CERN COURIER

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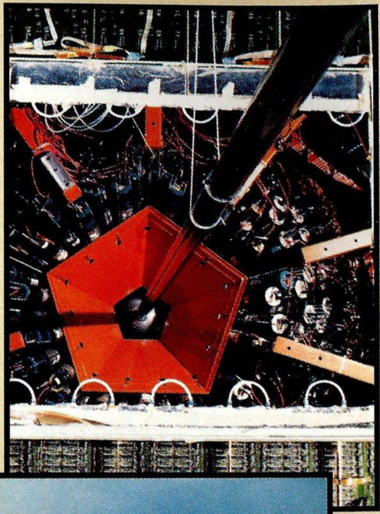
VOLUME 29 3 APRIL 1989

The World's Most Demanding Detectors...



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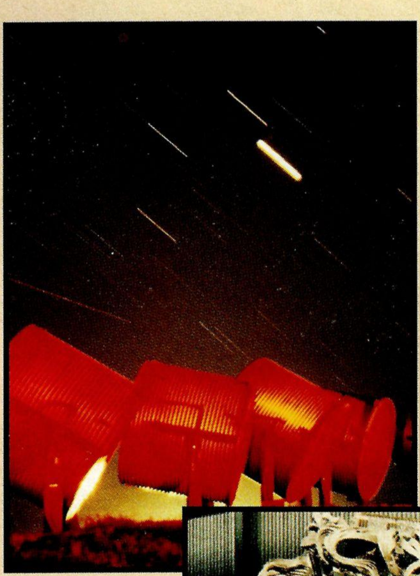

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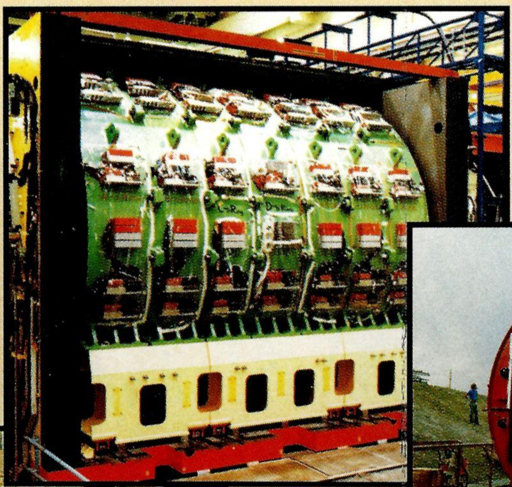

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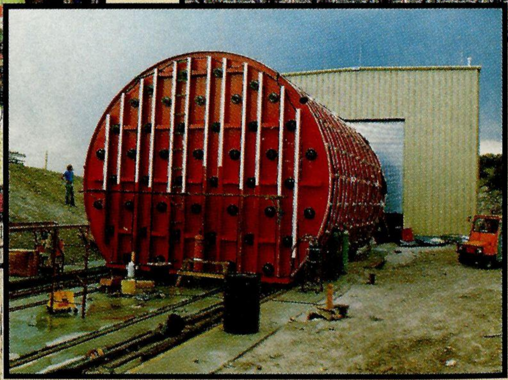

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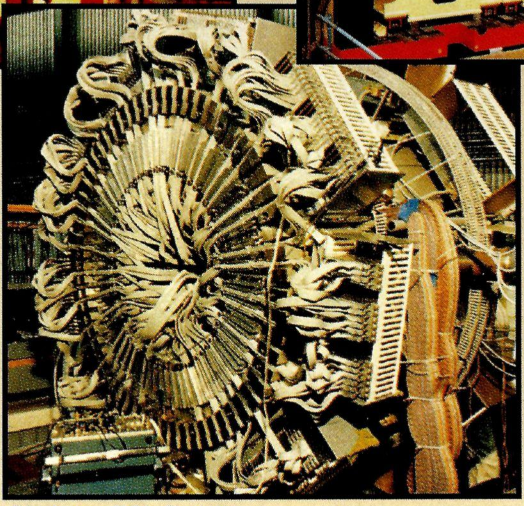

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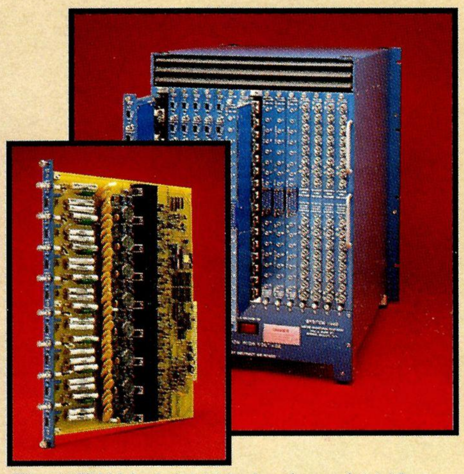

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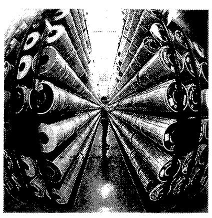

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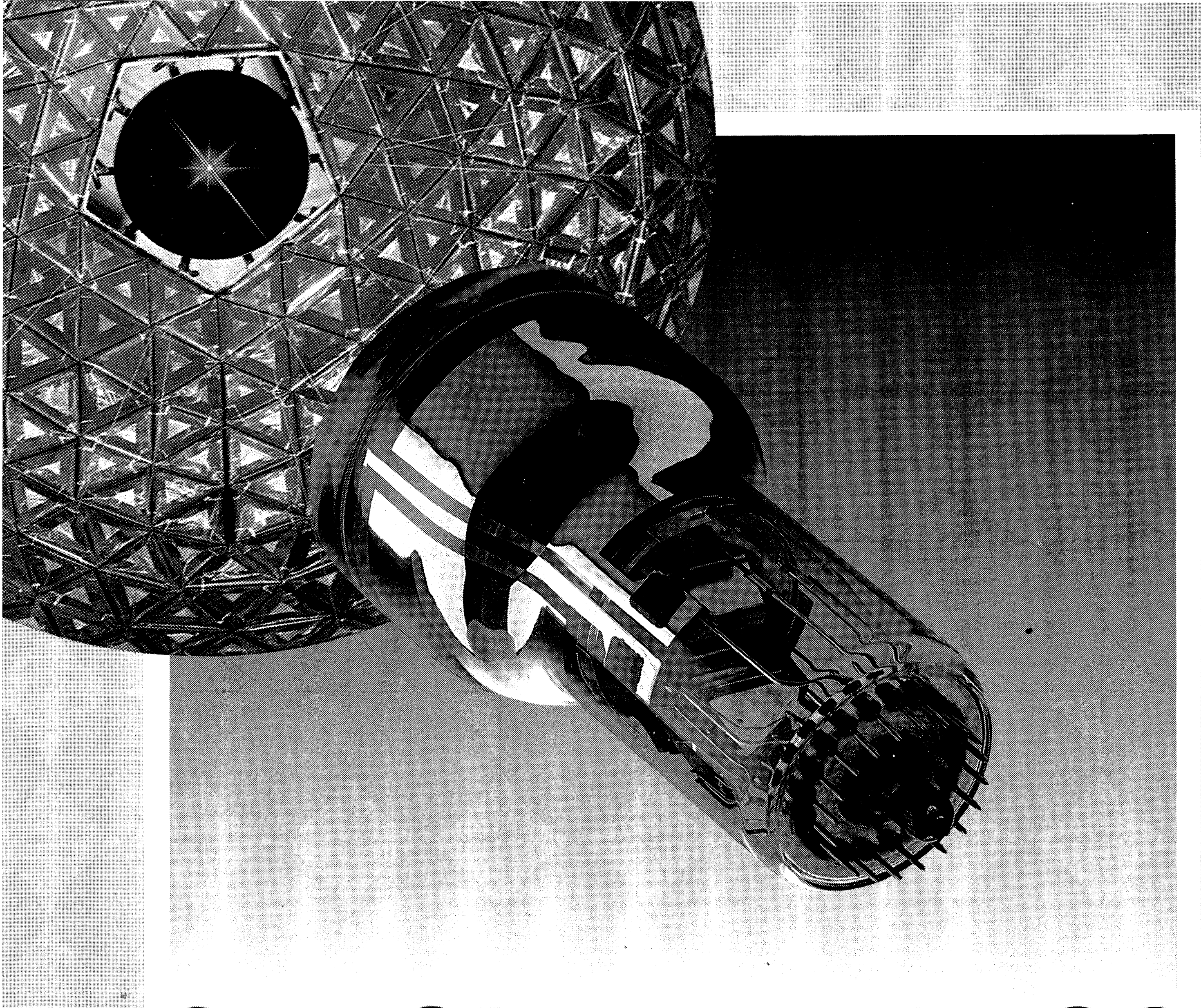

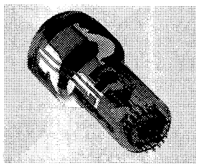

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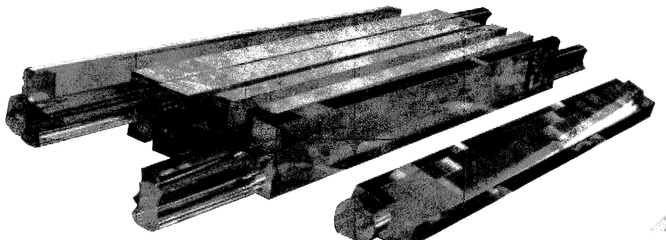
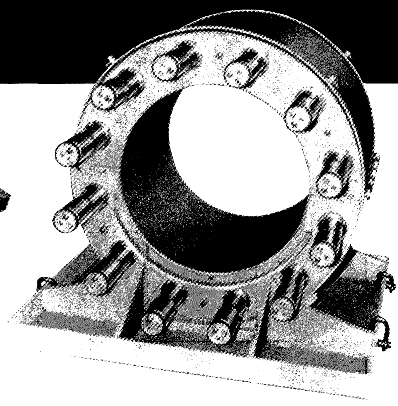
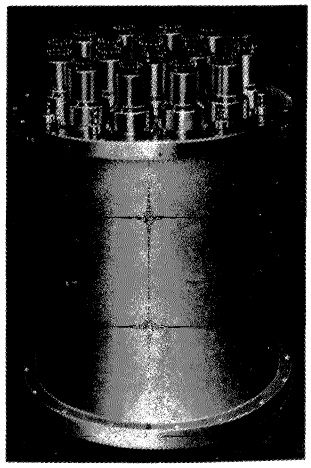
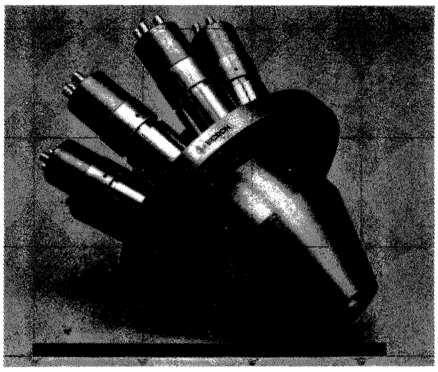


PSI LADS BARREL DETECTOR
Bicron BC-408 scintillator / light pipe assemblies



BOSTON UNIVERSITY
A 47cm x 56cm NaI(Tl) spectrometer providing 1.3% resolution for 130MeV photons





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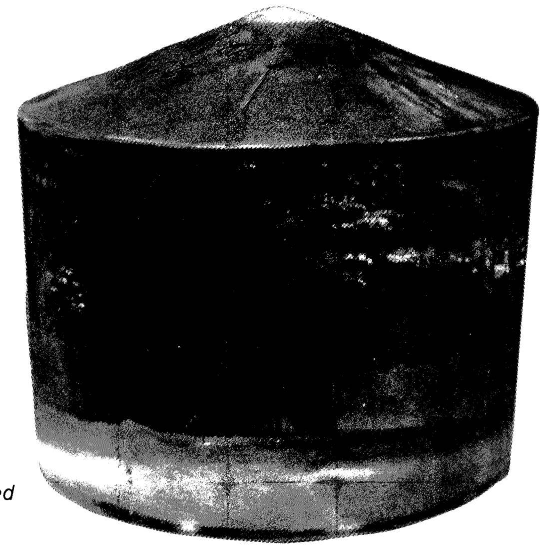

