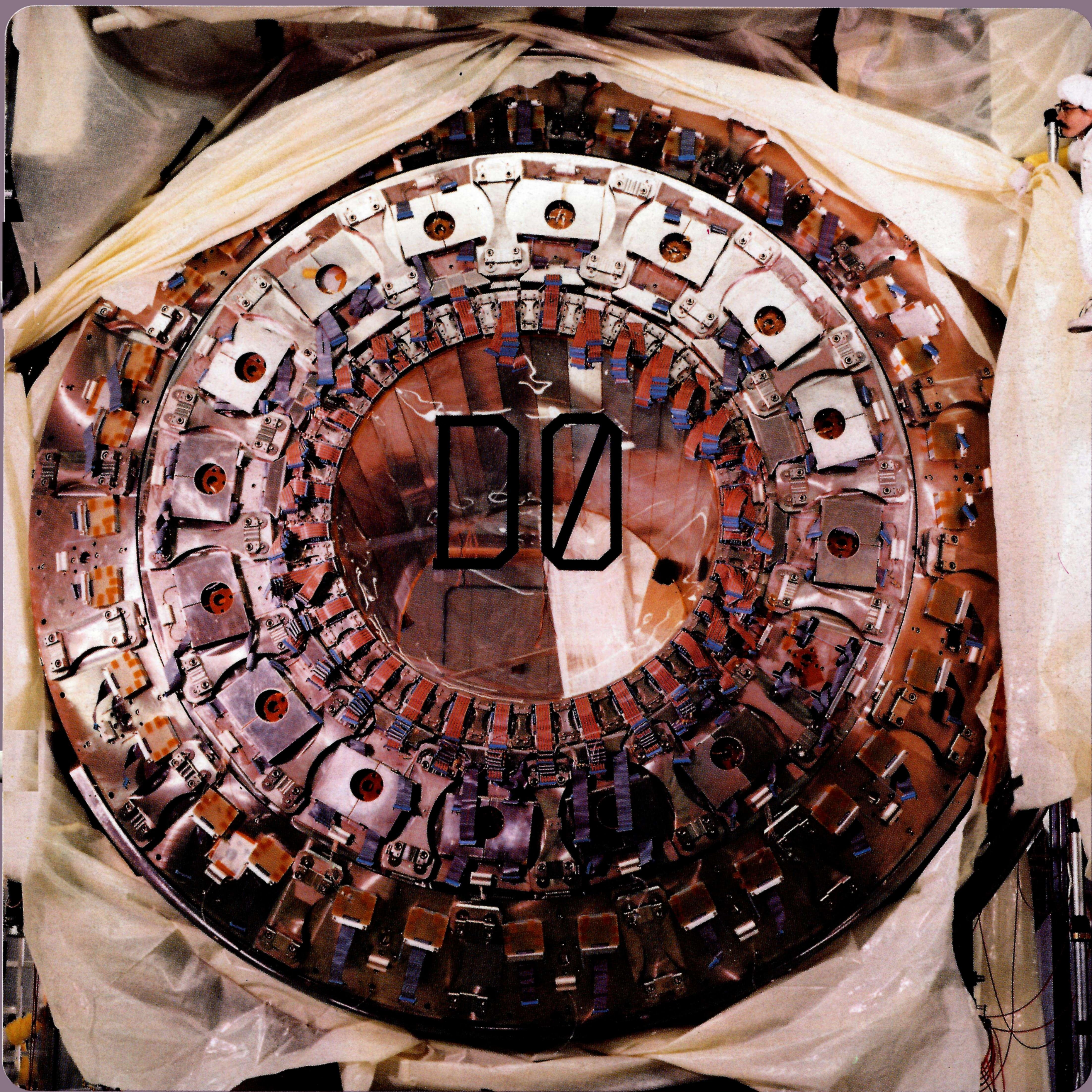
CERN COURIER

International Journal of High Energy Physics



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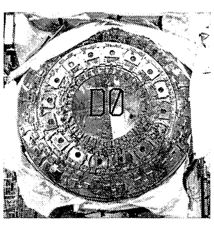

Cover photograph:
The central calorimeter for the DO experiment at Fermilab's proton-antiproton collider, showing the concentric electromagnetic, fine hadronic and coarse hadronic module rings inside the cryostat shell – see page 6 (Photo Fermilab).

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Around the Laboratories

CERN
LEP delivers

One year ago, with the world catalogue of Z particles – the electrically neutral carrier of the weak nuclear force – containing a few hundred examples, it sounded extravagant when proponents of CERN's new LEP electron-positron collider promised a hundred thousand Zs by Christmas 1989.

Despite the difficulties of commissioning the largest particle accelerator ever built, with a heavy commitment to machine development runs – vital for the machine's success but yielding no physics, and a series of shutdowns both scheduled (such as for the formal inauguration ceremony on 13 November) and unscheduled (to save power on cold winter days), the four experiments – Aleph, Opal, Delphi and L3 – between them attained the hundred thousand Z mark just before the machine's and-year shutdown.

The brief pilot run in August was followed in September and early October by two systematic scans of the Z region around a collision energy of 91 GeV. Towards the end of this period the superconducting 'low-beta' quadrupoles came into action for the first time to squeeze the beams tighter and boost the collision rate threefold. Initial physics results from these runs gave a precision fix on the Z mass and showed that there is only room for three types of neutrinos (December 1989 issue, page 19).

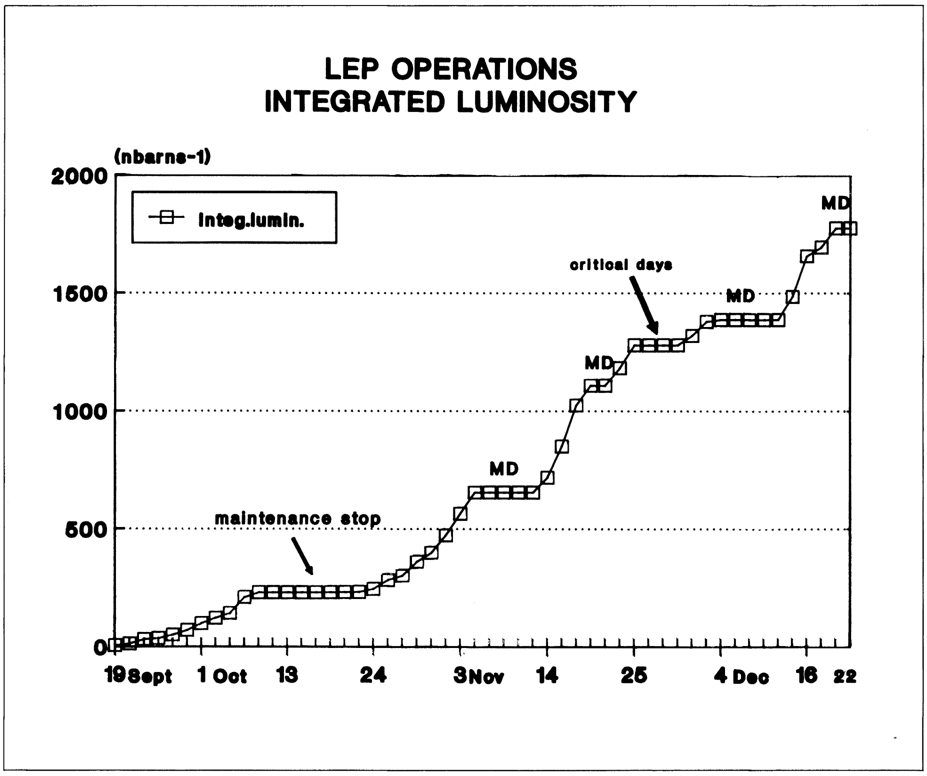
Subsequent runs concentrated on extending the Z scan. Typical (single) beam currents were 1 to 1.5 milliamps and colliding beam luminosities attained 4.9 x 10^{30} per sq cm per s. Beam lifetimes regularly exceeded ten hours.

The onset of winter saw the first imposed cuts due to CERN's special arrangements with the French electricity supply. Despite these and other unscheduled interruptions, the Z score continued to mount steadily, allowing the experiments to refine their Z parameters and to look more closely at patterns of Z decay, checking that the particle has equal affinities for electron, muon and tau lepton channels (lepton universality).

Towards the end of the year, the 27-kilometre ring had its first taste of coasting 20 GeV protons for a precision comparison with 20 GeV positron performance to obtain a better calibration of LEP energy. Previously, Z measurements were clouded by a systematic 45 MeV beam energy uncertainty.Machine development, both in 1989 and when the machine restarts in March, is geared mainly to increasing currents and squeezing the beams tighter together so that LEP can approach its design luminosity of 1.7 x 10^{31}, but also towards longer-term goals of higher energies and beam currents.

The experiments will embark on their search for the long-awaited Higgs particle, the generator of mass in the electroweak picture, while ongoing machine studies will also investigate LEP's potential for handling spin-oriented (polarized) beams.

1989 LEP operations summary chart showing a healthy increase in the growth of integrated luminosity (a measure of the accumulated number of electron-positron collisions). During machine development periods (MD), LEP continued to run but supplied no collisions for physics. The 'critical days' were enforced shutdowns to shed electricity load in cold weather.



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Looking deeper at spin

The first round of experiments in the North Area of CERN's SPS proton synchrotron included a considerable investment in studies using high energy muon beams. This paid off with important contributions to physics, particularly in the measurement of the quark/gluon content (structure functions) of nucleons.

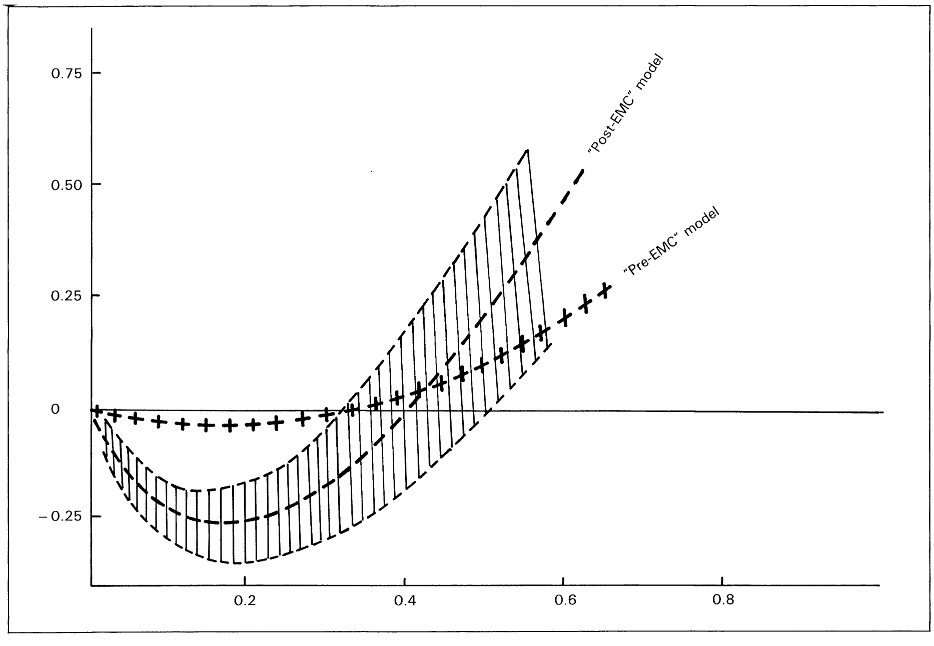
As well as unravelling the deep inner structure of protons and neutrons, this information provided unexpected new physics insights, such as the discoveries by the European Muon Collaboration (EMC) experiment of the 'EMC Effect' – the dependence of the quark structure of nucleons on the surrounding nuclear environment – and of the surprise that the spin of the proton is not carried by its component quarks (June 1988, page 9). This spin effect was even more marked when the EMC data was combined with older results from Stanford experiments using polarized electron beams.

