The University of Colorado at Boulder is committed to diversity and equality in education and employment.*

Texas Tech University

RESEARCH ASSOCIATE POSITION
EXPERIMENTAL PARTICLE PHYSICS

The Department of Physics at Texas Tech University (TTU) has an opening for a Research Associate position in experimental particle physics. We are looking for an outstanding physicist who will concentrate the majority of his/her efforts on the CMS experiment at CERN. The TTU group is responsible for several significant components of the CMS forward calorimeters, e.g. absorber design, optics engineering, photodetector readout and calibration. In addition, the group actively participates in the CDF experiment and contributes in several areas: calorimeter front-end electronics, online calibration and monitoring, design and commissioning of the calibration database and the silicon vertex detector upgrade. The physics emphasis of our group consists of Higgs searches, Supersymmetry, B-physics and Electroweak physics.

The person filling this position will be contributing to the ongoing particle physics research at TTU with frequent trips to Fermilab and CERN. Applicants for the position should have a Ph.D. or equivalent degree in experimental particle physics. **Please send an application including curriculum vitae and publication list, and arrange for three letters of recommendation to be sent to Nural.Akchurin@ttu.edu or: Prof. Nural Akchurin Texas Tech University Department of Physics Box 41051 Lubbock, TX 79409-1051 Applications will be accepted until November 30th, 2000 or the position is filled.**

Texas Tech University is an equal opportunity/affirmative action employer.

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

DESY invites applications for the position of a

Physicist or computer scientist (m/f)

For the data analysis of the DESY experiments distributed high-performance computer systems and interactive user interfaces have to be designed and developed. Especially the requirements of the experiments and the DESY-groups have to be analysed and suitable concepts for the implementation of CPU- and memory architectures have to be explored and developed. Essential part of the task is further the planning, development and realisation of concepts for the protection of computer systems and data against unauthorized access.

Applicants should have a degree in natural science or computer science or equal knowledge and skills; sound knowledge of high energy physics, modern operating systems (especially UNIX), in the fields of distributed computer architectures, of data networks based on TCP/IP and network filesystems (NFS, AFS) and in the field of object oriented technologies.

The applicants are expected to have many years of experience in the design, development and implementation of computing and memory systems for data analysis of high energy physics experiments and many years of experience with distributed centralised network architectures including network filesystems (NFS, AFS) and Storage Area Networks (SAN).

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

Letters of application including curriculum vitae, list of publications and the names of three referees should be sent before **November, 30th 2000**.

DESY, Personalabteilung, Notkestraße 85, D-22603 Hamburg
Code-number: 89/2000 **www.desy.de**

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

University of Bielefeld

Postdoctoral Position in Experimental Particle/Hadron Physics

The experimental particle physics group at the University of Bielefeld has an immediate opening for a postdoctoral research fellow to work on the COMPASS experiment at CERN.

The COMPASS collaboration is presently setting-up its experiment for scattering high energy muons off polarized protons starting in the year 2001. The main goal is to measure parton spin distribution functions, in particular the contribution of gluons to the nucleon spin.

The Bielefeld group has responsibilities for the solid state polarized target, which is a central and important part of the COMPASS apparatus. It involves low temperatures (<100mK) from a dilution refrigerator, high mag-netic fields (~2.5T) and microwaves to spin-polarized protons. More information to this can be found at:
http://wwwcompass.cern.ch/compass/detector/target/welcome.html.

The successful candidate should provide skills and be familiar with techniques in the fields of cryo-physics, vacuum-physics, and/or apparatus control. He should strengthen the team working on the target and participate in data-taking. The candidate is expected to be resident at CERN (Geneva). The salary will be based on the German BAT IIa pay scale. The contract would be for a period of two and a half years. Please send applications or inquiries to:

Professor Dr. G. Baum,
Universität Bielefeld,
Fa-kultät für Physik,
Universitätsstr. 25, D-33615 Bielefeld,
Tel. +49-521-106-5383,
e-mail: baum@physik.uni-bielefeld.de

TWO FIXED TERM RESEARCH ASSOCIATE POSITIONS IN PARTICLE PHYSICS

Rutherford Appleton Laboratory, Oxfordshire

The Particle Physics Department at the Rutherford Appleton Laboratory invites applications for two Research Associate positions in particle physics. The appointments will be initially for three years, with a possible extension by up to two years.

One of the vacancies is to work on the BaBar experiment which has already recorded the world's largest sample of B meson data and will continue to run with increased luminosity in coming years. The RAL BaBar group is active in CP violation and mixing studies in both the charm and bottom sectors. You will be expected to work principally on data analysis while also contributing to the development of RAL based data analysis facilities for the whole of the UK collaboration. The work will involve close contact with the UK University groups, and will require periodic travel to SLAC and elsewhere. You may be based at SLAC for one year during the initial three year appointment.