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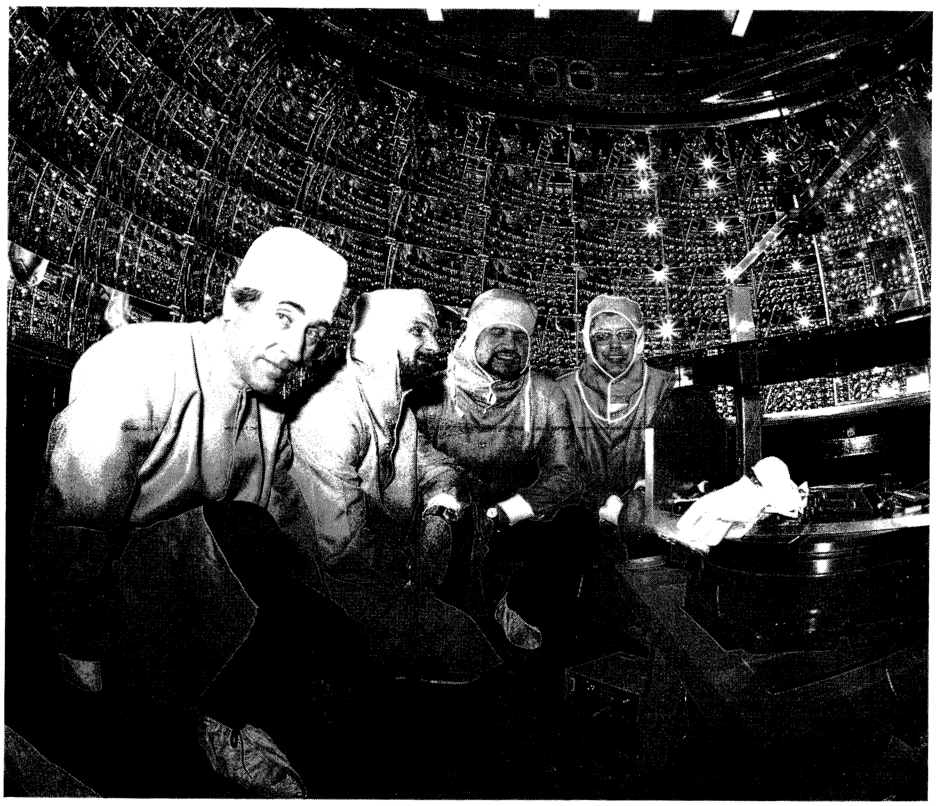
Wirechambers in action

Clinical cleanliness for the mirrors of the barrel Ring Imaging Cherenkov Counter (RICH) for the DELPHI detector being assembled for CERN's new LEP electron-positron collider. 288 of these parabolic mirrors have been manufactured by Bofors, Sweden, following a method developed at CERN. They give excellent reflectivity of 85 per cent in ultraviolet light and an angular resolution of about a milliradian. RICH progress was covered at the recent Vienna Wirechamber Conference.

(Photo CERN 126.2.89)



For a specialist meeting, the traditional Vienna wirechamber conference covers a large range of science and technology. Its roots are in particle physics – where many detectors using this technology have been developed – but applications continue in other fields such as medicine, astrophysics and condensed matter studies.

Medical applications were stressed in the introductory talk and in a special discussion session by detector wizard Georges Charpak (CERN), inventor of many of the basic wirechamber techniques.

For some years good ideas have been emerging for wirechamber applications in radiography, tomography and nuclear medicine, but none of them had been generally adopted. Now a possible breakthrough may have been made in the Soviet Union. L.I. Shekhtman of Novosibirsk described a clinical X-ray scanner using a point source lined up with horizontal slits in front of and behind the patient, and an ingeniously designed wirechamber behind the second slit to pick up unscattered X-rays. Each 50-mm sensewire points directly at the point source so there is no parallax when X-rays convert at different depths in the gas (xenon-CO_2) mixture. The device is scanned vertically over the patient, giving a very modest radiation dose. Wire hits are converted by online computer into a projected image with good contrast and millimetre resolution. Three such units are already in use in USSR hospitals, one of them in a Moscow gynaecology clinic where it is particularly useful in comparing the sizes of the unborn baby's head and the birth canal. Ten more scanners are being built for other hospitals and plans are being drawn up for industrial manufacture.

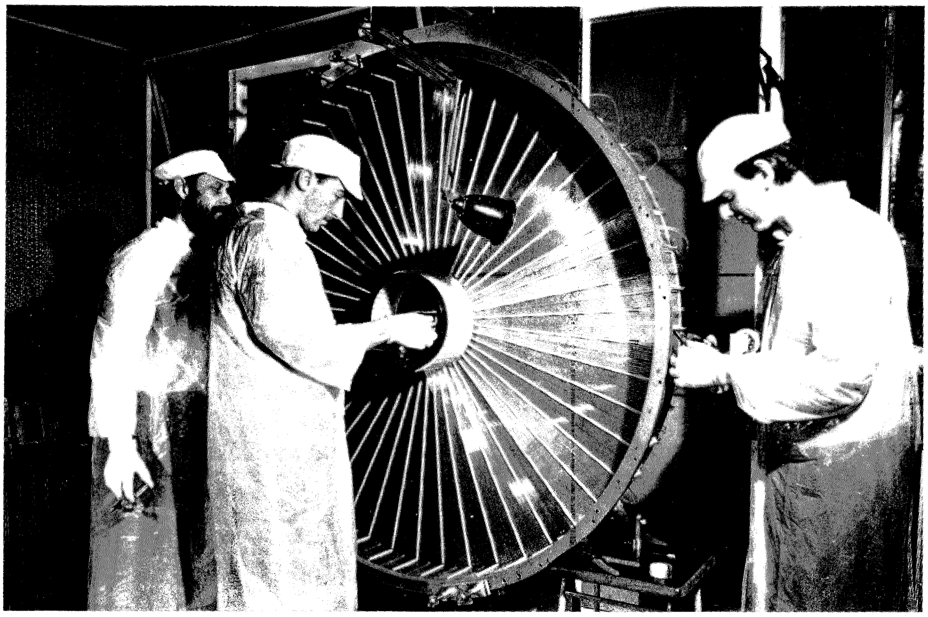
Other medical applications come from a growing class of detectors exploiting the conversion of ultraviolet photons to electrons in the gas of a multiwire or drift chamber. A number of groups use it in positron-emission tomography (PET), where the characteristic back-to-back gamma-rays from the annihilation of a stopped positron with an atomic electron leads to a precise picture of the radioactive tracer in a patient's body.

One promising PET approach is to convert the gamma rays to ultraviolet scintillation in thin barium fluoride crystals mounted between multiwire proportional chambers containing the low ionization energy gas TMAE. Electrons released in the gas by absorption of ultraviolet light are multiplied by the chamber to give a clear signal, and coincident signals in chambers on either side of the patient give the line of the back-to-back gammas, again with millimetre precision. London's Royal Marsden Hospital has given Eddie Bateman of the UK Rutherford Appleton Laboratory a contract to build such a system, based on prototype work by a Delft group, reported in Vienna by R.W. Hollander.

TMAE is used in a similar way to convert near-ultraviolet Cherenkov light into electrons in the ring-imaging Cherenkov counters (RICH) used in particle physics. Examples reported at Vienna included the impressive and elaborate devices being built for experiments at big new electron-positron colliders.

The 'CRID' for the SLD detector at Stanford's new SLC linear collider (reported by Greg Hallewell) and the RICH for the Delphi experiment at CERN's LEP collider (reported by Stefan Haider) both drift electrons for more than a metre on an array

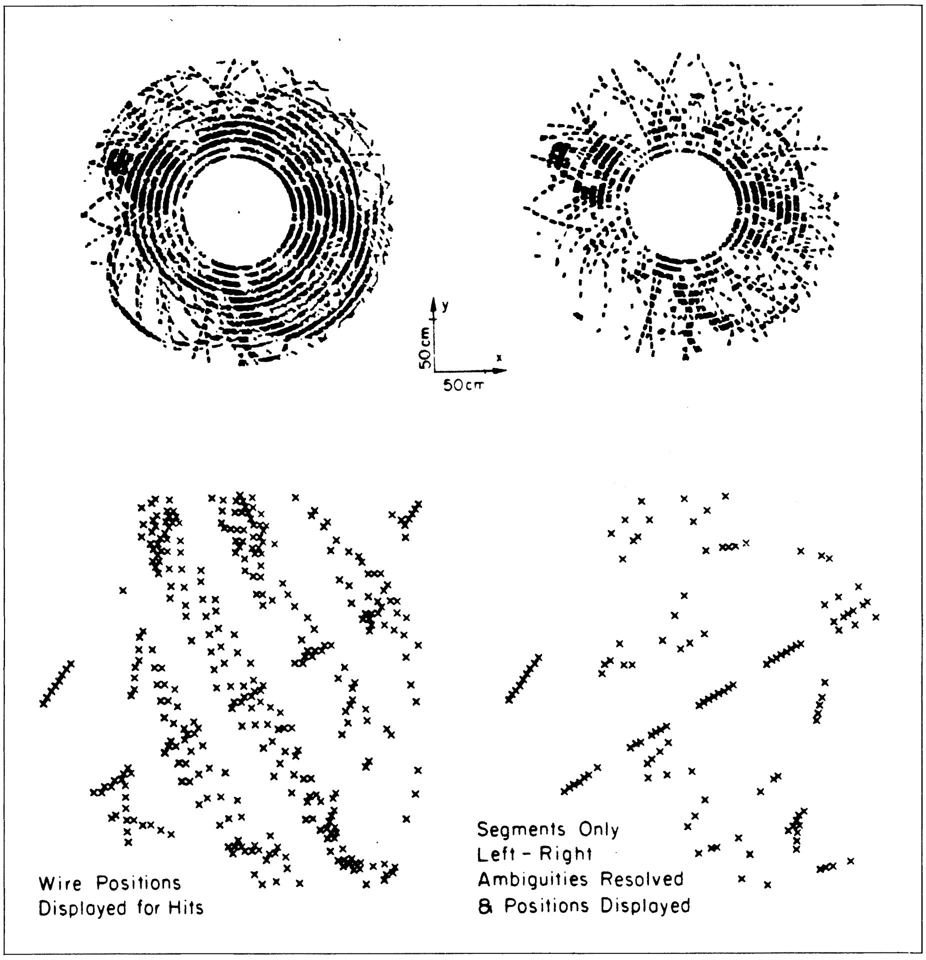
The 1104th wire is in! One of the radial-wire drift chambers being built at Liverpool for the HERA electron-proton collider under construction at the German DESY Laboratory in Hamburg.



of carefully shielded sensewires. The diameter of the ring of converted electrons, coming from a focussed ring of Cherenkov light, measures the velocity of the particle passing through the radiator. If the particle momentum is known from curvature in a magnetic field, then its mass can be calculated and identification made. These are both elaborate and complicated detectors, full of new technology, but prototypes have given very encouraging results. Delphi's RICH will be in action later this year when LEP begins operation.

David Anderson (CERN and Fermilab) pioneered the use of thin condensed layers of liquid TMAE on chilled metal cathodes to convert ultraviolet photons. Vladimir Peskov at CERN has found other liquids even more efficient as photocathodes for vacuum ultraviolet photons. To underline how safe these liquids can be, he paused in his talk to take a swig from a bottle of ethyl ferrocene.

Graham Beck reported on a radial-wire drift chamber (see photo) being built at Liverpool for the H1 detector at the HERA electron-proton collider under construction at the German DESY Laboratory in Hamburg. This will both track forward-produced particles resulting from the collisions, and convert transition-radiation X-rays from



Gail Hanson's group at Stanford is looking at the detectors needed to cope with the flood of particles produced at the next generation of proton colliders. While simulations of typical 40 TeV (40,000 GeV) proton-proton collisions look daunting (top left), powerful track-finding algorithms clean up the picture, and close-ups show clear track segments (below). The simulation assumed a 'straw-tube' chamber with each sensewire inside an aluminized mylar tube, making for a more rugged assembly.

layers of thin fibres in front of the chamber. Like the Novosibirsk clinical chamber, it is filled with a xenon mixture to convert X-rays.

Just as Cherenkov light can be used to identify particle masses up to a few tens of GeV, so transition radiation is used to identify highly energetic particles and to separate pions from electrons up to hundreds of GeV. The NA31 neutral kaon study at CERN (July/August 1988, page 7) has also just been fitted with a transition radiation detector (reported by Harry Nelson of CERN) to help reject background from the different decays of neutral kaons.

Impressive were the results from the giant Time Projection Chambers (TPCs) and their derivatives in today's collider experiments, including those for the experiments being installed at CERN's new LEP collider. Despite detector diameters and lengths of several metres, LEP experiments are citing track precisions of 100 microns.

The smaller pictorial drift chambers, called 'vertex chambers' because they help extrapolate tracks back to the interaction vertex inside the collider beampipe, are now achieving 20 micron resolution. To do this they use a 'slow' gas such as dimethylether (DME). Unfortunately DME attacks many otherwise useful materials, but M. Jilaby of Florida took a close look at DME compatibility.

Physicists grappling with the problems of the next generation of proton colliders were reassured by Gail Hanson of Stanford who has been looking into new kinds of central tracking devices. While the simulated raw data is frightening, track-finding algorithms quickly clean up the picture, and tracks soon begin to show up. With physicists pushing for bigger hadron colliders (such as LHC for the LEP tunnel at CERN and the proposed US Superconducting Supercollider, SSC), this work suggests that the detectors needed to extract the physics from these machines are no longer a dream.