The EMC Effect sparked off a series of investigations and led to much thinking on the role of quarks and gluons in heavier nuclei (September 1985, page 270). The spin effect too caught many theoreticians on the wrong foot, and led to speculation that it reflects some deeper aspects of inter-quark forces.

To probe deeper into this important question, a new Spin Muon Collaboration (SMC) will continue the tradition of muon studies at the SPS using both spin-oriented muons and target protons and deuterons. The target spins will be rapidly switched to minimize systematic effects in measuring asymmetries, and the use of proton and deuteron targets will open up the neutron spin structure to give a first check on important theoretical predictions.

The original EMC spectrometer, including the on-line computer and data acquisition system and with additional tracking chambers, was considerably upgraded by the New Muon Collaboration (NMC) which continued and extended the structure function measurements.

The SMC experiment will use a new muon polarimeter and improved target polarization equipment to handle both protons and deuterons with frequent reversals of the spin direction. A few modifications are also proposed for the spectrometer to improve beam efficiency and stability and the detection of the scattered muon. With preparations already underway, the experiment is scheduled to being taking data next year.



Expected variation of the spin asymmetry of the neutron (vertical axis) with the fraction of the neutron momentum carried by the struck quark, showing old and new ideas and (shaded) the accuracy expected by the new Spin Muon Collaboration experiment at CERN.

Handling low energy antiprotons

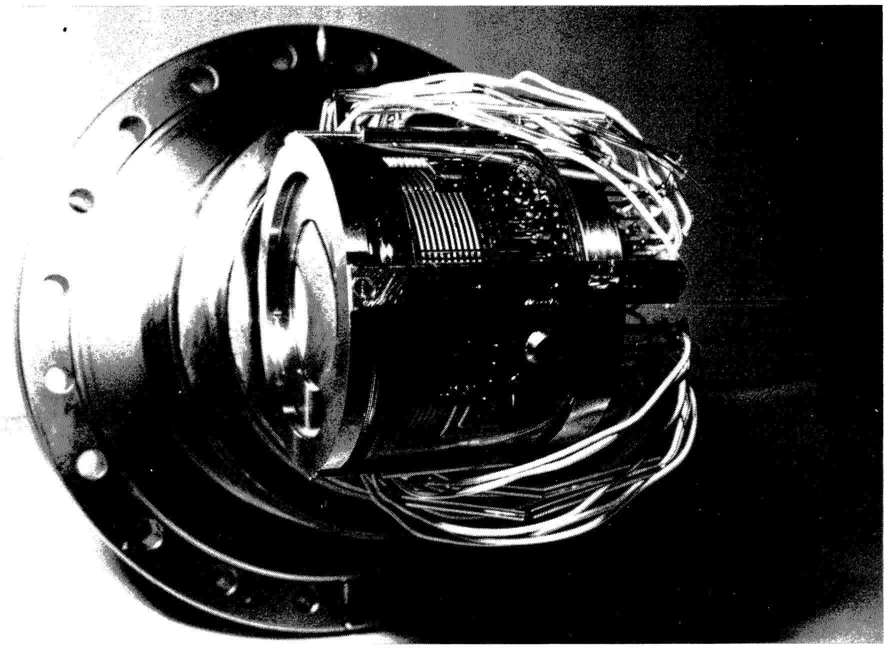
The LEAR low energy antiproton ring at CERN takes its antimatter beams down to very low kinetic energies – less than 10 MeV – for a unique range of physics studies. However even these modest energies are too high for a series of experiments aiming to explore the effects of gravity on antimatter.

Two experiments use trapping techniques to produce ultra-cold antiprotons. A Harvard/Mainz/Washington team (September 1989 issue, page 23) has taken antiprotons down to a few millielectron volts, while a Los Alamos/NASA/Texas A and M/Colorado group will look at the way cryogenic antiprotons drift under gravity.

A third group (CERN/Orsay) will

Scintillator – position-sensitive photomultiplier assembly developed by a CERN/LAPP (Annecy) team as a beam profile monitor for a very low energy experiment at CERN's LEAR low energy antiproton ring.

(Photo CERN 153.6.89)



use precision mass spectrometry to look for any proton-antiproton mass difference using a radiofrequency quadrupole to slow down LEAR's antiparticles.

LEAR experiments conventionally rely on multiwire proportional chambers to monitor their antiproton beam profiles, however at very low energies the particles become eadily degraded by the gas-separating windows of these chambers. To overcome this, a CERN/LAPP (Annecy) team has developed a new technique using inorganic scintillator on the photocathode of a commercial position-sensitive photomultiplier, picking up the antiproton annihilation products and providing two-dimensional displays. Successful tests have also been made on very low energy (80 keV) negative hydrogen ions produced by the CERN/Orsay equipment. With no outgassing (sublimation products) the technique looks promising for high vacuum conditions.

UNITED STATES
From here to 2000

When it becomes operational, the 87-kilometre Superconducting Supercollider proton ring – SSC – now approved to be built in Ellis County, Texas, will dominate the skyline of US particle physics. However SSC experiments would not get underway in earnest until about the year 2000, and to achieve an orderly transition into the SSC era while maintaining continuity in the 'base' (non-SSC) programme, a special subpanel has been set up by the High Energy Physics Advisory Panel – HEPAP – which counsels the US Department of Energy in its role as major paymaster of US particle physics.

After an initial organizational meeting in Washington last year, the new subpanel, chaired by Frank Sciulli of Columbia, met at the SSC in January and Cornell in February. After going on to Brookhaven, Fermilab and Stanford in March, it reconvenes in Williamsburg in April to write its report.

Under a variety of budget scenarios (constant, rising, falling) the subpanel will examine the interrelation of existing and proposed US high energy physics facilities (including upgrades), the interface between the base programme and the SSC, the implications for university groups, the importance of ongoing accelerator R and D work, and programme balance, including use of accelerators and other experimental facilities both inside and outside the US.

The other subpanel members are Barry Barish (Caltech), Ed Berger (Argonne), Alex Chao (SSC), Frank Close (Tennessee), Gail Hanson (Indiana), Walter Hoogland (CERN), David Leith (SLAC), Laurence Littenberg (Brookhaven), Hugh Montgomery (Fermilab), Uriel Nauenberg (Colorado), Steve Olsen (Rochester), Marjorie Shapiro (California), Robert Siemann (Cornell), Bruce Winstein (Chicago), Michael Witherell (Santa Barbara), Stan Wojcicki (Stanford) and Michael Zeller (Yale).

The plan is for recommendations to be in place in time for the formulation of the DoE's budget for financial year 1992 (beginning October 1991).

Frank Sciulli of Columbia is chairman of a US subpanel on high energy physics research for the 1990s.

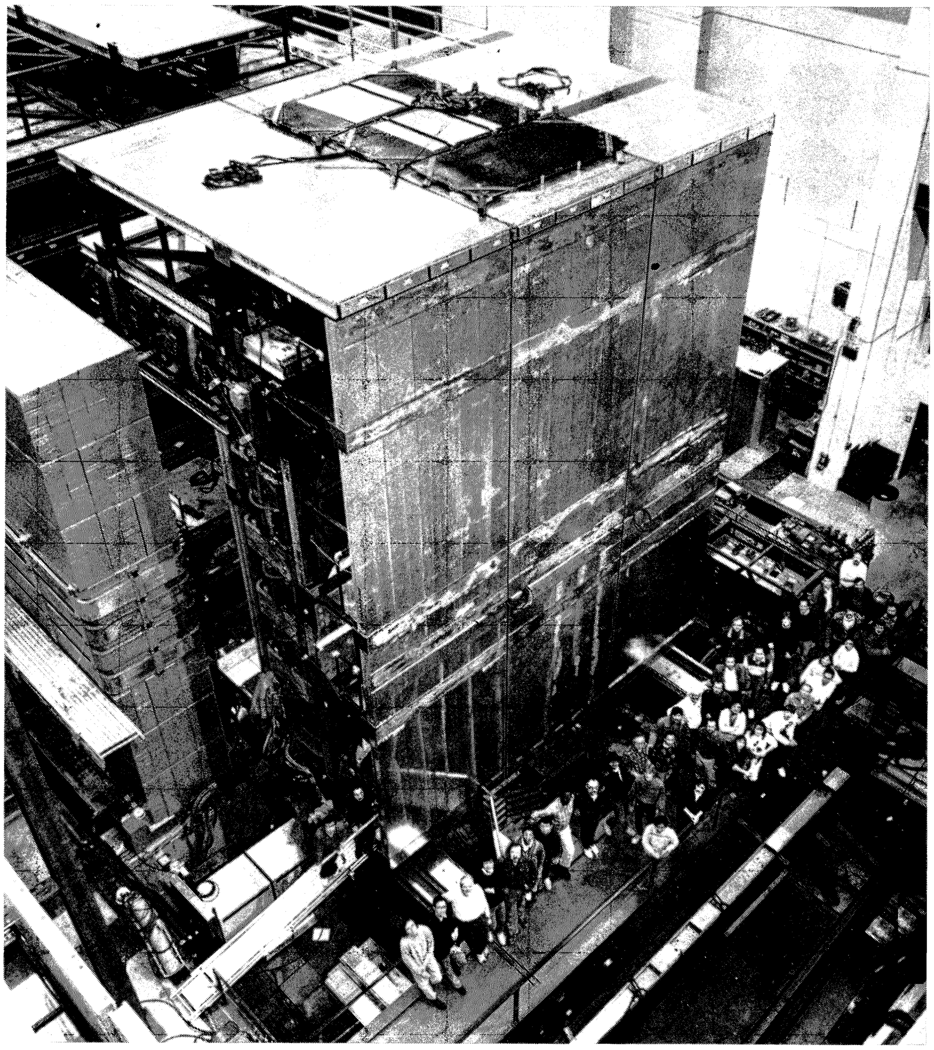
FERMILAB
DO central calorimeter

Preparations for the second experiment (codename DO) at Fermilab's antiproton-proton collider have gone into high gear in recent months, with the detector being readied for data taking in the next collider run, starting in July 1991.