The other vacancy is to work on physics studies and detector R&D for the future $e+ e^-$ linear collider. The RAL group is part of the international LCFI (Linear Collider Flavour ID) collaboration which is studying the design of a vertex detector matched to the challenging requirements of the TeV regime. As well as physics studies and detector simulations, the group is engaged in a dynamic programme of detector R&D, building on the pioneering work in CCD-based pixel detectors carried out at RAL for the past 20 years. You will have the opportunity to participate in all aspects of the programme, including a strong component of laboratory work in which the adventurous requirements for the detectors are being pursued.

Applicants should have a PhD in Particle Physics, or have equivalent experience. Further details of the BaBar post can be obtained from Dr Neil Geddes (Tel +44 (0)1235 445261, email: N.I.Geddes@rl.ac.uk). Further details of the Linear Collider post can be obtained from Prof Chris Damerell (Tel +44 (0)1235 446298, email: C.J.S.Damerell@rl.ac.uk). More information about the RAL Particle Physics Department can be obtained from: http://hepwww.pp.rl.ac.uk/public/ppd.html The salary range is between £18,620 & £26,600 (Pay award pending). Progression within the salary range is dependent upon performance. A non-contributory pension scheme and a generous leave allowance are also offered. Application forms can be obtained from: Operations Group, HR Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) or email recruit@rl.ac.uk quoting reference VN1993/00. More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 17 November 2000.

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

CLRC

COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

RESEARCH ASSOCIATE (Subatomic Physics)

TRIUMF, Canada's national research facility for particle and nuclear physics, is currently seeking 1 or 2 Research Associates who will join the Canadian HERMES group from the University of Alberta, Simon Fraser University and TRIUMF. The main goal of the HERMES experiment is to measure the spin dependent structure functions of the proton and the neutron using deep-inelastic scattering of polarized positrons from polarized gas targets at HERA. However, a rich program of physics using unpolarized targets has emerged, greatly increasing the physics reach of the experiment. The Canadian group is responsible for the transition-radiation detector used to distinguish between positrons and hadrons, and for particle identification algorithms used in the analysis of the data. Our physics analysis efforts currently focus on: the spin structure function g1(d); semi-inclusive hadron asymmetries and polarized quark distributions; gluon polarization; quark fragmentation functions; and vector meson production. The group has also designed and constructed new drift chambers used in the study of charm production.

The Research Associate(s) will spend a third of the time on hardware support or technical analysis, and the remainder of the time on physics analysis. Incumbents will be expected to spend a significant amount of time at DESY in Hamburg, Germany, and the remaining time will be spent at TRIUMF in Vancouver. Applicants must have a Ph.D in nuclear or particle physics, and be available to begin as soon as possible. The appointment is initially for two years, but is renewable upon mutual agreement. Salary is commensurate with experience.

TRIUMF is an equal opportunity employer and, while preference will be given to qualified Canadian citizens and permanent residents, we invite all qualified applicants to submit resumes including names of 3 references to: **TRIUMF Human Resources Competition #797-0910, 4004 Wesbrook Mall Vancouver, B.C., Canada V6T 2A3. Fax (604) 222-1074. Further information can be obtained by contacting Dr. C.A. Miller (miller@triumf.ca) or Dr. M. Vetterli (vetm@triumf.ca)**

Tenure Track Assistant Professor - Experimental Particle Physics

The Physics Department at the University at Albany anticipates hiring an Assistant Professor on a tenure track line starting in Fall 2001. The position is subject to final budget approval.

The candidate will be expected to contribute to the existing program in experimental particle physics. Candidates for this position should have a Ph.D. in Experimental Particle Physics and at least three years of post-doctoral experience, specializing in semiconductor particle detectors. We are looking for an outstanding candidate with strong commitment to teaching as well as research. The Albany High Energy Physics Group is part of the CLEO collaboration at Cornell University and the ATLAS collaboration at CERN. Please send resume to

Prof. M. Saj Alam (alam@hepmail.phy.albany.edu)
Faculty Search Committee
Department of Physics (www.albany.edu/physics)
University at Albany
1400 Washington Avenue, Albany, NY 12222.

The University at Albany is an Equal Opportunity/Affirmative Action, Immigration Reform and Control Act, and Americans with Disabilities Act Employer.

Departmental Contact: Ellen Kelly (ebk03@cas.albany.edu) phone (518) 442-4501, 4500 fax (518) 442-5260.

Associate Scientist

Superconducting Magnet Development

The Technical Division of Fermi National Accelerator Laboratory has available an excellent research position for Associate Scientist in superconducting accelerator magnet development. Our world-class superconducting magnet R&D program is developing state-of-the-art magnets for upgrading the Tevatron, the world's highest-energy collider; for Fermilab's central involvement in CERN's Large Hadron Collider; and for forging the way to the next generation of accelerators. The successful applicant will play a leading role on magnet design, fabrication and testing, and will join an experienced team of physicists, engineers and technicians. Research is directed specifically at Nb_3Sn accelerator magnets of field strength greater than 10 Tesla.