From David Miller

25 years of CP mystery

A quarter of a century ago, great physics was happening at Brookhaven's Alternating Gradient Synchrotron (AGS). February 1964 saw the discovery of the omega-minus particle, confirming the underlying symmetry of the strongly interacting particles and opening the door to today's quark picture of particle constituents. Just a few months later came another major AGS discovery, eventually earning the Nobel Prize for James Cronin and Val Fitch in 1980. The two discoveries make an interesting physics counterpoint.

The omega-minus and its implications for the strong nuclear force can be packaged relatively easily for mass consumption (March issue, page 1), but the second 1964 AGS milestone has to be handled more circumspectly. Its message for the weak nuclear force (beta decay) is no less important, but 25 years down the line, the real physics behind this subtle effect is still largely uncharted.

In 1956, Tsung Dao Lee and Chen Ning Yang had suggested that the weak nuclear force might be very sensitive about the direction in which things happen. This was soon confirmed by a series of precision measurements of beta decay, showing that if the parent nuclei are lined up, the electrons prefer to come off on one side rather than the other.

This intrinsic 'handedness' also switches from particle to its antiparticle counterpart, so that physicists searching for a good weak force invariant turned to 'CP' – a combined particle/antiparticle and left/right reversal.

The strange world of the neutral kaon

When physicists say the neutral kaon is a strange particle, as usual they are being very precise. It carries an extra quantum number – strangeness – not found with ordinary nucleons but nevertheless rigidly conserved when the strong nuclear force is at work. However under the weak nuclear force the neutral kaon behaves strangely by anybody's standards.

The electrically neutral kaon and its antiparticle are distinguished only by their strangeness labels – good for strong interactions, but which get mixed up by the weak force. In the CP framework, the neutral kaon has two variants, useful because in the early 1960s physicists knew that the neutral kaon comes in two kinds – short-lived ones decaying into a pion pair, and others living about a hundred times longer before decaying into three pions. In a neutral kaon beam, the short-lived kind decay away in about 10^{-10} seconds, so that even after a few metres only the long-lived variety remains. The CP idea seemed to point in the right direction.

To dig deeper into neutral kaon physics, Cronin and Fitch, working with J.H. Christenson and René Turlay, wrote in 1963 an experimental proposal which ran to just a page and a half, in marked contrast to the detailed descriptions tabled by today's big collaborations. 'Fortuitously the equipment of this experiment already exists,' they wrote. The idea was to take a pion pair detector from the old Brookhaven Cosmotron and put it in the neutral beam from the new AGS. In addition, they would run parasitically with an upcoming study using muon beams.

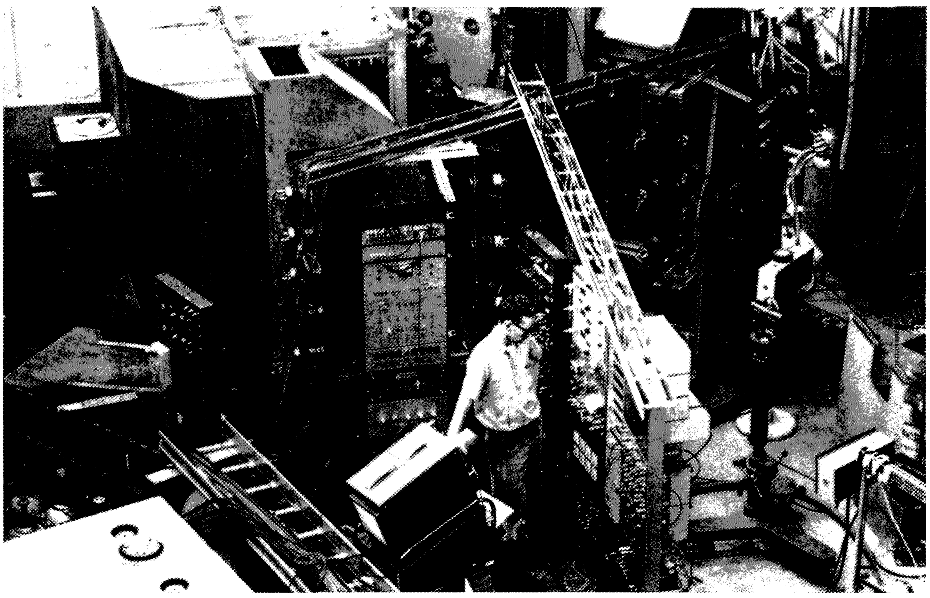
'If you can show that you don't cost anybody anything, they'll let you in,' said Val Fitch. And they went in fast. Just two months after the proposal was written they were taking data. The original aim of the experiment was to look at the delicate interplay of strong and weak neutral kaon interactions ('regeneration'), but by October, they had seen something else and, thinking they had fallen victim to unrepresentative statistics, waited for it to 'go away'.

In a sample of 22,700 long-lived kaon decays, and after painstakingly eliminating all spurious background effects, they were left with 45 examples where only two pions emerged (as in the short-lived decays). After trying for about six months to find a conventional explanation, they finally published their result – about one neutral kaon in five hundred decayed in a 'forbidden' way.

This mixing of the neutral kaon and its antiparticle by the weak nuclear force is unique among the commonly known particles and sets the stage for some enigmatic physics. (In 1987 experiments at CERN and at the German DESY Laboratory saw the first signs of analogous behaviour, but not CP violation, with the neutral B mesons carrying the beauty quantum number.)

CP violation is surely telling us something. It can be accommodated, but not explained, in a scheme linking the weak decays of particles using a total of six kinds of constituent quarks – possibly more, but certainly no less. To uncover the mechanism driving the effect is one of the major challenges facing today's particle physicists.

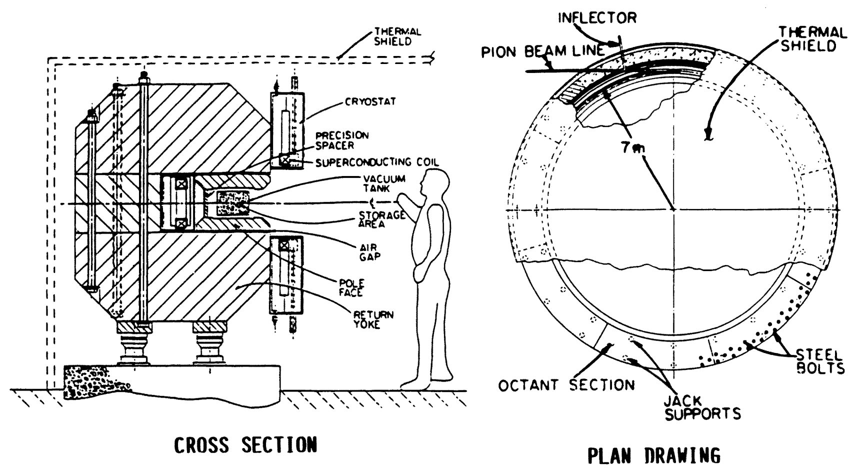
The high kaon fluxes promised by proposed new meson 'factories' would provide a useful new probe of CP violation (see page 16).



The modest setup of the Brookhaven experiment which 25 years ago discovered the puzzle of CP violation.

Around the Laboratories

Configuration of the new muon storage ring being built at Brookhaven for precision measurements on the magnetic moment of the muon.



BROOKHAVEN Running rings round muons

Since its discovery in 1938, the muon has been a mystery. 'Who ordered that?' asked the late Isidor Rabi incredulously on hearing the news of its discovery.

Why does the muon behave like a heavyweight electron, with 200 times the mass of the everyday atomic particle? In today's otherwise highly successful Standard Model with three 'generations' of basic particles, the muon is part of the membership fee. In this sense the mystery has merely deepened, and one of the goals of ongoing theory is at least to find a clue to this puzzle, if not solve it. A new experiment being mounted at Brookhaven will play a vital role in this effort.

Electrons and muons are electrically charged particles which spin on their own axis, and thus act as tiny magnets. According to classic 1930s quantum mechanics, this magnetic moment should point in the direction of the spin. However additional interactions, for example with the cloud of 'messenger' particles carrying the forces felt by the electrons and muons, produce tiny additional effects which shift the direction of the magnetic moment.

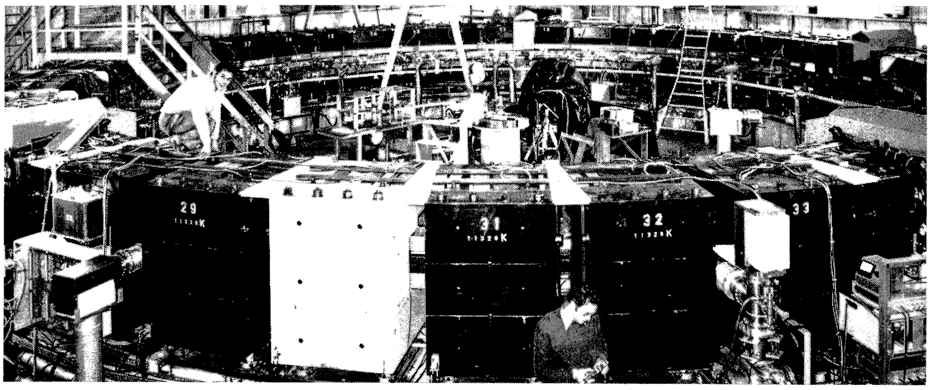
The explanation of this additional ('anomalous') magnetic moment (called g-2 in the trade) of the electron, agreeing with the best precision experiments could attain, has been one of the major triumphs of modern quantum electrodynamics. For the electron, only electromagnetic effects contribute significantly, but for the much heavier muon other mechanisms come into play.

An epic series of experiments at CERN during the 1960s and 70s centred on an increasingly accurate determination of the muon's magnetic moment, eventually attaining a precision of 7.2 parts per million. This muon g-2 value has played a central role in establishing that the particle behaves like a heavy version of the electron.

Meanwhile the theoretical prediction has also been refined as subtle additional radiative corrections have been calculated and as knowledge of other possible contributions has firmed up. It can now be written down to 1.3 parts per million, six times better than the experimental value. Nevertheless the astonishing agreement between theory ($1.16591947 \times 10^{-3} \pm 1.43 \times 10^{-9}$) and experiment ($1.1659230 \times 10^{-3} \pm 8.4 \times 10^{-9}$) shows that the muon is a very well behaved particle.

Now a new experiment is being built at Brookhaven to give 20 times better precision, down to 0.35 parts per million! In the same way that the original electron g-2 measurements underlined the validity of quantum electrodynamics, these new muon measurements will determine the contribution of the W and Z bosons, the carriers of the weak nuclear force, thereby testing the detailed formalism ('renormalizability') of the electroweak picture which links electromagnetism with the weak nuclear force. Discrepancies could also reveal new particles, such as additional carrier bosons or the long-awaited 'Higgs' particles which give electroweak particles their mass, and other possible new effects.

The new experiment, a collaboration of scientists from Brookhaven, Boston, City College New York, Columbia, Cornell, Fairfield, Heidelberg, KEK (Japan), Los Alamos, Michigan, Mississippi, Novosibirsk, Riken (Japan), Sheffield, Tokyo, and Yale, will follow the method



◄ *Classic experiments at CERN measured the magnetic moment of the muon with phenomenal accuracy.*

(Photo CERN 55.9.74)

▼ *Aerial view of construction progress at the Continuous Electron Beam Accelerator Facility (CEBAF), Newport News, Virginia, showing (right) excavation of the tunnel for one of the 0.4 GeV linacs, and one recirculating arc, eventually to connect with the second linac.*

pioneered at CERN. A muon storage ring will be built, 14 metres in diameter, with a homogeneous magnetic field and a quadrupole electric field.

Pions (supplied by the Alternating Gradient Synchrotron, AGS) injected into the new ring will decay into polarized (spin oriented) muons. The characteristic precession due to the anomalous muon magnetic moment will show up in the correlation between the spin direction of the muons orbiting in the ring and the distribution of the electrons produced when the unstable muons finally decay.

The ring will be operated at a momentum of 3.094 GeV, the so-called 'magic' figure where the g-2 precession frequency depends only on the magnetic field, not on the electric field. Since the precision of the precession frequency measurement depends on the homogeneity of the magnetic field, separated superferric bending and focussing elements will ensure that the magnetic field is homogeneous down to one part in 10 million, measured by nuclear magnetic resonance techniques.

The accuracy of the CERN experiment, impressive at the time, was limited by statistics. The Brookhaven experiment will have a more intense primary proton beam (producing the pions), and systematic errors (primarily due to the magnetic field uncertainty) will also be considerably reduced.

Present plans call for the storage ring and experimental apparatus to be built over the next four years, with commissioning in the fall of 1992. At this time the new AGS Booster ring will be in operation, giving the high intensity needed for the experiment.

