CERN COURIER

INTERNATIONAL JOURNAL OF HIGH ENERGY PHYSICS

VOLUME 35 | 6 | SEPTEMBER 1995

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Distributed to Member State governments, institutes and laboratories affilliated with CERN, and to their personnel.

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CERN COURIER is published monthly except January and August in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management.

Printed by: Drukkerij Lannoo nv
8700 Tielt, Belgium

Published by:

European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
tel.: +41 (22) 767 61 11,
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tel. +41 (22) 767 41 03,
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USA: Controlled Circulation
Second class postage paid at Batavia, Illinois

ISSN 0304-288X

Volume 35
No. 6
September
1995

Covering current developments in high energy physics and related fields worldwide

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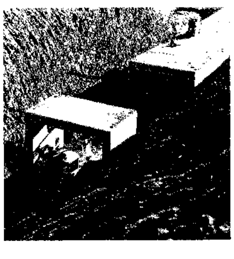

Cover photograph: Moving precast elements into place at Fermilab for the new 150 GeV Main Injector to provide an improved particle supply to the superconducting Tevatron. In addition, the new Main Injector will provide capabilities for neutral kaon studies and for neutrino beams. Some 2/3 of the 3.3 kilometre Main Injector tunnel has been completed.

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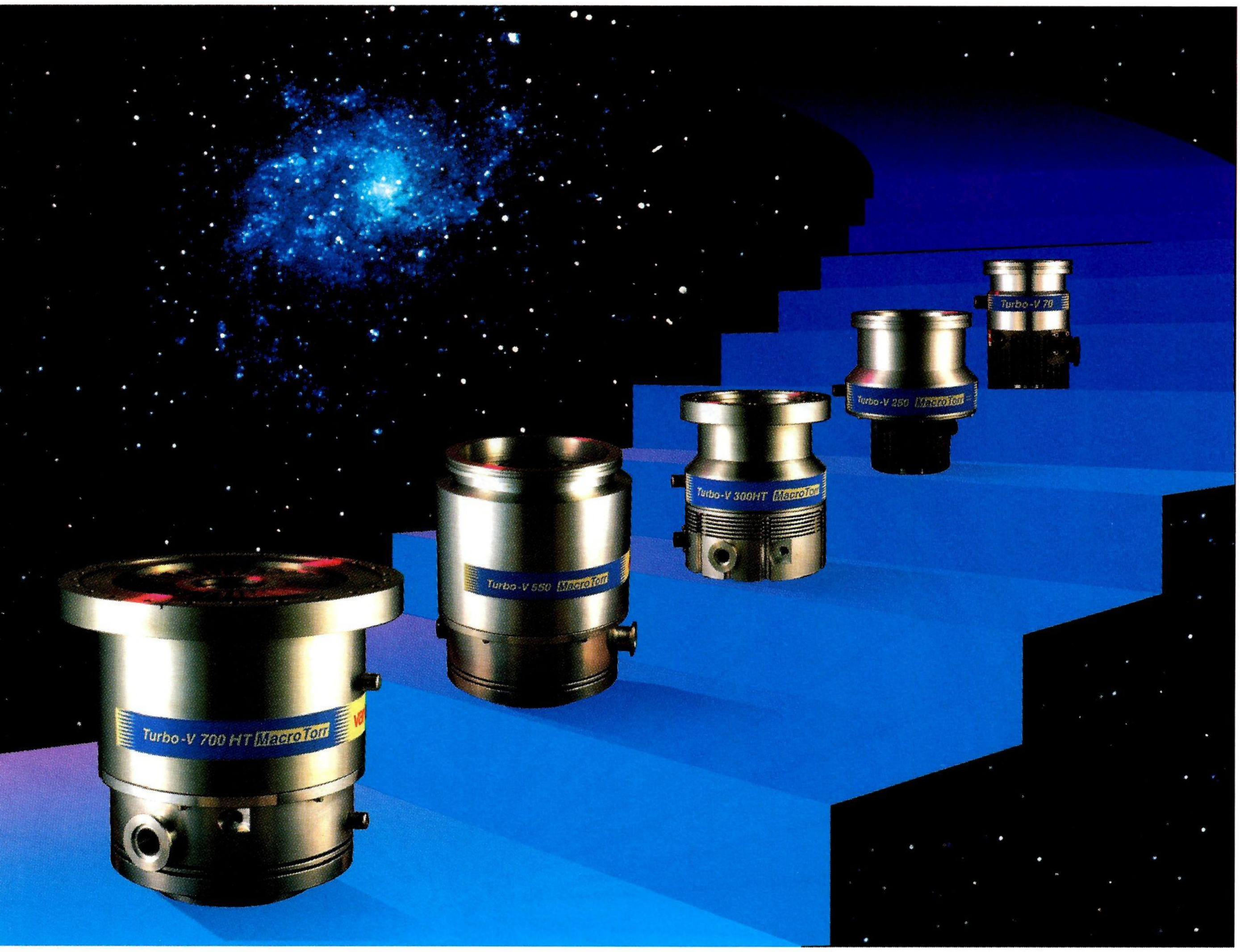

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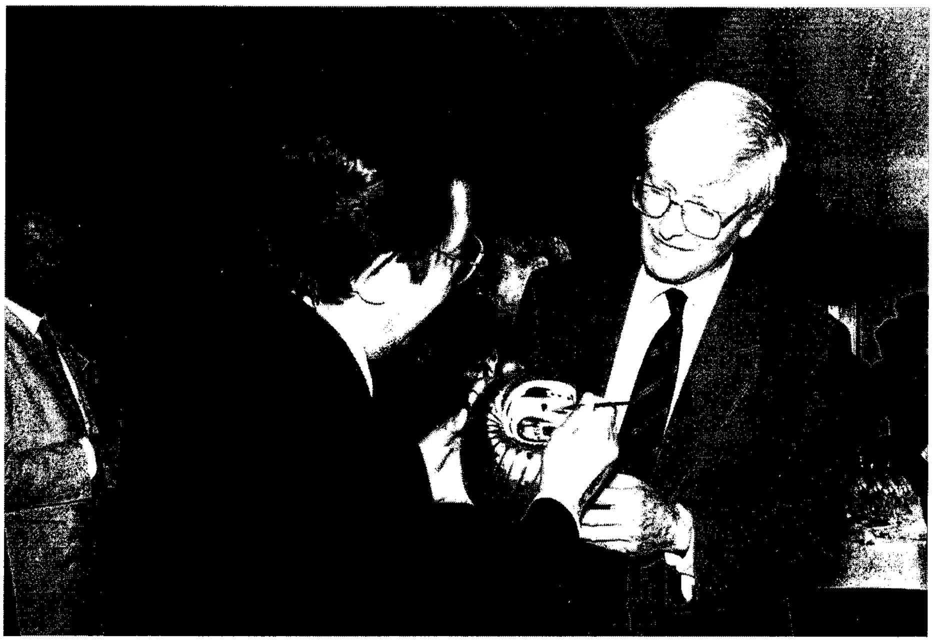
LHC goes global

At the June meeting of CERN's governing body, Council, Kaoru Yosano (left), Japan's Minister of Education, Science and Culture, and CERN Director General Chris Llewellyn Smith paint one eye of a 'daruma' talisman, marking commencement of Japanese collaboration in CERN's LHC proton-proton collider project. In Japan, daruma dolls are traditionally kept in a shrine awaiting the successful fulfilment of an ambition, when the remaining eye is painted.



As CERN's major project for the future, the LHC sets a new scale in world-wide scientific collaboration. As well as researchers and engineers from CERN's 19 European Member States, preparations for the LHC now include scientists from several continents. Some 50 per cent of the researchers involved in one way or another with preparations for the LHC experimental programme now come from countries which are not CERN Member States.

Underlining this enlarged international involvement is the recent decision by the Japanese Ministry of Education, Science and Culture ('Monbusho') to accord CERN a generous contribution of five billion yen (about 65 million Swiss francs) to help finance the construction of the LHC. This money will be held in a special fund earmarked for construction of specific LHC components and related activities.

To take account of the new situation, CERN is proposing to set up a totally new 'Associate State' status. This is foreseen as a flexible bilateral framework which will be set up on a case-by-case basis to adapt to different circumstances. This proposal was introduced to CERN Council in June, and will be further discussed later this year. These developments reflect CERN's new role as a focus of world science, constituting a first step towards a wider level of international collaboration.

At the June Council session, as a first step, Japan was unanimously elected as a CERN Observer State, giving them the right to attend Council meetings. Introducing the topic at the Council session, Director General Chris Llewellyn Smith sketched the history of Japanese involvement in CERN research. This began in 1957 and has gone on to include an important experiment at the LEAR low energy antiproton ring using laser spectroscopy of antiprotonic helium atoms, the new Chorus neutrino experiment using an emulsion target, and a major contribution to the Opal experiment at the LEP electron-positron collider.

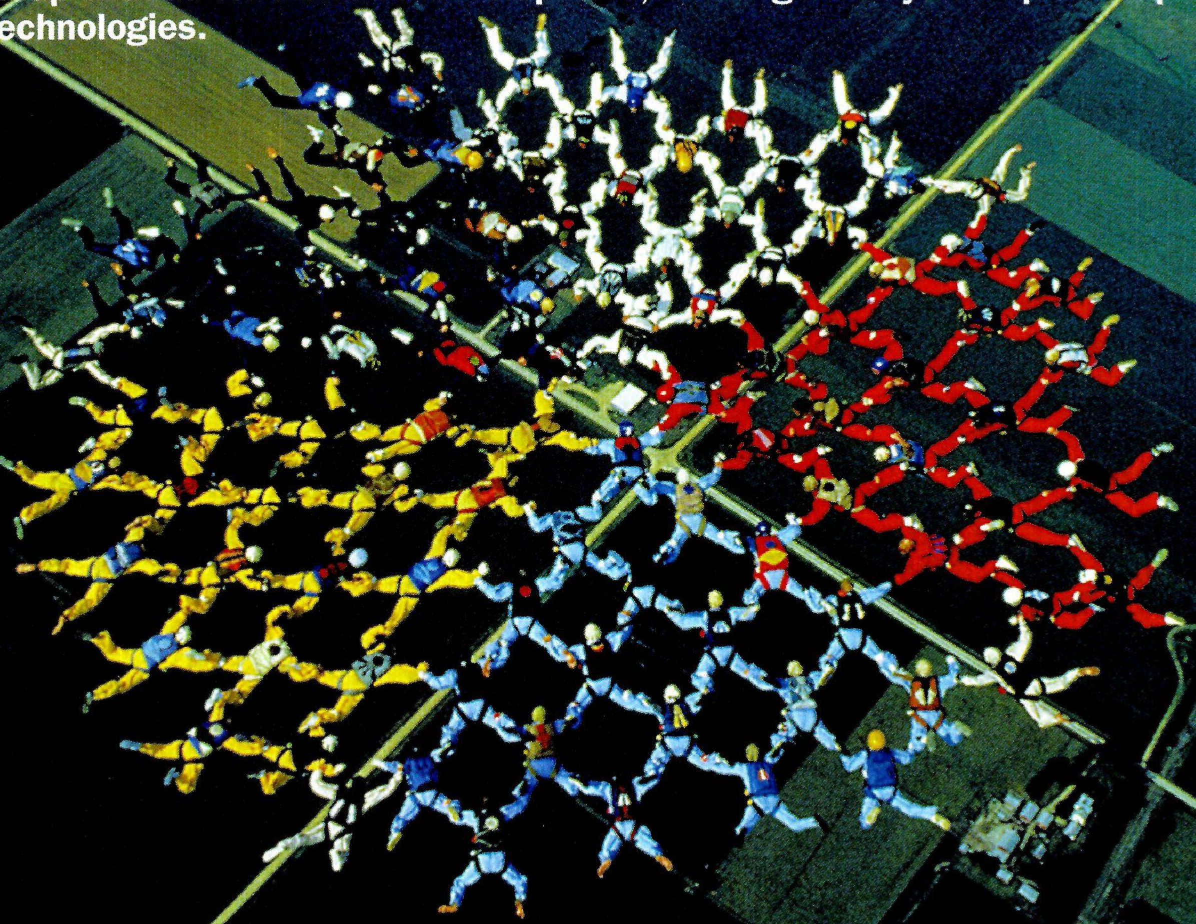
In welcoming the development, many Council delegates looked forward to a fruitful new collaboration. They also pointed to the achievements of Japan's KEK Laboratory and its collaborative schemes, now a focal point of the world particle physics scene.

A surprise item was the speech, in Japanese, by A. Herdina of the Austrian delegation. Strictly speaking Mr. Herdina was breaking the rules, as only English, French and German are catered for at CERN Council meetings, but in this instance everybody was happy that the Austrian delegate made his point.

Speaking at the Council meeting (in English) in his new capacity as Observer State spokesman, Kaoru Yosano, Japan's Minister of Education, Science and Culture, recalled his country's international tradition of cooperation in particle physics. Under a long-standing US/Japan agreement, Japanese teams are prominent in the CDF collaboration at the Fermilab Tevatron in the US, where the sixth ('top') quark was discovered earlier this year.

At the 'memorable Council meeting', Minister Yosanu pointed out that his country's wish to contribute to the LHC project at an early stage. He said that large scientific projects like the LHC 'captivated the imagination of citizens' and looked forward to the opening of new scientific frontiers.

Discussions with other major Non-Member States, involved in the LHC programme, including the US, Canada (see page 15), Russia, Israel and India, are underway and in some cases negotiations are at an advanced stage.



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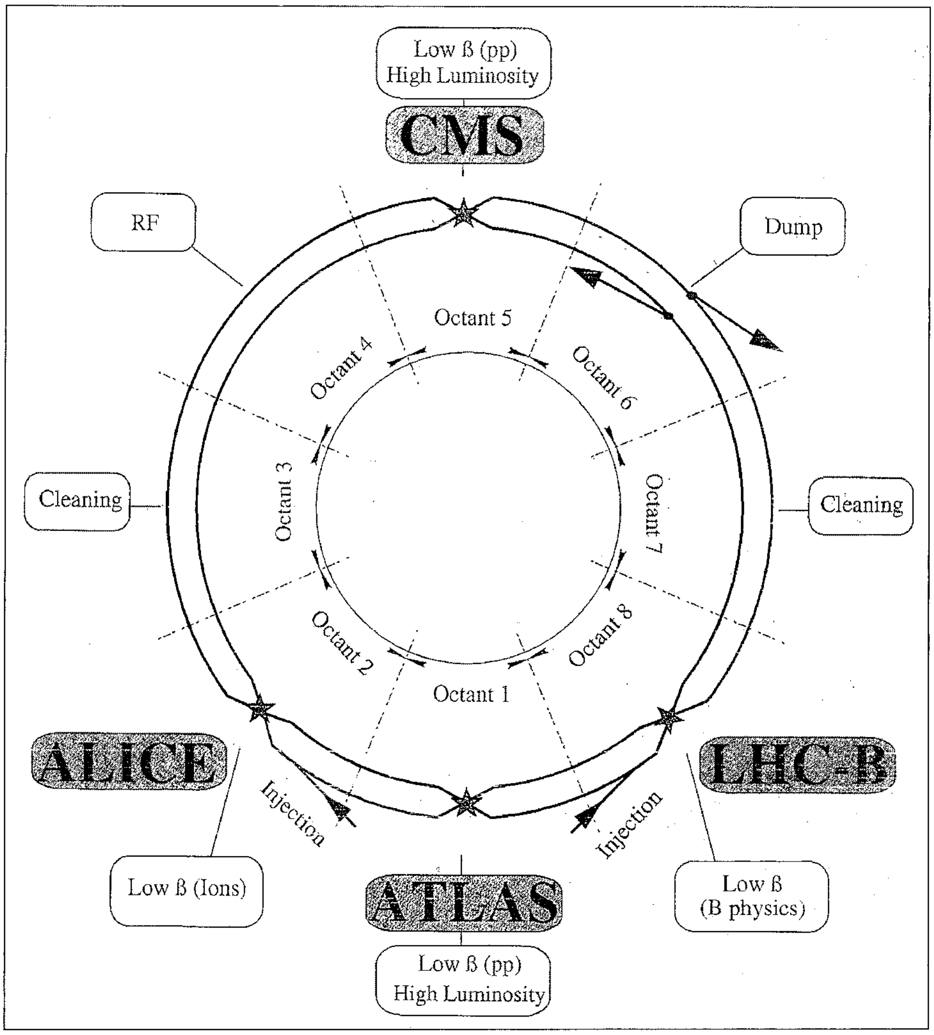
Proposed layout of the LHC ring, serving four experiments.



A walk round the LHC

To expedite the commencement of excavation and construction work for the LHC, the general layout of the tunnel has been essentially finalized. The LHC and the LEP electron-positron collider share CERN's 27-kilometre tunnel with its eight symmetrically-placed access shafts, where the even-numbered regions 2, 4, 6 and 8 are currently occupied by LEP's L3, Aleph, Opal and Delphi experiments respectively.

The LHC layout foresees four beam crossing points, each one tailored for a planned experiment, with services such as power supplies and cryogenics in the even-numbered points, where maximum use can be made of existing LEP facilities.

At Point 1, nearest the main CERN site, the LHC beams will cross in a low beta (compressed beam) insertion and provide high luminosity collisions for the ATLAS detector (June, page 9).

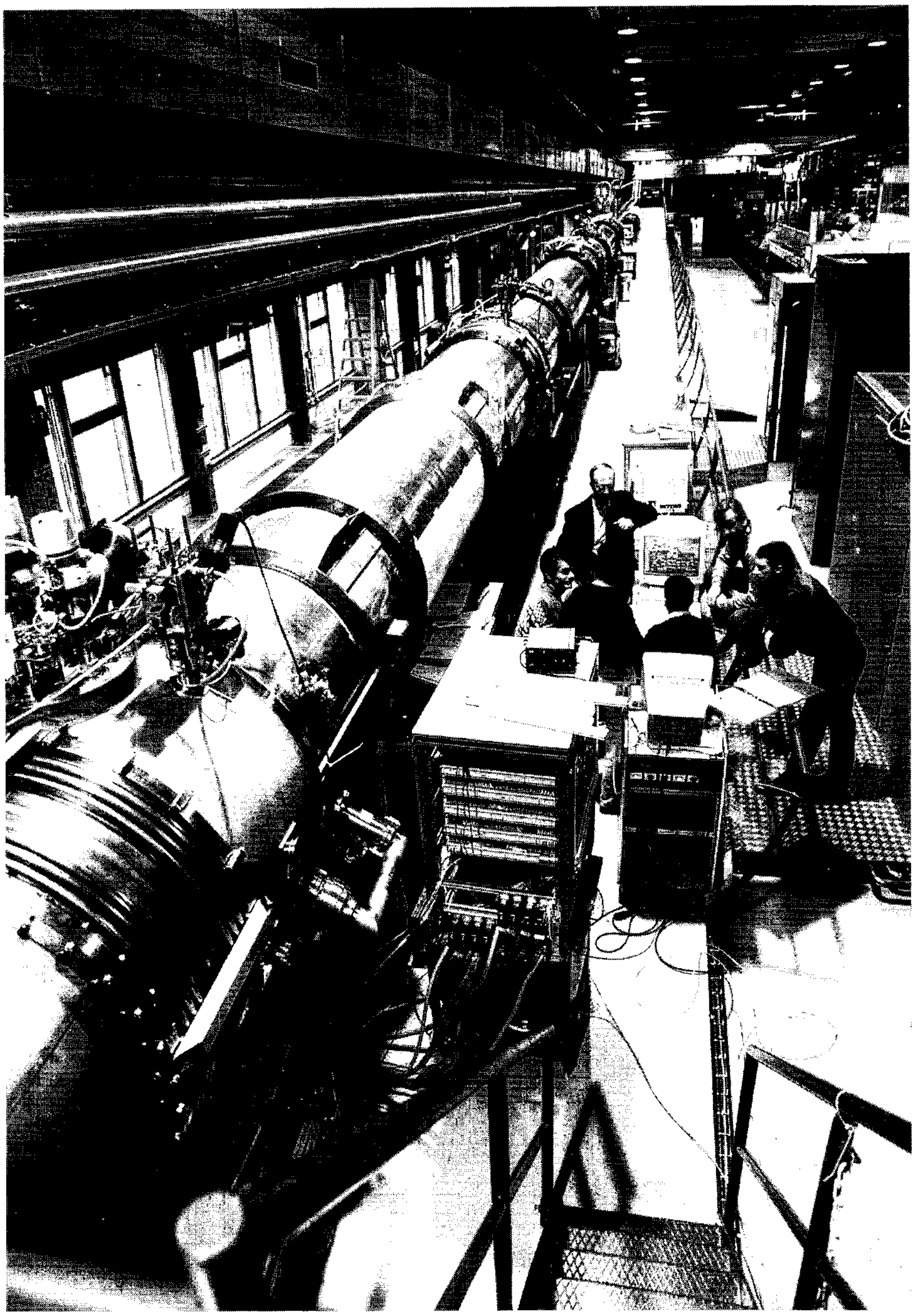
Proceeding clockwise round the machine, at Point 2 the beams will cross in a similar insertion which will be mainly used to provide the highest possible luminosity ion-ion collisions for the ALICE detector. The straight section at Point 2 will also contain the injection elements for the clockwise LHC proton ring - a horizontally deflecting current septum and a horizontal fast kicker magnet. This is somewhat different to the system initially envisaged but requires a more straightforward modification of the tunnel.

The injection lines for both LHC rings will use normal conducting magnets rather than the previously proposed superconducting ones. These injection lines will only be required for a few hours per day and an expensive cryogenic system is unrealistic.

At Point 3, the LHC beams will not cross, but will pass through a special insertion with normal conducting dipoles forming a double "dog-leg" on each beam. This will trap any secondary particles from a set of collimators designed to remove peripheral protons which might otherwise go on to strike the vacuum chamber and risk quenching neighbouring superconducting magnets.

Another non-crossing point is Point 4, where the beams will be pushed further apart (to almost 50 cm) to allow room for superconducting radiofrequency cavities on each beam. This recent innovation, which is still under study, aims to reduce the effects of beam loading, particularly difficult to handle during injection, and significantly reduces the overall radiofrequency power requirements. Separate accelerating cavities for the two beams will also increase flexibility, allowing acceleration and collision of different particles in each beam - for example protons against ions.

After careful study, it has been



The LHC string test continues to give encouraging results. As well as the superconducting magnets, interest focuses on such questions as quench protection system and propagation.

decided that at Point 5 the beams will cross in an identical layout to that of Point 1 to provide high luminosity collisions for the CMS detector (June, page 5).