The Associate Scientist position has an initial term of three-years and the possibility of extension and growth into a regular research appointment on the Fermilab scientific staff. A Ph.D. or equivalent in physics or engineering is required, and at least two years experience in experimental high-energy physics, accelerator science, or superconducting magnet or materials technology. The successful candidate must have a demonstrated record of accomplishment as evidenced by publications, reports, and presentations; have leadership potential; and must have good communication skills in English, both oral and written.

Located 40 miles west of downtown Chicago on a campus-like setting, Fermilab provides competitive salaries, an attractive benefits package, and excellent opportunities for personal and professional growth. Please forward a CV and three (3) letters of recommendation to:

Fermilab

Dr. Peter Limon
Fermilab
P.O. Box 500, MS-316
Batavia, IL 60510-0500
U.S.A.

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UNIVERSITY of GLASGOW
DEPARTMENT OF PHYSICS AND ASTRONOMY

RESEARCH ASSOCIATE IN PARTICLE PHYSICS

£16,775 - £25,213

A position is available, initially for up to two years, to work on the LHCb experiment. We are looking for an outstanding applicant with experience in Experimental Particle Physics who has, or is about to obtain, a PhD. The post is based in Glasgow but will involve periods of work in Geneva and at RAL.

The Glasgow group has made major contributions to the Research and Development of particle identification using the LHCb-RICH detector. We plan a continuing programme of physics simulation and software development together with photon detector development and implementing the mechanics and alignment of the upstream RICH in LHCb.

For further particulars see our website at http://ppewww.ph.gla.ac.uk/lhcbfps.html or E-mail: p.soler@physics.gla.ac.uk Applications, including CV, publications list, and the names and addresses of two referees, should be sent by 30 Nov 2000, to Prof. D H Saxon, Kelvin Building, University of Glasgow, Glasgow G12 8QQ, Scotland.

The University is committed to equality of opportunity in employment.
The University of Glasgow is an exempt charity dedicated to teaching and research.

UNIVERSITY OF CALIFORNIA, SANTA BARBARA DEPARTMENT OF PHYSICS

Faculty Position in Experimental High Energy Physics

The Department of Physics at the University of California, Santa Barbara invites applications for an assistant professor position in experimental high-energy physics. The UCSB HEP program is forming a new group to work on hadron-collider physics (CDF and CMS), and it has existing groups working on heavy-quark physics (BaBar and CLEO) and dark-matter searches (CDMS II). The faculty in the group are Claudio Campagnari, Joseph Incandela, Harry Nelson, and Jeffrey Richman. We seek candidates with outstanding ability in both instrumentation and data analysis. The UCSB HEP group has excellent technical resources and staff, as well as a long history of major detector construction projects and analysis results. Information about our program is available at **http://hep.ucsb.edu**.

Candidates for the position should have a Ph.D. or equivalent degree in physics, an outstanding record of scholarship, and should be committed to excellence in teaching. Candidates should submit a statement of current research interests and pursuits, a curriculum vitae, and a list of publications and should arrange for at least three letters of recommendation to be sent to: High Energy Search Committee
Attn: Prof. Jeffrey Richman
Department of Physics
University of California
Santa Barbara, CA, 93106
(E-mail: richman@charm.physics.ucsb.edu; please do not send applications using e-mail attachments.)

Applications will be considered starting January 1, 2001 and will be accepted until the position is filled. The University of California is an Equal Opportunity/Affirmative Action Employer committed to excellence through diversity.

JOINT TENURE-TRACK FACULTY POSITION EXPERIMENTAL NUCLEAR/PARTICLE PHYSICS UNIVERSITY OF NEW MEXICO - RIKEN/BNL RESEARCH CENTER

The Department of Physics and Astronomy of the University of New Mexico in partnership with the RIKEN BNL Research Center at Brookhaven National Laboratory invites applications for a tenure-track Assistant Professor position in experimental nuclear/particle physics.

We are searching for someone with primary interest in the spin-physics program of the PHENIX experiment at RHIC, as well as its heavy ion program. The department also has activities in particle astrophysics and strangeness physics, and candidates with additional interests in those fields are particularly encouraged to apply. The expected starting date is in August 2001. For the first five years residence at BNL for approximately six months per year will be expected. The minimum requirements for this position include a Ph.D. and a minimum of one year post-doctoral experience in experimental nuclear/particle physics, scholarship in experimental nuclear/particle physics as documented by a publication record, and a commitment to teaching and/or record of teaching experience.

For complete information, see
www.unm.edu/~oeounm/facpost.html.

Application materials, including letters of reference, must be received by December 31, 2000. Candidates must send a curriculum vitae, a list of publications, a brief summary of research and teaching experience, and must arrange for three letters of reference to be sent separately to both Prof. B. Bassalleck, Search Committee Chair, Department of Physics and Astronomy, University of New Mexico, 800 Yale Blvd. NE, Albuquerque, N.M. 87131-1156 (e-mail: Bassalleck@Baryon.phys.unm.edu), and to Professor T.D. Lee, Director, RIKEN BNL Research Center, Building 510A, Brookhaven National Laboratory, P.O. Box 5000, Upton, Long Island, New York 11973.