(A one-year run with the collider finished last June, with a world record number of accumulated 1800 GeV proton-antiproton collisions for the big CDF detector (September 1989, page 13). With DO, Fermilab will consolidate its position as the world's premier proton-antiproton Laboratory, a distinction long held by CERN.)

A key DO milestone was passed on schedule late last year with the full complement of modules for the large angle central calorimeter installed in their cryostat. This calorimeter is crucial in DO's bid for accurate measurements of high transverse momentum jets, electrons and photons in complex multiparticle events, complemented with a large coverage muon detection system and a compact set of tracking and transition radiation detectors surrounding the intersection point.

The central calorimeter's three concentric rings (see cover photo) form a 260 cm long cylindrical annulus between radii of 85 and 220 cm. The inner ring has 32 electromagnetic modules (3 mm uranium absorber plates) surrounded by 16 fine hadronic modules (6 mm uranium plates) and then by 16 coarse hadronic modules (46.5 mm copper plates). The detector represents a considerable obstacle for the emergent particles, about 7 absorption lengths at normal incidence, and giving about 15,000 separate measurements of deposited energy.



The outer (muon) detector of the DO experiment for Fermilab's proton-antiproton collider in the experimental hall.

(Photo Fermilab)

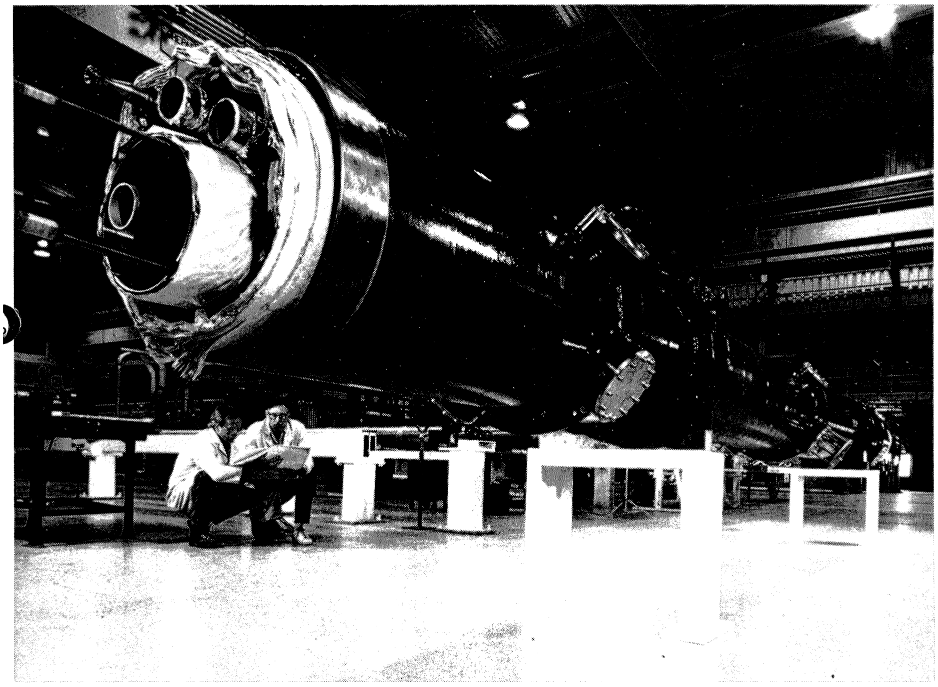
Tests assured the experimenters that their design goals had been attained – good energy resolution for electrons and for hadrons, equal response for electrons and pions, 2mm position resolution of electromagnetic shower centroids, and excellent linearity and stability.

Meanwhile installation of the 164 exterior muon chambers is progressing steadily. After the final cabling and closing of the central calorimeter, the detector will be moved into place and filled with argon. Later this year the calorimeter, together with all tracking and transition radiation detectors and the large angle portion of the muon toroids and chambers, will be commissioned and tested using cosmic rays while the installation of modules in the end calorimeters proceeds in parallel.

Fermilab's next proton-antiproton collider run is scheduled for next year.

Prototype 9.7 metre superconducting dipole for Brookhaven's proposed RHIC heavy ion collider

(Photo Brookhaven)



BROOKHAVEN RHIC magnets

Last year, Brookhaven's proposal for a Relativistic Heavy Ion Collider – RHIC – was scrutinized by the US Department of Energy and deemed to be ready for construction funding. The hope is that the money will be voted soon so that construction can get underway at the start of the new US financial year in October. * (see page 28)

The 3.8 kilometre RHIC tunnel was completed ten years ago for the doomed Isabelle/CBA proton collider project. For RHIC, Brookhaven's Tandem Van de Graaff and Alternating Gradient Synchrotron, together with an additional booster synchrotron now under construction, will provide a wide range of heavy ion beams for acceleration in the big ring up to 100 GeV per nucleon. To head the project, Satoshi Ozaki, who left Brookhaven in 1981 to oversee construction of the TRISTAN electron-positron collider at the Japanese KEK Laboratory, returns to the Long Island Laboratory.

Research and development for RHIC has been in high gear since 1987, when first funds earmarked for this work came in from the DoE, concentrating on the large superconducting magnets to hold the particles on course. Prototype full-length 9.7-metre dipoles were constructed several years ago, one at the Laboratory, the remainder at the West German plant of Brown Boveri (April 1987, page 21), and surpassed the nominal operating field of 3.45 tesla at 4.3 K.

Since then a second series of these dipoles has been built and tested at Brookhaven, supported in their cryostats by vertical posts in compression, using an idea borrowed from the magnet design for the Superconducting Supercollider (SSC) project in Ellis County, Texas. Next milestone this year is construction and testing of a full cell of the RHIC ring, with two dipoles, quadrupoles, sextupoles and corrector magnets. The complete collider, with its two interlaced rings, would need 288 arc dipoles.

In parallel, development work is pushing ahead for the detectors to monitor the collisions at RHIC's six beam crossing points (January/February issue, page 11).

Colour transparency

Thirty years ago Don Perkins, looking at the decay of very high energy neutral pions into an electron, a positron, and a photon (Dalitz decays) in cosmic rays, and noting that the electron-positron pair gave relatively little ionization (signal) during the first tens of microns of path length, explained that the ionization reflected the initial relative proximity of the positron and the electron.

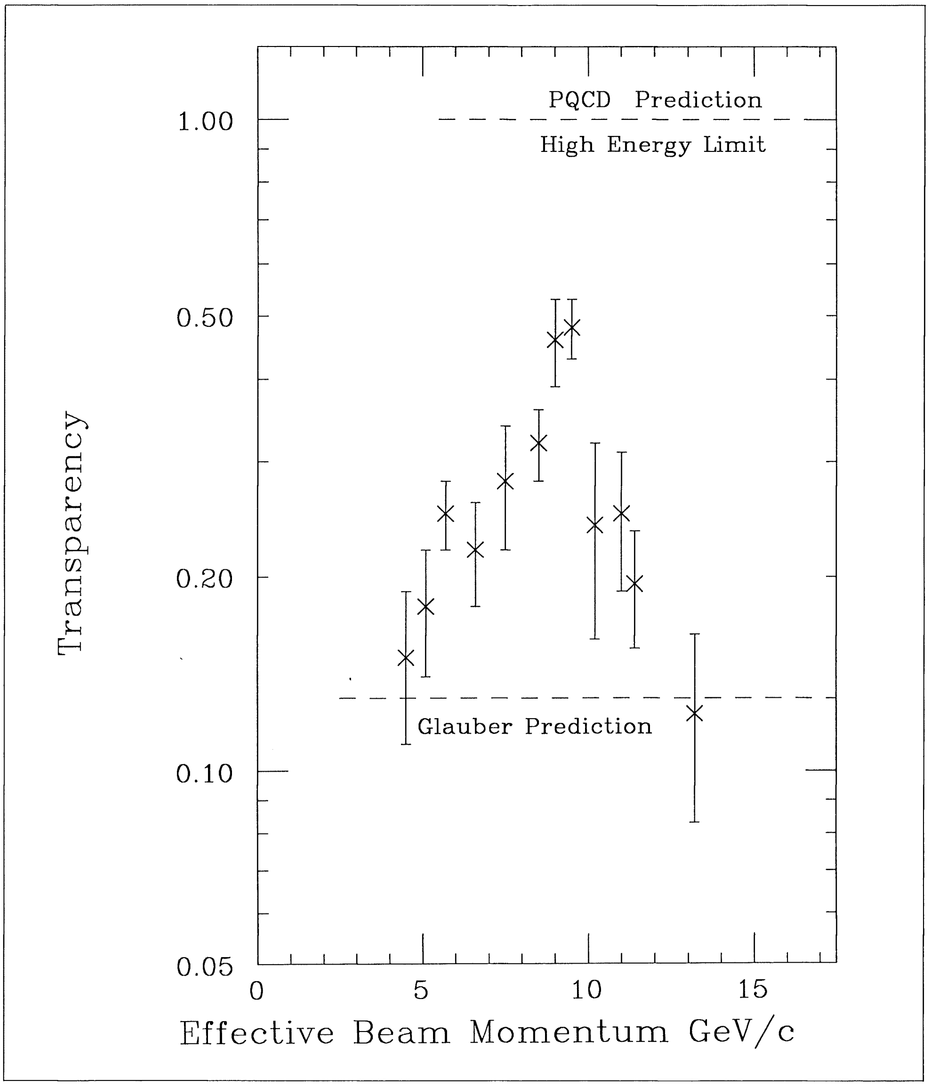
An electron-positron interaction vanishes if there is no separation between the charges. Only when the separation becomes comparable to the atomic scale does the effect approach that of two independent charged electrons. So the ionization from very high energy electron-positron systems produced very close together and remaining subatomic over many microns of path length can be used to measure the size of the charge neutral system.

A recent programme at the Brookhaven Alternating Gradient Synchrotron (AGS) is using the same principle to look at the basic hadronic interaction of hard elastic scattering, when the incoming particles 'bounce' violently off each another.

Calculations using quantum chromodynamics (QCD – the standard

theory of the strong 'colour' force involving quarks and gluons) show that when two protons scatter elastically in hard collisions (large momentum transfer), the initial and final state protons can briefly shrink to much smaller size (going as the inverse of the momentum transfer) at the point of interaction. Thus the proton's tiny constituents, including at least three quarks, can, albeit infrequently, occupy a space smaller than the normal proton diameter (1 fermi), before expanding again, the cycle taking place over a distance of many fermi. One explanation for the decreasing level of elastic collisions as the interactions become harder is that such a fluctuation becomes increasingly improbable.

To measure the size of the three-quark system involved in elastic scattering, the Brookhaven experiments study these processes in nuclear matter. Standard (perturbative) QCD calculations predict that in fixed angle quasielastic scattering (quasielastic because the target proton is initially bound in a nucleus), the soft interaction of the initial and final state protons with nuclear matter must vanish at higher energies. Just as the small charge-neutral electron-positron system does not interact with atomic matter, the small colour-neutral three-quark system will not interact with nuclear matter. This suppression of initial and final state nuclear interactions has been termed 'colour transparency'. The relevance of (perturbative) QCD calculations to these hard elastic scattering processes has been controversial, however this experimental programme provides a method for sorting contributions to hard elastic scattering. By 'turning off' in this way the soft component of the proton-nucleus strong interaction, the protons or pions become competitive with electrons and muons as probes of interior structure.

