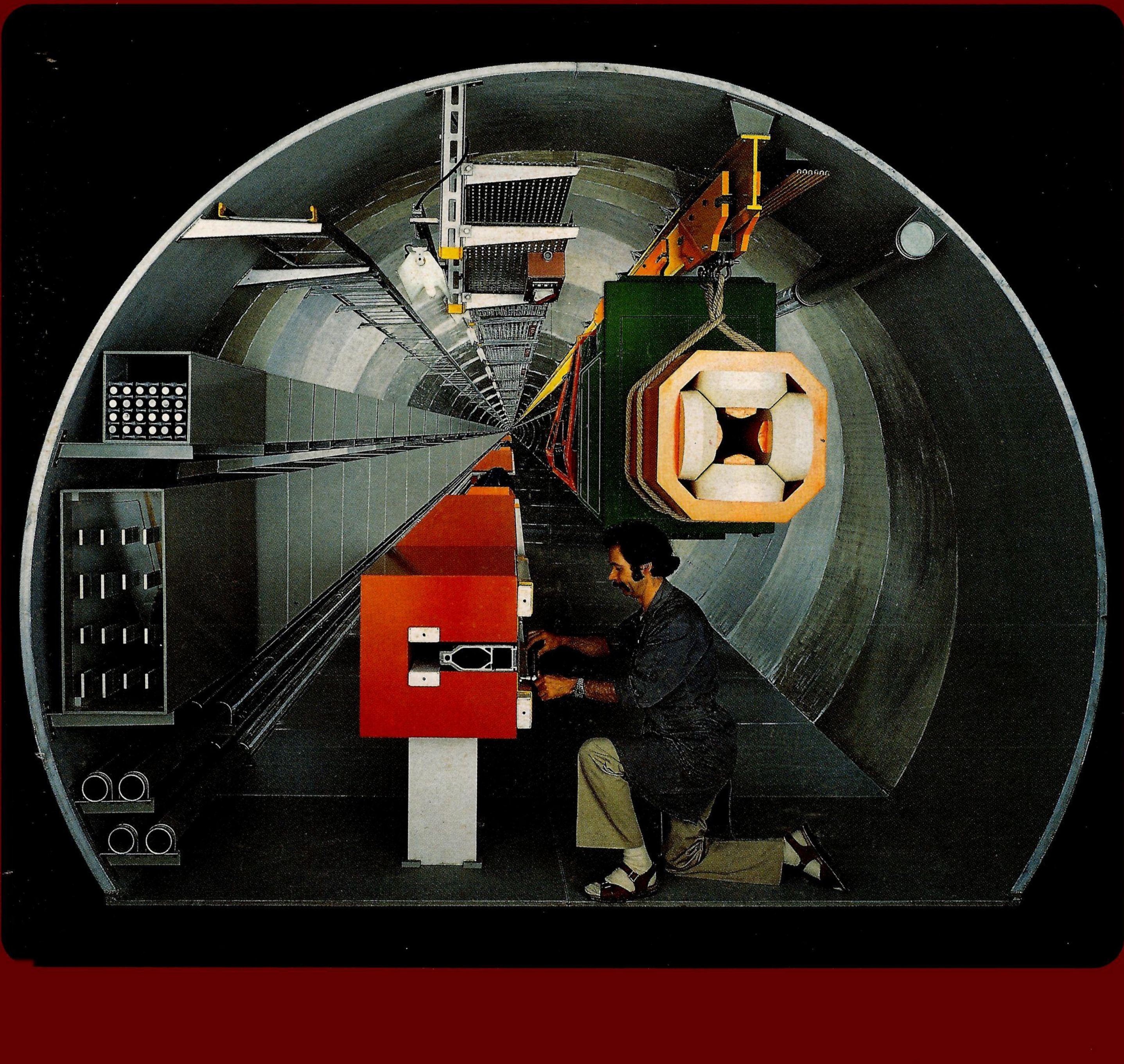
CERN COURIER

International Journal of High Energy Physics



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International Journal of the High Energy Physics Community

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VOLUME 25 Nº 2 MARCH 1985

Cover photograph: Construction of the 27 km tunnel for CERN's LEP electron-positron collider is progressing well, but not as well as this photograph might suggest! A mock-up of a magnet and the monorail transport system against a skilfully painted backdrop gives an uncanny sense of reality (Photo CERN X529A.8.84).

Stockholm revisited

Stockholm 1984 — Physics Nobel prizewinners Carlo Rubbia (left) and Simon van der Meer.

(Photo Dagens Nyheter)

The Nobel Physics Prize for 1984 was shared by Carlo Rubbia and Simon van der Meer of CERN for their decisive contributions to the project which led to the discovery of the W and Z field particles which carry the weak interaction. Five years before, Sheldon Glashow, Abdus Salam and Steven Weinberg had made the same trip to receive the prize for their crucial roles in piecing together the elegant 'electroweak' gauge theory which unified weak interactions with the electromagnetic force and predicted just where the W and Z particles could be found.

In December, the three theorists returned to Stockholm to participate with the 1984 laureates in a specially arranged panel discussion for Stockholm students. Introducing the proceedings, Bengt Nagel of Stockholm's Royal Institute of Technology played an extract from a recording made in 1979 which vividly demonstrated just how unexpected it was at the time that the predicted particles would be found so soon. Nagel paid tribute to the achievements of the CERN Collider.