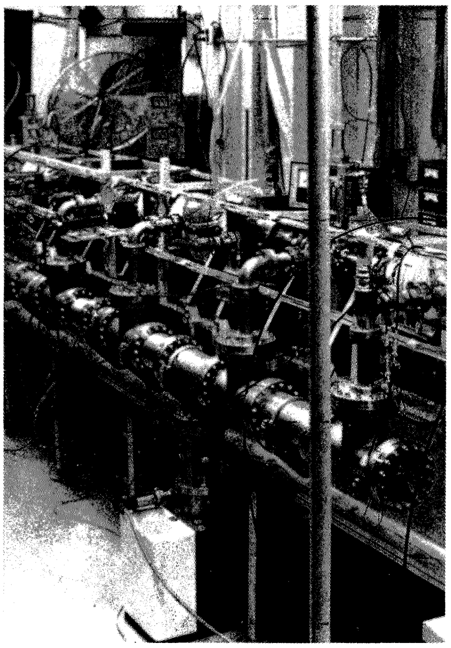
CEBAF
Construction progress

Tunnel construction and accelerator component prototyping, assembly and testing are all well underway at the Continuous Electron Beam Accelerator Facility (CEBAF), Newport News, Virginia. The 1.4 kilometre racetrack-shaped tunnel will house a pair of 0.4 GeV superconducting linear accelerators (linacs) connected by recirculation arcs. After five passes through the accelerator, continuous beams at up to 4 GeV will be extracted for simultaneous nuclear physics studies in three experimental halls.

The reinforced concrete enclosure for the injector area is complete, while excavation and concreting of the adjoining north linac and west arc is advancing.

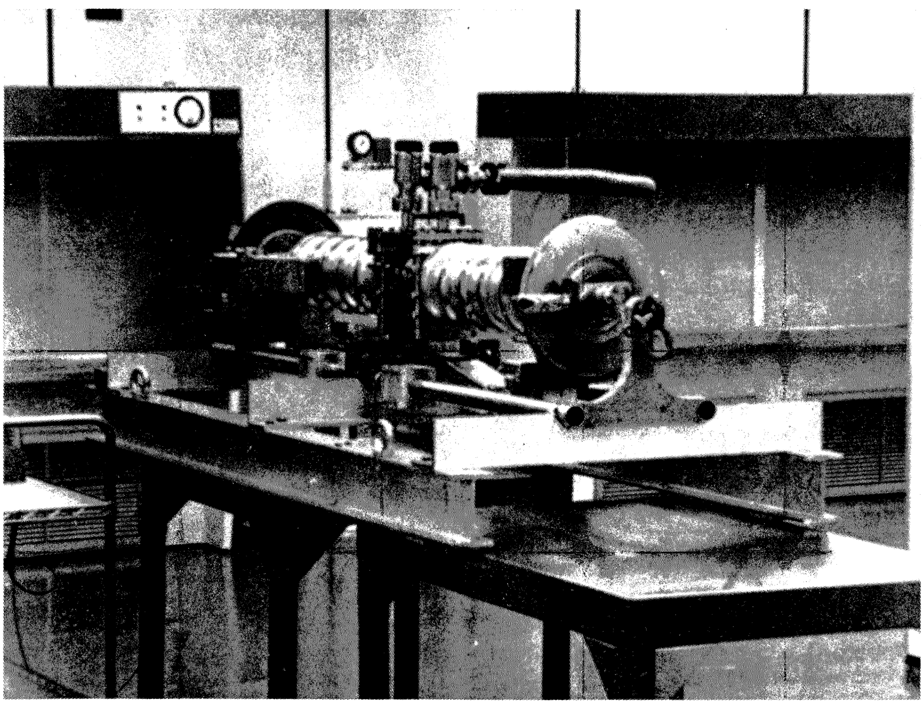
In CEBAF's test lab, chemical processing rooms and clean rooms are nearing completion to replace temporary facilities for preparing superconducting cavities from industry and assembling in their cryostats. Cavity and cryostat test areas have also been readied, and 2K liquid helium is available on site. Liquid helium for the accelerator will be supplied by a 4800-watt liquefier from CVI Inc.

Contracts for some 360 five-cell 1497 MHz niobium cavities will soon be placed. The first 9.6-metre eight-cavity cryostat built to production specifications and including components from industry is expected to be complete and tested by the summer. Major elements of the control system are in use for cavity, cryostat, radiofrequency and injector testing and for cryogenics. The injector gun has been operated extensively at 100 keV and meets beam quality require-



▲ *A 100 keV section of CEBAF injector beamline under test.*

▼ *A pair of five-cell superconducting radio-frequency accelerating cavities at CEBAF.*



ments. Bunching and capture sections have been installed, and acceleration to 500 keV is imminent.

Meanwhile the prospective nuclear physics users have been planning CEBAF's scientific programme and its necessary equipment. Late last year, a second round of letters of intent for experiments resulted in 90 replies from 233 physicists in 58 institutions. December saw the preliminary conceptual design report for this experimental equipment, including a pair of high resolution spectrometers for Hall A, a large acceptance spectrometer for Hall B and a high momentum spectrometer for use with additional user instrumentation in Hall C. Construction of these detectors will require major commitments among prospective users, and CEBAF has called for the necessary nuclear physics collaborations to be formed.

WORKSHOP
Scintillating fibre detectors

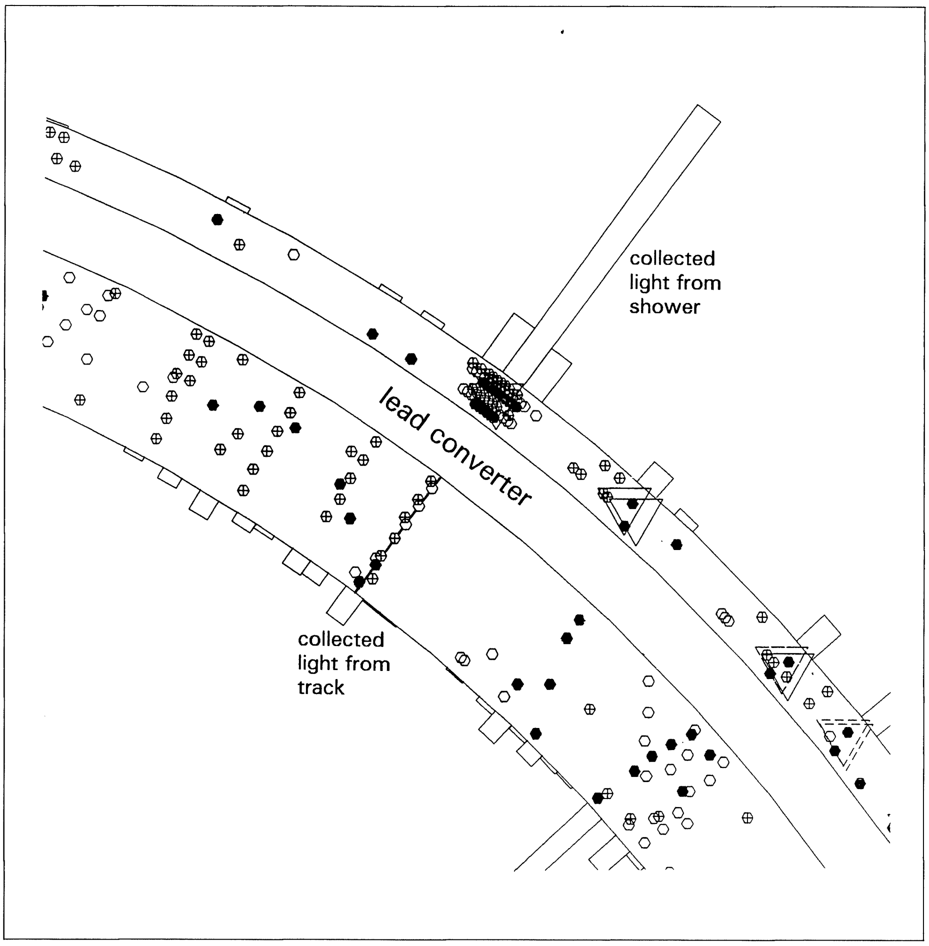
Scintillating fibre detector development and technology for the proposed US Superconducting Supercollider, SSC, was the subject of a recent workshop at Fermilab, with participation from the high energy physics community and from industry. Interest was so great and the agenda so full that the first two days' schedule lasted from 9.00 a.m. until after 10.00 p.m.!

Sessions covered the current status of fibre technology and fibre detectors, new detector applications, fluorescent materials and scintillation compositions, radiation damage effects, amplification and imaging structures, and scintillation fibre fabrication techniques.

Pioneer experimental data using scintillating fibres came from the new UA2 detector used very effectively for tracking and electron identification at CERN's proton-antiproton collider (June 1987, page 9). Other ongoing applications include the WA84 scintillation fibre target used at CERN to study B particle production, experiments E687 at Fermilab and E787 at Brookhaven, and Fermilab E774's ultra-high density tungsten-scintillating fibre electromagnetic calorimeter.

Turning to research and development efforts and new detector applications aimed at calorimetry (measurement of energy deposition), there were progress reports from the CERN/LAA spaghetti calorimeter project, the DELPHI small angle tagger and the University of Illinois lead/fibre electromagnetic calorimeter.

Tracking and identification of an electron in UA2's new scintillating fibre detector at CERN's proton-antiproton collider. The track shows up in the initial 18 layers of fibres, followed by a lead converter, where the electron produces a characteristic shower, picked up in an outer array of 6 layers of fibres.



The two sessions on fibre fabrication and fluorescent materials examined efforts to improve performance. Most scintillating fibre work uses standard plastic optical fibre technology and optical waveguides consisting of a polystyrene core with acrylic cladding. The thin fibres for use in future vertex detectors require materials giving high light output with minimal self-absorption. New organic scintillators with dopants achieving these properties were presented – for example PMP, developed in the context of the CERN/LAA scheme (October 1988, page 18). The discussion then turned to new techniques to improve the core/cladding interface and thus reduce troublesome multiple reflection losses.

The potential radiation damage from the intense SSC beams poses major challenges. Two review talks on radiation damage in polymers and on the design of radiation-hard materials gave a framework for future work on the radiation resistance of scintillation fibres. New studies of conventional plastic scintillator and on the development of new scintillator materials showed that the current technology can possibly be pushed as high as 10 Megarads.

The session on amplification and imaging devices covered a wide range of techniques – photomultiplier tubes, image intensifiers, CCDs and charge injected devices (CID). The new solid state photomultiplier developed by Rockwell International might provide excellent fibre tracking readout.

Summarizing, J.D. Bjorken correlated this emerging technology with the physics challenges of the next generation of fixed target and collider experiments. Scintillating fibre applications involving calorimetry show the most promise, with only small extrapolations of current technology needed to match physics requirements.

However tracking will require significant development in fibre performance (light yield and attenuation) and in readout technology. Although much work is still to be done, scintillating fibre detectors are already playing an important role and the general conclusion from the meeting was that this impact will increase significantly.

NEUTRINOS
Looking for oscillations

Several years ago, an Athens/CERN/Paris/Rome team working at CERN's 28 GeV PS proton synchrotron set out to look for possible decays of heavy neutrinos. No such effect was found, but as a by-product about a thousand neutrinos were captured in the downstream detector.

Coming from the decay of pions and kaons, the PS neutrino beam consisted mainly of neutrinos of the muon type, with less than one per cent of electron-type particles. However more neutrino interactions producing electrons were seen than expected, as though electron-type neutrinos made up about two per cent of the beam.

The setup of the Athens/CERN/Paris/Rome neutrino experiment at the CERN PS proton synchrotron with its helium gasbag which in 1984 saw an unexplained excess of electrons.

One possible explanation is neutrino 'oscillations'. In the conventional neutrino picture, these ethereal particles have no mass and the various types do not mix. But if the rules are slightly modified, the composition of a neutrino beam changes as it travels.

However the flimsy statistics of the experiment carried little weight, and the decision was taken to rerun with improved apparatus in the high intensity beam at Brookhaven's Alternating Gradient Synchrotron. (The collaboration now read Boston/Brookhaven/CERN/Paris.) The main part of the second-generation detector, 175 metres downstream of the neutrino source, was a 30 ton multiple sandwich of 3 mm iron plates and flash tubes of the type used by the Frejus (France) underground experiment looking for proton decay.

Again the electron-type neutrino content of the beam was estimated at less than one per cent. With 325,000 neutrino and 168,000 antineutrino events in the bag, careful analysis got underway, and after painstaking work to eliminate background effects and contamination, a net electron excess still remained, corresponding to about twice the estimated electron-neutrino content of the beam from the accelerator, tying in with the original result.

Despite the vastly increased data sample, the possible sources of error compound to reduce the reliability of the final result. The estimation of the electron-neutrino content of the beam also includes assumptions untested at the energies used by the experiment.

In the meantime many other experiments have looked for oscillations, without success, so the idea is going out of fashion, at least as far as terrestrial neutrinos are concerned. When it comes to neutrinos from outer space, there are still many interesting possibilities to explore.

WORKSHOP Electron-positron mystery

The tightly correlated electron-positron pairs seen in experiments at the GSI Darmstadt heavy ion Laboratory and elsewhere have yet to be explained. New particle or new effect? The question was highlighted at a recent Moriond workshop held at Les Arcs in the French Alps in January.