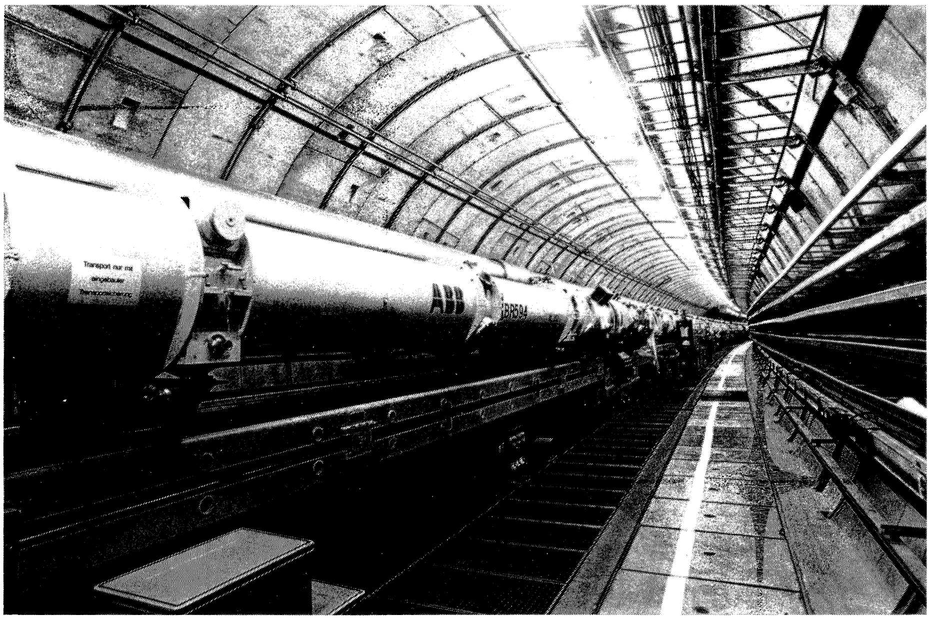


Marked variation in the transparency of aluminium to large angle proton-proton scattering, as seen by Brookhaven Experiment 834, showing the predictions of Glauber theory and of perturbative quantum chromodynamics (PQCD).

AGS Experiment 834 (Brookhaven/Minnesota/Penn State/SE Mass.) saw sharp changes in the transparency of aluminium and other nuclei in proton-proton elastic scattering as the momentum was varied from 4.5 to 13.2 GeV, showing that the hard and soft components of the scattering do not change smoothly with momentum.

To measure nuclear transparency effects in hadron-hadron quasielastic scattering at as high an energy as possible, a new detector is being constructed for an experiment by a Brookhaven/Michigan/Minnesota/Mt Holyoke/Penn State/SE Mass. team to achieve a sensitivity of one event in 4×10^{11} interactions for scattering angles near 90 degrees in the proton-proton centre of mass). Designed to handle more than 2×10^{7} interactions per second, it is expected to take its first data next year.

From Steve Heppelman



Part of the completed octant of the HERA electron-proton collider at the DESY Laboratory, Hamburg, showing the superconducting magnets of the proton ring above with the electron ring below. This octant of the proton ring is now under test. The electron ring was completed last year and supplied its first 27 GeV electron beams in September.

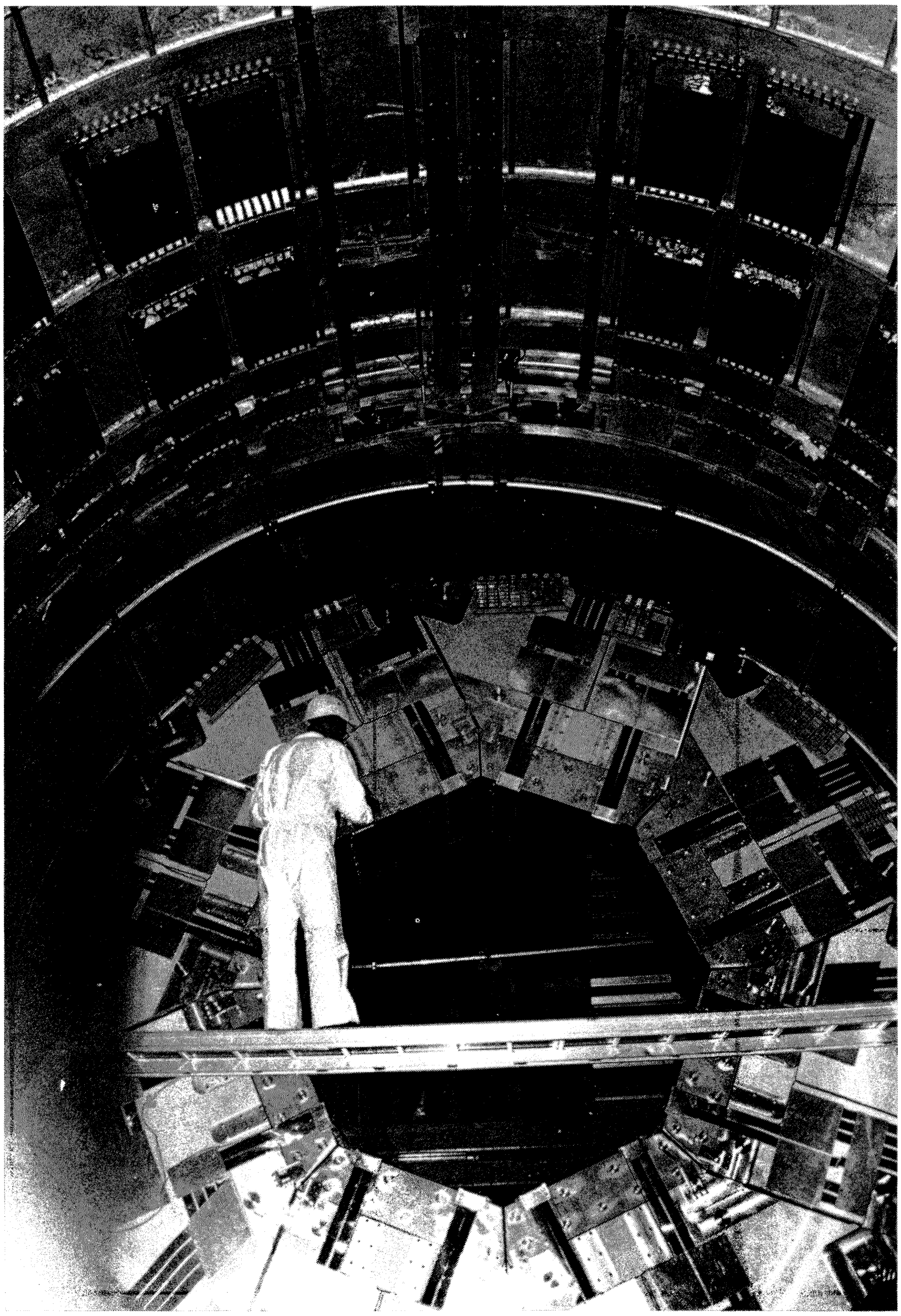
DESY
HERA superconducting magnets OK

The HERA electron-proton collider being built at the DESY Laboratory in Hamburg is the first accelerator using superconducting magnets manufactured by industry on a large scale. For this pioneering step several potential problems now seem to be all well under control, with important contributions coming from both the manufacturers and DESY's accelerator specialists.

The 224 superconducting quadrupoles for HERA's 6.4-kilometre proton ring (plus 22 spares) were delivered last year by Alsthom (France) and Noell (West Germany), with design and production procedures prepared by the French Saclay Laboratory. Most have been successfully tested and 162 are installed.

Construction of the 9-metre superconducting dipoles (422 required, 453 ordered) is now proceeding without major problems. These long dipoles have less components than the quadrupoles (which include correction coils and monitors), but had to pass severe tolerance tests, resulting in some minor modifications and improvements which delayed delivery.

The last months of 1989 saw the dipole supply rate improve considerably. By late January over 200 dipoles had been delivered by ABB of Mannheim and the Italian consortium of Ansaldo, Europa Metalli and Zanon. More than 135 had passed stringent quality and performance tests at DESY and 83 were in place in the HERA tunnel.



First 'wheel' of the liquid argon calorimeter for the H1 experiment at HERA being pushed into the cryostat.

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HERA's full complement of superconducting magnets should be in place by about September. All conventional (non-superconducting) magnets of the proton ring are already installed, tested and ready for running, while HERA's electron ring was operational last September (November 1989 issue, page 4).

With such a flying start it was possible to embark on a test of a first octant of the proton ring, starting at HERA's West Hall and continuing in the direction of the South Hall, covering the region where protons will be injected from the neighbouring Petra ring at 40 GeV. All magnets were in place by December and helium supply, including the distribution boxes, has been completed. Testing is underway.

Meanwhile the two HERA experiments H1 and Zeus are progressing well with installation in the North and South Halls respectively. H1 installed and tested its 6-metre-diameter superconducting solenoid and measured its magnetic field last year. The external wall of the liquid argon calorimeter cryostat has been mounted inside the coil and a first 'wheel' of the calorimeter has been pushed into the tank.

The first calorimeter module for Zeus arrived at DESY on 22 January from Canada and the second the next day from NIKHEF (Netherlands). Zeus' superconducting coil was installed in its iron yoke last year and during January and February was cooled down again with liquid helium from the central HERA plant and the field accurately mapped.