At Point 6, the beams will not cross but will pass through a special insertion with fast extraction elements to dump both beams if required into blocks which absorb the 2 x 334 MJ of stored energy.

At Point 7, another non-crossing point, room temperature magnets will be equipped with collimators to remove particles which would escape the acceleration cycle.

At Point 8, the beams will cross in a similar insertion to that of Point 2, this time for a dedicated B-physics experiment. The upstream straight section of the anti-clockwise ring will be used for injection.

Although as definitive as possible, this scenario retains some flexibility for the experimental programme at a relatively modest cost.

The LHC string test

The LHC string test assembled towards the end of last year (January, page 2) continues to give encouraging results. In the 1995 tests, nominal current was achieved (corresponding to a field of 8.36T) without a quench and when the current was further increased, the first quench occurred at 12,773 A, equivalent to a dipole field of 8.64T. Operation and tests have regularly used the region between nominal and maximum current (9 T maximum field).

In this initial phase, the test string uses two 10m dipole prototypes and a 3 m quadrupole prototype, together with dummy corrector magnets, making a total length of 35 m. The 110m support beam could eventually accommodate a full cell. It is mounted on a 1.4% slope, the steepest gradient in the LHC ring, and, as in the LHC itself, the magnets are installed in a single continuous cryostat.

Initial results have been so encouraging that during a scheduled interruption to upgrade the cryogenic plant a third dipole magnet will be added to the string, making it look almost like a full 50 m half-cell. This latest dipole, from Ansaldo, has already been thoroughly bench-tested.

Later these test magnets will be replaced by 14.2 m prototypes, a second generation quadrupole prototype and a complete set of corrector magnets to provide a full half-cell LHC prototype, with attendant service systems very close to the final configuration.

Each half-cell of the LHC's normal lattice will consist of four superconducting magnets - three twin-aperture dipoles and one twin aperture quadrupole - installed in a short straight section together with other elements such as correction magnets and beam observation pickups. The total length of 53 m constitutes the basic unit for the cryogenic feed, powering etc.

Besides testing magnets, the string test assembly has now also become an excellent testbed for the highly specialized cryogenics, power, vacuum and control systems needed to operate the LHC at superfluid helium temperatures (1.8K), the first

Around the Laboratories

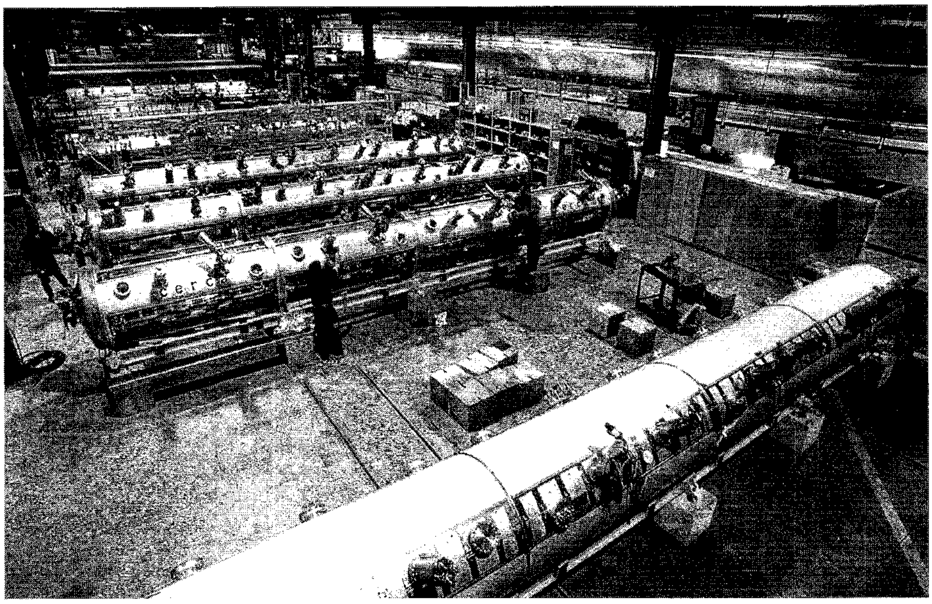
time such cryogenic systems will have been used on such a large scale.

When this work is underway, the magnets of the string can take a back seat, and interest focuses instead on such questions as understanding the behaviour of the quench protection system and investigating quench propagation from one magnet to the next. Because of the complicated plumbing, replacing an LHC magnet is not easy. However quenches due to beam losses may be inevitable during commissioning. The onset of small voltage differences can be used to trigger the quench protection system. Its final form will depend on experience with the string tests.

At its first cooldown at CERN on June 7, a 1-metre LHC model dipole magnet using niobium-tin conductor and designed and built by the University of Twente in the Netherlands in co-operation with CERN, NIKHEF and HOLEC and supported by the Netherlands Technology Foundation STW achieved at its first quench a record central field of 11.1 T at 4.4 K.

Niobium-tin operating at 4.4K was initially investigated as a possible conductor for LHC magnets, but the practical problems of handling this very brittle material and its very high cost led to a decision in favour of niobium-titanium at 1.8K. Niobium-tin has to be wound and then processed to produce the superconducting alloy (the 'wind-and-react' technique). In addition, the electrical insulation would have to withstand this difficult heat treatment. However this achievement is interesting for possible high field magnets for special applications, such as low-beta quadrupoles to compress the beams at the interaction regions.

Cryogenic modules containing superconducting radiofrequency cavities being prepared for installation in CERN's LEP collider, where they will provide additional accelerating power to take the electron and positron beams to higher energies.
(Photo CERN AC 17.4.95)



CERN
A hinge between LEP and the LHC

Later this year, if all goes well, the beam energy of CERN's LEP electron-positron collider should be increased to around 70 GeV per beam (collision energy 140 GeV), giving a foretaste of things to come. Since 1989, the 27-kilometre ring has been operating around 45 GeV per beam to feed its four physics experiments with a steady diet of Z particles, the electrically neutral carriers of the weak nuclear force. This has given precision results on vital parameters of the Standard Model.

Meanwhile work has been steadily pushing ahead to upgrade LEP to LEP2, installing superconducting radiofrequency cavities (January 1994, page 6) and ancillary cryogenics equipment to boost the machine's energy and reach new areas of physics interest. The initial goal is to produce pairs of W particles, the electrically charged counterparts of the Z.

As far as the machine is concerned, at these higher energies, the 'beam-beam' interaction between the contra-rotating electrons and positrons is reduced, so more particles can be pumped into the ring. To achieve this, LEP has switched to the new 'bunch train' scheme (see page 14) each train containing several 'carriages' (bunches) of particles.

To attain its physics objectives, LEP2's target is 500 inverse picobarns of integrated luminosity over the next few years. This is a challenge as LEP's integrated luminosity to date (since the machine was commissioned in 1989) is some 160 inverse picobarns, itself viewed as no mean achievement.

To reach higher energies, the accelerating power at LEP is being increased with installation of superconducting radiofrequency cavities. After initial trials with solid niobium, LEP2 relies on the more reliable performance provided by copper, with its better heat conduction properties, coated with a superconducting film of niobium. Even so heroic preprocessing is required to ensure optimal performance. After initial trials revealed welding weaknesses, the plumbing for the power couplers demanded a special effort, but this has been overcome. Overall, the development and installation programme for LEP2 cryogenics and associated equipment has been especially demanding.

Towards the end of this year LEP is scheduled to run equipped with 14 cryogenic modules (of which most are already installed), each module containing four superconducting cavities. These superconducting cavities complement LEP's existing accelerating system based on conventional copper cavities operating at room temperature. If all goes well, this should enable the beam energy to reach 70 GeV.

After an extended shutdown to accommodate the necessary installation work, LEP2 is scheduled to recommence operations next June with 32 superconducting modules. If all goes well, the beam energy could then attain about 80 GeV, and later in 1996, after installation of cryogenic units in all the available space in the ring (a total of 40 modules), the stage would be set for the beam energy to reach the threshold at which pairs of W particles will be produced.

Results at this higher energy will add to the list of precision Standard Model results. However many physicists are convinced that the predictable behaviour of the Standard Model is a reflection of an underlying layer of as-yet undiscovered 'supersymmetric' particles, which should make their appearance as energies attain the necessary production threshold.

After LEP, the next physics horizon will open up at CERN's LHC proton-proton collider, scheduled to begin operations in about ten years. The LHC will surely uncover a rich new vein of physics, but it is important that no fertile ground should be skipped in moving physics from LEP to the LHC.

By judiciously replacing LEP's original copper radiofrequency accelerating cavities with superconducting ones, the beam energy could be coaxed still higher, enabling LEP to explore a maximum of physics terrain. The exact strategy will be worked out over the coming months.

A major goal at higher energies is the higgs mechanism responsible for symmetry breaking in the electroweak picture and which thereby endows particles with mass. While the higgs domain will certainly open up at the LHC, LEP2 and the LHC must overlap so that no threshold higgs effects slip through any intervening crack.

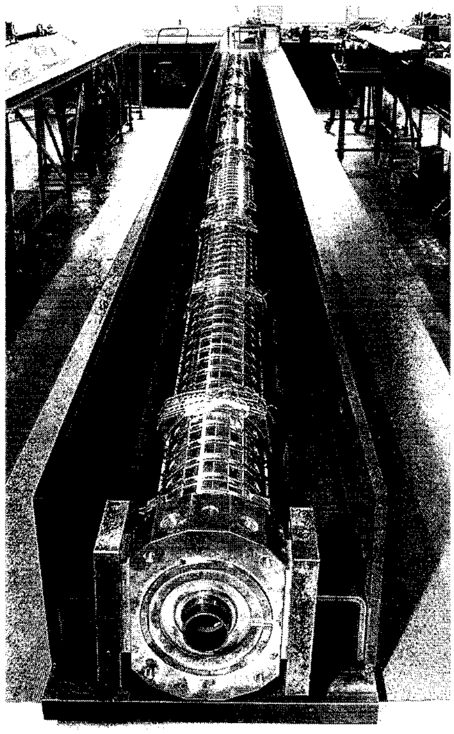
The higgs mechanism is susceptible to quantum fluctuations - particle exchanges classically not allowed but which can nevertheless happen transiently with energy 'borrowed' through the Uncertainty Principle.

The precision results at LEP show that such higgs effects are not yet visible, but, because the natural scale of electroweak interactions is so different to those of quarks and gluons, the effects should set in before energies reach a few TeV.

DESY
Choosing an electron route

In surveying the current particle physics scene, the European Committee for Future Accelerators (ECFA) meeting held at DESY, Hamburg, in June naturally highlighted work at the host Laboratory. A particular focus was development work for the next generation of linear colliders to accelerate electrons and positrons towards a total collision energy of 0.5 TeV.

Owing to the inherent simplicity of the annihilation process, the study of electron-positron interactions has yielded a wealth of information on the basic constituents of matter and the forces which act between them. Indeed, an electron-positron collider which covers the mass range be-



As part of the world-wide effort to develop the technology for the next generation of electron-positron linear colliders, the SBLC project at DESY is based on the well developed SLAC (Stanford) 3.0 GHz (S-band) approach. DESY in collaboration with SLAC, TH Darmstadt and industry has successfully developed a powerful S-band klystron yielding a peak power of 150 MW in a radiofrequency pulse 3 microseconds long. First 6 m accelerating structures have been built and are now being tested.

At the meeting of the European Committee for Future Accelerators (ECFA) held at DESY, Hamburg, in June, Bjoern Wiik, (left) Chairman of DESY's Board of Directors, and Chris Llewellyn Smith, Director General of CERN, gave useful snapshots of current and ongoing activities at their respective Laboratories.

(Photo M. Jacob)

tween the W-pair production threshold and 500 GeV with a peak luminosity of order 5 x 10^{33} $cm^{-2}s^{-1}$ will have a rich physics programme complementary to that at the LHC proton-proton collider to be built at CERN. Driven by the physics potential, there is at present a strong world-wide effort directed at providing the technical basis for the construction of TeV electron-positron linear colliders.

DESY, in collaboration with more than 30 institutions from 9 countries, is exploring two options, TESLA and SBLC, for a 500 GeV - 2000 GeV linear collider.

The TESLA approach is based on 1.3 GHz superconducting solid niobium cavities. There is general consent that a linear collider based on superconducting accelerating structures in an extremely attractive option. However, to be cost competitive with alternative approaches the accelerating gradient must be raised by a factor of five from the present value of some 5 MV/m to 25 MV/m while at the same time reducing the cost per metre of structure to 25% of its present value. To reach such high gradients in superconducting cavities the international TESLA Collaboration (October 1994, page 22) has set up an impressive cavity processing facility at DESY which includes hyper-clean rooms and special processing equipment. Indeed, the two first 9-cell niobium cavities reached gradients well in excess of 25 MV/m in a vertical test cryostat at 1.9 K under TESLA operating conditions.

The SBLC approach is based on the well developed SLAC 3.0 GHz (S-band) technology. DESY in collaboration with SLAC, TH Darmstadt and industry has successfully developed a powerful S-band klystron yielding a peak power of 150 MW in a radiofrequency pulse 3 microseconds long. First 6 m accelerating structures have been built and are now being tested.

At the moment both approaches are being explored, but within a year or so one of the projects will be accorded priority status.

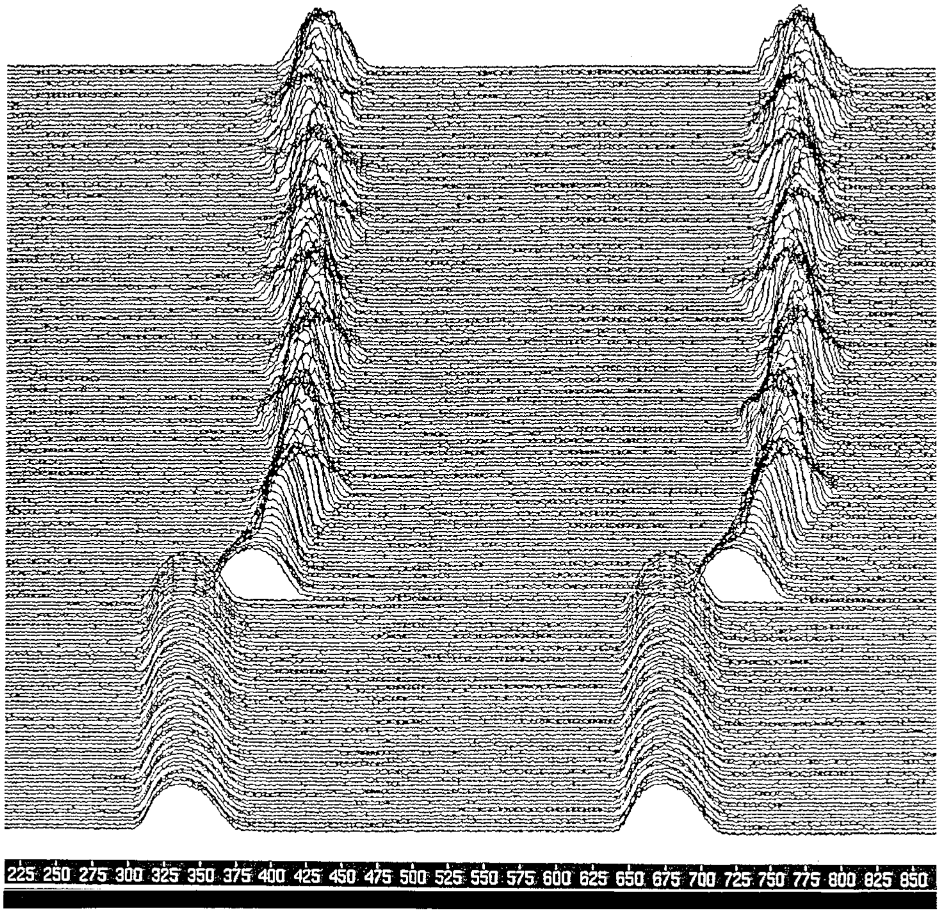
A review of the impressive progress made by various laboratories in developing the basis for electron-positron linear colliders was given by Sergio Tazzari, the chairman of the ECFA Advisory Panel.

In view of this fast progress in accelerators, increasing attention must now be given also to the design of experiments. Basing itself on several active European working groups studying at present the physics potential of future linear colliders, ECFA decided to set up, together with DESY, a series of workshops to develop conceptual designs of experiments and experimental areas.

At the ECFA meeting, DESY Director Bjoern H.Wiik pointed out that the laboratory now attracts some 2600 users from 33 different countries, nearly evenly split between particle physics and research based on synchrotron radiation. To meet the needs of both communities in the future, Wiik foresees a TeV-scale linear collider for particle physics capable also of feeding free electron lasers providing extremely bright short bursts of coherent light at angstrom wavelengths, realizing the old dream of an X-ray laser.

Meanwhile DESY's particle physics continues to be centred on the unique HERA electron-proton collider. As work progresses (see following story) to push HERA towards its design luminosity of 1.5 x 10^{31} $cm^{-2}s^{-1}$, a task force is now investigating the possibility of boosting the HERA luminosity to several times its design value. They will also explore the option of storing polarized protons.

Completing the European picture at the ECFA meeting, CERN Director General Chris Llewellyn Smith surveyed the status of CERN's forthcoming LHC proton-proton collider, where the accent now is on accommodating additional nations into the CERN fold (see page 1). CERN Accelerator Director Kurt Hübner described the detailed work now in progress to install superconducting accelerating cavities to double the collision energy of CERN's existing LEP electron-



'Mountain range' display for two of the eight bunches in the Brookhaven Alternating Gradient Synchrotron (AGS). Each horizontal trace spans 700 nanoseconds and is repeated every 200 microseconds. The beam intensity is 7 x 10^{12} protons per bunch. The picture shows transition and the subsequent quadrupole-mode bunch oscillations.

positron collider from its present level around the Z resonance at 91 GeV to create pairs of W particles and explore new physics horizons (see page 6).

Bjarne Stugu of Bergen introduced the results of a recent ECFA survey on the sociology of large physics experiments. We will publish these interesting results in a forthcoming issue.

HERA progress

With first interesting physics results in hand, the immediate goal at DESY's HERA electron-proton collider is to push for the design luminosity of 1.5 x 10^{31} per sq cm per s. A major development in this direction was a switch last year to running with positrons, rather than electrons, sidestepping problems due to ionic contamination of the beam.

Running this year continues with positrons, and peak luminosity is expected to improve due to larger stored currents. However the goal is still to provide the advertised electron-proton physics, and new pumping solutions, using ion getter pumps, similar to those used in CERN's LEP ring, are being investigated. On the proton side, the DESY III synchrotron is supplying its design current, but not all of this can be transferred to the HERA ring yet. Improving the proton transfer lines should remove this bottleneck.

The major Zeus and H1 physics experiments at HERA have now been joined by the Hermes experiment employing a polarized gas target to shed further light on the origin of the nucleon spin (December 1993, page 19). Spin rotator magnets act on the transversely polarized HERA electron beam to groom it for Hermes collisions. Next year will see initial running in for components of the HERA-B detector (June, page 20).

Zeus and H1 continue to probe deeply into the structure of the proton, showing that the gluon content of the proton still increases steeply as x (momentum fraction) decreases. While this is interesting, it is also puzzling, as eventually the rise has to stop. The two big experiments also continue to study the 'rapidity gaps' - suggesting that the incoming electron 'bounces' off a pointlike object inside the proton which carries no colour. These events are of considerable interest.

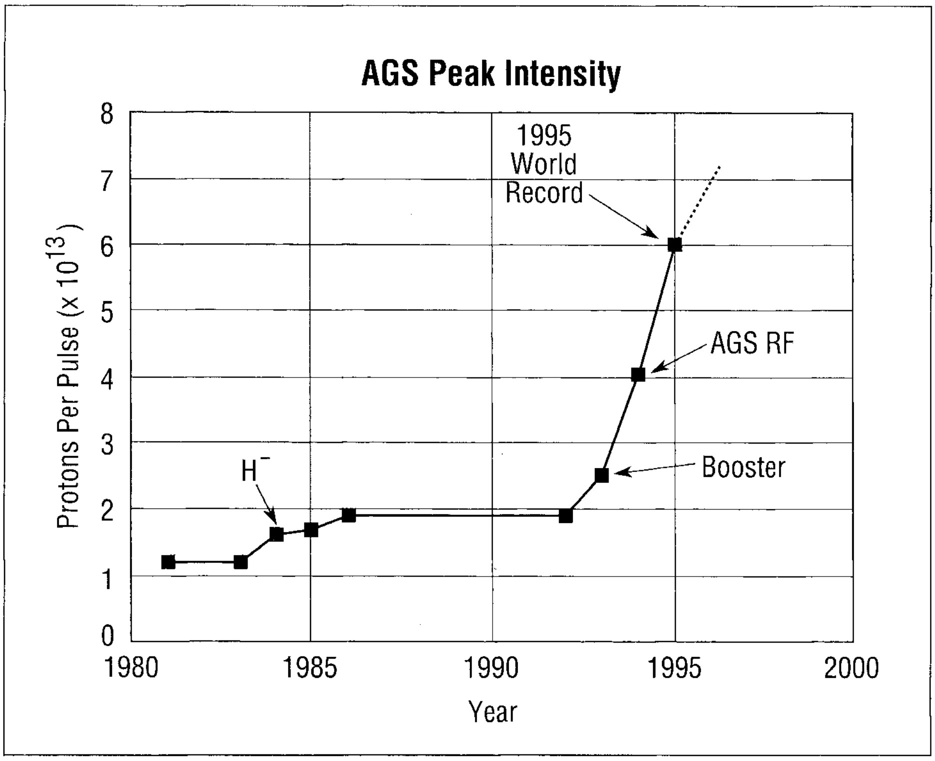
(A forthcoming workshop will look at future HERA physics - see page 54).

BROOKHAVEN Proton goal reached

On March 30 the 35-year old Alternating Gradient Synchrotron (AGS) exceeded its updated design goal of 6 x 10^{13} protons per pulse (ppp), by accelerating 6.3 x 10^{13} ppp, a world record intensity. This goal was set 11 years ago and achieving it called for the construction of a new booster and the reconstruction of much of the AGS.