Fast-moving particles can experience enormous localized electromagnetic fields, and interesting effects can result. For example an electron traveling near the velocity of light can feel a magnetic effect due to its spin alignment that is comparable to its own rest mass. Other effects have been seen using the local fields inside crystals (June 1987, page 17). For two colliding heavy nuclear ions, these effects are large enough to produce electron-positron pairs. Moreover the electrons could be tightly bound, while the positrons are repelled by the positive electric charge of the nuclei and emerge alone.

Several years ago, experiments got underway at GSI to investigate positron production in heavy ion

How to visit CERN

Comment visiter le CERN

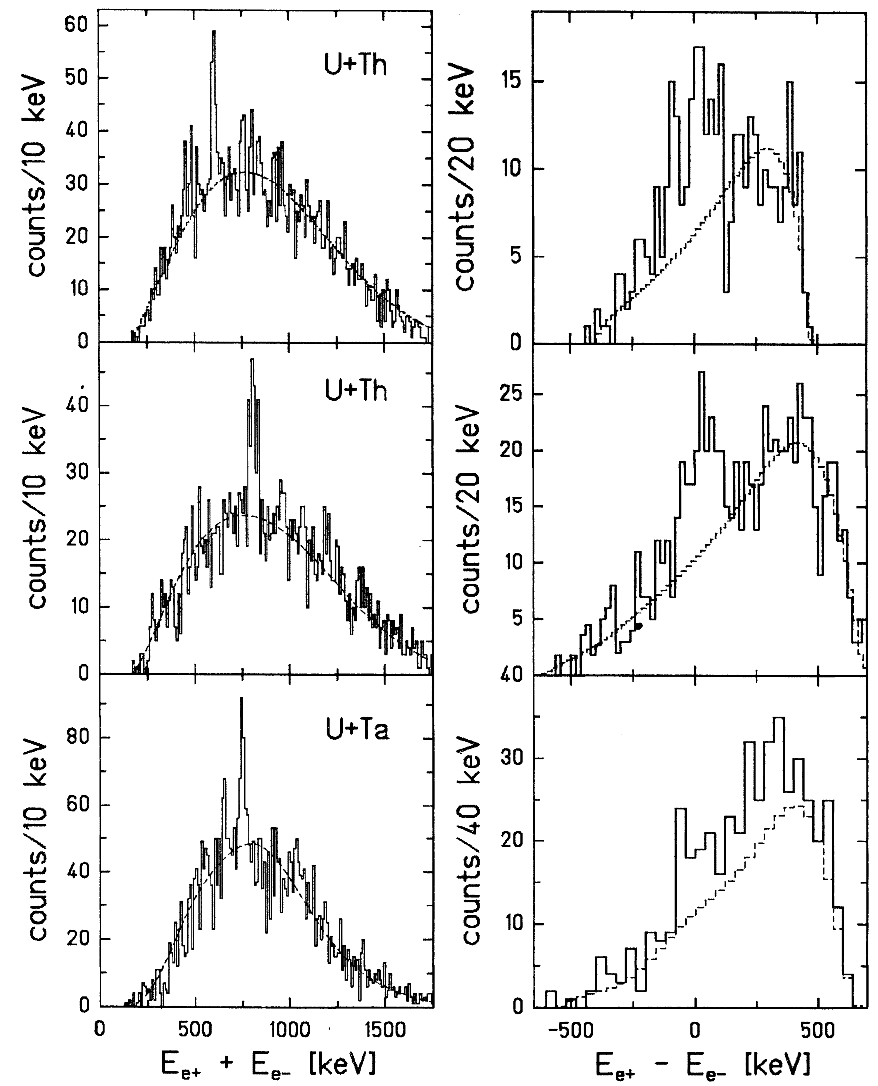
Organized visits take place only on Saturdays, at 9.30 a.m., and/or 2.30 p.m. The visits last about three hours and are free. The minimum age limit is 16 years.

Les visites commentées ont lieu seulement le samedi, à 9 h. 30 et/ou à 14 h. 30. Elles durent environ trois heures et sont gratuites. La limite d'âge minimum imposée est de seize ans.

Please write or call:
Ecrire ou téléphoner:

CERN
Visits Organization / Organisation des Visites
1211 GENEVA 23 Switzerland
Tel. 022/83 40 52 or/ou 83 41 02
Telex 419 000 CER

Left, sharp lines in the electron-positron spectra seen by the EPOS experiment at the GSI Darmstadt heavy ion Laboratory in collisions of uranium ions with thorium and with tantalum. Right, the energy difference of the electrons and positrons shows a much broader structure, suggesting that the particle pairs result from the decay of something at rest in the centre-of-mass of the colliding ions. (The energies are kinetic, and do not include rest masses.)



collisions. One unexpected result was the discovery by the EPOS experiment in 1985 of sharp positron peaks, and further investigation showed the positrons coming off back-to-back with electrons.

The Moriond meeting included detailed presentations of the ongoing heavy ion studies at GSI. P. Kienle reported on the ORANGE experiment with its additional spectrometer enabling electrons and positrons to be measured in coincidence. Recent data for uranium-uranium and uranium-lead collisions at energies around 5.9 MeV per nucleon show an 809 keV electron-positron line together with indications of additional lines. The electrons and positrons emerge back-to-back and the energies preclude conventional mechanisms (nuclear internal pair conversion).

The current status of the pioneer EPOS experiment was reviewed by D. Schwalm (Heidelberg) and P. Salabura (Frankfurt, Cracow). EPOS has now looked closely at collisions of uranium ions with thorium and with tantalum, and has consistently found a group of three sharp lines in the electron-positron energy spectrum, with broad distributions in the spectrum of the corresponding energy difference. The lines are at 608 ± 8, 760 ± 20 and 809 ± 8 keV with thorium and 620 ± 8, 748 ± 8 and 805 ± 8 with tantalum.

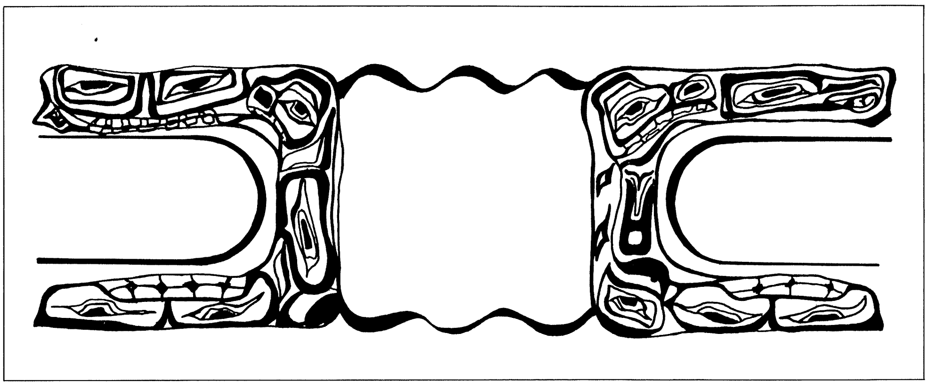
The narrowness of the lines together with the broad structure in the electron-positron energy difference suggests a cancellation of kinematical effects such as would occur if the two particles resulted from the decay of an object at rest in the centre-of-mass of the colliding ions. On the other hand, first direct measurements by EPOS of the correlation of the electron-positron pairs for uranium/tantalum show only the 620 and 805 keV lines being back-to-back decays, the 748 line being less easy to accommodate.

EPOS also sees how the line intensities depend on beam energy. The two GSI experiments do not see the same dependence of the production rate on total atomic mass.

Possible explanations concentrated on three themes. Strong field electrodynamics was the original motivation for the experiments and reproduces satisfactorily the smooth electron-positron background, but it is difficult to concoct a mechanism producing such sharp lines. Exotic new electrodynamics is another possibility, but no other such effects have ever been found. The third option is the decay of new extremely light particles, only a few times the mass of the electron. However such entities have not been seen in other searches, despite considerable effort. The results so far imply that the light particles would have to be more than about a hundred times the size of a nucleon, with the number of observed lines suggesting a complex behaviour. A. Schäfer reviewed the situation.

There was general agreement that more data is needed so that the unexplained lines can be better analysed. New projects were described by K. Stiebing (Frankfurt) for EPOS and F. Calaprice (Princeton) for the new APEX study to be installed at the ATLAS tandem linear accelerator at the US Argonne Laboratory (March 1987, page 22).

From H. Bokemeyer (GSI Darmstadt) and B. Müller (Frankfurt)



The logo of the recent rare decay symposium held at Vancouver – a possible mechanism for a forbidden decay, as seen through local Indian eyes.

SYMPOSIUM
Rare decays

Late last year, a symposium entitled 'Rare Decays' attracted 115 participants to a hotel in Vancouver, Canada. Contrary to the belief of some of the other clients of the hotel, these participants were not dentists, but particle physicists interested in checking conventional selection rules to look for clues of possible new behaviour outside today's accepted 'Standard Model'.

For physicists, 'rare decays' include processes that have so far not been seen, explicitly forbidden by the rules of the Standard Model, or processes highly suppressed because the decay is dominated by an easier route, or includes processes resulting from multiple transitions.

The timing and the location of the meeting followed a recent decision by Canadian federal and regional government to support a preconstruction study for the proposed 'KAON' project to provide intense particle beams, using the existing TRIUMF cyclotron as injector (September 1988, page 1). Such a scheme would provide increased precision for checking selection rules for the decays of kaons and heavier particles.

In his introduction, W. Marciano centred on the physics around the (Cabibbo-Kobayashi-Maskawa) matrix of six quark 'flavours' describing the quark transitions in weak decays. He pointed out the rich information coming in from the study of kaon decays, and the insights which would follow from seeing certain decays (kaon to pion and two neutrinos, or long-lived neutral kaon to neutral pion and electron-positron pair) made possible by multiple transitions. New physics would unblock conventionally forbidden processes such as the decay of a neutral kaon into a muon and an electron.

Still in kaon decays, Y. Kuno (TRIUMF) reported on the search for a pion and two neutrinos at Brookhaven, while W. Morse (Brookhaven), W. Molzon (Irvine) and T. Inagaki (KEK) looked at the search for a neutral kaon giving a muon and an electron in two experiments at Brookhaven and one at the Japanese KEK Laboratory. These groups are also looking for other forbidden neutral kaon decays, providing useful limits. Some decays (such as a neutral kaon into a muon pair) are ruled out by direct transitions but can go through subtle weak-electromagnetic routes and are seen at a low level.

M. Zeller (Yale) covered the quest at Brookhaven to find examples of a positive kaon going into a positive pion and two leptons (muon or electron). This also provides useful limits on other unconventional processes such as a neutral pion decaying into an electron-positron pair. This work at Brookhaven is continuing.

Turning to the physics of heavy quarks, F. Gilman (SLAC) explored the possibilities of using the B mesons (carrying the beauty quantum number) as a scenario for CP violation, a phenomenon seen so far only with neutral kaons.

Both the ARGUS experiment at the German DESY Laboratory (reporter J. Prentice, Toronto) and CLEO at Cornell (J.Kandaswamy) have seen how the neutral B mesons mix (like their lighter K meson counterparts), but the Cornell group cannot corroborate the charmless B decay claimed by ARGUS (October 1988 issue, page 3). The new CLEO II detector could clarify the situation.

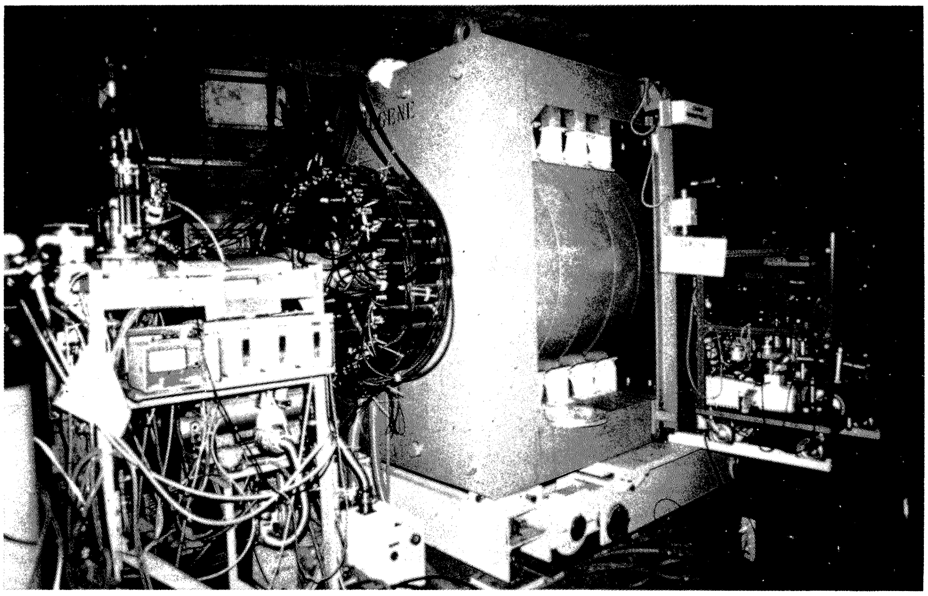
M. Perl reviewed the decays of the heavy tau lepton and looked at the possibilities of ideas for tau 'factories'. B. Holstein examined some additional kaon physics possible with a kaon factory. Summarizing the meeting, A. Astbury (Victoria) looked into a sometimes murky crystal ball but nevertheless foresaw a bright future.