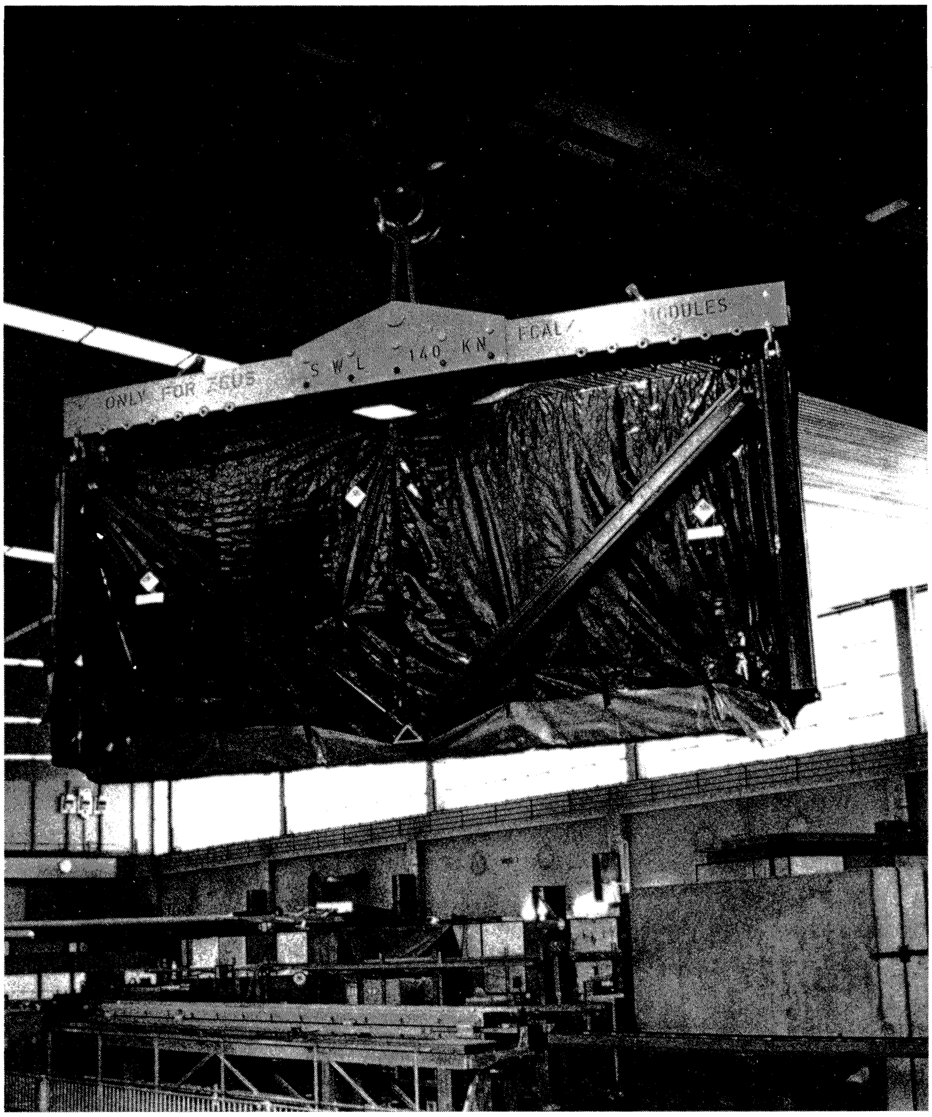
Theory workshop

The 12th edition of the annual Theory Workshop at the German DESY Laboratory in Hamburg concentrated on scalar particles (zero spin, even reflection parity), in particular the scalar version of the Higgs particle, the symmetry breaking agent and source of mass in the electroweak theory.

The Higgs particle discussions looked at two main questions - a theoretical upper mass limit, and the physics implications if these bounds are violated.

Higgs bounds from general principles (unitarity) were reviewed by K.-H. Schwarzer (Munich), giving a broad limit of 700 GeV, which can moreover come down to as low as 145 GeV, depending on the choice of the quantum chromodynamics scale parameter.

Mass limits for both the Higgs particle and the sixth ('top') quark were covered by M. Lindner (CERN)and K. Sibold (Munich) using renormalization group techniques.



First 11-ton depleted uranium/scintillator calorimeter module for the Zeus experiment at HERA arrives at DESY.

(Photos P. Waloschek)

DESY Theory Workshop Organizing Committee Chairman Dieter Schildknecht of Bielefeld (right) with Harald Fritzsch.

With the Higgs limits depending on a perturbation approach, the arguments can be turned upside down to say that a non-appearance of the Higgs signals a breakdown of perturbation theory. Using the non-perturbative lattice technique, I. Montvay (Hamburg) showed that Higgs bounds roughly coincide with those coming from the renormalization group and unitarity approaches, so that theorists can conclude fairly confidently that the absence of a Higgs particle below about 650 GeV would require at least some overhaul of the underlying electroweak formalism.

Higgs hunting in the context of standard and extended electroweak pictures was covered by J. Gunion (UC Davis), while M. Chanowitz (Berkeley) looked at the possibilities of investigating Higgs in particular and electroweak symmetry breaking in general at multi-TeV proton colliders, examining the implications if the Higgs would be heavier than expected.

Heavy Higgs implications were also looked at by G. Gounaris (Thessaloniki), this time for their impact on precision (radiative correction) electroweak studies. F. Feruglio (Geneva) investigated symmetry breaking alternatives to Higgs.

Other scalar particle possibilities (axions, dilatons,..) were covered in both laboratory and astrophysics scenarios.

Returning to the Higgs, M. Veltman concluded with 'The Higgs particle: to be or not to be, that is the question', reviewing in the light of perturbation theory many of the questions asked and proposals tabled during the meeting.

From Dieter Schildknecht (Organizing Committee Chairman).

B MESONS
Beauty without charm

Under the action of the weak force, the heavy quark constituents of strongly interacting particles decay into lighter quarks, giving other particles, as in the familiar beta-decay transformation of neutrons into protons.

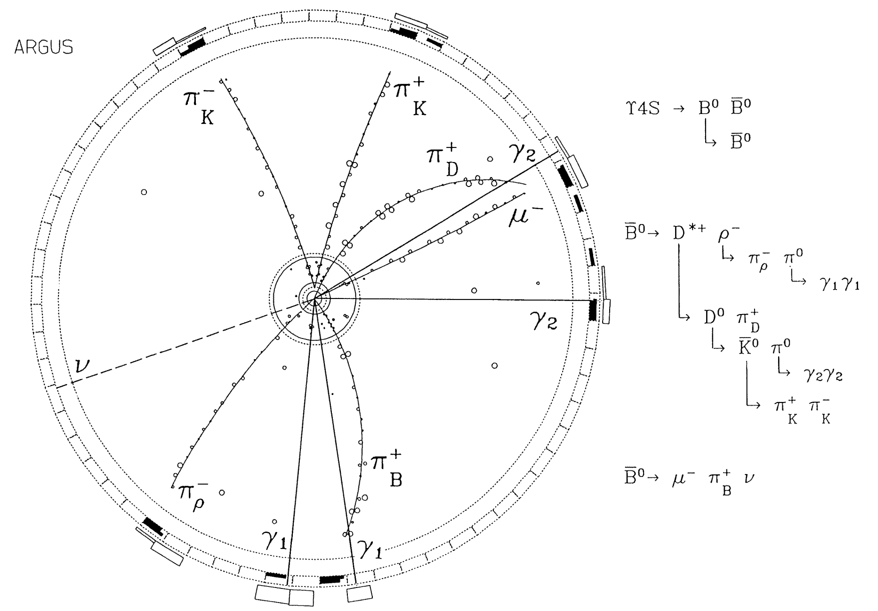
The interrelation between the weak force and quarks was extended in 1963 when Nicola Cabibbo showed how weak decays of particles containing strange quarks could be related to other such decays by a mixing parameter.

Looking at the selection rules of weak decays, Sheldon Glashow, John Iliopoulos and Luciano Maiani proposed in 1970 an extended picture containing four types of quark, dramatically confirmed in 1974 with the discovery of charmed particles.

In 1972, Kobayashi and Maskawa enlarged the description to cover six types of quark, grouped into three doublets – up and down, strange and charm, beauty and top – the minimal set of quarks needed to accommodate the delicate violation of combined charge/parity (CP) symmetry. With the decay patterns of the Z particle, the electrically neutral carrier of the weak force, now indicating that there are only three kinds of neutrino, and hence six varieties of quark, this picture takes on added significance.

While most of the input parameters have to be determined from experiment, consistency conditions give a certain amount of predictive power. Thus it was expected that the B mesons, containing the fifth 'beauty' quark, would prefer to decay via charmed states.

However 'charmless' B decays



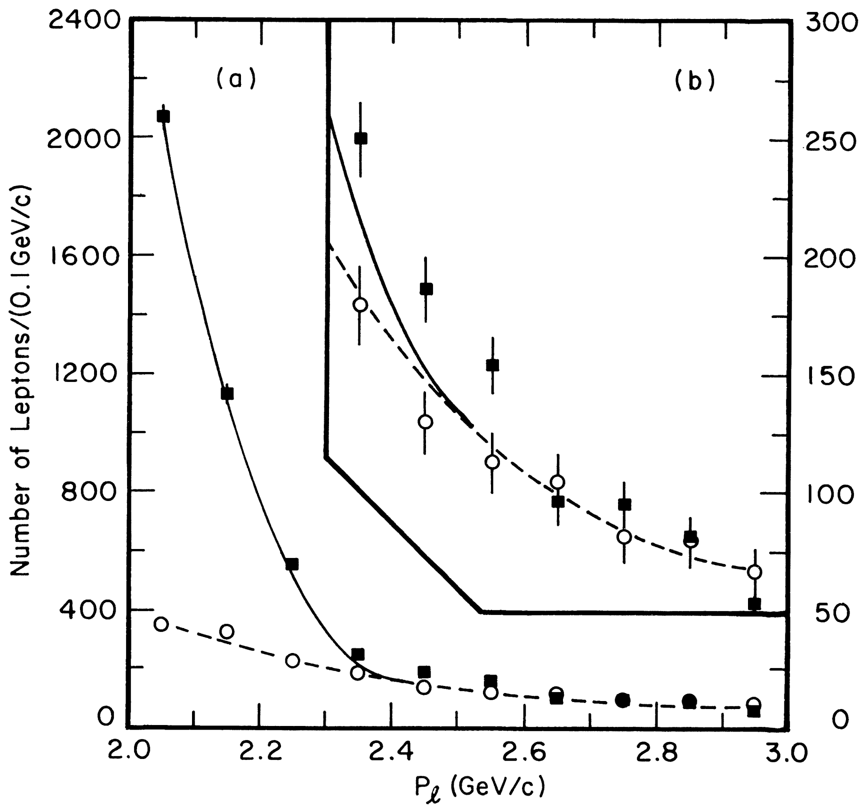
With the DORIS electron-positron collider at the German DESY Laboratory in Hamburg tuned to the upsilon 4S resonance at 10.575 GeV, the Argus detector saw this example of an upsilon decaying into a pair of neutral B mesons (carrying the fifth 'beauty' quark), one of which decays into a pion, avoiding an intermediate charm state. This event also shows the particle-antiparticle 'mixing' of the neutral Bs by the weak interaction.

should still happen, albeit at a reduced level, and their observation last year by the CLEO and ARGUS experiments at the CESR and DORIS electron-positron rings at Cornell and DESY, Hamburg, respectively, provides important new input for the six-quark picture.

The signature of these transitions is an excess of leptons (muons or electrons) above the kinematic limit for B decays via charmed particles. Tuning the colliding electron-positron beams to the upsilon 4S resonance (which decays into B pairs) and complementing the measurements with studies on the neighbouring electron-positron continuum (to estimate background), each group finds about 60 excess leptons.