Seldom have theoretical predictions and experimental discoveries followed each other so closely in the Nobel annals, and Weinberg, speaking first, thanked the Nobel Physics Prize Committee for 'the marvellous idea of inviting back the class of 1979 so that they could bask in the reflected glory of Rubbia and van der Meer'.

'By the mid-nineteen seventies we appeared to have a good understanding of the fundamentals of the particles which can be created in the laboratory,' continued Weinberg. 'However this understanding, as usual in physics, was incomplete. There were, and still are, a large number of loose ends — undetermined parameters whose values have to be taken from experiment — masses, scales, couplings, mixings, etc. In addition there was an obvious lack of total unification between the different sectors — electroweak and strong interactions, gravity still left out, quarks and leptons treated separately.

There has been a tremendous effort by theorists throughout the world which has proved almost entirely frustrating. While our experimental colleagues were going ahead and dazzling us with new discoveries, we theorists have been exploring one new idea after another — ideas of remarkable beauty and sublety — without the slightest success to show for our pains.

For instance there was the effort (in which my colleagues Sheldon

Steven Weinberg: 'a tremendous effort by theorists has proved almost entirely frustrating'.

(Photo CERN 356.12.79)

Glashow and Abdus Salam participated very actively) to make a grand unified theory to bring together the strong and electroweak interactions along the same lines as the electroweak unification. These grand unified theories led to a general expectation of an unstable proton with a lifetime just barely accessible to experiment. But so far, to our great sorrow, this has not been seen.

Many alternative models have been proposed, but none so far have crystallized as candidates for the 'true' theory. Despite all this theoretical activity, we have virtually nothing to show in the way of concrete predictions to compare with experiments.

Despite the fact that many of these new ideas look forward to a grand synthesis at extremely high energies, I think it is still possible that new things will turn up in experiments using current technology, and there are even signs of this happening.

The theorists may have their direction set for them by the experimentalists. But it is also possible that new theoretical ideas will be so successful that they will be able to explain all the missing numbers.'

In reply to a question by discussion co-moderator Celia Jarlskog on the new drive to link basic physics ideas with cosmology, Weinberg replied: 'Despite the great success in formulating qualitative solutions to cosmological problems, there has not been one quantitative prediction to rival, for example, the 1960s prediction of the helium abundance which gives any confidence that these cosmological scenarios have any reality.

I think the work is fascinating (I participated in some of it myself) but I don't see any hope that we will be able to confirm any of these ideas. Unfortunately they do not lead to precise quantitative predictions because long after its various initial phases, the Universe passed through a long period of statistical equilibrium in which all the interesting phenomena of the earlier epochs got washed out. In the 'grand cooking' of the Universe, we are now left with the final cosmic 'stew' without any idea of the individual ingredients that went into it.'

Simon van der Meer of CERN began by spelling out to the largely student audience some 'facts of life' about present-day particle accelerators. Larger and larger such machines are needed to probe smaller and smaller constituents of matter.

'Current thinking has concluded that it is no longer useful to use fixed target accelerators with most of the energy lost in hitting the stationary target particles. Instead the fashion is now colliders, with all the energy being effectively used. With colliders, people prefer to use electrons and positrons rather than protons. Proton and antiproton collisions are a mess, as the particles are full of quarks and gluons. The collision energy has to be shared between the constituent particles, and is effectively reduced.

On the other hand, protons are easier to handle in a circular machine, as light particles like electrons lose energy by radiation as they move in a circle. At CERN, we had the possibility of using protons and antiprotons in the existing SPS ring. Handling contra-rotating beams in a single ring this way is relatively cheap — much cheaper than building a new ring. However when we think about plans for higher energies in bigger rings, are these antiproton methods still useful?

We have done it, and it works. But only just, and the process is difficult and painful. We have to collect antiprotons all day long, and if the slightest thing happens, we lose them and have to start all over again. If we build a new machine, I would think it would be better to build two rings and handle protons. It's easier and more reliable, and the price difference is not all that big.

At CERN, we are now building the LEP machine, eventually to collide 100 GeV electrons with positrons. In the US, the new superconducting ring at Fermilab accelerates to 800 GeV, and 1000 GeV (1 TeV) is planned. A study is underway for a 20 TeV machine, and if the Americans build this, then we in Europe are in trouble. One plan currently being discussed is to use the LEP tunnel for a proton ring, which because of its limited size can at most provide about half the energy of the new US proposal. However it will be much cheaper, and if the US community doesn't get the money to build the new machine, we in Europe will be in a good position. That's our current dilemma.'

Abdus Salam began by acknowledging the contributions of the 1984 laureates and all the other people at CERN responsible for creating the proton-antiproton Collider. 'Van der Meer has talked of plans for the immediate future,' he continued, 'but I would like to look further ahead, in fact to the year 2006 — my eightieth birthday!

Theorists look at an energy of 10^{19} GeV — the so-called 'Planck energy' given by the Einstein equations. How are we to get at this energy? Present accelerators are limited by accelerating fields of

Simon van der Meer — 'our current dilemma'.