The University of New Mexico and Brookhaven National Laboratory are Equal Opportunity/Affirmative Action Employers and Educators.

INDEX TO DISPLAY ADVERTISERS

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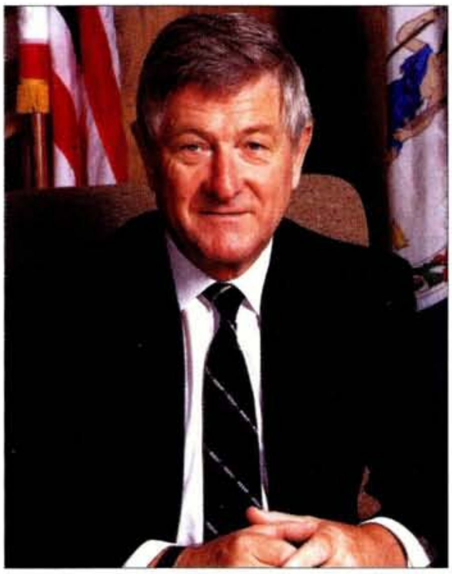
Hermann Grunder to head Argonne Lab

Hermann Grunder, for 15 years the dynamic director of the Thomas Jefferson National Accelerator Facility (Jefferson Lab), is to become director of the Argonne National Laboratory near Chicago. He succeeds Yoon I Chang, the associate laboratory director for engineering research who has served as interim director since July 1999.

Grunder foresaw the vital superconducting technology objective for Jefferson's CEBAF accelerator. Under his leadership the laboratory was completed on cost and on schedule and began operations in 1994. Christoph Leemann, recently named Jefferson Lab deputy director, becomes interim director during the search for a new director.

Well known in particle and nuclear physics circles, Grunder played a major role in pioneer heavy ion work at Berkeley. He received the Distinguished Associate Award from the US Department of Energy (DOE) in 1996, and the US Senior Scientist Award from Germany's Alexander von Humboldt Foundation in 1979. A native of Basel, Switzerland, Grunder holds a doctorate in experimental nuclear physics from the University of Basel and a master's degree in mechanical engineering from the Karlsruhe Institute of Technology in Germany.



Hermann Grunder will be the new director of the Argonne National Laboratory.

Argonne was the first US national laboratory, chartered in 1946. With sites in Illinois and Idaho, it has become one of the DOE's largest research centres, with approximately 4200 employees and an annual operating budget of about $465 million.

The University of Chicago has been Argonne's manager and partner throughout its history. The laboratory was formed in 1946 as an outgrowth of the Manhattan Project's Metallurgical Laboratory at Chicago where, in 1942, Enrico Fermi's team produced the first controlled self-sustaining nuclear chain reaction. From 1964 until 1979, Argonne was the home of the 12.5 GeV ZGS, the world's highest energy weak focusing proton synchrotron. The laboratory celebrated its 50th anniversary in 1996.

Today, Argonne performs research across a broad spectrum of scientific and technical areas and is home to a wide array of unique research instruments and facilities, including the Advanced Photon Source.

High-level US–LHC collaboration: US Department of Energy secretary **Bill Richardson** (centre) at CERN at an LHC interaction region quadrupole test cryostat, part of the US contribution to LHC construction and built by the US–LHC collaboration (hence the Fermilab logo). Left to right: DOE Office of Science director **Mildred Dresselhaus**, CERN LHC Division Main Magnet Group leader **Carlo Wyss**, CERN director-general **Luciano Maiani**, CERN research director **Roger Cashmore**, secretary Richardson, US UN Geneva ambassador **George Moose**, DOE High Energy and Nuclear Physics associate director **Peter Rosen** and CERN non-member state affairs advisor **John Ellis**.

Every few years, past as well as present members of CERN's distinguished Scientific Policy Committee gather at CERN. This time they were able to admire the mighty equipment being prepared for LHC experiments. Here, the first ring of the magnet barrel yoke for the CMS magnet forms the backdrop.

We're more than 99.99% empty space! That's just one of the messages awaiting visitors to CERN's recently refurbished Microcosm exhibition, which opened on 20 September. Microcosm was created back in 1985 to provide a much needed visitor centre for CERN. Since then, it has evolved considerably to combine elements of CERN's unique collection of scientific equipment with modern interactive displays. In this most recent refurbishment, interactive demonstrations of the four forces of nature have been added, along with working Rutherford and electron charge-to-mass ratio experiments. Visitors discover that they are over 99.99% empty space by peering into giant hands that show them with ever increasing resolution exactly what they're made of. Here, visitors to Microcosm try – unsuccessfully – to pull "quarks" from a "nucleon" in one of the exhibition's new interactive exhibits.