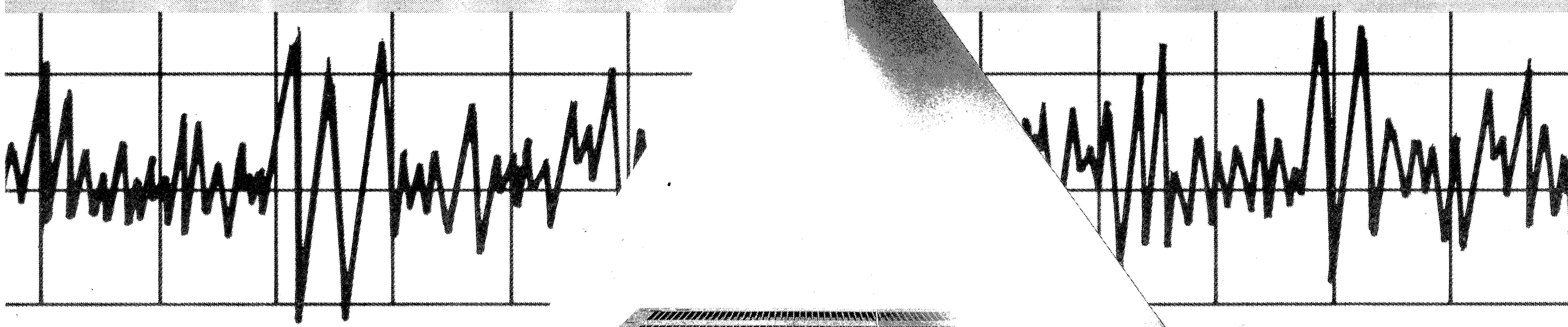
Unearthing the quark transition parameters needs a model to describe the overall decays, and there are several on the market. But broadly speaking the results show that there is about a ten per cent chance that a beauty quark will decay directly into a light quark, rather than via a charmed quark.

The interpretation of these quark decay parameters remains a challenge to theorists.



Lepton (electron and muon) spectra from the CLEO experiment at Cornell's CESR electron-positron ring taken both on (solid points) and away from (open points) the upsilon 4S resonance, showing the small excess of on-resonance points above 2.3 GeV due to B meson pairs decaying into particles containing light quarks without passing through an intermediate charm state. Note the different vertical scales in (a) and the enlargement (b).

The new performance standard



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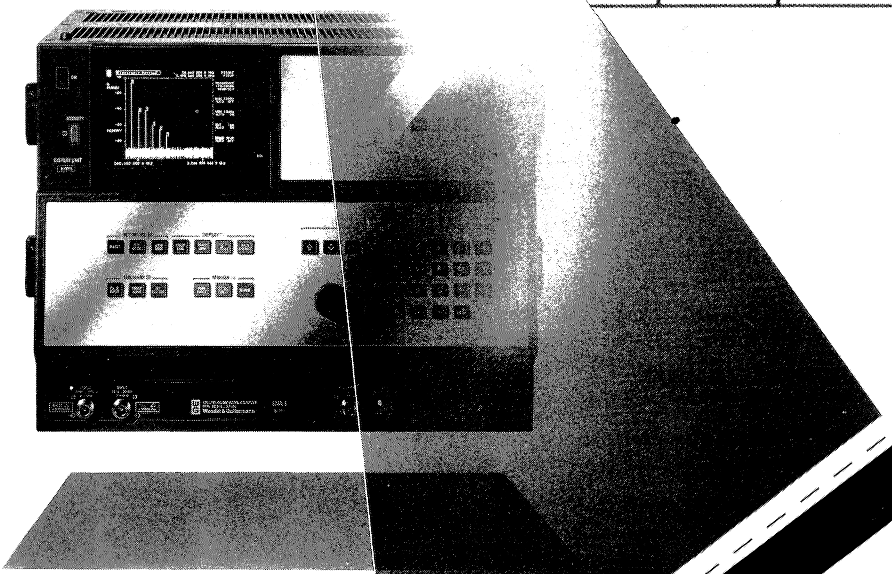

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CEBAF
Pushing ahead

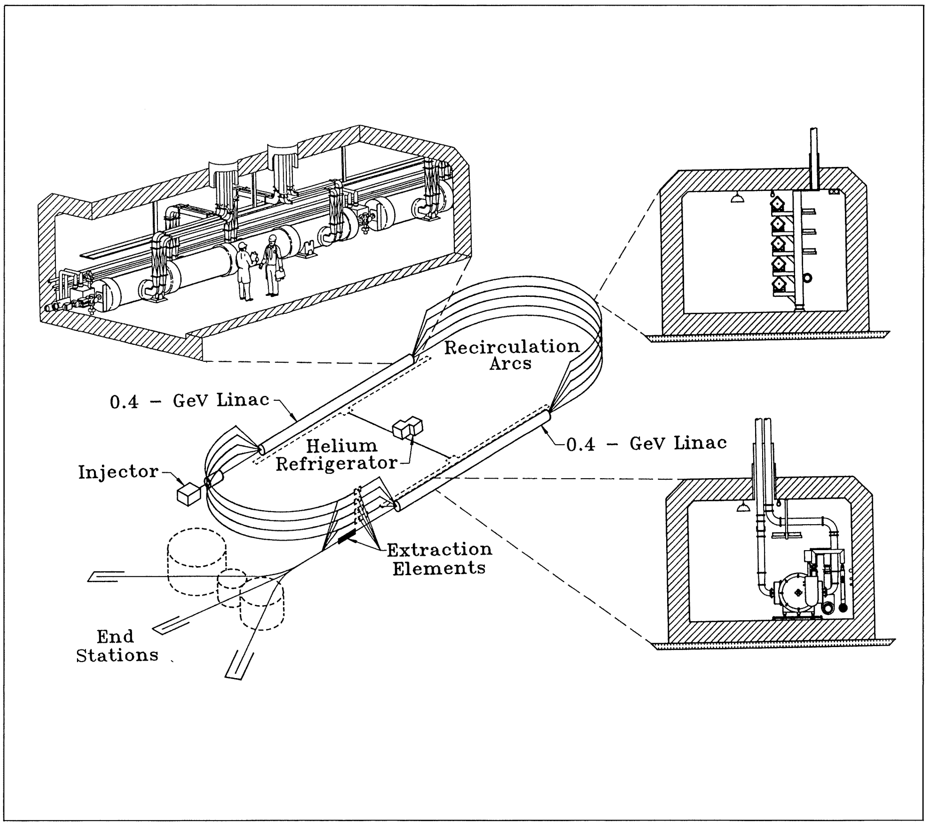
Accelerator component procurement, assembly, and testing are advancing in parallel with tunnel construction and preparations for experiments at the Continuous Electron Beam Accelerator Facility (CEBAF), Newport News, Virginia. A pair of parallel superconducting linacs connected by recirculation arcs will comprise the 4 GeV machine, serving simultaneous nuclear physics experiments in three end-stations. Initial accelerator installation and checkout should begin this year.

The accelerator's 1.4-km racetrack tunnel and associated surface buildings are three-quarters complete. The 4800-watt helium liquifier, built by CVI (Columbus, Ohio), is being installed in its building at the centre of the ring. Insulated helium transfer lines are in place to the completed north linac tunnel. Control system installation began in February in the machine control centre. Also in use are the north linac service building, a tunnel access building for equipment, and the injector service building.

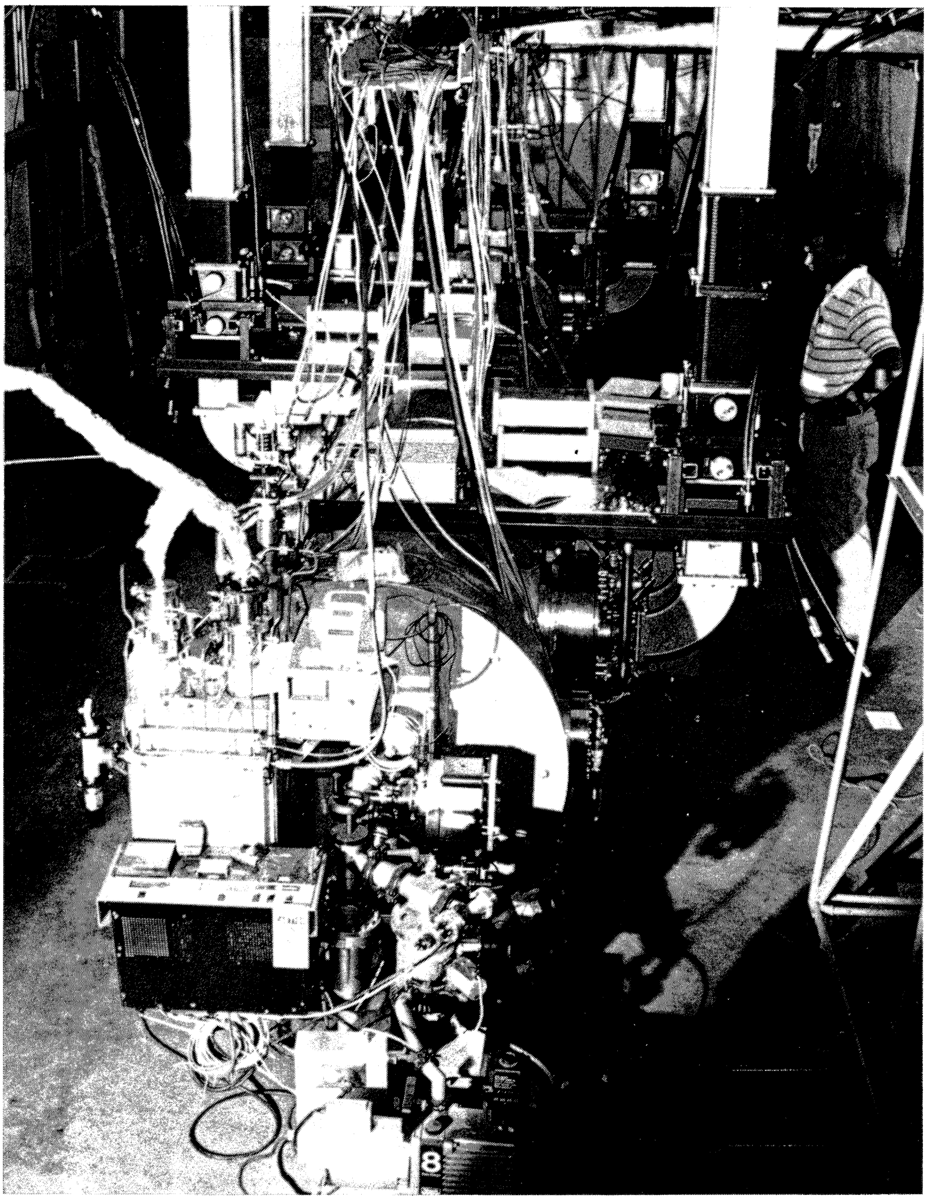
Federal German supplier Interatom has begun fabricating the five-cell 1497-MHz superconducting accelerating cavities to drive CEBAF's beams. They will operate in pairs at 2 K. A 20 MeV 'cryomodule' containing four serially linked cavity pairs, each in its own helium vessel, was tested successfully last year, as was a quarter-cryomodule containing a single cavity pair.