(Photo CERN 715.1.84)

about a tenth of a GeV per metre. On this basis we can propose machines of 10^4 GeV, but remember this figure of 10^{19} GeV. Beat-wave laser-plasma accelerators are on the horizon and could be a thousand times more powerful. Even so, 10^{19} GeV is still far away. But I am sure that by the year 2006 there will be newer ideas to exploit.'

Then Salam turned to the thorny problem of funding. 'We have to put a price on our curiosity and our search for basic knowledge. The usual amount suggested is one-tenth of two per cent of the gross national product — two per cent is the usual overall level of expenditure on science and research and development. As I come from a developing country (Pakistan), people ask me how I can justify vast expenditures on accelerators. My answer is always that in our technological society, the 'big sciences' are the big spenders and will take the place of nuclear armaments the day these stop being made. If our technological society wants to go forward, we will be its benefactors. The required level of funding is absolutely nothing compared to the current investment in nuclear submarines, but at the same time the support for science is being eroded in some countries. I shudder to think what this means for the future.'

Finally Salam took up his long-cherished dream of unifying all the forces of Nature. 'We do not seem to have been following the right path. The proton decay which was supposed to show the unification of the strong interaction does not seem to be materializing. However there is the possibility of an incredibly beautiful symmetry — the

Abdus Salam, seen here at CERN in 1979 with Leon Van Hove (standing, left) and John Adams (right), CERN's Directors General at the time. At Stockholm last year, Salam paid tribute to their roles in making the CERN proton-antiproton Collider possible.

(Photo CERN 361.10.79)

supersymmetry between bosons and fermions. There is no firm evidence for this yet, and if this symmetry really exists we will only know when we theoreticians can 'gauge' it, and that means the theory of supergravity. This means that the interactions get mixed up, they don't show themselves neatly and individually.

Going further, to extended supergravity, recent work suggested that the best dimension for the unification was eleven, and this eleven-dimensional theory was so beautiful that Stephen Hawking called it the Theory of Everything — TOE. But it didn't work and we had to backtrack.

So we are in the sad situation where we have many competing theories, but little to show for it. The moral is that physics will always be an experimental science, and we shall have to keep coming back to van der Meer and Rubbia and the accelerators.'

This was underlined by Carlo Rubbia. 'It seems clear that present day physics is back in the hands of the experimentalists. We are all waiting for a big surprise, we do not know from where.

As mentioned by Simon van der Meer, colliding beams — hadrons as well as electrons and positrons — are taking over from fixed targets. This very important revolution changes the picture of accelerators very much from when it was started fifty years ago by Lawrence.

In parallel, there is a big development in non-accelerator science. Not that long ago, it seemed that the only way to become famous was to have your own accelerator. Now there are ways of becoming famous without one.

There are two classes of such experiments — one looking for very small masses, neutrino mass or oscillations, and at the other and of the scale the proton decay experiments looking for effects of very big masses. The search for proton decay is still going on and there are great chances of finding it, if it is there, in the next few years.

In the accelerator field, we do not really know where new surprises are going to turn up. To me it is not obvious that we have to build new machines a hundred times more powerful than present colliders. New physics could be closer than we think. Already some glimpses of evidence at the CERN Collider suggest new things which are not completely understood (see May 1984 issue, page 139).

Remember the case of the J/psi. At the time the CERN Intersecting Storage Rings were operating at

Carlo Rubbia: 'new physics could be closer than we think'.

(Photo CERN 63.8.83)

about 60 GeV and the new particle had an energy of only 3 GeV. So it was not just a question of machine energy. It was discovered by looking more carefully at what had gone before.

The discovery of the W and Z particles brings in new mass scales, just as the discovery of the pion did. But when the pion was discovered, nobody suspected the wealth of new resonance states that would turn up. Likewise, we have no idea what the Ws can do when they get close to each other. What is the interaction of Ws like? There are lots of theories with lots of answers, but as an experimentalist I would like to see what any new spectroscopy looks like. This is an open experimental question and the only way to solve such questions is by more careful and more experiments.'

The final speaker, Sheldon Glashow, paid a tribute to the CERN Collider. 'Few of us believed that this machine would work so well and would find not just the W and Z but the top quark as well. It is a miracle.'

'There have been attempts to find surprises outside the high energy domain,' he continued. 'Free quarks, magnetic monopoles, neutrino masses and proton decay, and for a brief period I thought this was the direction to go. But it seems not to be the case. The surprises are coming from high energy physics and despite their modesty Carlo Rubbia and Simon van der Meer are sitting on a bomb.'

Glashow then adopted a more philosophical viewpoint. 'There

Sheldon Glashow: upwards and downwards paths.

(Photo CERN 327.12.79)

are two very distinct approaches to the mysteries of elementary particle physics. I call them the upwards path and the downwards path. Abdus Salam and Steven Weinberg, for example, follow the latter — starting from some brilliant idea, like the Einstein approach, one attempts to go from a theory of everything to the mundane silly little effects seen at accelerators. This downwards path is a difficult one which began with Einstein's brilliant discovery of general relativity in 1917 and has continued downhill ever since!

The upwards path is a dirtier business. We listen to our experimental colleagues and try to glean little bits and pieces that do not fit into our standard and arrogant picture of the universe.