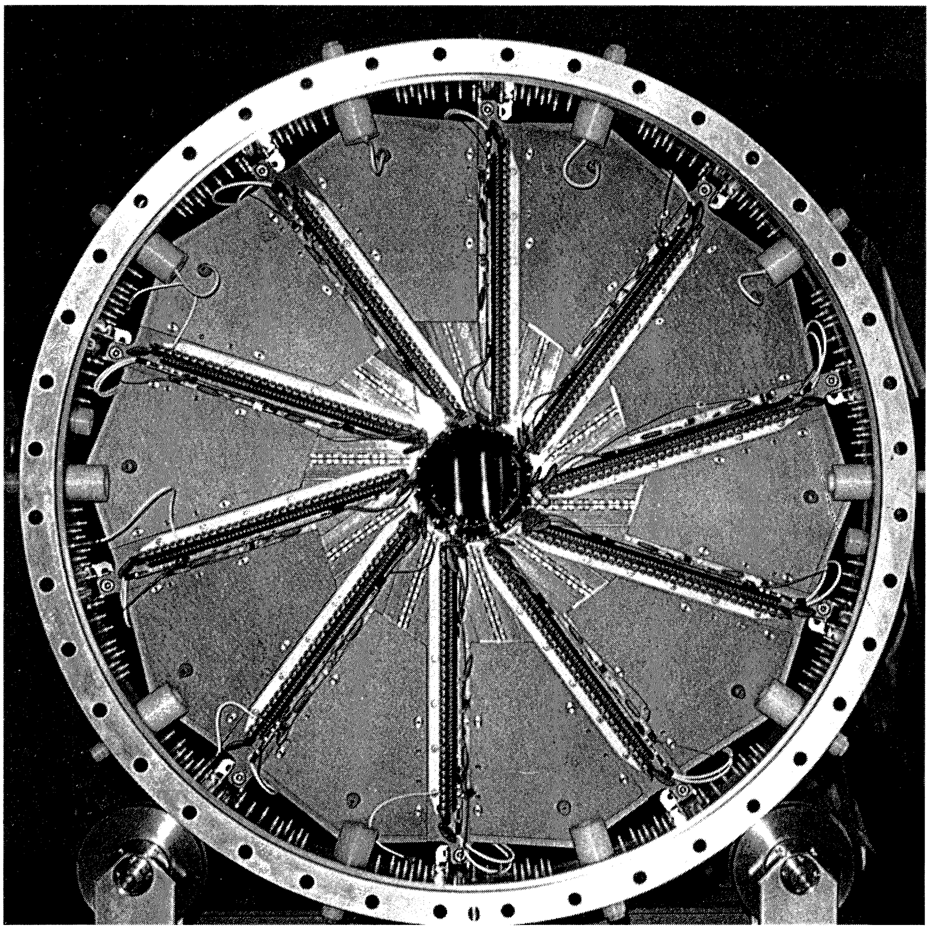
The symposium included a session on CP violation, but for the specialists the meeting was followed by a one-day workshop on the possibilities in this sector opening up at a kaon factory such as that proposed for TRIUMF. However fresh insights should still come from fixed target experiments such as NA31 at CERN, which has already measured important new CP violating effects (July/August 1988, page 7), and E731 at Fermilab (May 1988, page

16), together with new results from low energy experiments at CERN's LEAR low energy antiproton ring.

New CP information could come from additional three-body neutral kaon decay states (neutral pion and electron-positron pair), which need a lot of kaons. The polarization (spin orientation) of the muons coming from charged kaon decay has also whetted physicists' appetites.

Physicists love to poke around in odd corners of nature, looking for clues of unexplained new behaviour. This quest has paid dividends in the past and will surely continue to do so.





Above, the Diogene full solid-angle detector used for heavy ion physics at the Saturne II synchrotron at the French Saclay Laboratory, seen from the beam end. Below, an end-on view of the central Diogene chamber, showing its ten sectors of drift chambers.

SACLAY Diogene

Collisions of energetic (relativistic) heavy ions carrying from about 200 MeV to 1 GeV per nucleon open up the study of nuclear matter far from its equilibrium point, thus providing additional insights into the rules governing its behaviour (particularly its equation of state).

With this in mind, the Diogene full solid-angle detector at the Saturne II synchrotron at the French Saclay Laboratory was built by a Clermont-Ferrand/Saclay/Strasbourg collaboration. It uses a central cylindrical chamber whose 10 drift chamber sectors reconstruct electronically the trajectories of the secondary particles emerging from the nuclear collision and bent in a

Above, first of 646 superconducting magnets in the proton ring of the HERA electron-proton collider at the German DESY Laboratory in Hamburg.

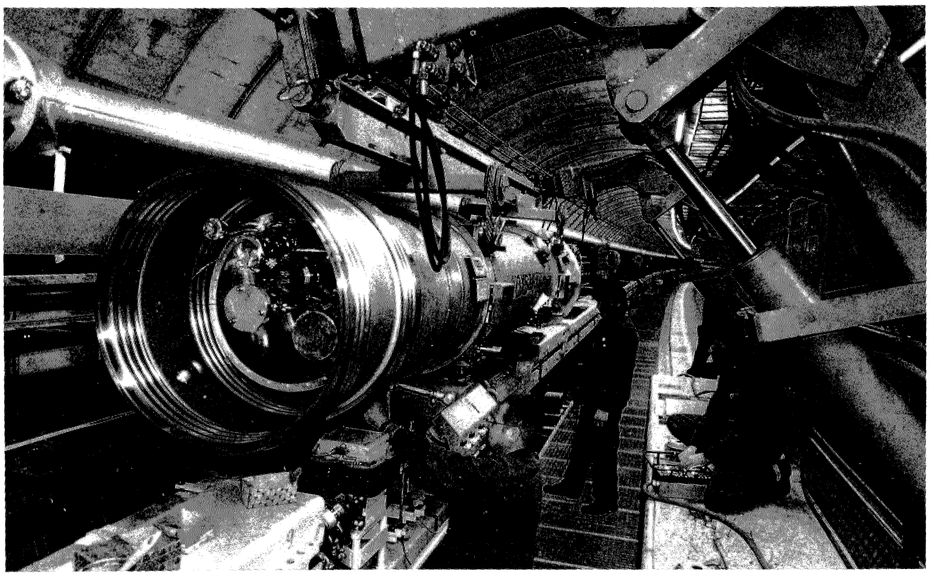
Supplied by the Canadian TRIUMF Laboratory, a radiofrequency accelerating cavity is installed in readiness for the HERA proton ring (below).

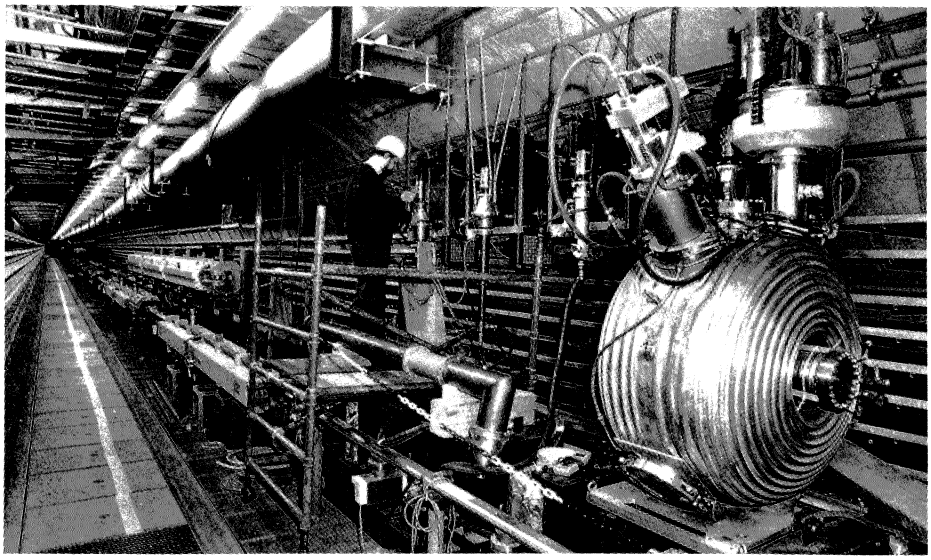
uniform 1 Tesla magnetic field provided by a solenoid. A barrel of 30 plastic scintillators surrounding the chamber can select different levels of multiplicity (number of secondary particles).

A wall of plastic scintillators completes the detector in the forward direction. Particle identification in the chamber follows from energy loss and track curvature measurements, while the plastic wall exploits energy loss and time-of-flight to differentiate between particles with different electric charges.

First Diogene studies (using alpha particles and neon ions) looked at production of pions (giving nuclear compression energy) and of protons (giving temperature, transverse energy,...). Two-particle correlation measurements probed hadronic matter densities after the initial expansion following the collision. Ongoing studies include measurements of the production of composite particles and of projectile fragmentation.

These initial results provide a useful new window on the behaviour of nuclear matter, and will be a useful lead-in to the results expected soon using the full solid-angle detector at the GSI Darmstadt heavy ion Laboratory.





DESY HERA progress

On 1 March, the first of 646 superconducting magnets was installed for the proton ring of the HERA electron-proton collider being built at the German DESY Laboratory in Hamburg. Over 150 of these magnets have so far been delivered from French, German and Italian industry. Before installation, magnets are tested and measured in a special hall at DESY.

In January, the iron structure supplied from the Soviet Union for the H1 detector at HERA was completed in its underground hall. Meanwhile 6-metre diameter aluminium disc supports for the depleted uranium calorimeter of the second HERA experiment, Zeus, were mounted. The two experiments will intercept HERA's first collisions in 1990.

HERA's electron ring stored its first beam last year (October 1988, page 20) and is now being prepared for the next run, scheduled for August, when radiofrequency power and other technical installations should then be ready to take beams to 26 GeV. Higher energies will result from superconducting accelerating cavities, to be installed later.

Proton injection is progressing well with the new Linac III injecting

50 MeV negative hydrogen ions into the DESY III proton synchrotron, which on 22 February supplied its first 7.5 GeV protons. From May, the modified PETRA ring will be tested out for its new role in preparing electrons and protons ready for injection into the main HERA ring.

WORKSHOP
Thermal field theory

The early history of the Universe is a crucial testing ground for theories of elementary particles. Speculative ideas about the constituents of matter and their interactions are reinforced if they are consistent with what we suppose happened near the beginning of time and discarded if they are not. The cosmological consequences of these theories are usually deduced using a general statistical approach called thermal field theory.

Thus.75 physicists from thirteen countries met in Cleveland, Ohio, last October for the first 'Workshop on Thermal Field Theories and their Applications', sponsored by the US Department of Energy and Case Western Reserve University and organized by K. Kowalski (Case), N. Landsman (Amsterdam), and Ch. van Weert(Amsterdam).

One of the originators of the modern era of gauge field theories in thermal equilibrium, R. Jackiw (MIT), spoke about new methods for describing the nonequilibrium processes believed to be a crucial but poorly understood feature of the evolution of the Universe. With a full programme of talks, this subject was a major feature of the workshop and seems to be a growth area for future research.

Quantum chromodynamics (QCD), the theory of the quark constituents of hadrons, was the scenario for most of the talks on equilibrium methods. There was a special panel discussion on recent problems in perturbative thermal QCD relating to the occurrence of plasmons. In other applications of the equilibrium theory, A. Das reviewed the situation in supersymmetry at finite temperature and R. Norton (UCLA) spoke about superfluidity. Two half-day sessions covered applications to the early Universe.

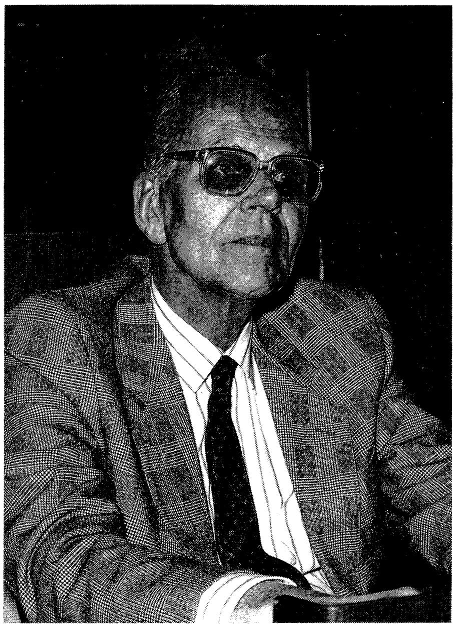
After extensive reviews of gravity theory and the 'inflation' modulating the initial Big Bang, E. Mottola (Los Alamos) spoke about particle number violation at high temperature while L. Wijewardhana (Cincinnati) outlined results on temperature-induced effects. The statistical mechanics of domain walls and cosmic strings and their effects on phase transitions were discussed by E. Copeland (Fermilab), H. Hodges (Santa Cruz) and R. Rivers (Imperial College London). A special session on the statistical mechanics of strings, especially fundamental strings, concluded with a general forum on the physical interpretation of thermal string theories above the Hagedorn temperature (when further heating starts to boil off pions).