The tested units are identical to those being assembled for the full

Layout of the Continuous Electron Beam Accelerator Facility (CEBAF) now under construction at Newport News, Virginia, US.



Aerial view showing CEBAF construction progress.



Fully instrumented CEBAF cryomodule under test.

accelerator. Twenty cryomodules are required for each 400-MeV linac, with the recirculating beam passing five times through both linacs to reach 4 GeV. Two and a quarter additional cryomodules will make up the 45 MeV injector. CVI is fabricating the inner helium vessels; Meyer Tool (Oak Lawn, Illinois) is making the outer vacuum vessels and associated cryostat components.

In the tested cryomodule, the average accelerating gradient exceeded the cavities' 5 MeV/m design specification, showing no degradation from the 7.3 MeV/m achieved earlier in vertical tests of cavity pairs. This result boosts confidence in the hermetic cavity pair approach, where twin cavities are kept continuously under vacuum.

At CEBAF the tested quarter-cryomodule and the injector's 500 keV room temperature section have been linked for 5 MeV testing. This equipment and the tested cryomodule will be moved subsequently to the tunnel and connected as a partial injector configuration for a 25 MeV test scheduled to begin in November.

The main goal of this test is to integrate permanent accelerator systems for the first time. While testing has relied, for instance, on helium from a small cryogenics facility and radiofrequency from prototypes of the klystrons now being produced in quantity by Varian (Palo Alto), the 25 MeV test will use the central helium liquifier and ten production klystrons installed in the service building above the tunnel, all controlled from the machine control centre.

When the contract for some 300 recirculation arc dipoles is placed this spring, most of the accelerator equipment supply sources will have been decided.

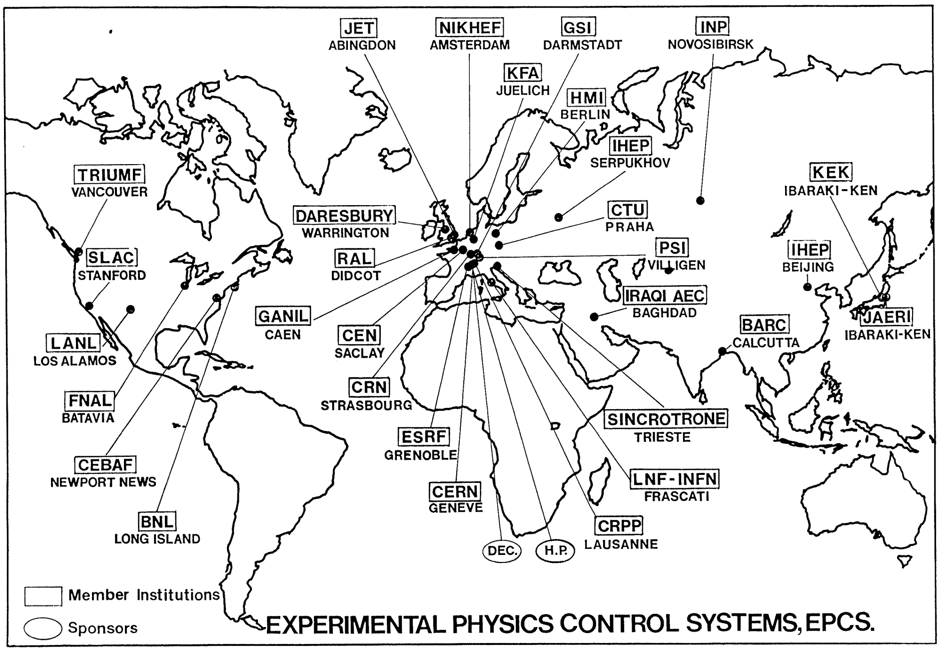
Meanwhile scientific programme efforts have focused on defining optimal experiments and completing conceptual designs of the spectrometers and detectors for each of the three experimental halls. CEBAF's Program Advisory Committee, chaired by John Schiffer of Argonne, will recommend an initial three-year physics programme from a total of 47 proposals requesting some 45,000 hours of beam time from collaborations involving 245 scientists in 60 institutions.

Collaboration members assist in designing experimental equipment and preparing for its construction and assembly. Two 4 GeV/c high resolution spectrometers are planned in Hall A for exclusive experiments (where the nuclear final state has to be fully specified). Hall B's large-acceptance spectrometer is aimed at bias-free investigation of hadronic final states in inelastic electron scattering and detection of multiparticle final states. Hall C's moderate resolution high momentum 6 GeV/c spectrometer, together with specialized second arms, will provide a diverse physics menu. Construction of a 3700 square-metre building for work on experimental equipment has begun, while work for end-stations is scheduled to begin this spring.

Some 700 people attended the dedication of CEBAF Center, the Laboratory's main administrative building, on 20 October. A new 28-room guest house, contributed by the city of Newport News, is in use for collaboration members and other visitors.

CEBAF's staff now numbers over 300. Construction should be complete in 1993, with first physics in the following year.

CONTROL SYSTEMS
More for experimental physics



The European Physical Society's Interdivisional Group on Experimental Physics Control Systems (EPCS) spreads its wings. (Stop press – the National Accelerator Centre, Faure, South Africa, has just joined.)

The European Physical Society's Interdivisional Group on Experimental Physics Control Systems (EPCS) ended 1989 on an optimistic note, welcoming its 30th member institution and having substantially enlarged its range of activities.

Since its foundation in March 1986, the group has sponsored two major international conferences on accelerator and large experimental physics control systems. A successful first meeting, organized by Berend Kuiper (CERN) and held in Villars-sur-Ollon in the Swiss alps in fall 1987, was followed two years later by a larger event in Vancouver, organized by Don Dohan of the local TRIUMF Laboratory.

In addition, the group has sponsored topical workshops and seminars. At a meeting at the European Synchrotron Radiation Facility in Grenoble in January 1989, specialists considered the development of a software 'toolkit' to implement the large number of application programs required for modern accelerator controls.

A suggestion was to adopt computer assisted software engineering tools (CASE) for exchange of designs, and of entire packages. Such tools are gradually appearing on the market and facilitate collaboration in large software projects, both for large physics experiments (e.g. Aleph at LEP) and machine control systems (e.g. SPS-LEP).

A seminar on CASE held at CERN last June followed up the Grenoble application software kit workshop and aimed at introducing these ideas to centres unfamiliar with this methodology. A closed session covered licence policy and other financial matters with CADRE Technologies, the vendor of Teamwork, a specific CASE product. As a result CADRE has revised its policy towards the experimental physics laboratories and is offering particularly favourable conditions to European EPCS member institutes.

A workshop on real-time systems for microprocessors, organized by J.F.Gournay (Saclay) and T.T.Luong (GANIL, Caen) in Chamonix, also in January of last year, surveyed currently available real time systems, including popular solutions for experimental physics controls. The meeting showed how the demands of experimental physics are slowly moving towards a reduced spectrum of systems, and that manufacturers are making a real effort to develop compatible products.

EPCS has also set up a Controls Protocols Committee, chaired by Guy Baribaud of CERN, to define standards for operating different families of devices, looking for common solutions. So far two working groups are investigating protocols for power converters and beam instrumentation, chaired respectively by Baribaud and Gian Paolo Benincasa, also of CERN, and have attracted good membership. The issues at stake have a strong economical impact: standard interface, standard and hence more reliable software, more efficient maintenance, clear separation of responsibilities between controls specialists and device specialists, etc. This work is in conjunction with corresponding projects sponsored by CERN's Technical Board for Process Controls and Electronics for Accelerators (TEBOCO).

So far a consensus has been reached on a standard model describing the behaviour of power converters. The more recently formed instrumentation-oriented group has taken its first steps towards defining a common protocol, and after an initial successful implementation at CERN, will look at the

protocol's validity for other applications.

Finally EPCS was able to assist the Joint European Torus (JET), in Culham UK, by loaning workstations, donated by Digital Equipment Corporation and Hewlett Packard, to initiate a study on future JET controls.

EPCS was conceived as the response to a controls specialists' requirement for a platform to exchange information, share experiences and initiate studies and collaboration. As well as Western Europe, the 30 member Laboratories also cover Eastern Europe (USSR, Czechoslovakia), North America (US and Canada), and Asia (India, China, USSR, Iraq, Japan).

From Axel Daneels (EPCS Chairman)

DETECTORS
Electronic detectors in medicine

Twenty years ago, the development by Georges Charpak's group at CERN of the multiwire proportional chamber and the drift chamber revolutionized particle detection, bringing substantial improvements in accuracy and response.

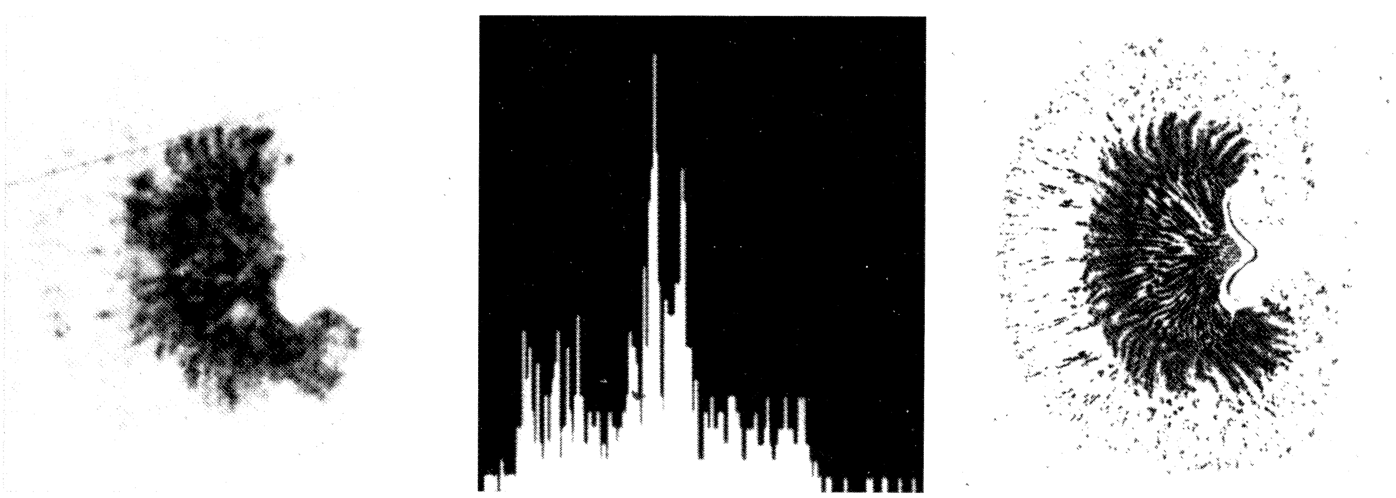
Spinoff applications in other fields include the study of macromolecules using soft synchrotron radiation X-rays (March 1987, page 7). At the higher X-ray energies of conventional clinical radiography, the low absorption rate in gas-filled electronic detectors means that films still provide the optimal means of imaging large surfaces.