As my theoretical colleagues have already said, the downwards path is not getting very far. But the upwards path is not getting very far either!

Simon van der Meer spoke about international competition in high energy physics. I don't think we should regard this as competition any more. It was when it was cheap, but today it has become very much more expensive. I hope that what has been an active competition in the past will evolve into a fruitful collaboration. The success of CERN — a collaboration of 13 nations — will be usefully expanded. Let me say today, to be rebroadcast in five years, that this Nobel Prize, awarded to these distinguished and very deserving Europeans, will mark the beginning of a high energy physics collaboration with the other countries of the world.'

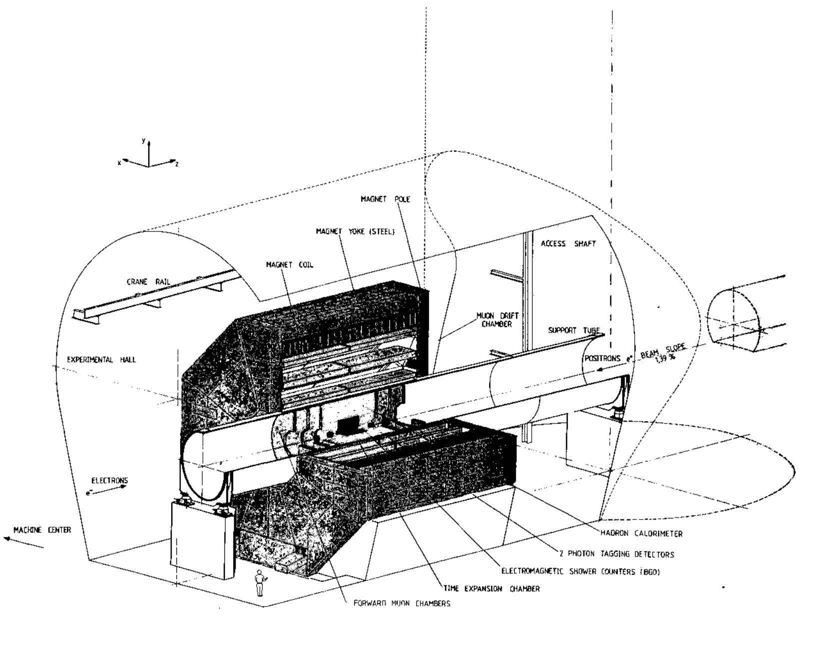
L3 — experiment for LEP

To conclude our series of articles on the four big experiments for the giant LEP electron-positron now being built at CERN, we turn to the L3 study. (The other three experiments are DELPHI — see July/August 1984 issue, page 227, ALEPH — see September 1984 issue, page 269, and OPAL — see November 1984 issue, page 375.)

While the other three experiments have concocted fancy acronyms, the title L3 simply stems from the fact it was the third letter of intent to be received back in 1982 when ideas for LEP experiments were first tabled. However the modest label is no reflection on the experiment's ambitions, and L3 head Sam Ting is still looking for a suitable name for his experiment.

Our understanding of the fundamental forces of Nature leans on two basic pillars, gauge invariance and the mechanism of spontaneous symmetry breaking. Gauge invariance, which provides the field theories to describe electromagnetism, the electroweak unification and inter-quark forces, is now well understood.

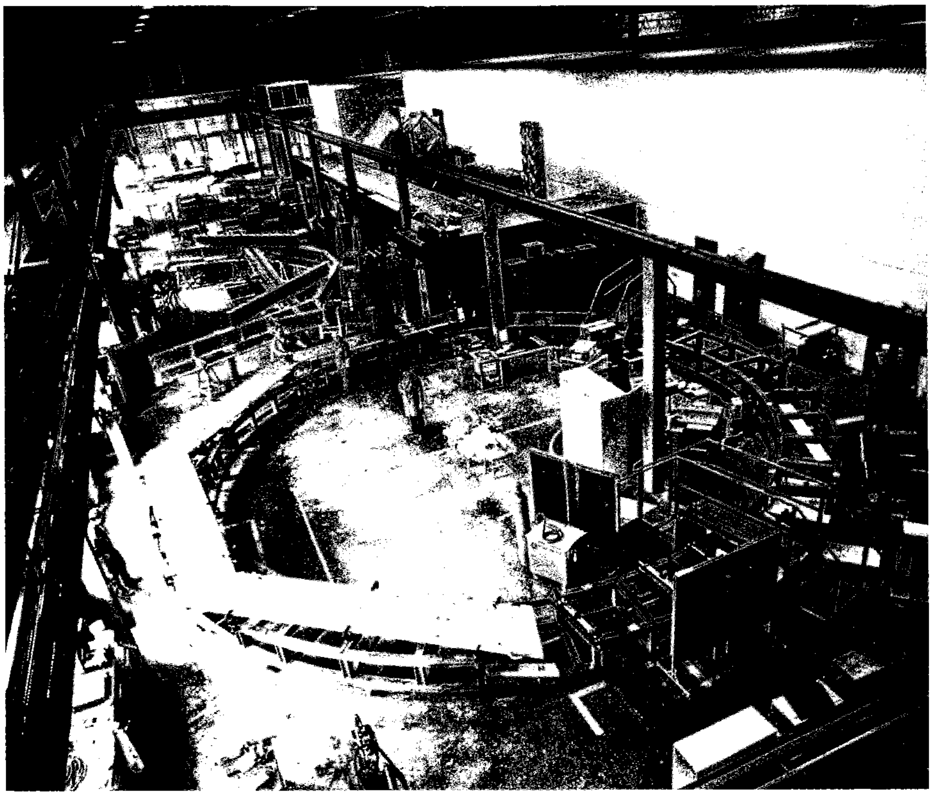
However spontaneous symmetry breaking, which provides for example the mass scales of the electroweak theory, is on less sure ground. Underlying this mechanism are new particles, yet to reveal themselves — the 'Higgs' bosons. There are no clear-cut predictions of where these objects will be found (unlike the very precise predictions for the W and Z gauge particles). To uncover signs of these particles at LEP will require precise measurements of relatively rare processes. L3 has been designed with this firmly in mind. An additional aim is to carry out pre-