The booster was completed in 1991, and reached its design intensity of 1.5 x 10^{13} ppp in 1993. The AGS reconstruction was finished in 1994, and by July of that year the AGS claimed a new US record

Brookhaven Alternating Gradient Synchrotron (AGS) peak intensity record. The intensity has increased largely through hardware improvements such as negative hydrogen ion injection, Booster injection, and AGS upgrades. The average operating intensity is only 5 or 10 percent below the peak intensity.



intensity for a proton synchrotron of 4 x 10^{13} ppp, using four booster pulses. Reaching the design intensity was scheduled for 1995.

In 1994, the AGS had seemed to be solidly limited to 4 x 10^{13} ppp, but in 1995 the operations crew, working on their own in the quiet of the owl shift, steadily improved the intensity, regularly setting new records, much to the bemusement of the machine physicists. The physicists, however, did contribute. A second harmonic radiofrequency cavity in the booster increased the radiofrequency bucket area for capture, raising the booster intensity from 1.7 to 2.1 x 10^{13} ppp.

In the AGS, new radiofrequency power supplies raised the available voltage from 8 to 13 kV, greatly enhancing the beam loading capabilities of the system. A powerful new transverse damping system successfully controlled instabilities that otherwise would have destroyed the beam in less than a millisecond.

Also in the AGS, 35th harmonic octupole resonances were found. The fringe field of the extraction septum magnet, which is operated dc to reduce mechanical stresses, contributes about half of the strength of these resonances. A full octupole correction system will be installed, but meanwhile two very small octupole magnets were available and fortunately reduced the losses until the design goal could be reached.

The accompanying 'mountain range' figure shows what is taken to be the next intensity limit. The picture starts shortly before transition, with smooth and uniform bunches. After transition quadrupole-mode bunch oscillations develop for the protons within the radiofrequency bucket. These oscillations result from the rapid changes that must be applied to carry the beam cleanly through transition. While visually dramatic and technically fascinating, these oscillations themselves have no present effect on the beam intensity but the underlying phenomena causing them is expected to limit further increases until it is removed.

CORNELL
Bunch trains provide higher luminosity

The new colliding beam technique - "bunch trains" - at Cornell's electron-positron Storage Ring (CESR) has led to a new world record for colliding beam luminosity - 3.3 x 10^{32} $cm^{-2}s^{-1}$.

In the bid to increase reaction rate for any particular process, this luminosity is pushed as high as possible. Once all other luminosity-increasing cards have been played, the only practical way of making a large gain in luminosity is to increase the frequency of bunch-bunch collisions by increasing the number of bunches stored in the ring.

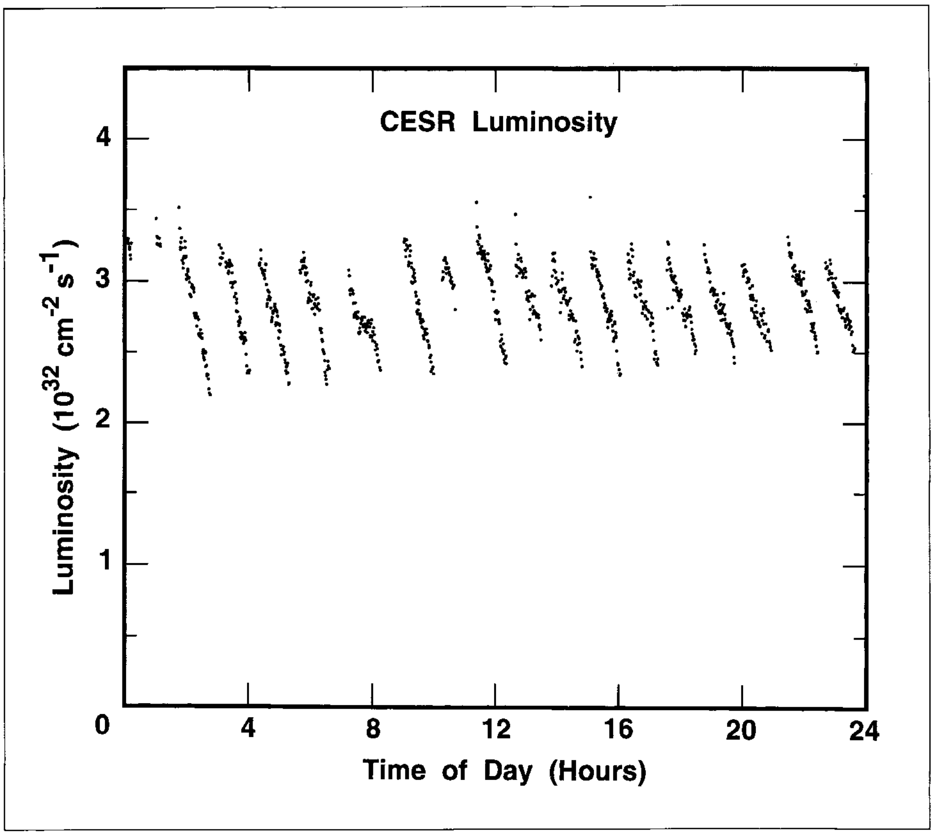
However this is not without its own problems:

• If the two beams travel the same orbit, the n bunches in one beam collide with the n bunches of the other at 2n points around the ring, and the resulting cumulative nonlinear beam-beam effect (tune shift) severely limits the luminosity attainable at any interaction point.

• The destabilizing wakefield effects of bunches on each other increase as the number of bunches increases and the spacing between them decreases.

• The synchrotron radiation emitted by the beams becomes a severe problem as the total beam current is

CESR luminosity history on March 22, when CESR provided a new record integrated luminosity of 18 pb^{-1}.



raised: to overcome these effects means supplying radiofrequency power to maintain the beam energy, carrying away heat from the vacuum chamber walls, pumping out desorbed gases, and controlling X-ray backgrounds in the experiment.

In 1979, CESR was designed to run with a single bunch of electrons and a single bunch of positrons circulating on the same orbit and colliding head-on at two diametrically opposite points in the ring, where the CLEO and CUSB experiments were then located.

Ideally one could store multiple bunches and solve the multiple collision point problem by using separate rings for the two beams, as in the CERN ISR proton-proton collider and in the original DORIS two-ring configuration at DESY, Hamburg, making the two beams intersect only at the experiments.

A less expensive version of this two-ring scheme was accomplished at CESR in 1983, using 'pretzel' orbits in a single ring. The electron and positron orbits were oppositely deformed by electrostatic fields into scalloped trajectories that missed each other by about a centimetre wherever unwanted bunch-bunch collisions would otherwise have occurred.

This eventually allowed 9 bunches (separated by 280 ns) in each beam to collide only at a single point in the middle of the CLEO experiment (the CUSB experiment had been completed) to give a peak luminosity of 2.9×10^{32} at a beam energy of 5.3 GeV, more than four times the CESR design luminosity for that energy and a world record for colliding beams. The pretzel scheme has since been successfully adopted at Fermilab's Tevatron proton-antiproton collider and at CERN's LEP electron-positron ring (October 1992, page 17).

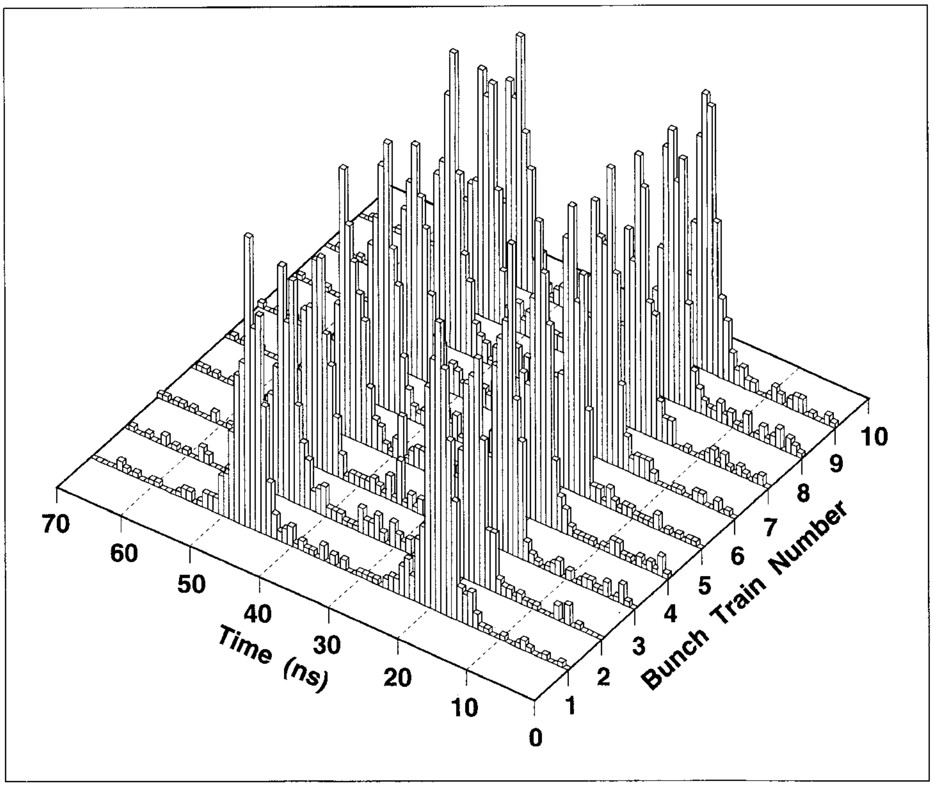
The two CESR beam orbits coincided in the region between the electrostatic separators closest to the CLEO interaction point, providing head-on collisions as in the original CESR design. Thus to avoid multiple interaction points, the spacing between successive bunches had to be greater than the distance between the separators, hence the maximum of nine bunches per beam.

This barrier has now been broken, thanks to a suggestion by Cornell accelerator physicist Robert Meller. In the new configuration, the beams cross at a small horizontal angle (± 2 milliradians) at the interaction point. Because the orbits diverge from the crossing point, successive bunches can avoid each other on either side of the interaction point.

Such a crossing scheme was tried in the original DORIS two-ring electron-positron collider, with unsatisfactory results. The sideways beam-beam interaction excited synchro-betatron resonances that limited the luminosity. An analysis of the DORIS experience indicated that these effects are worse when the product of crossing angle and bunch length is more than the bunch width.

Experience with the rather small angle of the new CESR configuration shows no significant degradation of luminosity due to synchro-betatron resonances. In the first trials of 18 bunches per beam, the peak luminosity has increased to the record level of 3.3×10^{32}. The 18 bunches travel in 9 bunch trains, each train consisting so far of 2 bunches 28 ns apart. An important factor in this success was a fast feedback system to counter the

The time structure of bunch trains at Cornell's CESR electron-positron collider observed in the CLEO time-of-flight counters. Each of the 9 trains contains 2 bunches separated by 28 ns.



multibunch instabilities. Further progress in increasing the number of bunches depends on measures to overcome the increased synchrotron radiation power. Some of these problems will be dealt with in the coming few months while CESR is shut down for upgrading. When the storage ring resumes operation in the fall, the Cornell accelerator physicists expect to push to new luminosity records using 9 trains of 3 bunches. The CESR Phase III upgrade, scheduled for completion in 1988, will make it possible to utilize 5 bunches in each of the 9 trains, providing a further increase in luminosity (CERN Courier, December 1993, p. 22). Since progress in heavy quark and lepton physics at CESR has always been paced by available collision rates, this should open up new opportunities in the CESR experimental programme.

American Physical Society beams recognition

Prestigious prizes recently awarded by the American Physical Society (APS) include the Robert R. Wilson Prize and the The Outstanding Doctoral Thesis in Beam Physics prize, both awarded at the 1995 Particle Accelerator Conference, 1-5 May, in Dallas, Texas.

Established in 1986, the Wilson Prize recognizes and encourage outstanding achievement in the physics of particle accelerators, and is awarded this year to Raphael M. Littauer of Cornell: "For his many contributions to accelerator technology, in particular his innovative conception and implementation of a mechanism to provide multifold increases in the luminosity of single-ring colliding beam facilities by the establishment of separated orbits of opposing, many-bunch, particle beams. This work has enabled the Cornell Electron Storage Ring (CESR) to achieve record luminosities for electron-positron storage rings; the concept has been adopted, equally successfully, at the other major high energy facilities of the world."

The 1995 APS award for Outstanding Doctoral Thesis research in Beam Physics goes to Dun Xiong Wang for his experimental and theoretical investigations in longitudinal beam dynamics. A native of Shanghai, Dun Xong Wang came to the US to pursue graduate studies at the University of Maryland at College Park, receiving his PhD in 1993. Since September 1993, he has been a staff scientist at CEBAF in Newport News, Virginia, working in the Accelerator Performance Group and on the coherent synchrotron radiation detection project.

CERN
Bunch trains at LEP

Following two years of very successful running with its pretzel scheme (October 1992, page 17), CERN's LEP electron-positron collider started up this year with a completely new configuration. To boost luminosity still further, this designed to allow operation with four trains of up to four bunches of particles per beam.

Both the pretzel and the bunch train schemes increase the number of bunches (beyond the original four) by separating the orbits of electrons and positrons in places where the additional bunches pass by the others. Although the whole point of LEP is to collide beams, any unproductive collisions away from the experiments are to be strenuously avoided: the beams can only stand so much beam-beam interaction.

Without additional investment in the detectors and because of features of the initial (room-temperature) radiofrequency system, the pretzel scheme was limited to eight bunches per beam, evenly spaced around the ring. The long-range horizontal pretzel separation bumps in the arcs were replaced by short vertical bumps on both sides of each experiment. These create a few locations where bunches can pass each other with the relative impunity of the residual beam-beam force between well-separated beams.

The scheme at Cornell's CESR collider exploits a crossing angle to substitute a train for each bunch allowed by the pretzels. The LEP scheme, on the other hand, does away with the pretzel separation and has no crossing angle at the interaction point. In all these schemes, the beams are separated by electrostatic separators.

In the LEP pretzel scheme, complex residual effects in the arcs of the machine limited the single-bunch current. However the currents at 20 GeV injection were much more than could be collided at the Z resonance. The main motivation for the change to bunch trains was the expectation that the limits at injection would be less severe, allowing higher single-bunch currents for LEP2.

At the higher LEP2 energies, the beams become stiffer and beam-beam effects will be weaker. The total beam current will instead be limited by the radiofrequency power required to compensate the energy lost by synchrotron radiation. Maximum luminosity will be attained by packing the current into as small a number of bunches as possible. Although four fat bunches would be ideal, eight is likely to be the practicable optimum.

Following an encouraging test at the end of 1994, LEP was started up in April with the full bunch train configuration. Initial operation was hampered by mishaps related to hardware and electricity supply and it took time before the operations crews and accelerator physicists had any opportunity to confront the complexities of the actual bunch train scheme. For the rest of this year, it has been decided to run with four trains of three bunches, and to do a precision energy scan around the Z.

With LEP's role as a precision machine, there has been a rush of theoretical activity which is helping to understand some newly discovered consequences of residual beam-beam effects and the separation bumps. The combination of the two unleashes a cause-and-effect cascade of subtle differential effects between bunches in a train. Collisions involving different bunches in the trains can have different distributions of centre-of-mass energies. Substantial progress has already been made to compensate for these effects.

TRIUMF Five-year plan

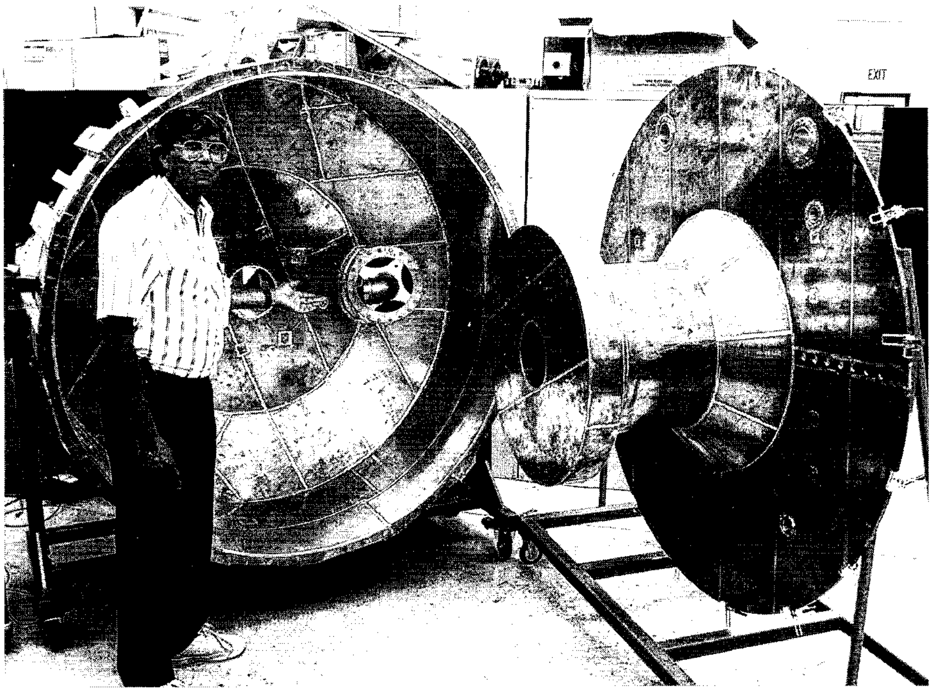
The Canadian government recently announced approval of a five-year-plan for TRIUMF, giving the Vancouver Laboratory assured funding until the year 2000. Besides continuation of the multidisciplinary science programme at the 500 MeV cyclotron, this will allow construction of ISAC-1, a new on-line isotope separator. At the same time, TRIUMF will also be responsible for Canadian "in-kind" contributions to international science at CERN's LHC proton-proton collider (see page 1). The federal plan strengthens TRIUMF's role as a national facility, run by a consortium of universities across Canada. In addition, TRIUMF will have even stronger international links.

The federal government has allocated a total of $166.6 million to TRIUMF over the next five years. In addition, the provincial British Columbia government, a long-time supporter of TRIUMF, has already agreed to provide approximately $10 million for conventional construction.

The nature of the accelerator contributions to the LHC has not been finally decided, although two areas are under discussion - the upgrade of the accelerator chain, and construction of the two 'beam cleaning' insertions. The former would involve provision of various new systems (radiofrequency, magnets, power supplies, kickers, etc) for the Booster, PS and SPS synchrotrons; indeed activity is already underway in some areas, such as model studies for a new 40 MHz system for the PS.

The acronym of the new facility, ISAC-1, is short for Isotope Separator & ACcelerator. A prototype first stage already exists in TRIUMF. ISAC-1 will use the intense proton beam from the TRIUMF cyclotron to create powerful beams of exotic, short-lived, radioactive nuclei which will be accelerated in a new structure.

The facility will be of interest to an international community of astrophysicists, who will be able to



Full-scale model of a new 40 MHz radiofrequency cavity for the CERN PS, built and now being used at TRIUMF to study higher-order modes and damper designs.

Photo P. Harmer, TRIUMF

simulate the formation of elements in stars and in the early universe; and to physicists studying nuclear structure and the behaviour of unusual atomic nuclei. There will also be programmes of condensed matter research and biomedical physics.

TRIUMF's principal function as a meson factory is to provide intense beams of protons, pions, muons and neutrons for particle and nuclear physics research, starting from the 200 microamp negative hydrogen ion beam in the cyclotron. Continued support will allow full exploitation of new instruments, such as the SASP-MRS dual-arm spectrometer and the CHAOS large-solid-angle pion spectrometer. Intense polarized proton beams also support experiments on spin-dependent effects and parity-violation.

Traditionally, muon beams at TRIUMF are used as a unique probe of the properties of matter. This muon spin rotation programme covers the study of new materials with commercial potential, such as high-temperature superconductors and semiconductors. The programme, which involves Canadian scientists in close collaboration with physicists from Europe, Japan and the USA, will continue vigorously within the new plan.

The TRIUMF life science programme will bring innovations to various medical fields. For instance Canada's first proton therapy centre, which uses a focused beam of protons to treat tumours of the eye, is ready for operation. Positron emission tomography (PET) and the development of new isotopes for nuclear medicine form an important part of this programme.

TRIUMF will also be able to maintain its existing strong programme in technology transfer, which currently includes work on a novel type of detector for explosives or contraband hidden in airport luggage. The continued on-site commercial production of isotopes for medical use is also assured, as is a collaborative effort with a local company on the production of small medical cyclotrons for the international market (January, page 11).

Because the approved funding is 15% less than that requested, the ISAC-1 and CERN programmes will have to proceed more slowly than originally planned, and there will be some reduction in staff. Nevertheless, the new funding represents a slight increase over that received in recent years, and is a major success in the context of across-the-board cuts for other sectors of Canadian science and technology.

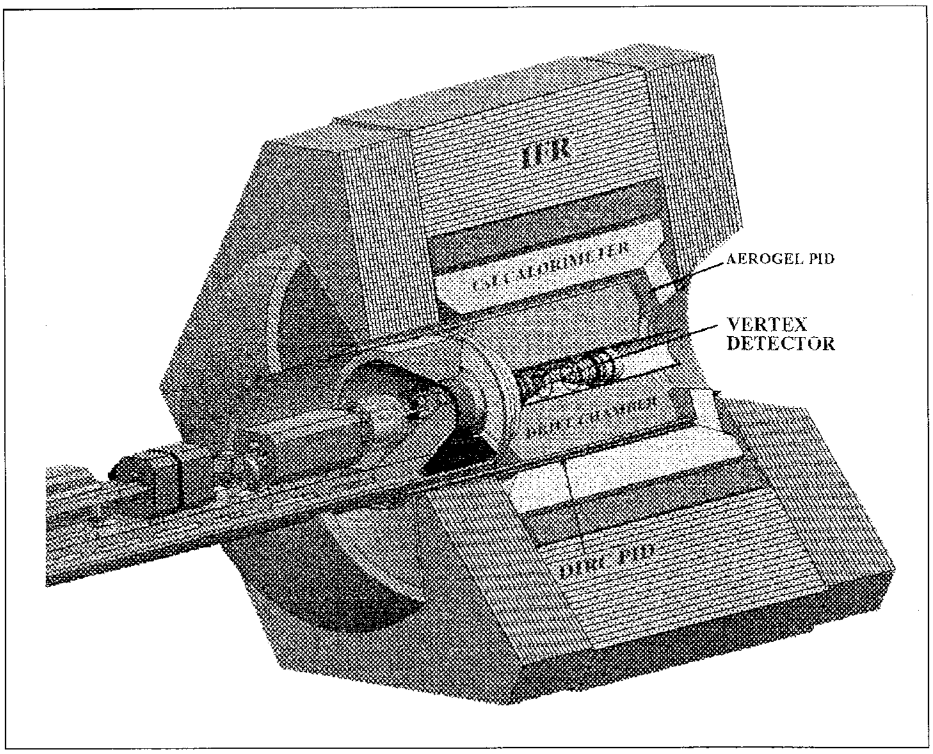
BaBar - a new detector to study CP violation in the B system

To explain why the Universe is dominated by matter and has so little antimatter needs a mechanism which distinguishes matter from antimatter. This is accomplished, together with a few other conditions, by introducing the non-conservation of CP symmetry in the theory describing the interactions between the particles at the early stage of the universe.