James "BJ" Bjorken (right) has had a big impact on particle physics and the development of the Standard Model. Among other contributions, he was the first to interpret the early results of the 1967 MIT–SLAC deep inelastic electron-scattering experiments in terms of pointlike constitutents of the proton, eventually recognized as quarks. To honour him for his decades of service to the field, SLAC held a symposium, "BJ's Day in the Sun", on 16 September. Speakers included his thesis advisor and coauthor Sid Drell, his graduate student Helen Quinn, his SLAC buddy and 1990 Nobel laureate **Dick Taylor** (shown with him above), and his Fermilab boss, Leon Lederman. They brought back many fond memories of "the good old days" at SLAC. (Photo Harvey Lynch.)

The eighth European School of High-Energy Physics, held in Caramulo, Portugal on 20 August–2 September, attracted 101 students from 27 different countries, together with four Portuguese "observer students". The percentage of female students taking part this year was, at 25%, the highest yet in this series of schools. During the school, two of them celebrated birthdays – **Dorothea Samtleben** of Hamburg (right) and **Alina Radu** of Berne.

An exhibition, Science Bringing Nations Together, organized by CERN and the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow, was held in the European Parliament, Brussels on 11–15 October. The opening ceremony on 12 October featured welcome speeches by **Carlos Westendorp** (chairman of the European Parliament Committee on Industry, External Trade, Research and Energy – seen here speaking), CERN director-general Luciano Maiani, JINR director Vladimir Kadyshevsky, International Science and Technology Centre deputy director Ioannis Antoniou and director-general of the European Commission Research Directorate-General Achilleas Mitsos. The exhibition was also visited by European Commission commissioner for research Philippe Busquin and other distinguished guests.

Baier 70th birthday

27 September marked the 70th birthday of eminent particle physics theorist Vladimir Nikolaevich Baier, head of the theory group at the Budker Institute of Nuclear Physics in Novosibirsk. He started his scientific career in Novosibirsk soon after the foundation of the Budker Institute and played an important role in the formation of its theory division. Professor Baier is known for his fundamental contributions to quantum electrodynamics at high energies, including the theory of inelastic processes, radiative corrections and radiative polarization. Together with his students he formulated the operator approach to quantum electrodynamics in external fields and developed a universal quasi-classical method for the description of high-energy processes. During recent years his team developed a new theory of interactions of electrons, positrons and photons with oriented monocrystals. For many years, Baier has been teaching at Novosibirsk University. Many of his pupils have become well-known scientists.

Vladimir Nikolaevich Baier – 70th birthday.

Earlier this year, three distinguished physicists were awarded honorary doctorates by Johann Wolfgang Goethe University, Frankfurt – left to right, Hermann Grunder, director of the Jefferson Laboratory, Newport News, Virginia; Marcos Moshinsky, creator of modern Mexican physics and famous for Moshinsky transformations in group theory; Rudolf Bock, inertial confinement specialist and emeritus scientist at the GSI heavy-ion laboratory, Darmstadt; they are seen with Reinhard Stock, Dean of Frankfurt Physics. (Photo Frankfurter Allgemeine Zeitung.)

Pakistan Minister of Science and Technology Atta-ur-Rahman (right) with (left to right) CERN CMS experiment spokesman Michel Della Negra, Hafeez Hoorani of Quaid-i-Azam University, Islamabad, and Jim Allaby of CERN. Pakistan has a substantial commitment to the CMS experiment at CERN's future LHC collider, including plans for a regional computing centre.

Light entertainment

As a medium of our fundamental senses, light is essential for all forms of visual art. Light is also the basis for many industrial and research instruments. Specialist company Electron Tubes is well known for its light-detection products including photon-counting tubes, hemispherical photomultipliers and the smallest ultrarugged light detector in the world.

As part of its commitment to light, Electron Tubes recently took up the opportunity of working with kinetic artist Peter Keene, who draws inspiration from industrial and technological equipment. The company supplied him with a set of 8 inch hemispherical photomultipliers to create a kinetic sculpture to react to audience movement.

See "http://www.electrontubes.com".

An example of the work of kinetic artist Peter Keene, now busy making art from photomultiplier tubes.