Overall layout of the L3 experiment for the LEP electron-positron collider now under construction at CERN.

General view of the winding workshop at CERN for the big L3 magnet coil. The coil half-turns are electron beam welded on the table in the foreground. A third of the coil has already been completed.

(Photo CERN 798.5.84)



cise measurements of the standard electroweak sector. All this will require in-depth analysis of 'missing mass' — energy carried off by invisible particles like neutrinos — and detailed spectroscopy of the produced clusters ('jets') of electrons, muons, photons and hadrons.

The L3 collaboration includes Lund from Sweden, Siegen and Aachen from West Germany, Zeuthen from East Germany, Budapest from Hungary, NIKHEF from the Netherlands, ITEP Moscow from the USSR, ETH Zurich, Geneva, Lausanne and CERN from Switzerland, Annecy and Lyon from France, Florence, Rome and Naples from Italy, Madrid from Spain, Bombay from India, Beijing and Hofei from China, and a big US contingent — Caltech, Carnegie-Mellon, Harvard, Johns Hopkins, Honolulu, Michigan, MIT, Northeastern, Oklahoma, Ohio State, Princeton, Rutgers and Yale. Involving some 400 scientists, it is the first major physics collaboration involving Western Europe, the USSR, the USA and the People's Republic of China.

The detector features a large magnetic hall enclosing an easily modifiable central detector, with physics objectives extending beyond those of the initial phase of LEP running (collision energies of around 100 GeV). The design places great emphasis on high precision (one per cent) measurement of photon, electron and muon momenta, together with good resolution of hadron jets and precise information from the interaction vertex.

To be installed 50 m below ground, the detector will be enclosed in a 8000 ton solenoid, 15.6 m high and 13.6 m long, providing a central field of 0.5 t. At the centre of this magnetic 'cave' will be the vertex detector, a 'Time Expansion Chamber' (TEC) extending 50 cm radially from the interaction point and providing high spatial and track separation resolution.

Surrounding the vertex detector will be another novel feature — an electromagnetic calorimeter consisting of a cylindrical array of 12 000 crystals of bismuth germanium oxide (BGO), read out by photodiodes insensitive to magnetic fields. The raw material for the 10 tons of BGO comes from the Soviet Union and is sent to CERN prior to shipment to China, where it is made into crystals at the Shanghai Institute of Ceramics.