CP violation - the subtle disregard of physics for a combined particle/antiparticle and mirror reflection symmetry - was first observed in kaon decays 30 years ago by J.H. Christenson, J.W. Cronin, V.L. Fitch and R. Turlay but has defied a unique and fundamental explanation ever since.

However at the turn of the century we should begin to understand its origin as the next generation of kaon decay experiments at CERN and

The BaBar detector at the PEPII asymmetric B factory at SLAC, Stanford will study CP-violation with B mesons containing the fifth ('b') quark, where the CP-violation effects are expected to be larger. The detector should be operational by 1999, about six months after the startup of the new collider, scheduled for the fall 1998.



Fermilab on the one hand and new detectors at the Fermilab Tevatron, at DESY's HERA collider and as B programmes at Cornell (December 1993, page 22, KEK in Japan (April 1994, page 18) and SLAC, Stanford (PEPII - March 1994, page 10) on the other hand produce their first data. These new detectors will open up the study of CP-violation in another system - B mesons containing the fifth ('b') quark, where the CP-violation effects are expected to be larger.

For the latter, a major recent development has been the approval of the Technical Design Report of the 'BaBar' detector by the SLAC Experimental Program Advisory Committee.

A large international collaboration of about 480 physicists and engineers from 10 countries (Canada, China, France, Germany, Italy, Norway, Russia, Taiwan, UK and US) will instrument the unique interaction region of the PEP II asymmetric electron-positron B Factory at SLAC. The BaBar detector is scheduled to be operational by 1999 about six months after the startup of the new collider, scheduled for the fall 1998.

BaBar's ultimate goal is to observe CP violation in the B meson system in a large variety of modes. This systematic study should provide either a comprehensive understanding of the phenomenon or eventually explore a new domain. Many B decay modes involving J/psis and kaons, D-meson pairs and light meson pairs should provide values for vital parameters which are directly linked to the origin of CP violation in the Standard Model.

If only three families of quarks and leptons exist and no new mechanism is generating CP violation, these parameters are related to the (Cabibbo-Kobayashi-Maskawa) matrix describing the mixing of the six different quark species. Whatever these quark mixings are, their probabilities have to add up to 100% - the CKM matrix has to be 'unitary'. This imposes conditions on the CKM matrix elements which are conveniently expressed in a 'unitarity triangle' diagram.

The sensitivity of BaBar after one year of operation at PEPII, during which an integrated luminosity of 30 inverse femtobarns is expected, will result in sensitivities of 0.059 and 0.085 for $\sin 2\alpha$ and $\sin 2\beta$, where α and β are two angles of the unitary triangle. This will constrain further the CKM matrix and lead to a powerful consistency test of the Standard Model in an as yet untested sector of the theory.

High performance and robust detectors are needed to accomplish this. The observation of CP asymmetries requires in particular:

- a large acceptance, a good efficiency and excellent particle identification for the modes which need to be fully reconstructed;
- a good momentum or energy resolution for the charged and neutral particles to overcome background;
- an efficient and relatively pure tagging of the b-quark content of the second B meson which is not fully reconstructed (electrons, muons and kaons will be used for this purpose);
- a precise measurement of the distance between the 2 B meson decays (of the order of 0.25 mm for beam energies of 9 GeV against 3.1 GeV as planned at SLAC).

The BaBar detector has been optimized to fulfil these criteria. It includes:

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1 - A silicon vertex detector

The distance between both B decays is measured by means of a

The cross shows the estimated sensitivity of BaBar after one year of operation at PEPII, during which an integrated luminosity of 30 inverse femtobarns is expected, resulting in sensitivities of 0.059 and 0.085 for $\sin 2\alpha$ and $\sin 2\beta$, where α and β are two angles of the unitary triangle. This is compared with present measurements (shaded region). This will lead to a powerful consistency test of the Standard Model in an as yet untested sector of the theory.

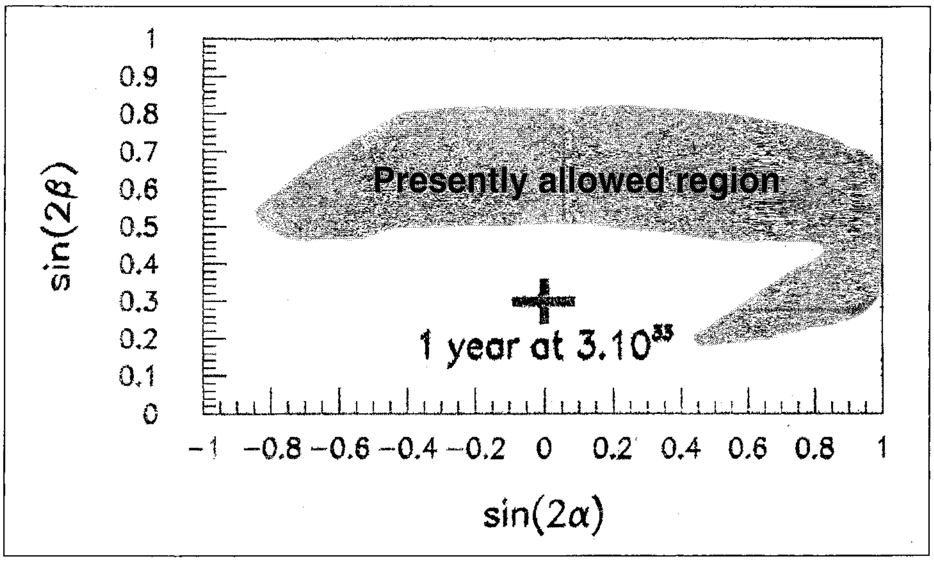
double-sided silicon vertex detector with strips running parallel and perpendicular to the beam direction. Five layers of silicon detector at a radius extending from 3.2 to 14.4cm from the interaction region are used to provide sufficient measurement possibilities ("redundancy") and for efficient tracking of the soft pions over 91% of the solid angle.

2 - A transparent drift chamber in a 1.5T magnetic field

Charged particle tracking is achieved in a cylindrical drift chamber with a total of 40 layers of axial and stereo wires. The inner radius and outer radius are 22.5cm and 80cm respectively. The momentum of the charged particles generated in B decays and reconstructed in the drift chamber is in the range 0.1-4.5 GeV/c. High resolution (120-140 microns) is obtained by operating the chamber in a magnetic field of 1.5T generated by a superconducting solenoid and by using a light gas, mainly helium, for the ionizing medium.

3 - Excellent particle identification

Particle identification, a key element of this detector, is necessary for good effective tagging efficiency. Electron identification is done by combining the cesium iodide calorimeter (see below) and the drift chamber. Muons are identified down to 0.5 GeV by instrumenting the flux return with 17 to 21 layers of Resistive Plate Chambers. This fine segmentation allows one also to identify long-lived kaons, thus increasing the sensitivity (to sin2β). Finally charged kaon identification is achieved over 90% of the solid angle with dedicated detectors based on Cerenkov light.



A novel technique (DIRC) in the barrel region is based on the collection of Cerenkov light produced by the particle traversing quartz bars. The light is internally reflected in the 4.8m-long bars and detected outside the flux return on an array of about 13000 phototubes allowing reconstruction of a truncated Cerenkov cone. In the forward region, kaon identification uses Aerogel Threshold Counters (ATC) with a combination of two different refractive indices (n_1=1.006 and n_2=1.055) possibly read out by fine mesh photomultipliers or hybrid photodiodes.

4 - Cesium iodide calorimeter

The average photon energy in B decays is about 200MeV. It is therefore very important to get a very low detection threshold (around 20MeV). Furthermore, excellent energy resolution is required to suppress background. These considerations have led to a calorimeter made of about 6800 cesium iodide crystals, presently the best option. Such a device is operating very satisfactorily in the CLEO II detector at the Cornell CESR electron-positron ring.

5 - Instrumented flux return

As mentioned above, Resistive Plate Chambers are used to instrument the flux return. Such chambers offer an efficient, robust and economical way to optimize the acceptance coverage.

The BaBar detector promises to explore the CP violation mechanism in unprecedented detail. This comprehensive study of an effect as yet not understood, despite having been discovered 35 years ago, will surely open up new directions in particle physics.

From Roy Aleksan, DAPNIA, Saclay

(An article on plans and progress at the PEPII collider at SLAC, Stanford, will appear in a forthcoming issue.)

GRAN SASSO
Reaching the parts that accelerators cannot reach

With most of the current experiments at Italy's Gran Sasso Laboratory now well underway, a workshop held earlier this year looked to the future. Gran Sasso was established in the late 1980s to study low rate processes where the laboratory's 1400 metre rock overburden and low natural radioactivity provide an ideal environment. Since then, it has become a major research centre, hosting several international collaborations. The workshop devoted half a day each to four key areas of underground physics, and clearly showed how the non-accelerator approach complements today's accelerator physics achievements.

At the close of a workshop held earlier this year to discuss plans for future experiments at Italy's Gran Sasso Laboratory, Carlo Rubbia presents the proposed future activities of the Gran Sasso laboratory to Italian science minister Giorgio Salvini. Salvini, seated in the middle, is accompanied to his left by Giovanni Schippa, rector of L'Aquila University, Enrico Garaci, President of the CNR, and Enrico Bellotti. To his right are Luciano Maiani, Nicola Cabibbo, and Piero Monacelli.

Solar neutrino physics is one of Gran Sasso's main activities, with the Gallex detector half filling one of the laboratory's three experimental halls. Gallex has already made important measurements of the solar neutrino flux, providing first evidence for the proton-proton fusion mechanism which is the solar powerhouse. The next generation experiment, Borexino, will go one step further, measuring the energy distribution of solar neutrinos as well as their flux. The experiment will also be sensitive to neutrino oscillations through its ability to pick out muon and tau neutrinos.

Borexino uses boron instead of gallium as the active medium, and is currently in the trial phase. Benchmarking tests with the counter test facility (CTF) have already demonstrated the experiment's feasibility, paving the way for full scale construction. Further ideas for future detectors based on several different active media were also discussed, and a proposal for a helium TPC detector, HELLAZ, was presented. With a threshold of around 240 keV, comparable to that of Gallex and Borexino, HELLAZ would give another handle on neutrinos from the proton-proton reaction, the most abundant source of solar neutrinos.

Neutrinoless double beta decay, dark matter searches, and certain low rate processes in nuclear physics all require the quiet, low radiation surroundings that only an underground laboratory can offer. The Gran Sasso workshop considered all of these, as well as an intriguing proposal to install a low energy accelerator in the laboratory.

Another key area of the Gran Sasso programme is high energy cosmic ray physics, which provides the only foothold on energy scales beyond the reach of current accelerators. The EAS-Top experiment, situated almost directly above Gran Sasso's halls at Campo Imperatore, studies extensive air showers in the 10 TeV - 10 PeV range and presents the opportunity of studying such events in coincidence with the underground detectors.

Two other experiments, the Large Volume Detector (LVD), designed to look for neutrinos from stellar collapse, and the Monopole Astrophysics and Cosmic Ray Observatory (MACRO) also have the ability to study high energy processes through the TeV muon component of cosmic rays. The high energy sector, however, is only one aspect of cosmic ray physics. LVD will continue to look for neutrinos from dying stars, whilst the search for a Grand Unified monopole will continue at MACRO. Meanwhile, a proposal that the next generation of gravity wave detectors be built in the low noise underground environment of Gran Sasso was presented.

'Long baseline' neutrino oscillation experiments (two detectors a long distance apart in the same neutrino beam) were considered in Gran Sasso's original design, and formed the subject of the final session of the

Portuguese high energy physics is centred on CERN, supported by a national hub at the Laboratory for experimental high energy physics and related R&D projects (LIP), with centres in Lisbon (Head, Jose Gago, right) and Coimbra (Head, Armando Policarpo).

workshop. Piero Monacelli, the laboratory's director, reiterated Gran Sasso's enthusiasm for the project, and described how present infrastructure might be adapted, and new halls added to accommodate such experiments.

Possible designs to steer a CERN neutrino beam to Gran Sasso, and two proposals for dedicated detectors were presented. Carlo Rubbia gave a status report on the ICARUS detector (April 1993, page 15), saying that an intermediate half kiloton liquid argon calorimeter would be brought to Gran Sasso in the near future. Apart from being an important test bed for ICARUS, this detector could also perform interesting research into atmospheric neutrinos and proton decay. For the long baseline study, another 'Baby ICARUS' detector could be installed at CERN.

CERN and Portugal

In its continual tour of CERN Member States, the European Committee for Future Accelerators (ECFA) visited Lisbon, Portugal, on 21-22 April, where it met at the Instituto Superiore Tecnico, a technical university with 9,000 students.

Portuguese particle physics is in a particularly healthy situation, having developed considerably following Portugal's admission to CERN in 1985. With support from Brussels, scientific infrastructure has developed rapidly, although the science base has yet to attain the levels seen in larger nations.

The 45-strong population of experimentalists in Portugal, including 14 PhDs, represents a 2.5-fold increase since Portugal joined CERN ten years ago and is in line with the goal stated at the time. This successful development of experimental particle physics has benefited much from physicists returning from abroad (mainly France and the UK).

The direct result of the efforts of a few individuals (notably J.M. Gago), this splendid achievement provides an excellent role model for new and potential CERN Member States.

At present, particle physics represents some 30% of all Portuguese physics publications. This very special role (and the financial support it implies) provides a visible target, but one which can be defended as it provides a catalyst for other national scientific developments.

The national hub is the Laboratory for experimental high energy physics and related R&D projects (LIP), with centres in Lisbon (Head, J.M. Gago) and Coimbra (Head, A. Policarpo). LIP, with close links to two universities in Lisbon and to the University of Coimbra, has developed into a centre of expertise and training in electronics, computing and software engineering.

Present LIP funding is some 2 million Swiss francs/year (70% in Lisbon and 30% in Coimbra), covering most of the salaries of the non-university people, the remainder being supported by grants from Portuguese and European programmes. Portugal's contribution to CERN's 1995 budget is 10.3 million Swiss francs. This is 75% of the eventual national contribution, rising on a sliding scale established when Portugal joined CERN ten years ago. This 'discount' in Portugal's contribution to the CERN budget goes into its national effort. Hopefully this funding will not suffer once the CERN contribution reaches its cruising altitude.

With no national accelerator, Portuguese research in particle physics is fully focused on CERN, with prominent participation in LEP (Delphi) and in heavy ion research (NA 38). Portuguese researchers also collaborate in the NA 50 and 51 experiments and in CP-LEAR, as well as some solid state research based on the Isolde on-line isotope separator.

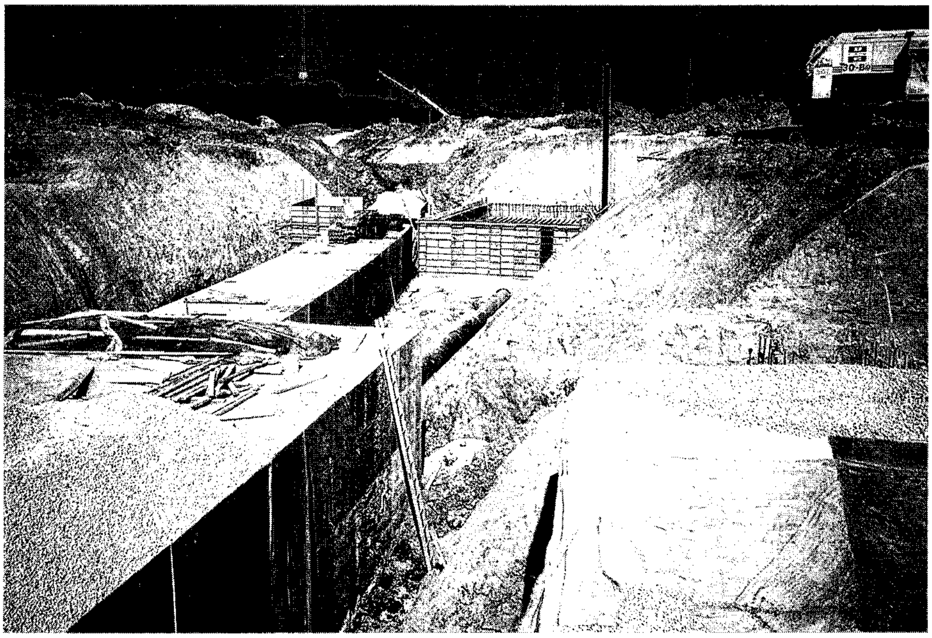
For the future, there is some involvement in both in ATLAS and CMS experiments for the LHC proton-proton collider and in related research and development (gaseous detectors, RICH techniques, liquid xenon calorimetry, scintillating fibre calorimetry and read-out systems and data transfer). LIP plans to participate to both Atlas and CMS, contributing to the tile calorimeter and calorimetric trigger respectively. Because of this involvement in specific detector elements, Portugal is able to make important contributions to these two major LHC experiments.

Theoretical particle physics has also boomed, with the number of theorists more than doubling. Currently there are 36 researchers (26 PhDs) in a national network based at Lisbon's GTAE (Grupo Teorico de Altas Energia, Head G.C. Branco) and including CFIF (Study of Fundamental Interactions) at Lisbon's Instituto Superiore Tecnico. GTAE also supports astrophysics.

With the university system expanding, there has been no problem so far finding positions for good young researchers, but this expansion cannot continue indefinitely. The need for stable research positions, independent of those offered by the universities, is already pressing.

The Portuguese-CERN Committee, set up in 1986, has played an important role, and the value of contracts for Portuguese industry has increased significantly. Portugal is exemplary in its willingness to develop its scientific research as a support to its budding high-tech industry.

At Fermilab, construction is now underway for the new 150 GeV Main Injector. The pipe to the right of the tunnel is an abort line.



Accelerator update

When the Accelerator Conference, combined International High Energy and US Particle versions, held in Dallas in May, was initially scheduled, progress nearby for the US Superconducting Supercollider was high on the preliminary agenda. With the SSC voted down by Congress in October 1993, this was no longer the case. However the content of the meeting, in terms of both its deep implications for ambitious new projects and the breadth of its scope, showed that the worldwide particle accelerator field is far from being moribund.

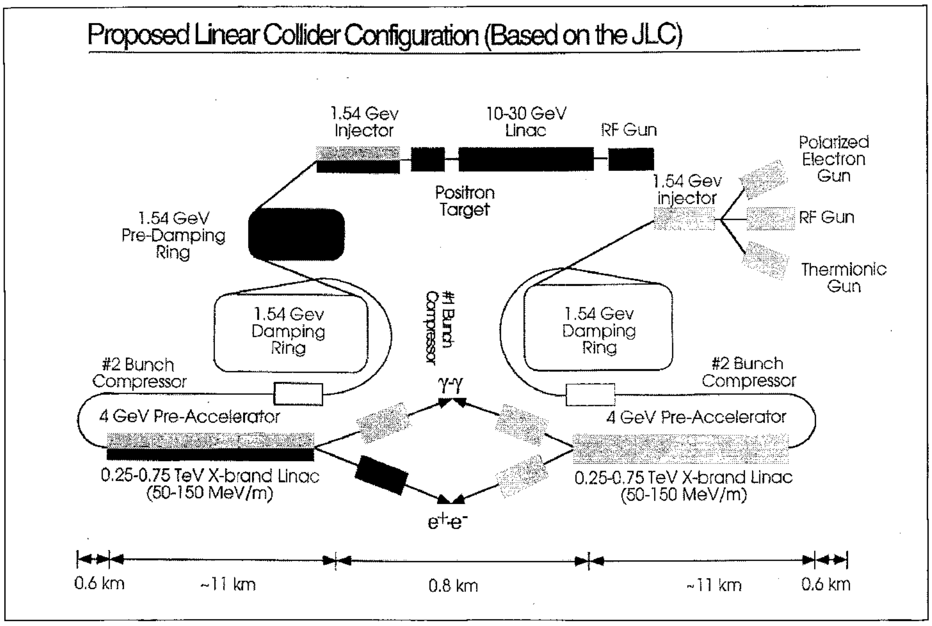
A traditional feature of such accelerator conferences is the multiplicity of parallel sessions. No one person can attend all sessions, so that delegates can follow completely different paths and emerge with totally different impressions.

Despite this overload, and despite the SSC cancellation, the general picture is one of encouraging progress over a wide range of major new projects throughout the world. At the same time, spinoff from, and applications of, accelerators and accelerator technology are becoming increasingly important.

Big machines

Centrestage is now CERN's LHC proton-proton collider, where a test string of superconducting magnets is operating over long periods at the nominal LHC field of 8.36 tesla or more. The assignment of the underground areas in the existing 27-kilometre LEP tunnel is now quasi-definitive (see page 3).

For CERN's existing big machine, the LEP electron-positron collider, ongoing work concentrates on boosting performance using improved optics and bunch trains. But the main objective is the LEP2 scheme using superconducting accelerating cavities to boost the beam energy (see page 6). After



23 kilometres in length - a possible scheme for a next-generation electron-positron collider.

some initial teething problems, production and operation of these cavities appears to have been mastered, at least under test conditions.

A highlight at CERN last year was the first run with lead ions (December 1994, page 15). Handling these heavy particles with systems originally designed for protons calls for ingenuity. The SPS has managed to accelerate them making full use of the travelling wave properties of the SPS 200 MHz system.

For Fermilab's Tevatron, the US flagship machine, construction is now underway for the new 150 GeV Main Injector to provide an improved feed to the superconducting ring. This will ultimately boost Fermilab's proton supply to 6 x 10^{13} protons per pulse for fixed target work and, with additional recycling and buffer rings for precious antiprotons, the proton-antiproton collision luminosity could climb to 10^{33} per sq cm per s. As well as feeding the Tevatron, the new Main Injector will provide capabilities for neutral kaon studies and for neutrino beams.

Such a high collision rate has much physics potential - CP-violation in the B particle sector and/or the discovery of supersymmetric particles. The improved Tevatron and LEP2, as well as Cornell CESR electron-positron collider and new B-factories being built at SLAC and at KEK, Japan, will ensure that no physics falls through any intervening energy gap between them and the LHC.