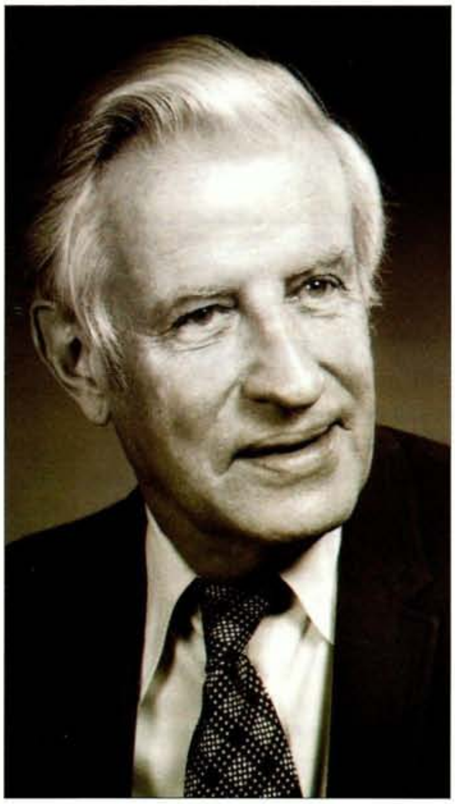
John Blewett 1910–2000

Accelerator pioneer John Blewett died on 7 April, just a few days short of his 90th birthday. Born and educated in Toronto, he completed his PhD at Princeton in 1936. After a postdoctoral year at the Cavendish Laboratory in Cambridge, in the twilight of the Rutherford era, Blewett worked at General Electric's Research Laboratory from 1937 until 1946. There, in 1945, he calculated that the energy of a beam of circulating electrons should lose energy through the dissipation of radiation, resulting in a tiny reduction in the radius of the electron orbit. Following this prediction, "synchrotron radiation" was duly observed at General Electric in 1947.

Meanwhile, in 1946, Blewett had moved to Brookhaven, where he stayed for the remainder of his long and active career. He contributed to the development and construction of a series of major machines at Brookhaven – the Cosmotron, the Alternating Gradient Synchrotron (AGS) and the Light Source, as well as working for the Isabelle collider. Blewett proposed applying the principle of strong focusing to linear accelerators immediately after the invention of this principle for synchrotrons in 1952.

From 1953 until 1954, at the invitation of CERN machine pioneer Odd Dahl, Blewett worked with the small group designing CERN's Proton Synchrotron. US Cosmotron experience and the design approach for the new AGS were thus integrated into European thinking.

In 1993 Blewett was awarded the American Physical Society's Robert R Wilson Prize.



John Blewett 1910–2000.

Courier Web site

The *CERN Courier* Web site – available at "http://www.cerncourier.com" – was set up when the responsibility for publishing the magazine was passed to Institute of Physics Publishing in October 1998. Although it has a different appearance to the printed version of the magazine, the Web site nevertheless contains all the editorial material published in each issue (the printed advertisements are not reproduced on the Web site). The site is updated as soon as each new issue is printed, usually near the end of the month preceding the cover date.

Latest figures show that about 150 people visit the site every day (about one person every 10 minutes), each of whom view about three pages, taking about 4 minutes to do so.

As well as the homepage (the "front door" to the site) and the table of contents pointing to the latest issue, the Web site features a back issue archive with full online content dating back to October 1998.

The valuable search feature enables users to sift through all these online articles using keywords, and is a useful tool to remind the editors what they have written in the past!

The Web site also gives information about how to subscribe to regular copies of *CERN Courier* (see also p3 of any issue). Indispensable data for advertisers can be found the online media pack.

There are also contacts for feedback, editorial and sales, and links to online resources for the high-energy physics community.

MEETINGS

Snowmass 2001, A Summer Study on the Future of Particle Physics is scheduled to take place in Snowmass, Colorado on 30 June–21 July 2001 with Ronald C Davidson and Chris Quigg as co-chairmen. Contact Cynthia M Sazama, Conference Office, MS 122, Fermi National Accelerator Laboratory, PO Box 500, Batavia IL 60510-0500; e-mail "sazama@fnal.gov"; fax +1 630 840 8589.

Correction

The person seen signing CERN's VIP visitors' book on p36 of the September issue is Bulgarian Deputy Minister of Education and Science Christo Balarev, not the Minister. We regret the error.

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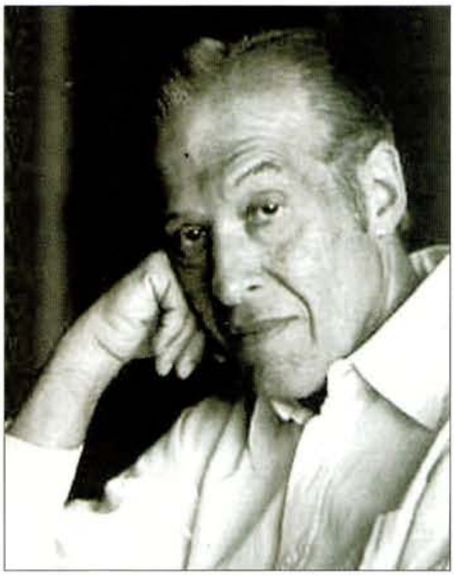
BOOKSHELF

Climbing the Mountain: The Scientific Biography of Julian Schwinger by Jagdish Mehra and Kimball Milton, Oxford, ISBN 0198506589.

Climbing the Mountain is the first full-length biography of Julian Schwinger. There is also a companion volume, *A Quantum Legacy* (World Scientific), edited by Milton, which complements a previous collection of Schwinger papers edited by C Fronsdal, M Flato and K Milton. An earlier volume, *Julian Schwinger, the Physicist, the Teacher and the Man* (World Scientific), is a compilation of tributes delivered at various memorial symposia by friends and former students and edited by Jack Ng. There is also a third volume, *QED and the Men Who Made It: Dyson, Feynman, Schwinger and Tomonaga* by S S Schweber (Princeton University Press).