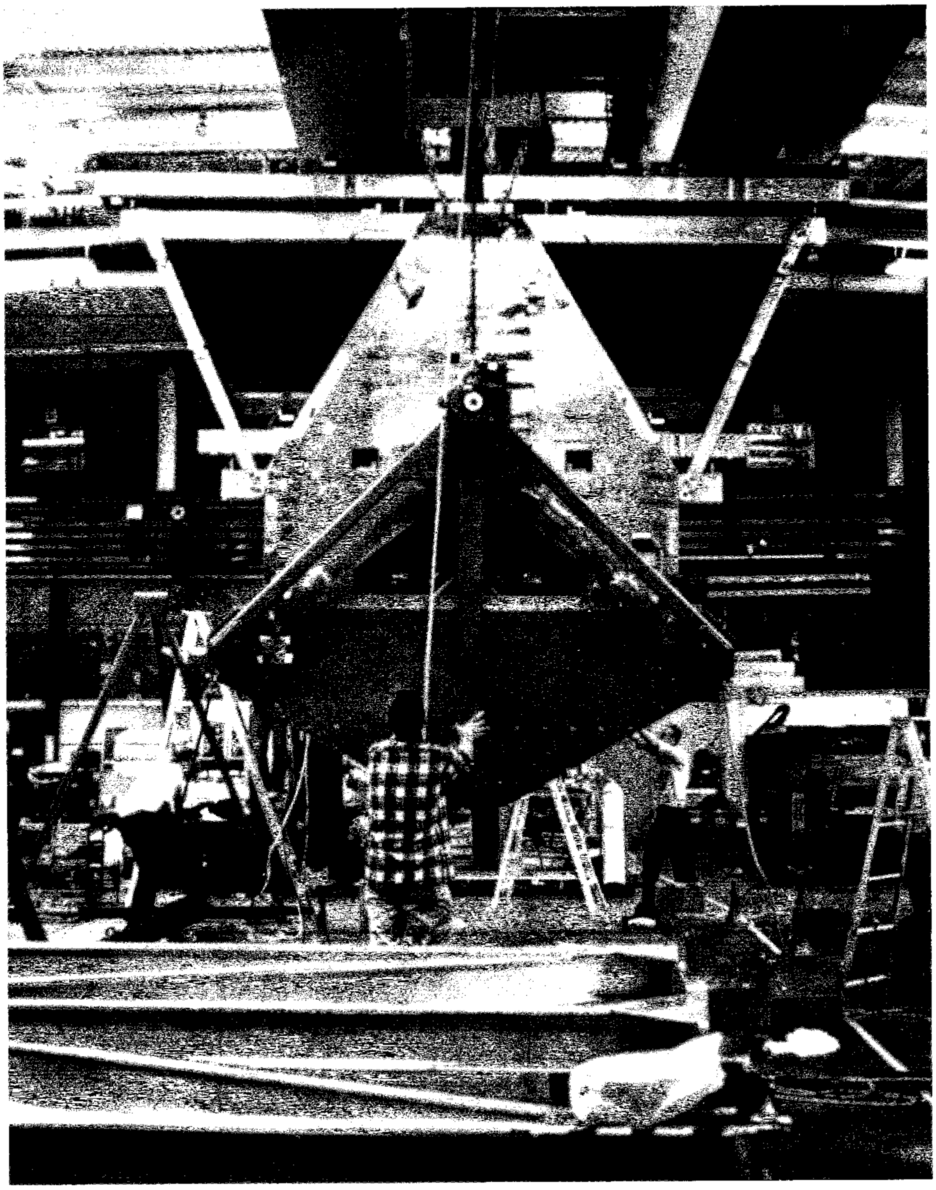
The electromagnetic calorimeter will be followed in turn by the 400-ton hadron calorimeter, and a muon spectrometer arranged in three layers.

The inner detector will be supported by an adjustable octagonal tube, 50 mm thick and weighing 170 tons, concentric with the beamline and extending almost the length of the experimental hall. In this way the detector components can be moved independent of the outer magnet structure.

The large hadron calorimeter, housed inside the support tube, will be sectioned to allow access to the BGO and vertex chamber within. The muon chambers will be supported outside the tube, and the detector will be completed with hadron endcaps and with forward detectors for two photon physics and for luminosity measurements.

Responsibility for the big magnet and the experimental area is shared by CERN, ETH Zurich, ITEP Moscow and MIT. The 168 turns of the magnet coil are being electron

L3 muon chamber manufacture underway at Harvard. Tests have shown that a completed octant can provide muon pair mass resolution of one per cent at the Z^0 mass.



welded from heat treated Anticorodal 41, offering better mechanical strength than pure aluminium with only marginally less conductivity. Its rated current is 30 kA, and the 4 MW of generated heat will be removed by water cooling.

The coil will be mounted in a frame built of Soviet steel using an ingenious modular construction method. As well as increasing the field homogeneity, the steel frame will boost the magnetic field itself by 30 per cent. One third of the coil has already been completed at CERN, and the delivery of the Soviet steel runs according to schedule.