At Europe's other big machine, the HERA electron-proton collider at DESY, Hamburg, the emphasis is on getting the maximum proton supply from the DESY III synchrotron to the HERA proton ring. On the electron side, tests will be made of getter pumps to improve HERA electron ring conditions and permit high current running with electrons, rather than positrons (see page 10).

At Brookhaven, the new booster has accomplished what its name suggests, with proton levels climbing to new world records beyond 6 x 10^{13} per pulse (see page 10), while preparations for the RHIC heavy ion collider are in full swing.

Also relying on superconducting cavities are CEBAF's recirculating linacs at Newport News, Virginia, which have now reached their nominal energy with five passes (June, page 20). However an increase in accelerating field in the superconducting cavities should enable CEBAF to climb higher in energy. A full commissioning report will appear in a forthcoming issue.

Superconducting cavities have been tested with high beam currents in Cornell's CESR electron-positron ring, which has established a world record for collision luminosity at 3.3 x 10^{32} (see page 11). The importance of Cornell's work in machine physics was underlined by the award of the American Physical Society's Robert R. Wilson Prize to Raphael M. Littauer of Cornell (see page 14).

Linear accelerators

With much effort now invested in development work for the next generation of electron-positron linear colliders, the 2-mile linac at SLAC, Stanford, assumes increased importance as a 'model' machine.

Collision luminosity is nearing 10^{31}, but the trump physics card is polarization, where 80% levels have been achieved in the electron beam.

Laboratories throughout the world are contributing to the ongoing effort. Many avenues are being explored, but the main challenge is the effi-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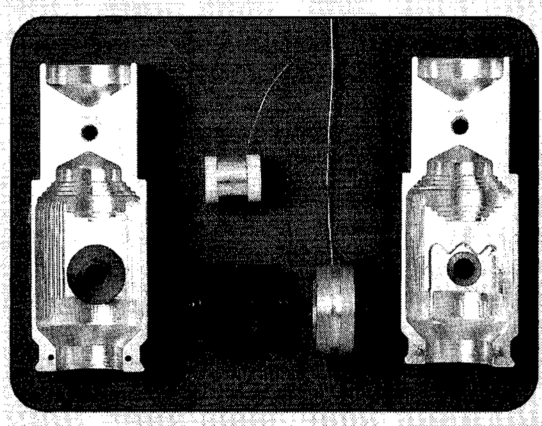

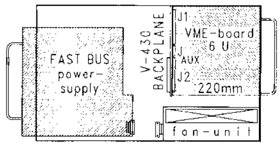
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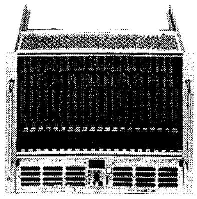

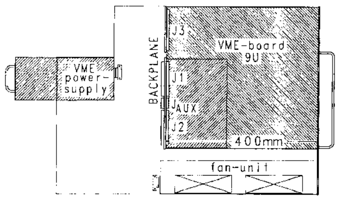
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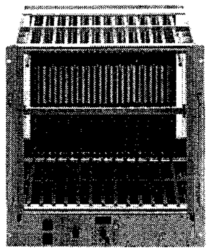

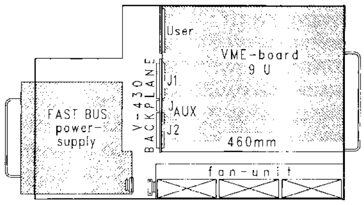
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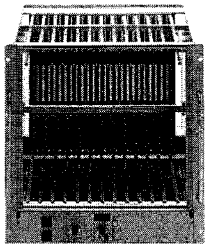

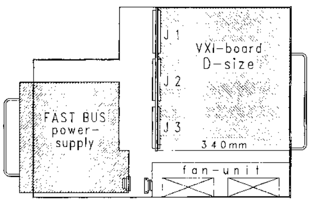
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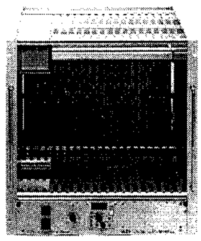

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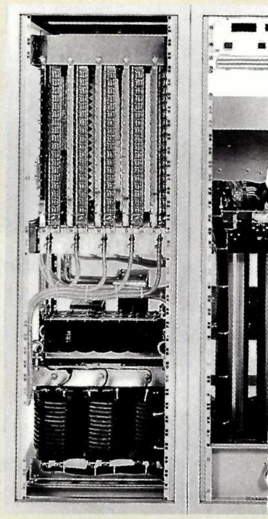

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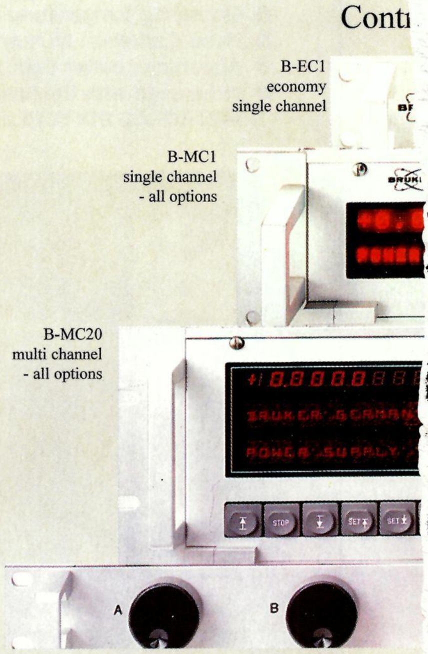

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ciency of transferring mains power to the beam.

With so many avenues under study, covering frequencies from 1.3 GHz (DESY S-band) to 30 GHz (CERN's CLIC scheme) the main question is which route to take. Test results over the next few years will help select an optimal route.

Factories

Several new 'factories' - high luminosity colliders providing a copious supply of new particles - are under construction. At SLAC, Stanford, the PEP-II B factory is being built by a Berkeley/Livermore/SLAC collaboration. Particles from the 2-mile linac will feed a high energy (11 GeV) and low energy (3 GeV) ring, giving asymmetric collisions which facilitate viewing the highly unstable B particles. Its design luminosity is 3 x 10^{33}, which could climb to 10^{34} with a (low beta) beam squeeze. The BaBar detector (see page 16) would benefit from 1999.

Also using an asymmetric approach is the Japanese KEK B-factory (April 1994, page 18), with 8 and 3.5 GeV rings supplying a collision luminosity of 10^{34}, with first collisions expected in 1998. These rings would be built in the tunnel originally built for the Tristan electron-positron ring, soon to be dismantled.

Using lower energies is the DAPHNE phi-factory ring at Frascati, near Rome, where commissioning should begin late next year.

Completing the current electron-positron collider picture are Beijing's BEPC machine (luminosity 7 x 10^{30}) and Novosibirsk's VEPP4M (looking for 7 x 10^{31}). Both these laboratories also have aspirations to build tau/charm factories.

Synchrotron radiation

Synchrotron radiation, once a useful by-product of electron rings, now has its own thriving community. The largest new ring to come into operation is the Advanced Photon Source at Argonne with 7 GeV beams. A 'third generation' machine, it has very low beam emittance designed for optimal exploitation of beam wigglers and undulators in straight sections.

Another third generation machine now operational is the Pohang Storage Ring in South Korea using 2 GeV beams. The Russian 2.5 GeV ring in Moscow, named Siberia II in recognition of its design team, is another new arrival. New synchrotron radiation projects in the pipeline include the Swiss Light Source and the French Soleil project, where beam emittances will be reduced to about 3 nm. The ring at Duke, North Carolina (March, page 8), was specifically developed to supply beams to a free electron laser.

(In our article earlier this year on the Duke installation, the injector was claimed to be the second highest energy linac in the US, after the 2-mile SLAC machine. In fact CEBAF's linacs and the Cornell injector are more powerful than Duke.)

In the free electron laser sector, many new projects are being investigated. Orsay's CLIO already delivers many hours of infra-red radiation to users, while at the other end of the spectrum the Linac Coherent Light Source, based on the SLAC beam, could reach wavelengths down to 0.15 nm (gamma rays). CEBAF is also considering entering this field (September 1994, page 20). Free electron lasers should benefit from ongoing development work for linear colliders.

Applications

The September issue of the CERN Courier highlighted the growing range of applications to which particle accelerators can be harnessed.

This usefulness was covered in special streams at the Dallas meeting.

Some highlights: Free electron lasers are used for precision work such as eye surgery and dental treatment; X-ray lithography for microcircuit manufacture is booming as the need for chips increases - each person in the US already effectively owns the equivalent of 30 million transistors; X-ray holography is another expanding field, where the trend is to use higher energies (1-4 keV).

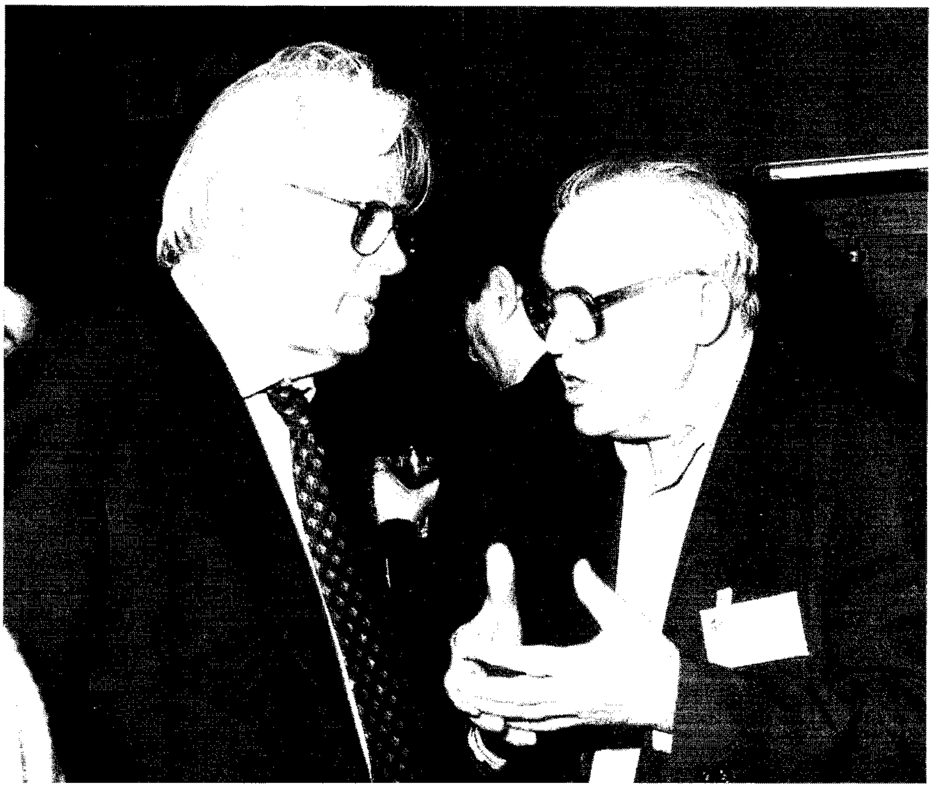
Particle beams have been used for cancer therapy for almost 60 years. In the past, this work has been mainly confined to the sidelines of major accelerator centres, but now purpose-built cancer therapy centres are opening their doors or being planned. Thousands of patients have now been treated and success rates of up to 85% are claimed.

The Japanese HIMAC (Heavy Ion Medical Accelerator in Chiba) using ions with energies up to 800 MeV per nucleon began clinical trials last year and GSI Darmstadt will soon follow. Another new centre, this time with protons, could be provided by a proposal to exploit the linac originally built near Dallas for the defunct SSC. Spare capacity at the Fermilab linac could also be used for cancer therapy, although the general trend is for purpose-built centres.

Less well explored but also with considerable potential are ideas for high current proton machines to drive new energy sources, for radiopharmaceutical production, or for nuclear waste transmutation.

A highlight of the Dallas meeting was Gus Voss' 'farewell' speech following his recent retirement from the DESY Laboratory in Hamburg, extracts from which will be published in a forthcoming issue.

(Information compiled by Daniel Dekkers, Helmut Haseroth, Albert Hofmann, Kurt Hübner, Eberhard Keil, Stuart Turner and Ted Wilson)



Georges Charpak (left), the inventor of the multiwire proportional chamber, in discussion with Vice-Director of Novosibirsk's Institute for Nuclear Physics Benyamin Sidorov at this year's Vienna Wire Chamber Conference.

DETECTORS
Vienna - beyond the wire

In 1986, at the fourth Vienna Wire Chamber Conference, Georges Charpak, the inventor of the multiwire proportional chamber, had confidently announced "Les funérailles des chambres à fils". Was this the writing on the wall for the conference series as well as this type of detector technology?

The demand for detector innovation, coupled with imaginative thinking on the part of the organizers, have kept the Vienna venue at the forefront of the physics calendar. An additional boost to the success of the series was certainly the Nobel Prize awarded to Georges Charpak in 1992.

While the major topic naturally is still wire chambers, alternative technologies are also covered. However in fields like calorimetry or ring imaging Cherenkovs, a sample of only a few prominent detectors were presented, giving some participants the impression of a biased selection.

The fact that silicon detectors, electronics and track reconstruction strategies were, with the exception of the invited talks, restricted to poster presentations led to the same conclusion. As a result the organizing committee saw that it will have to revise its brief for the next conference.

The conference opened with philosophical thoughts by Nobel Prizewinner Georges Charpak. The first day at Vienna is traditionally devoted to applications of gaseous detectors outside high energy physics. L. Shektman gave an overview of wire chambers for medical imaging. Further applications in medicine and in other fields like biology and space science were described by subsequent speakers. The exciting idea of flying a spectrometer on a balloon to study the fraction of electrons and positrons in cosmic rays attracted a lot of attention.

The next day covered wire chambers in general. V. Polychronakos presented applications of cathode strip chambers in muon spectrometers for experiments at CERN's LHC proton-proton detector. Certainly the challenges of LHC for detector development dominated many presentations. Both ATLAS and CMS demonstrated different approaches to mastering the difficulties of covering large areas with precise detectors capable of resolving consecutive bunches. Proposed techniques included thin gap chambers, straw drift tubes, pressurized drift tubes, resistive plate chambers.....

Next year will see the commissioning of Frascati's DAFNE phi factory, and several presentations were made by the DAFNE FINUDA and

KLOE collaborations. Remarkable is KLOE's large volume drift chamber, with results from a 3 m^3 prototype.

Although silicon detectors are strictly not within the scope of the conference, it is traditional to have an invited talk on this subject. This year G. Lutz gave an excellent overview on standard detectors and new detector structures. He reported on the development of monolithic detectors with integrated electronics to avoid connection capacitances, implying the development of transistors built into detector technology.

A new and promising material, diamond films, was featured in two talks (by H. Pernegger and W. Oulinski). Irradiation studies with these materials show an increase in the signal response at low doses, possibly due to the passivation of charge traps and no degradation after irradiation with photons (10 Mrad), protons (5×10^{13} cm^{-2}) and pions (10^{14} cm^{-2}). The second talk looked at the production of microstrip detectors on diamond films and showed initial results from beam tests.

Progress was also reported on the development of precision noble liquid calorimeters. The large effort to build the liquid argon calorimeter for ATLAS to measure not only energy but also shower position with excellent timing was shown by D. Fournier. Results from the NA48 (CP-violation experiment) collaboration at CERN and from a group represented by V. Radeka showed that liquid krypton has also been mastered. Prototypes of the NA48 calorimeter achieved an energy resolution of 3.5 % and a timing resolution below 300 ps.

Detectors based on Cherenkov light are continuously being improved and employed in new applications. The presentations on Cherenkov detectors covered large working systems like the DELPHI RICH, new developments, for example for the HERA-B RICH, and new concepts like the optical discriminator shown by Y. Giomataris. The principle of the optical discriminator is that only light from particles traversing the detector under specific geometrical angles and emitting light under specific Cherenkov angles is guided to the photon detector. The geometrical angle can be a function of the impact parameter of the particle, thus allowing to B mesons to be tagged, for example.

A long session was devoted to microstrip gas counters (MSGC) and similar devices. A. Oed, one of the inventors, described the properties of MSGCs and spoke on new developments. LHC experiments, where designs soon have to be fixed, are making considerable efforts to understand and model the physics of MSGCs, an essential part of ongoing detector systems.

A major concern is still time stability for high rate operation. The results on stability using different substrate materials, strip materials and gas mixtures show some common tendency but not all the effects could be explained. Controversial discussions followed some of the presentations. It was further stressed that a careful choice of materials in contact with the gas (boxes, glue, ...) and the monitoring of the gas purity using a gas chromatograph is essential. Some groups favour a slightly different geometry - the so-called micro-gap chamber (MGC). Several MGC prototypes have been built to study the properties. A MGC coupled to a UV photocathode was used to build a photon detector with single electron response.

General aspects of tracking at high intensities, including trigger and software, were covered by D. Saxon. He pointed out that, especially for triggers, we are on a fast learning curve from ZEUS to HERA-B and to LHC. The appealing features of neural networks for pattern recognition, for the determination of masses, for energy and track parameters as well as for their implementation for triggers were shown by H. Kolanoski.

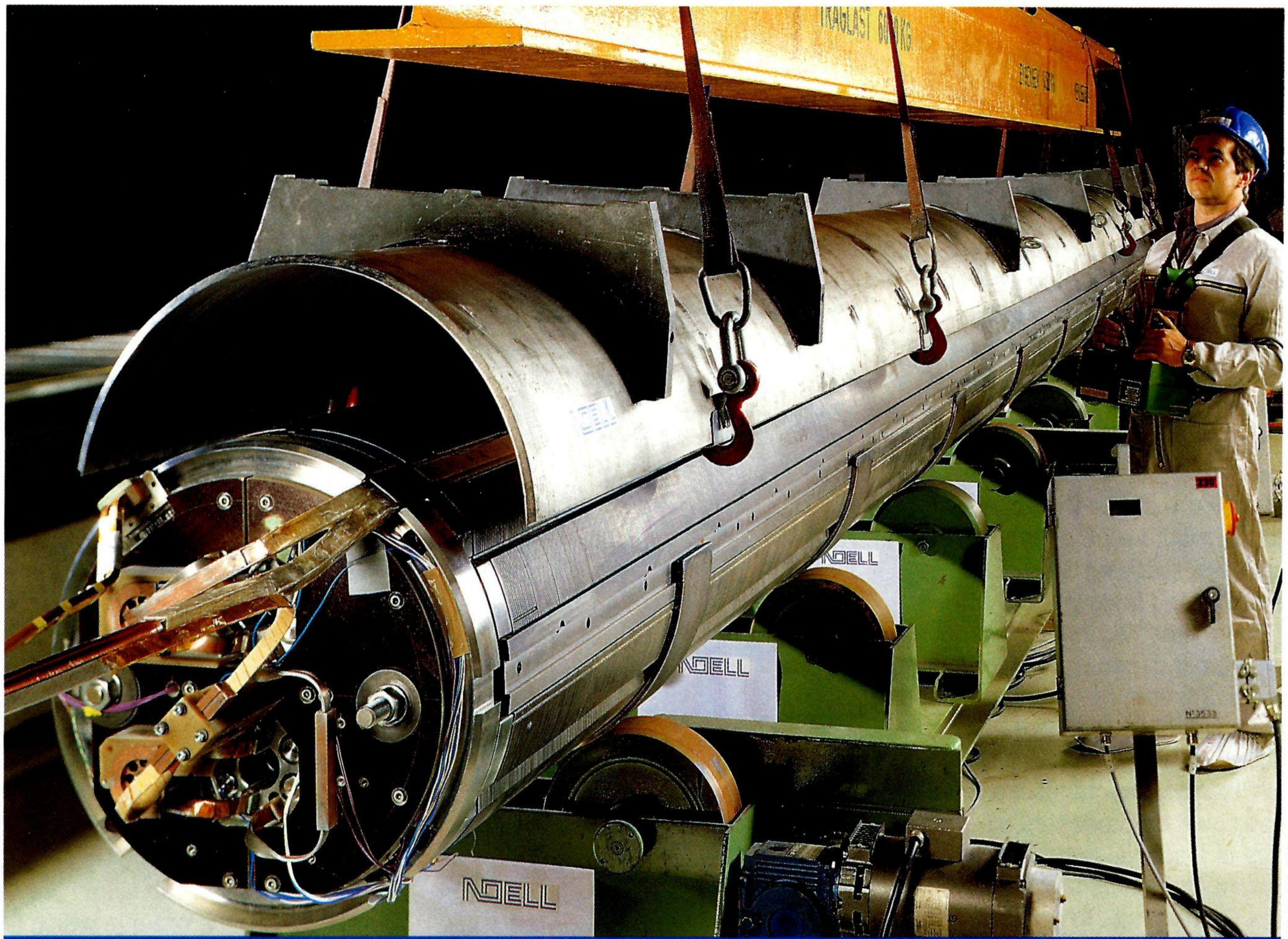
The outstanding features of cesium iodide as a secondary electron emitter were exploited by several groups. Cesium iodide gaseous detectors are used in detectors for UV light and fast RICH detectors to detect thermal neutrons and for imaging in various fields.

Requests for copies of transparencies of individual talks reflected the main interests of participants. It was no surprise that talks on MSGCs and MGCs were the most popular. These were closely followed by diamond detectors.

Industry again took an active role in the conference, but the idea to limit the industrial exhibition to the first half of the week was widely appreciated. In general contacts with industry have progressed to a new level, especially when viewing the challenge of LHC. This challenge will require close links between the physics community and industry to provide a cornerstone for future systems.