However a group at the Soviet Novosibirsk Laboratory has developed a chamber filled with xenon at 3 bar and using wires oriented towards an X-ray source collimated by lead slits. A line image is taken in just 8ms, and a useful volume can be scanned in a few seconds. In this way the dose for a chest radiography can be reduced to about 3 mrem, a tenth of what is normally required, a major advantage for radiation-sensitive cases in pediatrics and gynaecology.

In gamma-ray imaging, an electronic imaging camera developed at Houston has produced promising results, hinting at a much reduced radiation dose. Other efforts concentrate on picking up the scintillation from solids such as barium fluoride, thus combining the photon stopping power of a solid with the versatility of the electronic detector (May 1984, page 141).

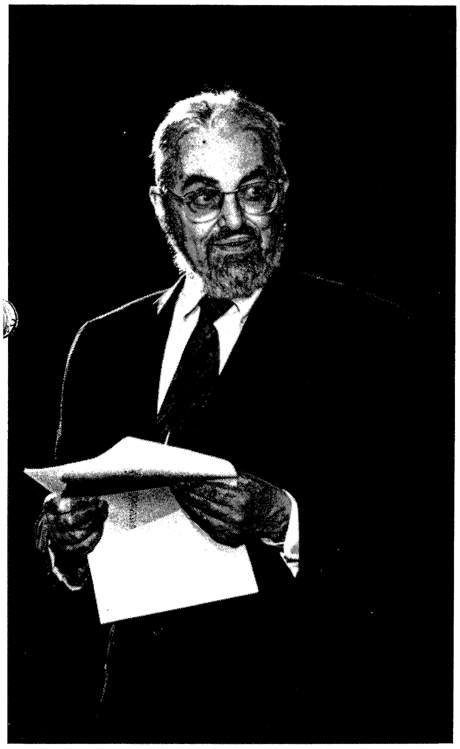
Electronic detection techniques are also being developed for use in autoradiography, where the samples are labelled by an appropriate radioactive emitter. With beta emitters, where imaging traditionally relies on film, amplification of wire chamber signals has given some results. A new technique being investigated by CERN and Geneva's Cantonal Hospital uses an image-intensified CCD camera to view the light emitted by electron avalanches in a multistep wire chamber. Resolution is improved, although still not as good as with film, but information can be gathered a hundred times faster and the formation of the image can be followed continuously.

Beta-ray radiography of a rat kidney (left) taken in 20 hours using a wire chamber viewed by an image-intensified CCD camera, showing tubules 50 microns across. Centre is the intensity distribution across the sample, with a pixel width of 40 microns. For comparison (right), is a conventional photographic image produced after three months.



People and things

Ernest Courant.



Ernest Courant retires

Brookhaven accelerator specialist Ernest Courant formally retired on 1 January. Arriving at the Laboratory in 1947, he went on to make important contributions to the 3 GeV Cosmotron, the world's largest particle accelerator when it came on line in 1952. In that year Courant, with Stanley Livingston and Hartland Snyder, proposed the strong focusing principle which revolutionized the design of high energy proton machines then on the drawing board at Brookhaven and at CERN, and went on to become a cornerstone of modern accelerator technology. He continues to be involved in ongoing projects, including Brookhaven's proposed RHIC heavy ion collider, and the US Superconducting Supercollider (SSC).

American Physical Society Prizes

The American Physical Society's Prizes for this year include: the Tom W. Bonner Prize to Vernon Hughes of Yale for his contributions to fundamental measurements, particularly using high energy polarized electron beams; the W.K.H. Panofsky Prize to Michael Witherell of UC Santa Barbara for his role in the detection and analysis of charmed particles; the J.J. Sakurai Prize to Toichiro Kinoshita of Cornell for the formalism behind precision tests of quantum electrodynamics and electroweak theory; and the Robert R. Wilson Prize to Kjell Johnsen of CERN for his leading role in the design, construction and performance of CERN's Intersecting Storage Rings.

Nuclear Theory in Washington

An Institute for Nuclear Theory has been established at the University of Washington, with major funding from the US Department of Energy. The Institute will host 3-6 month programmes on topics of current interest in nuclear physics, emphasizing the relationships to experimental physics and to neighbouring disciplines, beginning with quarks in nuclei (March-June) and nuclear astrophysics (June-September). The director is counselled by a National Advisory Committee – Gerald E. Brown (Stony Brook), Gordon Baym (Illinois), Torleif Ericson (CERN), Maurice Goldhaber

On 6 February Polish President Wojciech Jaruzelski of Poland visited CERN, where he was greeted by Director General Carlo Rubbia (right).

(Brookhaven), M. Gyulassy (Berkeley), Franco lachello (Yale), Steven Koonin (Caltech), Art McDonald (Chalk River), John Negele (MIT) J. D. Walecka (CEBAF), Frank Wilczek (Institute for Advanced Study, Princeton), and Lincoln Wolfenstein (Carnegie-Mellon). While a permanent Director is being sought, the Institute's interim director is Ernest M. Henley.

CERN School of Physics

This year's CERN School of Physics, organized jointly by the University of the Balearic Islands (Spain), the Spanish Interministerial Commission for Science and Technology (CICYT) and CERN, will be held in Mallorca from 16-29 September. Its aim is to teach aspects of high energy physics at the most up-to-date level to young experimentalists, mainly from CERN Member States. Emphasis is traditionally on theoretical physics, but this year will include a basic course on accelerator physics as well as a review of recent LEP results. Further information from Ms S.M. Tracy, 1990 CERN School of Physics, CERN, 1211 Geneva 23, Switzerland, phone Geneva 767 2724, fax 782 3011, or bitnet tracy at cernvm.cern.ch . Application deadline is 30 May.

US President's budget – funds for RHIC....

Funding to start construction of Brookhaven's Relativistic Heavy Ion Collider (RHIC) has been included in the budget proposal for fiscal year 1991 that President George Bush submitted to Congress on 29 January.

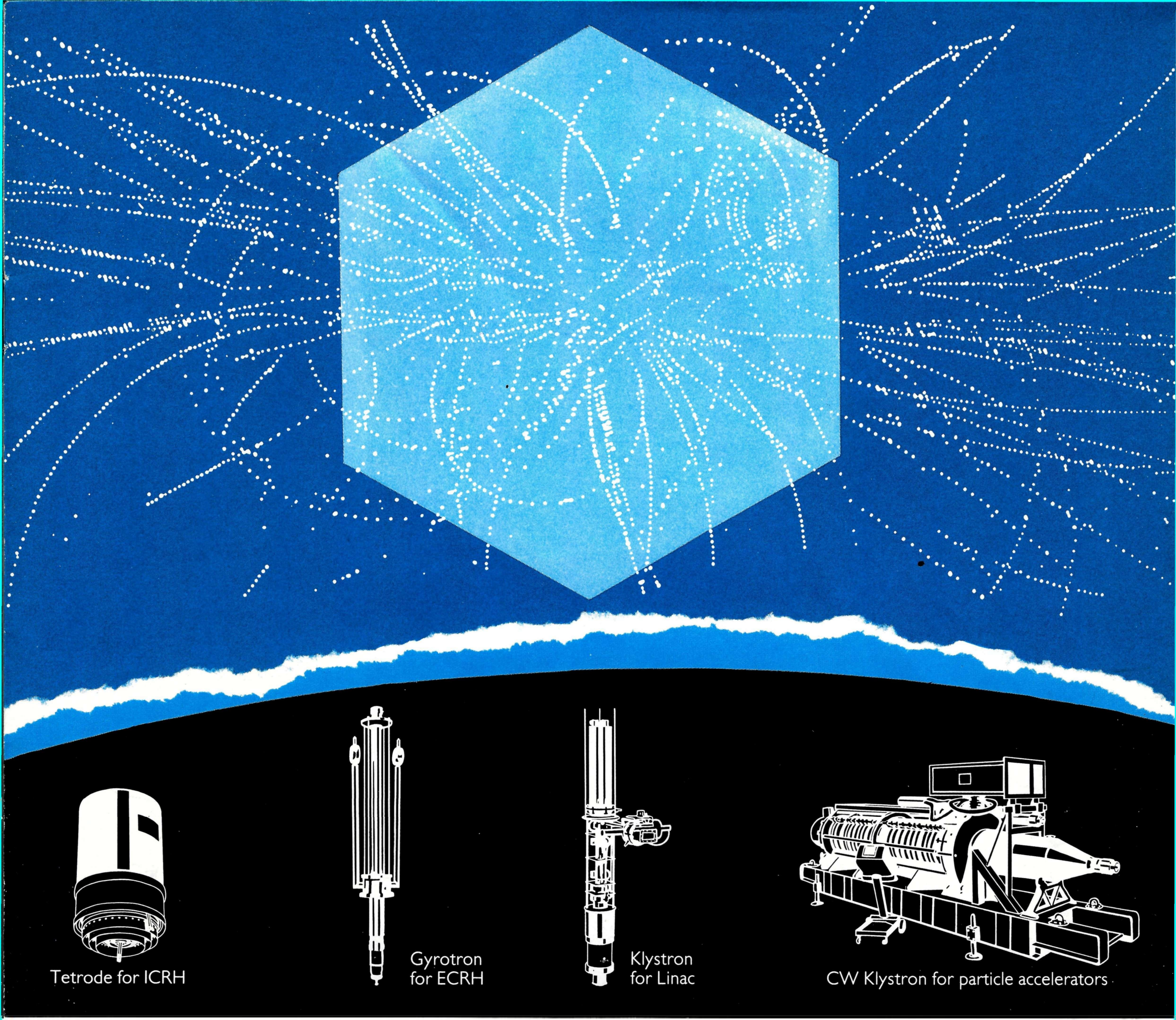
Designed to provide colliding beams of heavy nuclei at ultrarelativistic energies, RHIC has long been a high-priority initiative of the US nuclear physics community. When completed, the two ring, superconducting collider will use the Tandem-Booster-AGS complex at Brookhaven as injector, and will collide beams of ion species throughout the periodic table, covering a wide range of energies. The top beam energy for gold ions will be 100 GeV/nucleon. If approved by Congress, the funding would provide a total of $397 million for construction over six years. Roughly one-quarter of this total will go for detectors. The requested amount for fiscal year 1991 (beginning this October) is $15M for construction and an additional $6.8M for R&D.

...and increased funding for SSC

President Bush's budget request also includes $318 million for the Superconducting Supercollider to be built in Ellis County, Texas, up some 40 per cent from the initial funding in the current financial year. $169 million of this is earmarked for construction work, the remainder to support research and development, mainly for superconducting magnets.

Lady Renie Adams, wife of the late Sir John Adams, cuts the cake at the 30th birthday party for CERN's PS proton synchrotron, built by John Adams' talented team in the 1950s and still the kingpin of CERN's high energy particle beam system. With her, left to right; Gordon Munday, PS Division Leader 1973-81; Peter Standley, Division Leader 1965-72; PS pioneer Wolfgang Schnell; and Roy Billinge, Division Leader from 1982.

(Photo CERN 436.12.89)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