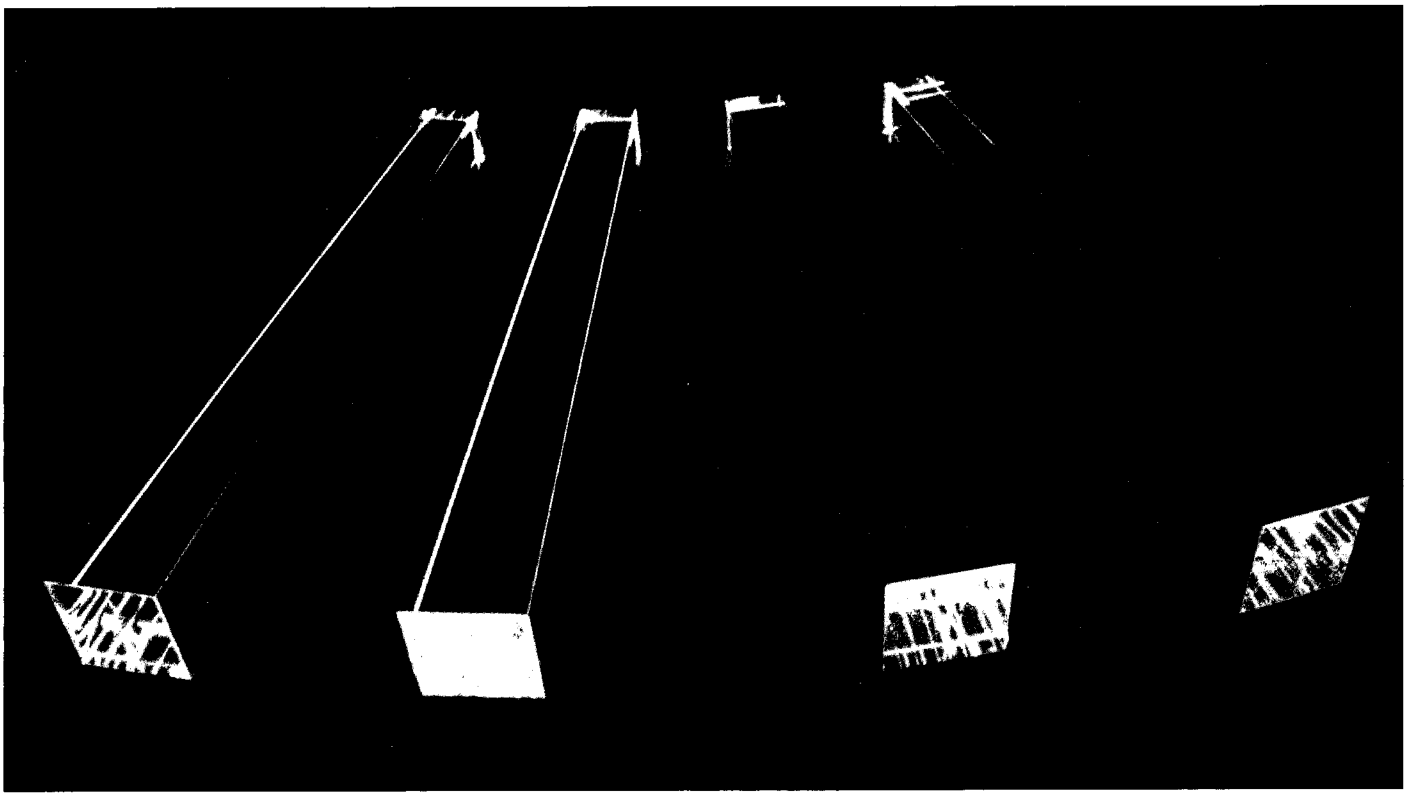
Great emphasis is placed on muon detection. Built by a NIKHEF, Madrid, ETH Zurich, Harvard, Johns Hopkins, MIT, Northeastern, Rutgers and Yale team, the large radial space between the solenoid and the hadron calorimeter will handle muon pair masses up to 160 GeV (good enough for a future hadron collider in the LEP tunnel). Filling such a large space with one big chamber poses obvious difficulties, and the detector will rely instead on three separate layers (16, 24 and 16 wires) sampling the muon tracks. This clustering in fact should give better intrinsic resolution than one big chamber with 56 uniformly spaced wires.

Each muon chamber will contain some 6 000 crossed field and sense wires. The muon chamber assembly will be supported on a large 'Ferris Wheel' structure. One octant of the muon chamber has been completed and calibration with ultra-violet lasers promises a muon pair mass resolution of one per cent at the Z^0 mass.

The hadron calorimeter is the responsibility of an Aachen / Florence / ITEP Moscow / Michigan / Rome / Bombay / ETH Zurich — EIR (see below) team. Hadron events are expected to make up about three quarters of electron-positron annihilations with LEP tuned to the Z^0 energy. As well as measuring total energy deposited, the calorimeter will give the direction of energy flow (very important for jet physics) and help with muon identification.

The octagonal barrel calorimeter (inner radius 87 cm and outer radius 213 cm) and endcaps will be built from some 400 tons of copper and uranium absorbers, interspersed with proportional tubes. The barrel structure will be grouped into cellular towers containing precision uranium plates provided by the Soviet Union and chambers developed at the University of Michigan. The whole structure will be assembled at the Swiss Federal Institute for Reactor

24 cm-long BGO crystals for the L3 electromagnetic calorimeter. L3's BGO needs mass production methods.



Research (Eidgenössisches Institut für Reaktorforschung — EIR).

The design of the detector places severe constraints on the electromagnetic calorimeter, which nevertheless must ensure good energy resolution over a wide range of electron and photon energies, good angular resolution for photons down to 50 MeV, efficient rejection of hadrons, and good separation of electromagnetic showers.

BGO's high absorbency relative to other scintillating materials (lead glass, sodium iodide) offers a more compact detector, so leaving ample radial space for muon detection. BGO was first exploited as a substitute for sodium iodide in X-ray tomography, and has since been used in positron emission tomographs, in nuclear physics, and in space experiments. As well as having high stopping power it is non-hygroscopic.

However it is conventionally expensive, and a big programme has been launched to manufacture the material cheaply in the required quantities. Mass production of BGO crystals has already begun at the Shanghai Institute of Ceramics. Tests indicate that the material has a resolution comparable with sodium iodide. BGO readout electronics is the responsibility of Lyon and Princeton and is progressing well. Mass production should begin later this year.

Participating in the electromagnetic calorimeter work are Aachen, Annecy, Beijing, Budapest, Caltech, Carnegie-Mellon, CERN, Geneva, Hofei, Lausanne, Lyon, Madrid, Munich, Moscow, NIKHEF, Princeton and Rome.

Inside the electromagnetic calorimeter will be the 100 cm diameter vertex chamber. A 'Time Expansion Chamber' (TEC) solution has been adopted to provide precision lifetime measurements, to measure charges and multiplicities, to distinguish between particle types and to reconstruct charged particle momenta.