The Wire Chamber Conference was followed by a one-day workshop on the application of gaseous and other radiation detectors in medicine and biology, organized by W. Bartl. As well as standard applications in radiography and positron emission tomography, wire chambers are also used to study rapidly-changing X-ray images. This opens new opportuni-

Superlatives for Superconducting Magnets



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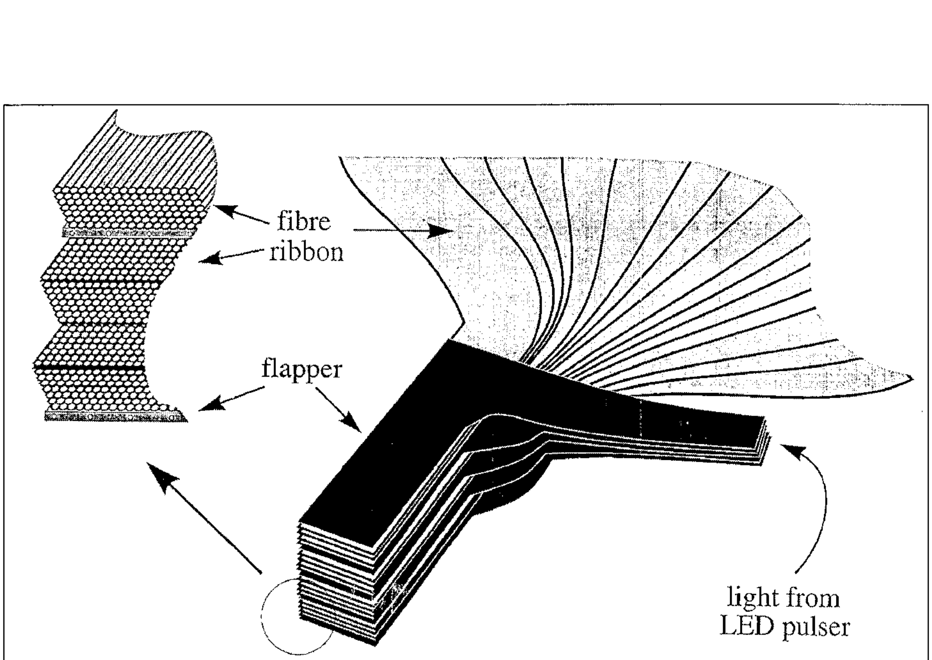
A special effort by the organizing committee ensured a wide attendance of scientists from the states of the former Soviet Union and from the countries of the eastern parts of Central Europe, for which Vienna is now the entry point to the European Union.

This year the conference again broke the record for the number of participants, reaching 300, in spite of the fact that the International Advisory Committee had had to reject many submitted papers, not so much because of their quality, but more because of limited progress since the previous conference.

Such 'rejected' contributions nevertheless could be presented as posters in a special open area, now a distinctive characteristic of the Vienna Conference. In the end, only a few applications had to be withdrawn.

The organizers were also reassured by the large number of young scientists attending. Hopefully this trend will continue for the next meeting (the 8th), to be held in 1998.

By Manfred Krammer and Meinhard Regler



Although wire chambers are no longer the major subject of the Vienna Wire Chamber Conference, the central physics objectives, such as high performance particle tracking, remain the same. This shows the opto-electronics readout system for a tracker based on scintillating fibres for the Chorus neutrino experiment at CERN. Comprising more than a million fibres with a total length of about 2,500 kilometres, it is claimed to be the largest fibre-based tracker built so far. For calibration, the fibre ribbons are interleaved with 'flappers' - spacers containing a few fibres - which are grouped and coupled to a LED pulser.

Looking hard at the electroweak force

While recent experiments have beautifully confirmed many of the predictions of the electroweak unification of electromagnetism and the weak nuclear force, some direct consequences of the electroweak symmetry involve special properties of the three force carriers - the electrically charged W and neutral Z carrying the weak force and the photon of electromagnetism. These special properties have yet to be measured accurately.

In the electroweak picture these force carriers (vector bosons) can interact with each other. These properties are 'non-abelian' - they are dependent on the order in which they are applied. [Most operations can be applied in any order, for example simple arithmetic: 6x(3+2) = (6x3)+(6x2). These are 'abelian'. An example of a non-abelian operator is the logarithm: log(x+y) does not equal log(x) + log(y).]

Summarizing the current theoretical and experimental understanding of these self-interactions, and discussing the prospects of measuring them in future experiments, was the purpose of the "International Symposium on Vector Boson Self-Interactions" held earlier this year at UCLA, the first meeting entirely devoted to this topic.

Progress in measuring the self-couplings of vector bosons has been fueled recently by the CDF and D0 Collaborations at Fermilab's proton-antiproton collider. Using data from vector boson pair production, these studies are extracting information on the WW-photon, WWZ and ZZ-photon interactions, as well as the

magnetic and electric quadrupole moments of the W boson.

At UCLA, Hiro Aihara (Berkeley) and Theresa Fuess (Argonne) summarized the CDF and D0 results from the 1992-93 run. Information on potential ZZ-gamma interactions can also be gained from single photon production at CERN's LEP electron-positron collider, as detailed by Peter Maettig (Bonn), and from rare B meson decays, reviewed by Steve Playfer (Syracuse).

Theoretically, the production of W-gamma and WZ pairs in hadronic collisions is of special interest due to zeroes when effects cancel each other out. These correspond to the absence of dipole radiation by colliding particles with the same charge/mass ratio, and are a sensitive test of the electroweak picture. The theoretical foundations of these zeroes were reviewed by Robert Brown (Case Western), while Tao Han (Davis) discussed ideas and developments to verify the effects experimentally.

Wider theories give more scope for deviations from the electroweak picture. However, if the scale at which new physics becomes apparent is of the order of 1 TeV, as is widely believed, such deviations will be much smaller than current experimental limits.

Future experimental data from vector boson pair production processes, however, are expected to dramatically improve the present limits. Numerical simulations, described by several speakers, indicate that new data at the Tevatron and LEP2 will be able to provide a 10% measurement of the self-couplings of W, Z and photons, whereas CERN's LHC proton-proton collider and a linear electron-positron collider with a collision energy larger than 500 GeV would reach sensitivities of better than 1% and 0.1%, respectively. Important cross-checks could also come from HERA electron-proton experiments.

While probing the self-interactions of W and Z bosons may not be the best way to discover new physics, as emphasized by summarizer Ian Hinchliffe (LBL), it constitutes a very important test of the electroweak picture. Furthermore, the experimental techniques developed to perform these precision measurements will be useful also in the search for the higgs boson and for new physics.

From Ulrich Baur, Steven Errede and Thomas Mueller

Primordial nuclei

The recent detection of intergalactic helium by NASA's Astro-2 mission backs up two earlier measurements by ESA and the University of California, San Diego, using instruments aboard the Hubble Space Telescope. Taken together, these results give strong evidence that this helium is primordial, confirming a key prediction of the Big Bang theory. The amount of helium the results imply could also account for some of the Universe's invisible dark matter - material which affects galactic motion but is otherwise undetectable.

According to theory, helium nuclei formed at around 100 seconds after the Big Bang, but the amount of helium depended on even earlier events. Initially, protons turned into neutrons with the same probability that neutrons turned into protons. But after about one second, the Universe had cooled down enough for the weak interaction to freeze out. Neutrons continued to decay into the slightly lighter protons, whilst the opposite reaction became much more scarce. At around 100 seconds, thermonuclear fusion reactions could begin, and all the neutrons that were left became absorbed into helium nuclei, leaving the remaining protons locked up in hydrogen.

The ratio of helium to hydrogen was therefore determined by events occurring when the Universe was just one second old. Standard models of primordial nucleosynthesis fix this ratio at slightly less than 25% by mass. All heavier elements were cooked up much later in the stars, and amount to less than 1% of the Universe's mass. These predictions have been borne out remarkably well by observation, although proof of the primordial origins of hydrogen and helium has remained elusive until now. Big Bang nucleosynthesis goes on to estimate that primordial baryonic matter in the form of light nuclei could account for around 10% of the Universe's dark matter.

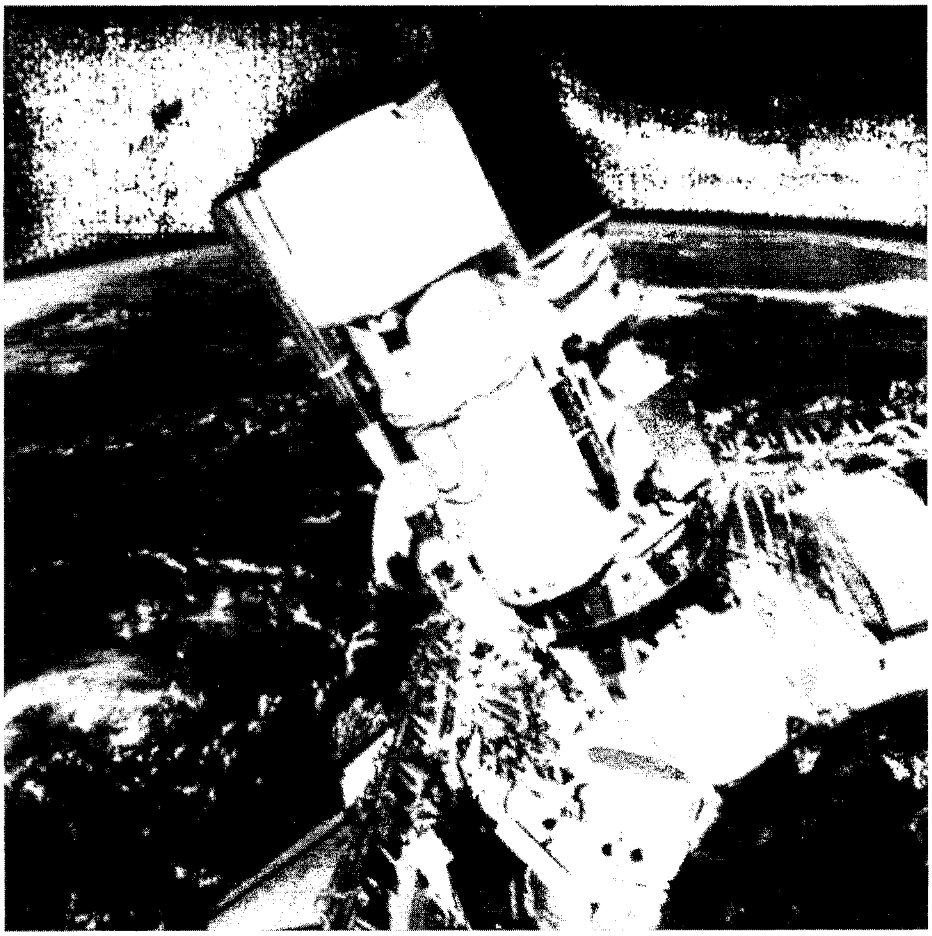
All three recent measurements used the same technique of looking at distant quasars, some of the most luminous objects in the Universe, to search for the wispy intergalactic medium. This was first applied 30 years ago by James P. Gunn and Bruce Peterson to look for neutral hydrogen. They reasoned that if hydrogen existed, it would absorb characteristic wavelengths of the quasar's spectrum as the atom's electron moved from orbit to orbit, removing spectral lines. When their search revealed nothing, it was postulated that in the extreme heat of the early Universe, all the hydrogen would have remained ionized, and therefore unable to absorb the quasar's light. So the hunt then switched to helium.While this normally has two electrons, it could have existed in a partially ionized state with just a single electron.

The first successful detection of this spectral absorption came in January 1994 when an ESA group looked at quasar Q0302-003 using the Hubble Space Telescope's (HST) Faint Object Camera. The number of suitable quasars available for Hubble to study is limited by the instrument's sensitivity. Such quasars must be very distant, and therefore receding very fast, giving a high redshift so that the quasar's absorption lines are redshifted into the range of the telescope. To compound the problem, they must also be unobscured by intervening galaxies. Quasar Q0302-003, with a redshift of 3.28 (some 10 billion light-years away), appears to be just such an object, and the absorption occurs exactly where calculations predicted it would.

When the ESA group's results were first published, and later backed up by the San Diego measurement using HST's Faint Object Spectrograph to observe another high redshift quasar, they were hailed as the first detection of the diffuse intergalactic medium. But the case was not yet proven, since similar absorption could have been caused by intergalactic gas clouds.

NASA's Astro-2 measurement in March this year chose a nearer quasar, HS1700+64, with a redshift of 2.73. This is a much brighter quasar than those used in the two previous measurements, and so provided a clearer signal. Nevertheless, the NASA result suffers exactly the same dilemma as ESA's; is the absorption due to gas clouds, or does it really come from the intergalactic medium between the clouds?

According to the Big Bang model, the more remote the galaxy, or equivalently, the higher the redshift, the more helium should be visible (up to a certain limit), because less of it will have been mopped up by nascent stars. This is precisely what the combined ESA and NASA results appear to show. There is still some debate about the precise nature of this helium, however. Could some, or even all of the absorption be due to clouds of gas obscuring distant quasars, or has the diffuse intergalactic medium finally been discovered? The answer has important consequences for the amount of baryonic dark matter locked up between the galaxies, but either way these results represent another feather in the cap of the Big Bang model.



The Hopkins Ultraviolet Telescope, seen here aboard the Space Shuttle Endeavour, provided a clear detection of intergalactic helium during NASA's Astro-2 mission earlier this year. This result, combined with earlier measurements made by ESA and the University of California, San Diego, brings important evidence for the Big Bang origin of the Universe.

(Photo Johns Hopkins University)

The challenge of neutrinos

by Christine Sutton

Neutrino pioneers - left to right, Paul Dirac, Wolfgang Pauli., Rudolf Peierls. (Photo AIP Niels Bohr Library)

Earlier this year, a team of physicists working at Los Alamos claimed a possible sighting of neutrino oscillations (June, page 13). However even before the claim appeared in the scientific literature, newspaper reports had leaked the possible findings and their implications.

Detecting particles which can pass unhindered through the Earth provides the ultimate physics challenge. Neutrinos have always captivated public imagination and make compelling reading. In the wake of the latest neutrino episode, Oxford physicist and science writer Christine Sutton looks back on the short but volatile history of the neutrino and its attendant publicity.

With the availability of high energy neutrino beams in the 1970s, physicists eagerly scoured each new batch of data for signs of exciting new physics. But few initial 'sightings' proved to be of substance. One of the major problems faced by such experiments, lies with neutrons produced outside the apparatus, either by beam particles or by cosmic rays.

Further reading: Spaceship Neutrino, by Christine Sutton, Cambridge University Press, 1992, ISBN 0-521-36404-3 (hc), 0-521-36703-3 (pb).

"Neutrinos", Maurice Goldhaber once remarked, "are remarkable particles: they induce courage in theoreticians and perseverance in experimenters". They are also no strangers to controversy, for they were in a sense born amidst it, and as recent work on neutrino oscillations demonstrates they continue to fuel debate. This is of course largely to do with the fact that neutrinos have no electric charge and experience only the weak nuclear force, making them supremely difficult to detect.

The debates surrounding neutrinos began in the first decades of the 20th century, before the particle had even been thought of. Studies pioneered by Lise Meitner and Otto Hahn suggested that the electrons emitted in beta-decay emerged with discrete energies. In these experiments a spectrometer bent the electrons according to their energy, and a photographic plate detected the electrons emerging through a movable slit, so yielding "lines" at various energies. But when James Chadwick used a point counter instead of a photographic plate, he could not find "the ghost of a line". Instead, he convinced himself that the energy of the beta-decay electrons varies continuously up to a maximum, with peaks ("lines") at only a few energies. And he was able to explain how the photographic technique could "fake" lines through its great sensitivity to small changes in intensity.

The First World War interrupted these investigations, but afterwards arguments between a continuous energy spectrum and discrete lines continued until 1927, when Charles Drummond Ellis and William Wooster at Cambridge published results from a definitive experiment in which they measured the total electron energy in a single decay process. If the electrons always started out with the same energy but lost varying amounts in subsidiary processes to give many lines, as Meitner believed, then the result would equal the maximum at the end of the spectrum. However Ellis and Wooster measured an energy equal to the average energy of the spectrum, so confirming that the electrons started out with

In 1953 Clyde Cowan and Fred Reines used a newly invented supply of copious numbers of neutrinos - a nuclear reactor - in the 'Project Poltergeist' experiment. This provided the first experimental evidence for interactions from a neutrino source.
(Photo Los Alamos)

a range of energies.

But this raised a new problem. If the electron shares the decay energy with the nucleus, this "two-body" process should always yield electrons of the same energy - provided that energy and momentum are conserved. No less a physicist than Niels Bohr suggested that these cherished laws of physics might well break down within the confines of the nucleus, but Wolfgang Pauli would have none of this. He suggested instead that an invisible third party was involved - the particle Enrico Fermi later dubbed the neutrino, or "little neutral one". In his famous letter of 4 December 1930 to Meitner and friends, in which he proposed the idea of the neutrino, Pauli said "For the time being I dare not publish anything ... and address myself confidentially first to you ...". He remained cautious, and although he presented the ideas at a meeting in Pasadena in July 1931, he did not have his talk printed. However (interestingly enough, in the light of more recent debates) a report did appear in the *New York Times*.

Pauli realized that his particle would be difficult to detect, and in 1934 Hans Bethe and Rudolf Peierls calculated an interaction cross-section of less than 10^{-44} cm^2, suggesting that "there is no practically possible way of observing the neutrino". But as Peierls commented 50 years later, they were not allowing for "the existence of nuclear reactors (or particle accelerators) producing neutrinos in vast quantities" or for "the ingenuity of experimentalists".

Almost any other particle imaginable is easier to detect than the neutrino. Being uncharged, it leaves no tracks in a detector such as a bubble chamber; and unlike the neutron it does not feel the strong nuclear force, so the probability for interactions is typically 20 orders of magnitude smaller. But anything that is created can in principle be detected. "Obviously", as Leon Lederman has written, "a particle that reacted with nothing could never be detected. It would be a fiction. The neutrino is just barely a fact."

To be sure of detecting even a few neutrino interactions you need as many neutrinos as possible and as large a detector as possible. But you also need to understand completely the backgrounds - the processes due to other particles that mimic the signal you expect for the neutrino. Undoubtedly, in all cases where results in neutrino experiments disagree with each other or do not stand the test of time, it is because the backgrounds have not been properly understood.

In their first attempt to detect the neutrino in 1953 Clyde Cowan and Fred Reines used a newly invented supply of copious numbers of neutrinos - a nuclear reactor - together with what was then a large detector with 300 litres of liquid scintillator. At first it seemed that the rate for the neutrino signal was as high when the reactor was off as when it was on. But then they realized that they had the hint of a signal above a background five times greater. Later studies, with the detector underground, showed that the background was due mainly to cosmic rays. So Cowan and Reines went to a more powerful reactor and built an improved detector to reduce the background. Here they found counts of typically 1.6 per hour with the reactor on, and 0.4 when it was off - and they declared the neutrino discovered.

Cosmic rays are a major problem with neutrino experiments, in particular because they give rise to neutrons outside the apparatus, which then look like neutrinos when they interact inside the detector. Neutron backgrounds played a major role in the efforts to understand neutrino interactions in the bubble chamber Gargamelle, which revealed "neutral currents" at CERN in 1973. This discovery proved to be a keystone in the development of the present Standard Model of particle interactions, but for a while it too became the centre of controversy.

The main difficulties arose with the classification of events in which a spray of hadrons (protons, pions etc) appeared as if from nowhere and were not associated with an identifiable muon. While these could be neutral current events due to neutrinos, they could also be due to neutrons, and the onus was on the Gargamelle team to show that they fully understood the ways in which neutrons could enter the detector from the surrounding material.

The team was put under additional pressure when conflicting signals came from the HPWF (Harvard, Pennsylvania, Wisconsin, Fermilab) neutrino experiment at Fermilab. Although the preliminary results from HPWF supported Gargamelle's findings of hadronic neutral currents, "improvements" to the HPWF detector, led to the conclusion that the neutral currents were not there after all, as the events now seemed to include muons, indicative of charged currents. This "un-discovery" caused great concern at CERN outside the Gargamelle collaboration, but in the end it was the HPWF team who realized that the muons were not in fact muons at all, but hadrons that had managed to "punch through" a reduced shield into the muon-detection apparatus.

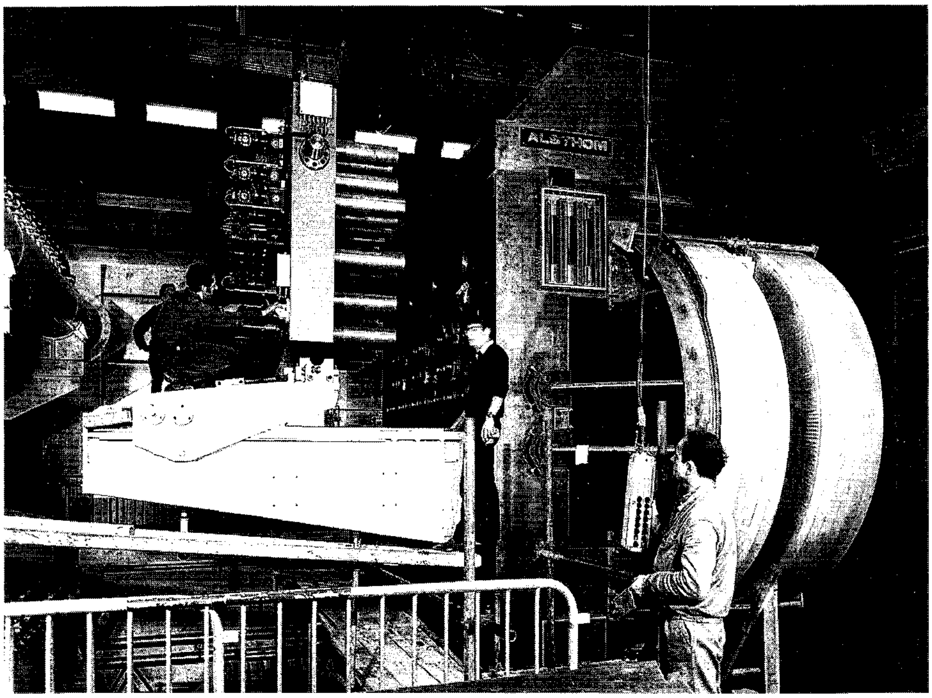
The following decade began with more excitement when in 1980 two experiments suggested that the neutrino might have a small but finite mass. In Moscow, Valentin Lyubimov and colleagues were using a spectrometer to measure precisely the high energy end of the spectrum of electrons from beta decay. The shape here depends critically on whether the neutrinos that share the energy with the electrons have any rest-mass energy. Lyubimov and colleagues claimed to have evidence for a mass between 14 and 46 eV - an exciting prospect as it implied that neutrinos from the big bang might together have sufficient mass eventually to halt the expansion of the Universe!

Meanwhile, across the world in California, Fred Reines claimed evidence of a different kind for neutrino mass (which again made the newspapers before publication in the scientific literature). In studying neutrinos from the Savannah River reactor, Reines and colleagues believed they had detected a smaller ratio between charged current and neutral current events than theory predicted. This suggested that the electron-neutrinos emitted by the reactor might have changed to muon-neutrinos which would not take part in the charged-current events detected in the experiment. To oscillate in this way, the two types of neutrino would have to differ slightly in mass, implying in turn that at least one type must have a finite mass.