The 2nd Workshop on Thermal Field Theories and their Applications will be held in Tsukuba, Japan in 1990.

Organizing committee of the Thermal Fields Workshop held recently at Case Western Reserve University, Cleveland, Ohio. Left to right N. Landsman (Amsterdam), K. Kowalski (Case Western) and Ch. van Weert (Amsterdam).

People and things

Leon Van Hove – 65 in February



Leon Van Hove 65

A special symposium at CERN on 20 February marked the 65th birthday of Leon Van Hove, eminent theorist and phenomenologist and CERN's Research Director General from 1976-80. With Maurice Jacob as session chairman, Wolfram Kittel highlighted Van Hove's talents in developing incisive pictures to describe the apparently complex phenomena of multiple particle production. Van Hove explained that he had seen this physics as an excellent means of exploiting the mass of off-resonance bubble chamber data which was otherwise discarded.

DESY Director Volker Soergel took over to summarize Van Hove's impressive career, with its beginnings in mathematics and then in solid-state physics and statistical mechanics. Arriving at CERN in 1960 to lead the Theory Division and confront particle physics, he went on in 1971 to succeed Werner Heisenberg at Munich's Max Planck Institute for Physics and Astrophysics. Van Hove's eventful five-year mandate as Research Director General saw the first fruits of experiments at the then new SPS proton synchrotron, the monumental decision to go for the proton-antiproton collider, which was to bring unprecedented honours to CERN, the careful grooming of the proposal for the LEP electron-positron collider and the start of preparations for its experimental programme.

Not covered by the speakers but no less important for that have been his widespread interests away from the front line of research, including his role in organizing the joint CERN/European Southern Observatory Symposia on Astronomy, Cosmology and Fundamental Physics, his work in pan-European research committees, and his efforts to further CERN's public image. CERN publications in general and the CERN Courier in particular have benefited considerably from his interest and constructive criticism.

On people

Theorist **John S. Bell** of CERN receives the 1989 Dannie Heineman Prize for Mathematical Physics, administered by the American Physical Society and the American Institute for Physics, 'for his numerous incisive original contributions to quantum theory and elementary particle physics; in particular for the Bell inequality, which has played a major role in theoretical and experimental work on the foundations of quantum mechanics'.

Sam Berman of Berkeley is the first recipient of the US Department of Energy Sadi Carnot Award. An eminent particle theorist at the Stanford Linear Accelerator Centre until 1977, Berman receives the award 'for his pioneering and creative contributions to the application of scientific methods in the areas of heat and light transfers in window materials and in the conversion of electricity to visible light; and for his contributions to the translation of these insights to the development of practical, economically viable products with the potential to save significant amounts of energy by reducing losses in windows and lighting'.

The Prix Paul Doistau/Emile Blutet of the Institut de France, Académie des Sciences, goes to **Jean-Marc Gaillard**, currently continuing an important role in the UA2 experiment at CERN's proton-antiproton collider. The prize, to be awarded in December, recognizes his important contributions to the study of weak nuclear interactions. After participating in the famous 1961/2 Brookhaven neutrino experiment with Leon Lederman, Mel Schwartz and Jack Steinberger, he helped make important measurements of the decays of neutral kaons and of hyperons.

A meeting at Caltech in January marked (some months prematurely) the 60th birthday of 1969 Nobellist **Murray Gell-Mann**. Speakers reflected the wide range of Gell-Mann's interests and accomplishments – complex systems, environment, society and the human mind as well as the fundamental laws of physics.

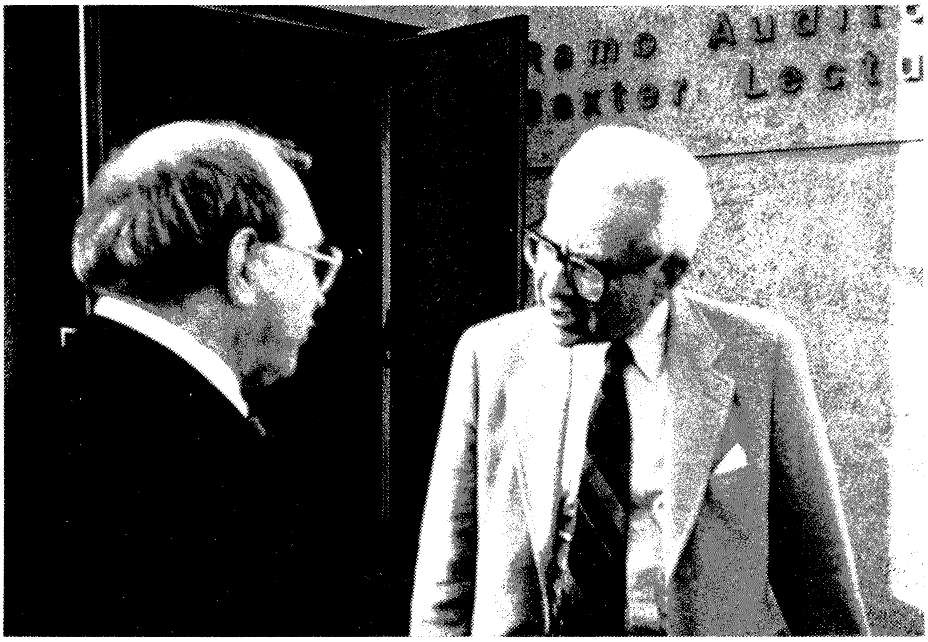
At a brief ceremony at the West German Consulate in Geneva on 24 February, **Dettmar Wiskott**, former CERN computer specialist who retired last year, received the Bun-

desverdienstkreuz (Federal Service Cross) in recognition of his 22 years of social work for the German community in the Geneva area.

Theorist ***Sidney Drell,*** *deputy Director of the Stanford Linear Accelerator Center (SLAC), has resigned as co-director of Stanford University's Center for International Security and Arms Control, a post he has held since 1983.*

Marcel Lazanski *has formally retired from CERN after many years as Leader of Finance Division. He was one of the pioneers at the Laboratory, helping to build the first CERN accelerator, the 600 MeV synchro-cyclotron, in the mid 1950s. He joined Finance Division in 1971 and in his farewell address to CERN Council he could look back on 1440 contracts, 600,000 orders and 1.2 million invoices for a total close to 6 billion Swiss francs.*

Alvin W. Trivelpiece, *formerly Director of the Office of Energy Research in the US Department of Energy, is the new Director of the US Oak Ridge National Laboratory, succeeding Herman Postma.*



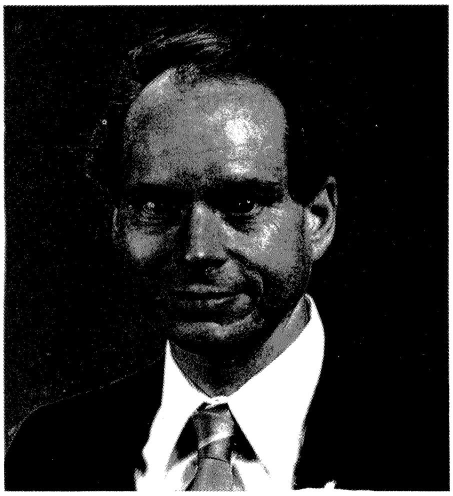
With Murray Gell-Mann (top right) at his 60th birthday event at Caltech is Yuval Ne'eman, co-author with Gell-Mann of the famous 'Eightfold Way' in the early 1960s (March issue, page 1).

Superstring superstars. Also at the Gell-Mann 60th birthday event were (below, left to right) Mike Green, Ed Witten and John Schwarz.

(Photos M. Jacob)

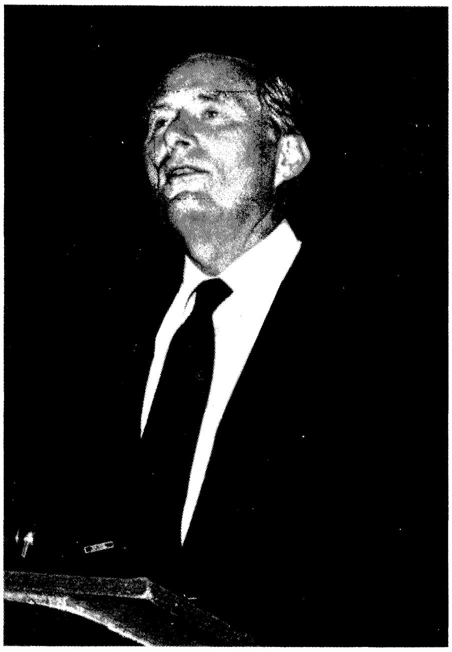
Fermilab moves

New appointments at Fermilab include Gerald Dugan as Head of Accelerator Division, replacing Helen Edwards, who has commitments to the proposed US Superconducting Supercollider, SSC. In Fermilab's Research Division, Robert Kephart becomes head of the CDF collider detector. For the CDF scientific collaboration, the spokesmen are now Alvin Tollestrup of Fermilab and Melvin Shocket of Chicago. Following the departure of Bruce Chrisman, Richard Lundy, Fermilab's Associate Director for Technology, becomes also Acting Director for Administration.



Gerald Dugan becomes Head of Fermilab's Accelerator Division.

Sir Alec Merrison 1924-1989



Sir Alec Merrison 1924-1989

CERN and the world of physics suffered a great loss at the sudden death on 19 February of Sir Alec Merrison.

Entering particle physics at the UK's Harwell Laboratory and the University of Liverpool, he arrived at CERN in 1957, where he collaborated in the historic first experiment at the new Laboratory, the measurement at the Synchro-Cyclotron of the decay of a charged pion into an electron. He returned to the UK in 1960 where he went on to become founding Director of the Daresbury Laboratory from 1962-69, overseeing the construction and commissioning of the NINA electron accelerator. In 1968-69 his working party made valuable recommendations on CERN's administrative structure, and his talents continued to be widely sought. His Presidency of CERN Council from 1982-84 was characterized by his adroitness and impeccable courtesy. Although a modest and unassuming person, he made his mark in government, commerce and the arts as well as in physics.

Alan Rittenberg 1938-1989

Alan Rittenberg died on 3 January after a long illness. After graduate research work with the Alvarez group at Berkeley, he went on to become a group leader in the Particle Data Group, and for nearly two decades was responsible for the organization, preparation and production of the Review of Particle Properties, the particle physicists' bible, and other publications. His attention to detail and constant striving for excellence played a major role in the accuracy and integrity of these works, from which the entire particle physics community has benefited.

Spinoff marketing

Lake Shore Cryotronics of Ohio has been granted exclusive rights to market a technique developed at Los Alamos for measuring the quality of new high temperature superconductors. The brainchild of Los Alamos engineer James D. Doss (November 1988, page 32), the eddy current technique will be incorporated into a new market product. In 1988, Los Alamos was one of the US National Laboratories selected to spearhead ongoing superconductor research and development. The agreement also follows a US Department of Energy directive urging laboratories to share new technology with industry.