Julian Schwinger – profound influence.

This biography describes Julian Schwinger's life as well as his work. The treatment of his scientific work is scholarly and well done. The challenge faced by this book is well stated in the preface: "Julian Schwinger was one of the most important and influential scientists of the 20th century...yet even among physicists recognition of his fundamental contributions remains limited." This is all the more remarkable since Schwinger had more than 70 students, many of whom became very distinguished, including three Nobel laureates.

Climbing the Mountain confronts this challenge by a very extensive discussion of Schwinger's manifold contributions. On the other hand one may still ask how it is possible that C N Yang can recall that when he entered the University of Chicago in 1946 as a graduate student, Julian Schwinger was already a legend (even before he had published his monumental papers on quantum electrodynamics), while in the year 2000 so little is known about Schwinger and so much is known about Feynman.

The answer lies partly in the personalities of the two men, but also in the beautifully simple and powerful diagrammatic notation invented by Feynman (which, in Schwinger's words, "like the silicon chip, would bring computation to the masses") and finally his separation from the mainstream in his later years.

The most important part of the Schwinger–Feynman story is summarized by the Michigan Summer Schools of 1948 and 1949. In 1948 Schwinger first described his breakthrough in QED to a wider audience, including Dyson, Kroll, Lee and Yang. It was then that Dyson wrote home that in a few months we shall have forgotten what pre-Schwinger physics was like.

In the following 1949 Michigan lectures, Feynman described his version of QED, but at that time he was unable to deal with vacuum polarization and it was not generally clear how much he had been able to accomplish.

By contrast, Schwinger had presented an essentially complete package: a manifestly covariant theory with which he had calculated in lowest order all the previously inaccessible consequences of QED. He had not only climbed the mountain but, more importantly, had shown that it could be climbed. Shorter routes were subsequently found. In the third year of the Michigan series, Dyson lectured and showed that the Schwinger theory and the completed Feynman theory were equivalent. This history, as well as the parallel work of Tomonaga, is well described in this book.

The Schwinger theory of 1948, while adequate for its original purpose, was, like every first invention, relatively crude and could not easily be pushed to higher order. Therefore during the 1950s he developed increasingly powerful calculational techniques. To this period belong the Schwinger action principle and the extensive use of Green's functions and functional techniques that are now part of the standard literature.

During the 1960s Schwinger began a total reconstruction of quantum field theory that he named source theory. Here he was attempting to replace the operator field theory, to which he had contributed so much, by a philosophy and methodology that eliminated all infinite quantities. He did in fact succeed in constructing an infinity-free formalism that was also receptive to new experimental information and new theoretical ideas. It was not simply a programme: Schwinger and his UCLA source theory group, K Milton and colleagues, showed that it was a very effective calculational tool. Source theory has not until now found extensive use in the general theoretical community, although it has elements in common with S Weinberg's use of phenomenological Lagrangians. Schwinger's determination to pursue this work for about 10 years led to his partial eclipse. Milton is obviously well qualified to review this period.

One of the more interesting chapters is entitled "Electroweak Unification and Foreshadowing of the Standard Model". Not so well known is Schwinger's role in the development of the electroweak theory. In 1941 he made the amazingly prescient remark that if the significant mass scale for nuclear beta-decay were of the order of several tens of nuclear masses, then there would be the possibility of an intermediate vector theory with a coupling of the order of alpha. The theory suggested by this numerology was essentially realized in 1957 in his beautiful paper "A Theory of the Fundamental Interactions" (1957 *Ann. Phys.* **2** 407). Schwinger comments on this paper (82) in the selected papers (edited by Flato *et al.*):

"A speculative paper that was remarkably on target: VA weak interaction, two neutrinos, charged intermediate vector meson, dynamical unification of weak and electromagnetic interactions, scale invariance, chiral transformations, mass generation through vacuum expectation value of scalar field. Concerning the idea of unifying the weak and electromagnetic interactions, Rabi once reported to me: 'They hate it'."

However, he was convinced and proposed a similar model to his student, Glashow. Thanks to the efforts of Glashow, Weinberg, Salam and 't Hooft the standard electroweak $SU(2) \times U(1)$ theory, bearing enormous similarity to Schwinger's paper of 1957, was born. The 1957 paper might well have led directly to the standard electroweak theory if it had not become bogged down in the infamous morass of 13 flawed experiments that seemed to imply that the beta-interaction was not VA.

Schwinger's independence of the mainstream is discussed in this biography and by ▷

many others including Schweber. It is said that he didn't like "conversational physics" but that meant only that he didn't like conversations unless they interested him. In fact he was quite open to new ideas.

The more accurate view is that he was simply an independent thinker who guarded his time and set his own goals, toward which he worked intensely and constantly. Much of his work he made no effort to publish. For some of his work, like the Bethe-Salpeter equation and the TCP theorem, he received no recognition.