Neither of these experiments turned out to stand the test of time. Nor did the excitement generated several years later by suggestions of a neutrino with a mass of 17 keV, again in an experiment using a spectrometer to measure the energy spectrum of beta-decay. In this case, Andrew Hime and his colleagues realized eventually that scattering effects were faking the appearance of this massive neutrino in several experiments.

So in a sense, the story comes full circle, echoing the early problems that Hahn and Meitner faced. But the important point to remember is that none of the "wrong" results with neutrinos is a waste of time. They inspire theoretical work that may eventually lead to new insights and even new discoveries. Indeed, this is the way that any scientific research works, with many wrong turns on the route to a proper understanding.

Leon Lederman - "a particle that reacted with nothing could never be detected. It would be a fiction. The neutrino is just barely a fact."


Preparing the Gargamelle bubble chamber at CERN in 1969. In 1973 the chamber took the first historic photographs of neutral current interactions.
(Photo CERN 409.9.69)

Neutrino book

Gargamelle and Neutral Currents - The Story of a Vital Discovery by André Rousset

André Rousset's book (in French - *Gargamelle et les Courants Neutres* - Ecole des Mines de Paris) tells the story of Gargamelle and the discovery at CERN in 1973 of neutral currents, the cornerstone of the electroweak theory. This vital discovery helped to give credence to the Standard Model of particle physics.

Rousset is both an observer and one of the key figures in the story. His book is lively and well documented; in it he uses archive material to ensure the accuracy of his information on dates, choices and decisions.

After an introduction to particle physics which puts into perspective the electroweak theory unifying weak and electromagnetic interactions, Rousset comes straight to the point. From the late 1950s onwards he was involved in the construction of the first heavy liquid bubble chambers by the BP1, BP2 and BP3 teams at the Ecole Polytechnique in Paris. For Gargamelle a bigger laboratory was needed, and it was at the CEA (French Atomic Energy Commission) in Saclay that the chamber was designed by teams from the Saturne accelerator and the Ecole Polytechnique. However, the decision to build Gargamelle was taken in 1965 through the impetus of André Lagarrigue, in defiance of the normal CERN procedures. Gargamelle was then in competition with the other big bubble chamber project, BEBC; was it really necessary to build two big chambers? The decision by Francis Perrin and the CEA to contribute "generously" to the project was probably what swung the decision.

Construction took five years, during which many problems were encountered, right up to the fault in the main part of the chamber which caused delays and, a few years later, was to prove fatal to the detector. As Rousset correctly states, Gargamelle was probably the first big detector designed to be built on industrial lines, in direct cooperation with industry. The reward: the first neutrino interaction was photographed on 28 January 1971.

While it was clear that neutrino physics was Gargamelle's main goal from the start, it was not obvious to all the physicists in the collaboration once the detector had been built that the primary objective was research into neutral currents. Rousset points out that the key role played by neutral currents in electroweak unification did not come to the fore until 1971, when Gargamelle went into operation. Here, he emphasises in an interesting manner the theorists' "green light", giving the go-ahead to the experimentalists. In fact, the European collaboration (Aachen, Brussels, CERN, Ecole Polytechnique, Milan, Orsay, UC London) was divided between a study of the quark-parton model, research into the intermediate boson... and research into neutral currents.

Gargamelle's first data were taken at the CERN PS (the SPS not yet being in operation), and the average energy of the neutrinos was only a few GeV. In a muon-neutrino interaction, either there is a muon among the final particles and it is said that there is a W exchange interaction (charged current), or there is a muon neutrino in the final state and there is a Z exchange interaction (neutral current). Neither the W nor the Z particles were known in 1972 and one of Gargamelle's goals was precisely the identification of the W particle (an impossible task, as we now know, since the PS did not

produce the required energy).

The first neutral current event was identified in early 1973 in Aachen. This was a leptonic neutral current, where a muon neutrino scatters off an electron, which crosses the chamber in a very specific way. However, André Rousset somewhat disregards leptonic neutral currents, to which he considers history has paid too much attention. May we be allowed to disagree, since the beauty of the picture is undeniable?

With perspicuity, Rousset expands on research into hadronic neutral currents, where the final state comprises an escaping neutrino and hadrons. The difficulty is in separating such an interaction from that which could be produced by the interaction of a neutron from the immediate chamber surroundings. Rousset gives a descriptive and detailed account of this complicated and painstaking work, without losing sight of the main points.

The first half of 1973 was highly emotionally charged for the collaboration, which took time to understand the data and finalize its analyses. The sociological aspect of the collaboration was also examined. The announcement of the discovery was finally made by Paul Musset at CERN on 19 July 1973 and the two papers were published in Physics Letters on 3 September. Musset had been the central figure during the construction period and had played a coordinating role in the analysis work.

André Rousset does not overlook the competition: at Fermilab, in the United States, the 'HPWF' collaboration placed its 60 tonne neutrino detector alongside the new 400 GeV accelerator, which went into operation in 1972. The neutrino energy was several tens of GeV and *a priori* it was easier to differentiate neutron interactions, the great neutral current simulators, from neutrino interactions. However, the detector was not easy to understand either. The HPWF's first results came hot on the heels of the Gargamelle announcement. There were fewer neutral currents, which disappeared altogether a few weeks later ... only to reappear at the beginning of 1974. This episode of "alternating" neutral currents worried... or kept the community entertained, for several months.

It was at the London Conference in July 1974 that the existence of neutral currents was conclusively established and accepted by the scientific community. Even today Rousset asks whether neutral currents had really been observed. This question, which is to his credit as a scrupulous physicist, may seem surprising; however, there was clearly no choice at the time: neutral currents had been predicted, even expected, by theory, and were by far the most simple interpretation of Gargamelle's results.

There are few reservations about Rousset's work. The book contains a few minor but unimportant errors (the chlorine solar neutrino detector was built in South Dakota and not Utah). A little more information on the discussion surrounding the possible existence of neutral currents in the small chambers before Gargamelle would have been welcome, and a comparison of Gargamelle's results with the present parameter values would have provided a useful perspective. Furthermore, it is perhaps regrettable that Rousset does not always adopt the necessary detachment, particularly when referring to the rival experiment in the United States at Fermilab (HPWF), but is that really to be expected from such an enthusiastic and ardent observer/participant?

In conclusion, one may be sorry, like Rousset, that this important discovery was not rewarded by a Nobel Prize. This can probably be ascribed to the early death of André Lagarrigue, the father of Gargamelle, in 1974, followed by the death of Paul Musset in an accident in 1985.

The collective scientific venture which led to the discovery of neutral currents is a wonderful story, to which André Rousset makes a very important contribution. Supplemented by Peter Galison's article ("How the first neutral current experiments ended", Review of Modern Physics 55 (1983) 477), it will make a fascinating read (in French) for all those who want to know the details of this famous chapter in the history of contemporary physics.

By Michel Spiro

(Michel Spiro, Michel Cribier and Daniel Vigaud are the authors of a new book 'La lumière des neutrinos', published by Editions du Seuil, Paris. A review of this book will appear in a forthcoming issue.)

Viewpoint

Don Perkins - keep one's eyes open for the strange and unexpected

Expecting the unexpected

At the biennial 'Rochester' international conference on high energy physics, held last year in Glasgow, Don Perkins of Oxford was in fine form when he gave the address at the conference dinner. For those who did not attend the conference, or for those (like the Editor of the CERN Courier) who attended the Conference but did not attend the dinner, the proceedings (including the full text of Perkins' speech, of which extracts are included here) are published as two volumes by the UK Institute of Physics Publishing (ISBN 0-7503-0125-2).

These proceedings are dedicated to the memory of Robert Marshak, who founded the Rochester meeting tradition in 1950 and who died in 1992.

A highlight of the Glasgow meeting had been the evidence from the CDF experiment at Fermilab's Tevatron proton-antiproton collider for the long-awaited sixth ('top') quark. At Glasgow, CDF did not claim that the top had been discovered. More modestly, they claimed that 'evidence compatible with the existence of the top quark' had been found. The definitive news of the top discovery had to await more data and was announced by CDF and the companion D0 Tevatron experiment earlier this year (April/May issue, page 1). Taking a more positive approach towards the 1994 top quark evidence, Perkins said 'Let me take the opportunity of congratulating our American colleagues on maintaining their unbroken record of discovering all the fundamental fermions (apart from the electron in 1897). The list is impressive: the positron in 1933, the mesotron (now the muon) in 1937, the electron neutrino in 1956, the muon neutrino in 1962, the tau lepton in 1975, the u, d, and s quark substructure in the mid- and late 60s, the c-quark in 1974, the b-quark in 1977 and finally the t-quark. A truly magnificent record.'

With the long-awaited top quark presumably in the bag, Perkins then turned to another long-awaited particle, the higgs, allegedly the origin of symmetry breaking in the combined electroweak picture of electromagnetism and the weak nuclear force.

'Even physicists have taken the higgs so seriously as to liken the hunt for it to the search for the Holy Grail. This could be an unfortunate analogy, since the Holy Grail was supposed to be something one could search for, but was destined never to find. In the past, such searches have sometimes led into wrong paths. When I started research some 47 years ago, the Holy Grail was the Yukawa quantum allegedly responsible for the short-range nuclear force. The story was that, if one could only find this particle, the secrets of nuclear forces would be revealed (simplistic perhaps, but people are equally naive today, claiming that we need to find the higgs to discover 'the secrets of mass' - whatever that means).

In 1947, Powell and his group at Bristol discovered a particle they christened the pion, which seemed to have all the right properties. Eureka! Today, 47 years older and wiser, the nucleon-nucleon potential is described by complicated formulae with several terms and arbitrary coefficients. The exact form depends on where you are (there is a Paris potential, a Bonn potential, etc). In short it's a mess, as it should be, as protons and neutrons are messy objects. Nor is the pion fundamental, but just the lightest quark-antiquark molecule. On the other hand no-one in those days knew what to do with the muon. Now we know that the muon is fundamental and presumably was a star player in the first microsecond or so of the Big Bang.

In 1947, not only were we getting the wrong answers, but not even asking the right questions. But it did not matter. Belief in the fundamental nature of pions and strange particles led to the great era of accelerator building and to higher energies and eventually to quarks.

Again early Grand Unified Theory models in the 70s predicted monopoles and proton decay at an accessible level: neither were found, but instead, underground detectors recorded the 1987 supernova burst. The lesson of all this is that our predictions are frequently wrong, in fact one finds something very different from what was expected, and even better! That is what makes particle physics exciting: Nature is full of surprises.

A detector that will only trigger on the higgs may well find nothing, so it is important to have general purpose detectors with the loosest possible triggers, and keep one's eyes open for the strange and unexpected.'

Bookshelf

The Particle Garden, by Gordon Kane: Addison Wesley, ISBN 0-201-40780-9

'Our universe as understood by particle physicists' is the subsidiary title of Gordon Kane's attractive new book. In setting out to present a balanced picture of particle physics, Professor Kane has written the sort of book which could easily motivate a young student to turn to particle physics research. (The author relates how he was turned on by reading a book about Einstein.)

In explaining particle physics wisdom, especially instructive is the distinction drawn in the book between 'Descriptive Understanding', 'Input and Mechanism Understanding' and 'Why Understanding'. The analogy uses a videocassette recorder (VCR): Descriptive Understanding corresponds to being able to work and handle a VCR which did not come with the appropriate documentation; Input and Mechanism Understanding means the ability to fix the VCR unaided if it goes wrong; and Why Understanding confers the ability to invent a VCR and make one.

The book also rues the unfortunate disappearance of the US Superconducting Supercollider megaproject.

An Introduction to Cosmology, by Jeremy Bernstein: Prentice Hall, ISBN 0-13-110504-3

Professor Bernstein is a successful physicist and science writer, and 'An Introduction to Cosmology' benefits from both these skills. It is both a textbook and a good read. The author explains that the book arose from a course he gave at the Stevens Institute of Cosmology. 'Teaching this course was one of the most pleasant tasks I have had as a professor,' he admits in the introduction. It shows. The physics arguments are well constructed, and the book is packed with anecdotes. The introduction is especially good, and a more general overview in Part 1, although very qualitative, introduces many very useful numerical ideas which help place terrestrial physics in a more humble context.

Fritz London: a scientific biography, by Kostas Gavroglu: Cambridge University Press, ISBN 0 521 43273 1

Fritz London died in 1954 at the age of 54. For thirty years he had made milestone contributions to theoretical physics and chemistry. As a student, London had explored the frontier between philosophy and physics - fertile ground with the difficulties of interpreting the new quantum mechanics. After work under Sommerfeld in Munich, he moved in 1927 to Zurich to work with Walter Heitler, developing the famous quantum theory of molecular bonds. After a period in Berlin with Schrödinger, he fled Germany for Oxford, where with his brother Heinz he proposed the first phenomenological picture of superconductivity. From Oxford he moved to Paris, where he turned his attention to the companion problem of superfluidity. These pictures were influential in the development of the ultimate quantum descriptions, as acknowledged in an 'afterword' to the book by John Bardeen.

This is an informative book about an influential scientist, whose peripatetic career produces some startling reading jolts such as 'Von Laue knew London from Berlin', and 'In 1936 London moved to Paris'.

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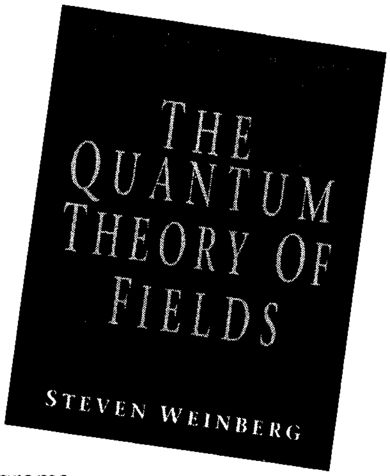

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People and things

Jean-Pierre Gourber will be Leader of the CERN's new LHC Division for three years from 1 January 1996.

Miguel Virasoro becomes Director of the International Centre for Theoretical Physics (ICTP), Trieste.

CERN elections and appointments

At its meeting on 23 June, CERN's governing body, the Council, decided to create an LHC Division as from 1 January 1996. The LHC Division will focus on the core activities related to the construction of the machine, namely superconducting magnets, cryogenics and vacuum together with supporting activities. Jean-Pierre Gourber was appointed Leader of the new LHC Division for three years from 1 January 1996.

Council also appointed Bo Angerth as Leader of Personnel Division for three years from 1 January 1996, succeeding Willem Middelkoop. Jiri Niederle (Czech Republic) was elected Vice-President of Council for one year from 1 July 1995.

ICTP Trieste Director

Distinguished theorist Miguel Virasoro becomes Director of the International Centre for Theoretical Physics (ICTP), Trieste, succeeding founding Director Abdus Salam, who continues to act as the Centre's President.

Born in Buenos Aires, Virasoro has worked in many countries during his career, and comes to ICTP from La Sapienza, Rome, where he has worked since 1982. He was in CERN's Theory Division from 1979-80, returning after a short summer break to stay until 1983. In elementary particles, he is acknowledged as one of the founders of string theory. He has also studied complex systems, statistical mechanics and neural networks.

EPS Prizes

The prestigious High Energy and Particle Physics Prize of the European Physical Society for 1995 goes to Paul Söding, Bjorn Wiik and Günter Wolf of DESY and Sau Lan Wu of Wisconsin for their milestone work in providing 'first evidence for three-jet events in electron-positron collisions at PETRA' (DESY's electron-positron collider).

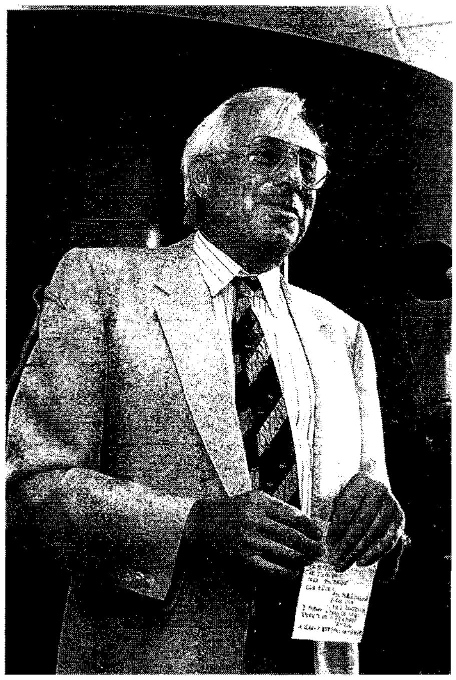
At DESY, Bjorn Wiik is now Chairman of the DESY Board of Directors, Paul Söding has special responsibility for the high energy physics institute at Zeuthen, Berlin, and Günter Wolf is formerly spokesman of the ZEUS experiment at DESY's HERA electron-proton collider. He is also Chairman of CERN's Scientific Policy Committee. Sau Lan Wu is a member of the Aleph collaboration at CERN's LEP electron-positron collider. Their work, which was done in 1979 when all four were members of the TASSO collaboration, demonstrated that the gluons of the strong interactions were a physical reality.

The existence of such three-jet events in electron-positron collisions had been predicted in a pioneer CERN Theory Division paper by John Ellis, Mary K. Gaillard and Graham Ross.

There has always been keen rivalry between the four 1979 PETRA collaborations - JADE, MARK-J, PLUTO and TASSO. In recognition of this, and in an unprecedented move, the EPS Executive Committee has awarded a special complementary prize to the four collaborations 'for establishing the existence of the gluon in independent and simultaneous ways'.

Also playing major roles in the 1979 accomplishments were Herwig Schopper, Chairman of the DESY Board of Directors at the time, and PETRA project leader Gustav-Adolf Voss, who ensured that such an excellent machine was built on schedule and within the allocated budget.

Günter Wolf (right) of DESY (currently Chairman of CERN's Scientific Policy Committee) and Sau Lan Wu of Wisconsin (currently a member of the Aleph collaboration at CERN's LEP electron-positron collider), share, with Paul Söding and Bjorn Wiik, also of DESY, the prestigious 1995 High Energy and Particle Physics Prize of the European Physical Society for their 1979 work in providing 'first evidence for three-jet events in electron-positron collisions at PETRA' (DESY's electron-positron collider) which demonstrated that the gluons of the strong interactions were a physical reality.



Günther Plass - planning for 'the tomorrow after tomorrow'

1995 ICTP Prize

The 1995 High Energy Physics Prize of the International Centre for Theoretical Physics (ICTP), Trieste, in honour of Steven Weinberg, has been awarded to Spenta Wadia of the Tata Institute for Fundamental Research, Bombay, whose work has received international acclaim. From 1978 to 1982, as a postdoctoral fellow at Chicago's Enrico Fermi Institute, he made important contributions in the study of gauge theories, both on the lattice and continuum. Since joining TIFR in 1982, his interests have included string theory and 2-dimensional quantum gravity, where he and his collaborators have made milestone contributions. He has also played an important role in the development of theoretical physics in India, having built up a TIFR research group which now constitutes one of the most important research centres in string theory and 2-dimensional quantum gravity. The award was handed over on 14 June during the ICTP Summer School in High Energy Physics and Cosmology. Professor Wadia spoke on "Quark Confinement and Dual Representation of Yang-Mills Theory in 2+1 Dimensions".

Günther Plass retires

After a 39-year career, Günther Plass retired from CERN at the end of May. He arrived at the new Laboratory in 1956 while the PS was under construction and preparations for its magnet ring were in full swing. With the PS in operation, attention turned to physics requirements. With Berend Kuiper, Plass developed a fast ejection system for protons to bombard an external target and manufacture secondary beams. In 1965 he went on to lead the construction of a PS neutrino area which was to become the scene of CERN's first major physics achievement, the discovery of neutral currents in 1973. He then turned to the construction of the Linac 2 injector which ensured a plentiful supply of particles and prepared the ground for new projects. At the same time he was influential in ensuring that CERN's next machine, the SPS, would be built on the CERN site rather than somewhere else in Europe. During SPS construction he was PS representative on John Adams' SPS design committee. Later in the 1970s, with the advent of CERN's antiproton scheme, he pushed plans for the LEAR low energy ring. Turning from LEAR to a much larger machine, LEP, he played a vital role in deciding its definitive configuration, reducing its planned circumference from 30 to 27 kilometres and building it on a slant to minimize tunneling under the Jura mountains. This smoothed the way for LEP approval by Council in 1981, when he was appointed deputy to LEP Project Leader Emilio Picasso. In 1983 he became leader of the new LEP division. With the 27-kilometre ring

Honorary doctorates at Chalmers University of Technology, Göteborg, Sweden, on 20 May. Left to right, Achim Richter of Darmstadt's Technische Hochschule and currently Chairman of CERN's ISOLDE Experiments Committee; author Marit Paulsen, who has played a major role in promoting environmental concern and in pushing for Sweden to join the European Community; and Sven-Erik Andersson, formerly ASEA Director and Joint Professor of Production Engineering at Chalmers.

which assured CERN's future complete, in 1990 he became Director of Accelerators. At a special retirement event on 24 May, Emilio Picasso paid tribute to Plass' contributions to LEP, from initial planning through construction and installation to final arbitration with contractors. Acknowledging his colleagues' tributes, Plass characteristically looked to the future, underlining the importance of planning for 'the tomorrow after tomorrow'.

On people

Gerard 't Hooft of Utrecht, who first demonstrated that the unified electroweak theory is renormalizable, is awarded the Franklin Medal.

UK Royal Society

New Fellows of the UK Royal Society include theoretician Richard Corrigan of Durham, experimentalist Robin Marshall of Manchester, and Joseph Rotblat, formerly professor of physics at a major London hospital medical school and prominent member of the wartime UK team at Los Alamos. New non-UK members include distinguished theorist and cosmologist John Wheeler of Princeton.