Three share Panofsky Prize

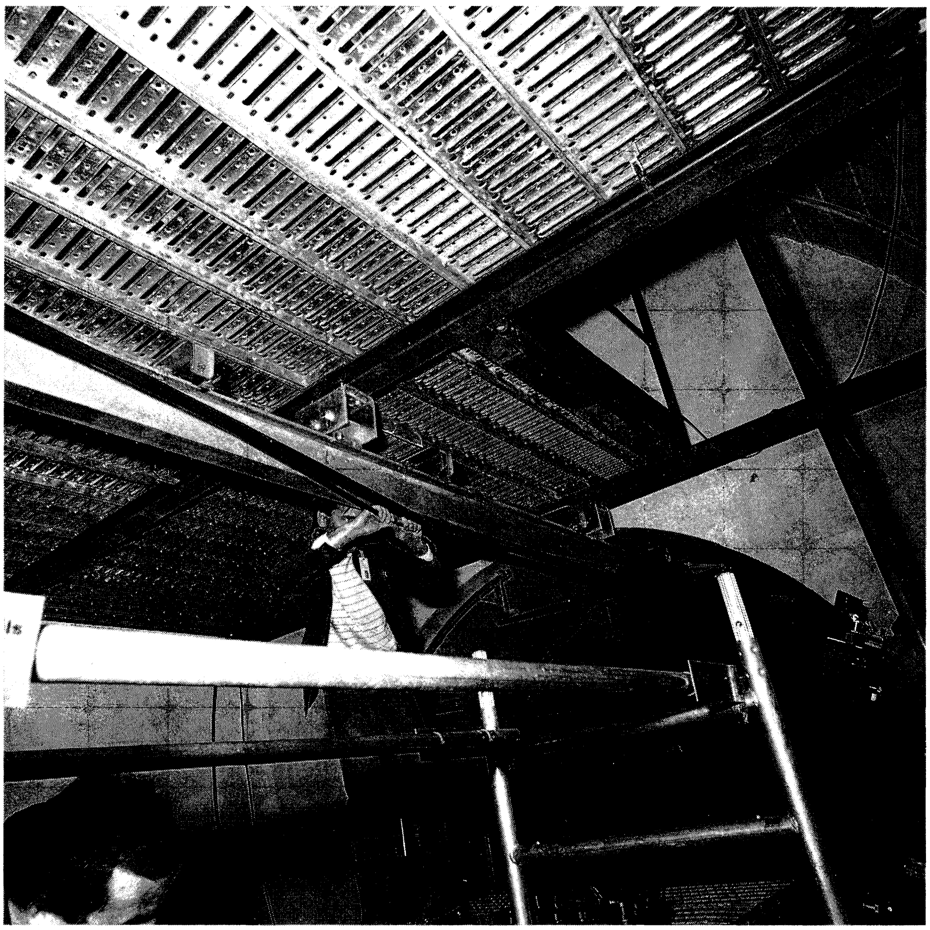
This year's Wolfgang K.H. Panofsky Prize (sponsored by the Division of Particles and Fields of the American Physical Society) will be awarded in May to Jerome Friedman and Henry Kendall of MIT and Richard Taylor of the Stanford Linear Accelerator Center (SLAC) for their leadership in the first 'deep-inelastic' electron scattering experiments which explored the far interior of nuclear particles.

According to the citation, 'These electron-nucleon scattering experiments, which were a vehicle for the discovery of the 'scaling' phenomenon, gave the first direct evidence for a charged, pointlike substructure inside the nucleon.' Further experiments with electron, muon and neutrino probes went on to show that these pointlike constituents were in fact the quarks predicted in the early 1960s by Murray Gell-Mann and George Zweig and paved the way for later physics advances.

As leaders of the famous MIT-SLAC collaboration, Friedman, Kendall and Taylor played a vital role in the conception and development of 'End Station A' at SLAC during the 1960s. This powerful complex of magnetic spectrometers, detectors and computers pointed the way for much subsequent fixed target work.

With civil engineering work for HERA complete, Hamburg mayor Ingo Münch hands DESY Director Volker Soergel the symbolic key to the HERA buildings.

(Photo DESY)

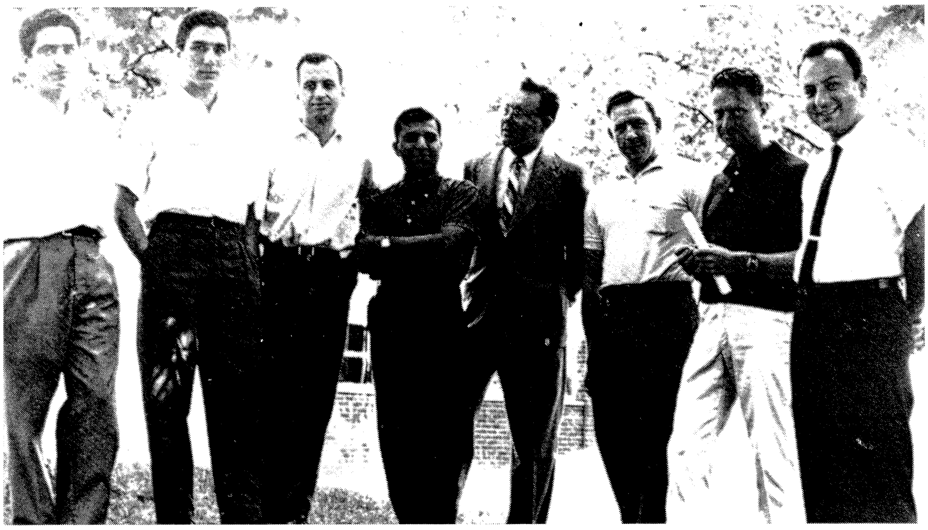


Welding the last rail link for the monorail transport system in CERN's new LEP electron-positron collider on 21 February. Within minutes, LEP components were being ferried across to begin installation of the last remaining octant of the machine. First LEP beams are scheduled for this summer.

(Photo 350.2.89)

Fermilab patent

Home to the world's largest single application of superconductivity – the four-mile Tevatron ring – Fermilab has been granted a patent for a new cryogenic support system developed at the Laboratory providing high structural strength with excellent thermal properties. Thermal efficiency results from low thermal conductivity materials configured with long heat transfer paths, along with heat interception and good insulation. Structural integrity follows from high strength materials with good cryogenic properties. The support can be configured for a wide variety of designs and simple geometries ensure precision quality production. Called the Compact Cryogenic Support (CCS), it is also a feature of the dipole magnet scheme for the proposed US Superconducting Supercollider, SSC.



CERN's phone number

From 22 April, CERN's general telephone number will change from Geneva 836111 to Geneva 767 6111. For direct dialling, use 767 followed by the four-digit internal number. Thus the CERN Courier's new number will be Geneva 767 4103. (The international dialling code for Geneva ends with 4122.)

Meetings

Hadron 89, the Third International Conference on Hadron Spectroscopy, to take place in Ajaccio, Corsica, France, from 23-27 September, will cover the important developments since Hadron 87 (KEK Japan) and look to the future. Participation will be limited to 120. Titles of contributions should be submitted as soon as possible with names of authors and the suggested speaker. Deadline for abstracts is 1 June. Further information from J.P. Stroot, EP Division, CERN, CH 1211 Geneva 23, Switzerland, bitnet hadron89 at cernvm.cern.ch

The 1989 Banff NATO Advanced Study Institute on Physics, Geometry and Topology will be held in Banff, Alberta, Canada, from 14-25 August. Further information from H.C. Lee, Theoretical Physics, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada K0J 1J0.

Neutrino line-up, continued. Top, the Brookhaven/Columbia neutrino experiment group pictured at Brookhaven in 1962 – left to right, Jack Steinberger, Dino Goulianos, Jean-Marc Gaillard, Nariman Mistry, Gordon Danby, Warner Hayes, Leon Lederman, Mel Schwartz. When Lederman, Schwartz and Steinberger received their physics Nobel Prize in Stockholm last year, former CERN Theory Division Leader and indefatigable physics personality photographer Maurice Jacob almost succeeded in reconfiguring the group. Only Warner Hayes was missing (middle photo). However at Brookhaven in February, Laboratory photographer Roger Stoutenburgh had the full lineup (bottom).

STR330 CERN Host Interface and Processor System - CHIPS -

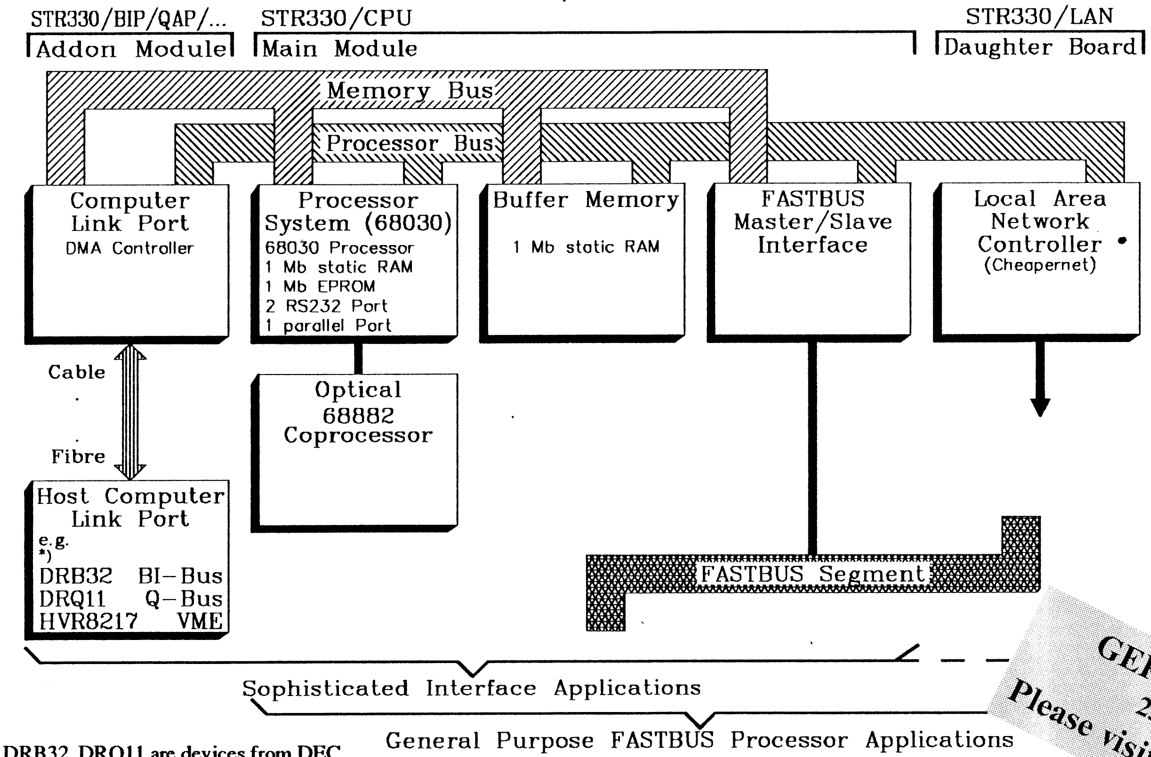
The STR330 CHIPS aims to provide:

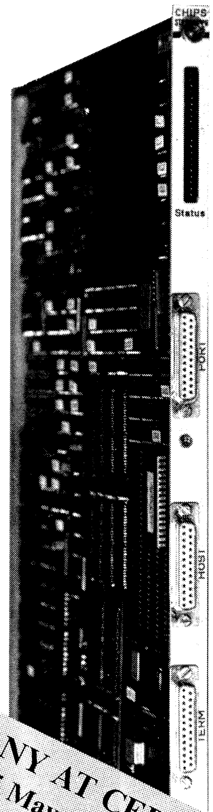
* **Modular and versatile state of the art interfacing between FASTBUS segments and DECworld, VMEworld, PCworld, ...-world.**
* **High performance, general-purpose FASTBUS processing.**

A user is able to adapt or vary his actual system configuration depending on his requirements:

* **FASTBUS to VAX-BI-bus interface**
* **FASTBUS to DEC Q-bus interface**
* **FASTBUS to VMEbus interface**
* **High-level trigger processor**
* **Supervising controller**
* **Front-end multiprocessing**

A system consists of a single-width FASTBUS processor board which contains elements that are necessary in either application, and a couple of add-on, daughter or auxiliary boards. The diagram gives a system overview.





*) DRB32, DRQ11 are devices from DEC
DVR8217 is a module from CES

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STR331 Optical Data Interconnect - ODI -

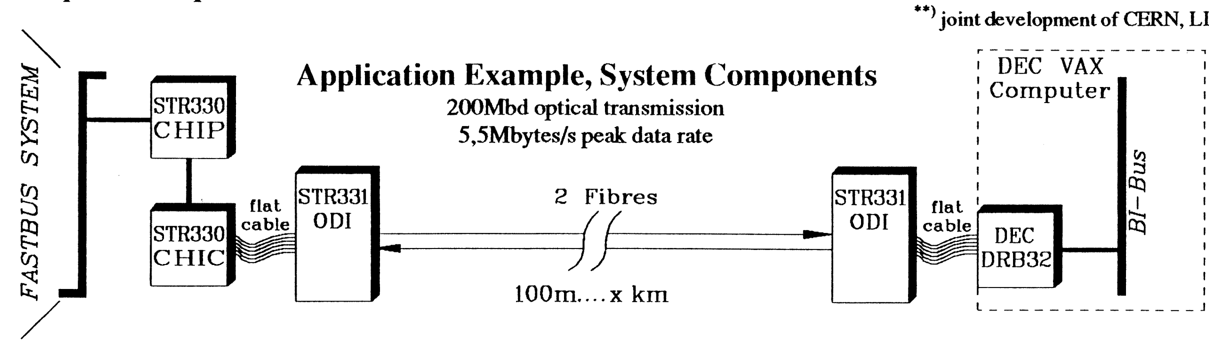
for DEC DRB32 Compatible Devices

The STR331**) ODI is designed to allow high speed point to point interfacing between two DEC DRB32 IO-register compatible IO-ports, separated by distance of up to **several kilometers**, with very high reliability.

Applications:

* **Long distance connection of a DEC VAX host computer located in a control room and a STR330 CHIPS FASTBUS interface or a STR501 AEB/EVI located down an experimental pit.**
* **Long distance connection of two DEC VAX machines in a point to point arrangment utilising all advantages of an optical transmission system.**

**) joint development of CERN, LIP(Portugal)



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