It is arguable that the creativity of an original mind such as Schwinger's or Dirac's would have been enhanced by more interaction with others in later years. In Schwinger's case, in spite of the undeniable handicaps of isolation, the following assessment appears in the Festschrift published on the occasion of his 60th birthday:

"His work during the 44 years preceding his 60th birthday extends to almost every frontier of modern theoretical physics. He has made far-reaching contributions to nuclear, particle and atomic physics, to statistical mechanics, to classical electrodynamics and to general relativity. Many of the mathematical techniques he developed can be found in every theorist's arsenal...He is one of the prophets and pioneers in the uses of gauge theories...Schwinger's influence, however, extends beyond his papers and books. His course lectures and their derivatives constitute the substance of graduate physics courses throughout the world, and in addition to directing about 70 doctoral theses, he is now the ancestor of at least four generations of physicists...The influence of Julian Schwinger on the physics of his time has been profound."
Robert Finkelstein, UCLA.

Managing Science – Management for R&D Laboratories by Claude Gelès, Gilles Lindecker, Mel Month and Christian Roche, Wiley Series in Beam Physics and Accelerator Technology, ISBN 0471185086.

Managing Science is a book based on a graduate level course given by the authors at several editions of the US Particle Physics Accelerator School.

The book contains a didactic presentation and in-depth discussion of a complete set of management issues affecting big scientific laboratories, as well as analyses of their possible evolutions. Items including motivations for creating a laboratory, decision-making systems, organization and communication, policy implementation, project methodology, infrastructure, human resources management, financial management and logistics are treated with a direct and comprehensive style. The discussions on alternatives and their associated risks and opportunities are very educational.

Of particular interest is the second part of the book, entitled "The Human Drama". The typical evolution of the life of a scientific laboratory is described in terms of three main stages - growth, steady state and decline, just as in individuals, according to age. The analysis presented on the way of revitalizing the laboratory, identifying what are only fluctuations which might give a wrong impression of revitalization, is very interesting and of particular importance for already old but successful scientific organizations. The experience of the authors, mainly from particle physics laboratories, and the fast-changing evolution of the organizational methods of this type of research make the analysis especially adequate for high-energy physics labs.

In summary, the book contains a complete and useful description of the management tools for major scientific organizations and can also be useful for consultation. The reference material is plentiful and well selected.
Juan-Antonio Rubio, CERN.

The Quest for Symmetry – Selected Works of Bunji Sakita edited by K Kikkawa, M Virasoro and S Wadia, World Scientific, ISBN 9810236433, £49.

World Scientific's series on 20th century physics includes scientific anthologies about many famous figures and/or edited by many authoritative names. Volume 22 continues this tradition and includes a collection of key papers (without commentary) on SU(6) symmetry, the strong coupling group, the string model, supersymmetry and the use of collective variables in quantum field theory. Especially interesting is the autobiographical introduction by a scientist born and educated in Japan but who has spent almost his entire professional career outside that country.

Insertion Devices for Synchrotron Radiation and Free Electron Laser by F Ciocci, G Dattoli, A Torre and A Renieri, World Scientific, ISBN 9810238320, £49.

A further volume in World Scientific's series *Synchrotron Radiation Techniques and Applications*, this provides much general coverage of the theory of charged particle transport, synchrotron radiation and free electron lasers before going on to the specifics of insertion devices (which generate synchrotron radiation) and X-ray optics.

Principles of Fusion Energy by A A Harms, K F Schoepf, G H Miley and D R Kingdon, World Scientific, ISBN 9810243359, £35.

Fusion energy powers the stars and is perceived as the ultimate source of energy on Earth. R&D work has followed diverse paths. Much effort has gone into the design and construction of a series of toroidal machines (tokamaks, stellarators) to contain the hot thermonuclear fuel. This approach was initially heralded as a fountainhead of inexhaustible energy, but attention is also focusing on more fundamental approaches such as inertial confinement of hot plasma and muon catalysis. This textbook provides a useful summary of the relevant physics and an objective overview of the possible systems that could allow and contain thermonuclear fusion.

XIX International Symposium on Lepton and Photon Interactions at High Energies, Stanford, California, 9–14 August 1999 edited by John Jaros and Michael Peskin, World Scientific, ISBN 9810241895, 920pp.

Proceedings of the meeting which traditionally includes only plenary sessions.

High Energy Physics 99: Proceedings of the International Europhysics Conference on High Energy Physics, Tampere, Finland, 15–21 July 1999 edited by K Huitu, H Kurki-Suonio and J Maalampi, University of Helsinki, Finland. Institute of Physics Publishing, ISBN 0750306610, 1000 pp, illus. hbk £220/$359.

This volume contains the 18 invited plenary presentations and 250 contributions to parallel sessions presented at the conference.

An Introduction to the Theory of Spinors by M Carmeli and S Malin, World Scientific, ISBN 9810242611, £35.

Spinor treatments can be easier to handle than conventional tensor approaches. This compact textbook provides an introduction to spinors and examples of their application in general relativity and gauge theories.