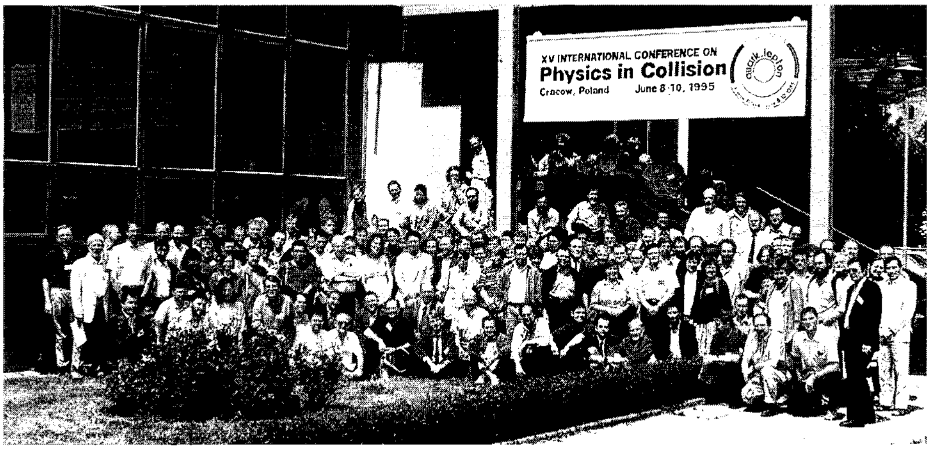
Meetings

The international workshop Diffraction-95 will be held in the Crimea (Ukraine) from September 7-11. The program will include lectures and contributions on hadron diffraction, polarization, small x physics, pomeron structure and collective properties of nuclear matter. Special seminars dedicated to advances in astroparticle and mathematical physics will be held outside the programme of the Workshop. Further information from: Galina V.Bugrij, Bogoliubov Inst.Theor.Physics, Kiev-143, Ukraine; FAX: ++7-044-2665998; Phone: ++7-044-2669123; e-mail: ABUGRIJ@GLUK.APC.ORG

An International Workshop on Single Particle Effects in Large Hadron Colliders will be held from 15-21 October in Montreux, Switzerland. Further information from E. Keil, CERN, CH-1211 Geneva 23, Tel: + 41 22 767 3426, Fax: + 41 22 783 05 52, e-mail:

Honorary doctorates at the Ecole Polytechnique Fédérale de Lausanne (EPFL). Left to right - Edward Kramer of Cornell (structure of complex molecules), Elliott Lieb of Princeton (mathematical physics) and Marie-Claude Gaudel of Orsay (software engineering), with EPFL President Jean-Claude Badoux and Maurice Jacob of CERN, who gave the keynote speech - 'Scientific research - dawn or twilight?'

The International 'Physics in Collision' Conference held in pleasant surroundings in Cracow from 8-10 June was the 15th of the series, whose objective is to present objective plenary reviews, giving a compact overview of the field. The conference was agreeably organized by the Marian Miesowicz Centre of Particle Physics, involving particle physicists from the High Energy Physics Department of the Henryk Niewodniczanski Institute of Nuclear Physics, from the Faculty of Physics and Nuclear Techniques of the Mining and Metallurgy Academy and from the Physics Institute of the Jagellonian University.



Ernest Walton 1903-95 (Photo David O'Callaghan)

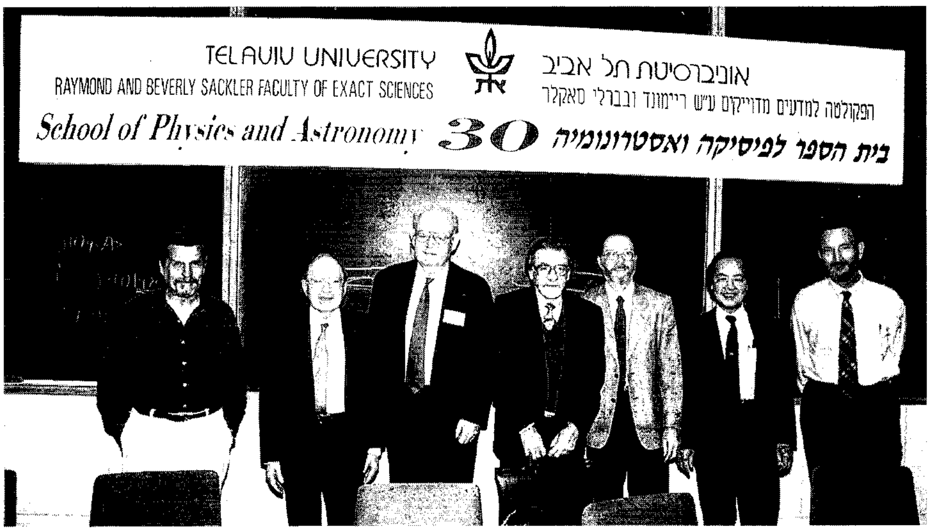
LHC95@CERNVM.CERN.CH WWW http://hpariel.cern.ch/keil/LHC95.html

The 12th International Symposium on High Energy Spin Physics - SPIN96 - will be held from 10 - 14 September 1996 in Amsterdam. For further information, contact: C.W. de Jager, NIKHEF, P.O. Box 4188, 1009 DB Amsterdam, The Netherlands, tel.: + 31 20 592 2163, fax: + 31 20 592 2165, email: spin96@nikhef.nl

Ernest Walton 1903-95

Irish physicist Ernest (E.T.S.) Walton, who shared the 1951 Physics Nobel Prize with John Cockcroft for their 1932 experiment which 'split the atom', died on 15 June. After initial studies at Trinity College, Dublin, he went to the Cavendish Laboratory, Cambridge, in 1926, where Rutherford was calling for higher energy particles to induce nuclear reactions. A gifted craftsman, Walton initially looked at the possibility of accelerating protons in an induction machine, a precursor of the betatron. With Cockcroft, he then built the famous pioneer high voltage (700,000 volt) accelerator which enabled protons to tunnel into light nuclei and in 1932 produce the first synthetic nuclear transformations - the first accelerator and the first accelerator experiment.

He returned to Trinity College in 1934 and became Professor in 1946. In his 1951 Nobel lecture, he said 'It



Earlier this year, a special symposium marked the 30th anniversary of Tel Aviv University's School of Physics and Astronomy. Left to right are Yakir Aharonov of Tel Aviv ('who spoke on Recent developments in Quantum Theory'); Yuval Ne'eman of Tel Aviv ('Conceptual Advances in the New Cosmology'); Benoit Mandelbrot of Yale and IBM ('Fractals in Physics'); K. Alex Müller of IBM and Tel Aviv ('Technical Advances in High Temperature Superconducting Technology'); Dean of Tel Aviv's Exact Sciences David Horn; T.D. Lee ('The Importance of Condensates'); and Tel Aviv Physics and Astronomy Chairman Asher Gotsman. The symposium also provided an opportunity to celebrate professor Ne'eman's 70th birthday. (Photo Israel Sun) *is difficult to see how particles of energy greater than 10,000 MeV (10 GeV) can be produced economically by existing methods. Further progress may have to await the introduction of new ideas"'. With the figure suitably redimensioned, this quote has subsequently been re-used on many occasions.*

William Fowler 1911-95

William A. Fowler, winner (with Subrahmanyan Chandrasekhar) of the 1983 Nobel Prize in physics for his work on the formation of chemical elements inside stars, died in March, aged 83.

A native of Pittsburgh, he pursued graduate studies on light radioactive elements at the California Institute of Technology, receiving his PhD in 1936. He maintained an association with Caltech's Kellogg Laboratory for most of his career, becoming institute professor of physics in 1970, a position he held until his retirement in 1982.

During World War II, he helped develop proximity fuses, rocket and torpedo ordnance, and atomic weapons, for which he was awarded the US government's Medal of Merit in 1948.

A sabbatical year in Cambridge pointed him towards nuclear astrophysics and it was his co-authorship (with Fred Hoyle and Geoffrey and Margaret Burbidge) of a 1957 seminal paper on the synthesis of the elements in stars that brought the greatest recognition. This classic paper helped create a basic model of star development, demonstrating that nuclear processes in stars could manufacture all the elements, starting with just the hydrogen and helium produced in the Big Bang.

Horst Foelsche

Horst Foelsche

Horst W. J. Foelsche, whose 30-year career at Brookhaven covered major accelerator contributions, died on May 21, aged 57, from complications of lung cancer.

Born in Darmstadt, he immigrated to the US with his family in 1958. He received his PhD from Yale in 1963, after coming to Brookhaven in 1960 for a research experiment on the 3 GeV Cosmotron. In May 1965, Foelsche joined the Lab's Accelerator Department.

After being appointed Head of Experimental Planning and Support Division in 1974, Foelsche went on to lead the Injection and Extraction Systems Division for the Colliding Beam Accelerator (CBA) project from 1977 to the project's cancellation in 1982, when he became Head of Alternating Gradient Synchrotron (AGS) Division.

In 1983 Foelsche was named Senior Physicist and took on the additional role of Project Manager for the Heavy Ion Transfer Line Project. In this effort, successfully concluded in three years, he was responsible for the heavy-ion transfer line from the Tandem Van de Graaff to the AGS, with an eye to injection into the proposed Relativistic Heavy Ion Collider (RHIC). He also made major contributions to the vital Booster project.

In 1986, he became Deputy Chairman of AGS Department, where he helped develop the Linac as an intense proton source for isotope production and cancer therapy.

In 1990, Foelsche became Assistant Head of the RHIC Project, also overseeing RHIC's Injection and Beam Dump System Division - resuming the design of the beam-transfer line from where it had been left when CBA was canceled.

Named Head of Magnet Division in 1993, Foelsche was appointed Associate RHIC Project Head the following year. Said RHIC Project Head Satoshi Ozaki, "As Magnet Division Head, Horst succeeded in the very difficult challenge of turning an R&D effort into highly effective production. Horst's efforts are to be seen everywhere in RHIC. Most important of all, however, he lives in the memory of so many who worked with and admired him."

Claude Itzykson 1938-95

Distinguished French theorist Claude Itzykson died on 22 May, aged 57, after a struggle with cancer. From 1963, he spent his career at Saclay but was a frequent traveller, with periodic visits to SLAC and CERN.

He was a world-renowned expert in field theory and in many domains of

BROOKHAVEN
NATIONAL LABORATORY

PHYSICS DEPARTMENT

The Physics Department is searching for the project leader for software for the STAR detector to be installed at RHIC, the Relativistic Heavy Ion Collider, currently under construction. The selected candidate will lead the software effort and contribute to the physics of the STAR detector.

Candidates must have an understanding of the software needs of large physics detectors including infrastructure, on-line, off-line, detector stimulation and data analysis and have demonstrated leadership in software for physics collaborations. You should have the following attributes: strong interest in and understanding of the physics needs of STAR; demonstrated organizational skills for software projects; demonstrated significant contribution to High Energy or Nuclear physics, and the ability to represent the needs of the STAR software at reviews and work in team environments with colleagues widely dispersed.

Candidates should also have good knowledge of structured software design, ability to develop project schedules and cost estimates, knowledge of C++, C and FORTRAN and knowledge of the implementation constraints of processors and networks.

Applicants should send a curriculum vitae and arrange to have three letters of reference sent to: Dr. Peter D. Bond, Physics Dept., Bldg. 510A, Brookhaven National Laboratory, Upton, Long Island, NY 11973-5000. Equal opportunity employer M/F/D/V.

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REVISED POLARIZED TARGET PHYSICIST **CEBAF**

The Continuous Electron Beam Accelerator Facility (CEBAF) is located in the city of Newport News, Virginia, about 150 miles south of Washington, D.C. CEBAF has completed the construction of a CW electron accelerator with an initial maximum energy of 4 GeV servicing three experimental areas with simultaneous beams of different energies and currents. The experimental areas are equipped with a variety of focusing spectrometers for coincidence experiments, and a large acceptance spectrometer for multiparticle detection. An important part of CEBAF's physics program requires the use of solid-state polarized targets. Experiments related to studies of the nucleon spin structure, the excitation of nucleon resonances, and the measurement of nucleon form factors utilizing such targets have already been approved. CEBAF is in the process of establishing a small group to support these targets. In this context, CEBAF invites applications for a Staff Scientist position in the Physics Division. The successfull applicant should have a Ph.D. in Experimental Physics or an equivalent combination of education and technical skills. Experience in the construction, operation, and maintenance of solid-state polarized target is required. The successful applicant is expected to work initially with the polarized target group at the University of Virginia in Charlottesville. (The UVA group is currently involved in the development of polarized targets for CEBAF and in the spin structure function measurements at the Stanford Linear Accelerator Center). The position is intended to be at the Scientist I entry level; however, in exceptional cases, a more senior position may be considered.
Applicants should submit a curriculum vitae to: CEBAF, Attn: Employment Manager, 12000 Jefferson Avenue, Newport News, VA 23606. USA. Please specify position #PR2132 and job title when applying. An Equal Opportunity, Affirmative Action Employer.

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FACULTY POSITIONS IN PHYSICS
University of California, Berkely

The Physics Department of the University of California, Berkeley intends to make two faculty appointments effective July 1, 1996. Candidates from all fields of physics are encouraged to apply. Appointments at both tenure-track assistant professor and tenured levels will be considered.

Please send a curriculum vitae, bibliography, statement of research interests, and a list of references to **Professor Roger W. Falcone, Chairman, Department of Physics, 366 LeConte Hall # 7300, University of California, Berkeley, CA 94720-7300, USA**, by Monday, November 27, 1995. Applications submitted after the deadline will not be considered. The University of California is an Equal Opportunity, Affirmative Action Employer.

Distinguished French theorist Claude Itzykson died on 22 May.

mathematical physics. He was the author (with Jean-Bernard Zuber) of the influential textbook 'Quantum Field Theory' (McGraw Hill, New York, 1980), which pointed out the importance and special role of gauge theories. He was awarded the Prix Langevin in 1972, the Robin Prize of the French Physical Society in 1988 and the Prix Ampère of the French Academy of Sciences in 1995.

George Theodosiou

George Theodosiou died in Athens on November 17, at the age of 48. His sudden death shocked his colleagues and friends in the physics community and in DELPHI in particular, coming at a time when his contribution to his home Laboratory (NCSR Demokritos) and to science was very large.

Born on the island of Lesbos, he graduated from Athens in 1969, received his Masters Degree from Notre Dame and his PhD from Cornell in 1977. The author of more than 110 publications, he was was also co-inventor of the technique "Reduction in Maximum Time Uncertainty of Paired Time Signals" (registered US Patent), used in several high energy physics experiments.

After working at Cornell and Fermilab, George Theodosiou joined DELPHI in 1987 and since 1988 had represented the Democritos Group at the DELPHI Collaboration Board. During the development and construction of DELPHI, he made important contributions to the RICHs such as the construction of field-wire frames for the Barrel RICH, and design and construction of the cooling system for the forward RICH preamplifiers. He supervised the theses of several graduate students, studying with them the electron-compositeness scale parameter Lambda, the fluctuations of the phase space variables in the final state products of Z hadronic decays, and several decay modes of the tau lepton.

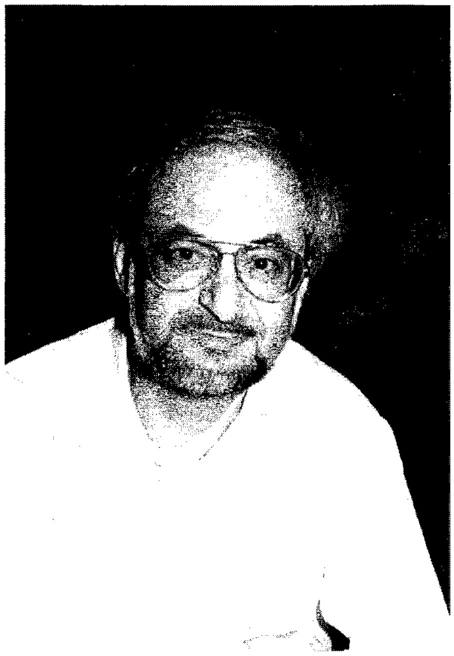
George Theodosiou was highly motivated, dedicated to his work and had a passion to contribute to experimental high energy physics in Greece. The high energy physics community in Greece and CERN have lost an important partner.

From his Greek colleagues

Themis Kanellopoulos 1916-1995

A remarkable man and had a remarkable career, distinguished Greek physicist Themis Kanellopoulos died of heart failure on 25 May, aged 79. After studying mathematics at Athens and subsequent prolonged military service, he went to Birmingham, UK, in 1953 at the age of 37 to work for his PhD.

George Theodosiou



In 1956 he became one of the first members of CERN's Theory Division, where he developed, with K. Wildermuth, the cluster model of nuclei. From 1960, as Scientific Director of the Greek 'Demokritos' National Research Centre, he established the first graduate school for physics in Greece. His drive and judgment were highly influential in promoting Greek science policy and research. From 1967 to the end of his career he worked in Tübingen. Themis Kanellopoulos was a warm-hearted man of great personal charm and with a highly developed sense of humour - qualities which built many strong friendships.

Roger F. Dashen 1938-1995

Roger F. Dashen of the University of California, San Diego, and Department Chair there from 1988-1994, died suddenly on 24 May. Before going to San Diego in 1986, Dashen was for 20 years at Princeton's Institute for Advanced Study, first as

Long Term Member (on leave from Caltech) and then as Professor.

A widely respected and much loved theorist, Dashen made important contributions to particle theory, statistical mechanics, and applications of path integrals. He was involved in pioneering work on current algebras, on which he produced, with Stephen Adler, an influential book. Dashen helped initiate use of chiral SU_3 x SU_3 as a strong interaction symmetry and was a coinventor of chiral Lagrangians. In recent work with collaborators at San Diego, he obtained important consistency conditions for the pion-baryon couplings in large-N QCD.

In statistical physics, Dashen showed how to relate the partition function to S-matrix elements, and how simulation studies could be used to bound the higgs mass (or the energy scale for new physics). He applied path integrals both to uncovering the complex substructure of the vacuum in QCD, and to making seminal contributions to the theory of sound propagation in random media.

He was elected to the US National Academy of Sciences in 1984 and was an active participant in the JASON summer study. To a generation of colleagues, he will be remembered as a stimulating collaborator and a steady source of innovative ideas.

From Stephen L. Adler

Leonardo Castillejo 1924-95

Leonardo Castillejo, who died suddenly in May, was a theoretical physicist whose influence far outweighed his publications. After not(!) getting his PhD at University College, London, he spent time at Birmingham and Oxford before returning as professor to UCL. He collaborated with Richard Dalitz and Freeman Dyson on the famous CDD ambiguity which had a major impact on the application of analyticity in particle physics in the 60s, with Mike Seaton on exchange effects in atomic scattering, and Gerry Brown on the electric dipole state in nuclei.

More recently, with Andy Jackson, he initiated studies of the nucleon-nucleon interaction in the Skyrme models and played an important role in establishing its connection to more familiar meson-exchange interactions. Possible relationships of Skyrmions with high-temperature superconductivity also fascinated him.

For most of us, finishing a problem presents an opportunity to publish. For Leonardo, the pride lay in posing a good question and in understanding the answer. It was difficult, sometimes impossible, to convince him to share his insights with a wider audience. He wrote infrequently but with enormous care and clarity. Leonardo always showed great charm and a complete lack of arrogance and it was a privilege to have known and worked with him.

Colin Wilkin

(Leonardo Castillejo was external examiner for many UK PhDs in theoretical physics. In 1967 his commissions included future CERN Director General Chris Llewellyn Smith and an embryonic CERN Courier Editor - Ed.)

Paul Urban 1905-95

Paul Urban died earlier this year aged 89. Long-serving head of Theoretical Physics at Graz, Austria, he is remembered also as founder of the successful Schladming Winter School in theoretical physics. He was also Editor of Physica Austriaca for many years. Unselfish and caring, he played a vital role in nurturing scientific culture in Central Europe during difficult times.

HERA physics workshop

After the successful startup of HERA and the first three HERA experiments H1, ZEUS and HERMES (see page 10) a workshop on the "Future Physics at HERA" aims to study in detail HERA's physics potential as well as possible HERA upgrade plans, including luminosity increase, polarized electron and proton beams, and storage of nuclei.

The workshop will start with a two-day meeting on September 25 at DESY during which the status and upgrade possibilities of HERA, the status of the experiments H1, ZEUS, HERMES and HERA-B, the latest physics results from HERA and short term physics plans will be presented. After talks on "QCD at HERA" and "New physics and HERA" the working groups will form.

Groups are planned for: Structure Functions, Electroweak Physics, Beyond the Standard Model, Heavy Quark Production and Decay, Jets and High P_T Phenomena, Diffractive Hard Scattering, Polarized Protons and Electrons, Light and Heavy Nuclei in HERA, and HERA upgrades and impacts on experiments. The

start-up workshop will finish with reports from the working groups in the afternoon of September 26. A meeting to review the progress of the working groups is planned for February 1996. The workshop will end with a meeting in May 1996.

The organizers are Gunnar Ingelman (Chairman), Albert De Roeck and Robert Klanner. Further information, including contact persons for working groups can be found under WWW:

http://www.desy.de/conferences/hera-workshop95.html

Persons interested in participating are asked contact the organizers via Email at HERA-WORKSHOP95@DESY.DE or addressed to HERA-WORKSHOP95, Mrs. H. Haertel, Fax +49 40 8998 3093.

Gilberto Bernardini 1906-95

Gilberto Bernardini, one of the elder statesmen of Italian physics, died on 3 August, aged 89. Born in Florence and a graduate of Pisa's prestigious Scuola Normale, he went to Florence as assistant professor, where he worked with Bruno Rossi and G.P.S. Occhialini. He then followed Rossi to Padua, and subsequently played a central role in early cosmic ray experiments, particularly the historic Italian studies of the 1940s which made widespread use of magnetic lenses and which went on to establish the existence of the mu meson.

After Bologna, he spent time at Rome (to help fill the gap after Fermi's departure to the US). After the Second World War, he worked at Columbia (where Leon Lederman was one of his students), proceeding later to Champaign-Urbana (Illinois). In the mid-1950s, he was one of the first scientists to work at CERN, and his physics experience and international background helped get the experimental programme at the Synchro-Cyclotron off the ground. During John Adams' 'emergency' mandate as CERN's Director General in 1960-61, he and Victor Weisskopf were Directors of Research. He initially continued in this role when Weisskopf was appointed Director General in 1961, and played a prominent part in the early neutrino experiments at CERN. He returned to Pisa in 1964 to direct the Scuola Normale, a position he held until 1977. He was the first President of the Italian Istituto nazionale di fisica nucleare (INFN), and served as President of the Italian Physical Society. He helped found the European Physical Society, becoming its first President from 1968-70.

Gilberto Bernardini 1906-95

CERN Courier contributions

The Editor welcomes contributions. These should be sent via electronic mail to courier@cernvm.cern.ch

Plain text (ASCII) is preferred. Illustrations should follow by mail (CERN Courier, 1211 Geneva 23, Switzerland).

Contributors, particularly conference organizers, contemplating lengthy efforts (more than about 500 words) should contact the Editor (by e-mail, or fax +41 22 782 1906) beforehand.

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