The cylindrical TEC will have alternate low field 'drift' segments, electrostatically isolated by fine grids from the neighbouring high field 'detection gap' segments. The potential between the cathode and the grid determines the velocity of ionization in the drift region (some 5 microns/sec). Thus clusters of electrons drift relatively slowly to the grid, where they cross into the detection gap (where drift velocity increases to about 50 microns/sec) and are multiplied at the anode.

In a conventional drift chamber, the drift time is measured from the edge of the anode signal (the first

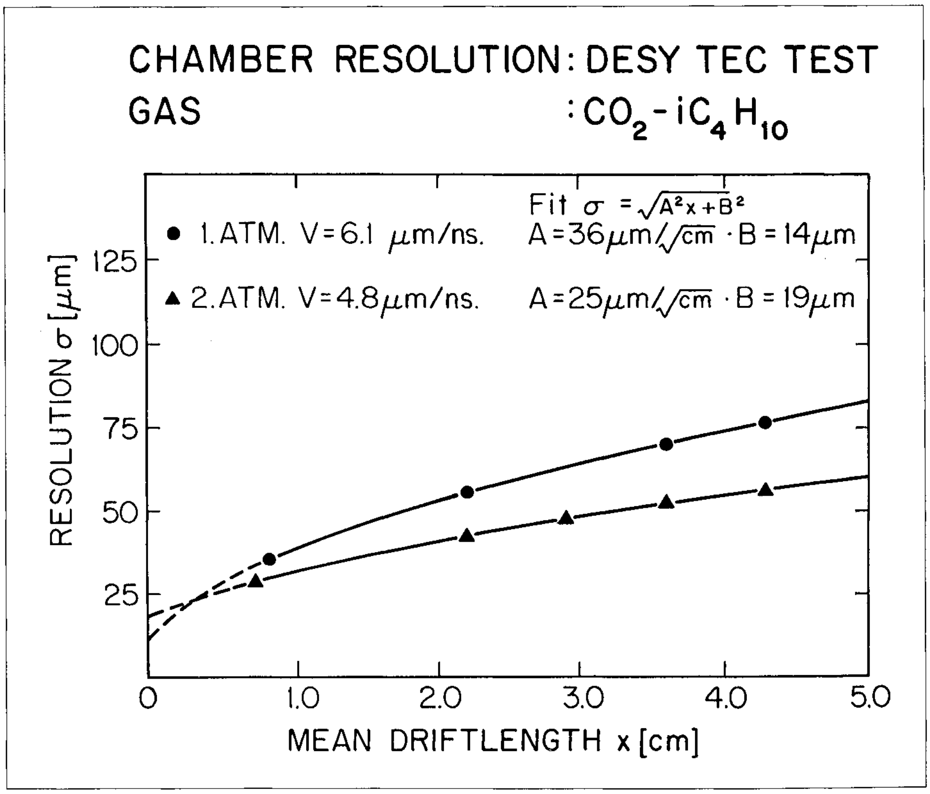
BGO manufacture at the Shanghai Institute of Ceramics.

electrons to arrive). However in the TEC, the anode signal will be serially digitized (100 MHz flash analog-digital converters) and stored in memory to provide a profile of the entire electron signal. Many prototype chambers have been developed by ETH Zurich and III Physical Institute, Aachen. Tests on a 40 by 40 cm chamber in an electron beam at DESY in Hamburg shows that this type of chamber will provide single track resolution of 25-30 microns and double track resolution of 220 microns. Construction of the final chamber should begin soon. Participating in the TEC project are Aachen, MIT, Ohio, CERN, Lund, Oklahoma, Siegen, Zeuthen and Zurich.

Close to the beam pipe on either side, two forward pairs of BGO electromagnetic calorimeters, preceded by proportional chambers, will be installed for two-photon physics by Carnegie-Mellon, CERN and Hofei.

The data acquisition system, strobed by the beam crossing signal, has to handle high event rates and about 100 Kbytes of information for each collected event. An initial selection will be based on a fast trigger using look-up tables and fast ADCs. The next level of triggering will carry on where this left off, providing more complete information (so that for instance a charged particle trigger will have access to information from all the vertex chamber wires). Subsequent software programmable trigger processors will correlate information coming in from all over the detector.

Before being passed on to the



Tests of a prototype of the L3 vertex chamber ('Time Expansion Chamber') in an electron beam at DESY. Construction of the final 100 cm diameter chamber will begin soon.

First neutrons from new machine

experiment's on-line computer and written to tape, the incoming data will be sifted by a final trigger using emulators to carry out such jobs as track finding and coordinate calculations.

While the L3 design leans heavily on past experience, the same experience also shows that physics isn't always predictable. Thus a flexible design, permitting rapid modification and evolution, as well as precision measurements, could pay dividends in this unexplored area of physics.

It was the culmination of an intense year of construction and commissioning when on 16 December the first neutron beams were obtained from the UK Rutherford Appleton Laboratory's new Spallation Neutron Source (SNS), and for the first time since 6 June 1978, when the Nimrod proton synchrotron was closed down, the Laboratory was back in the business of providing particle beams from an accelerator.

In 1976, with the decision to close down all home-based high energy physics research in the UK in favour of an increased commitment to CERN and other large Laboratories overseas, an ambitious plan was put forward to convert the Nimrod complex into a neutron source for other kinds of physics.

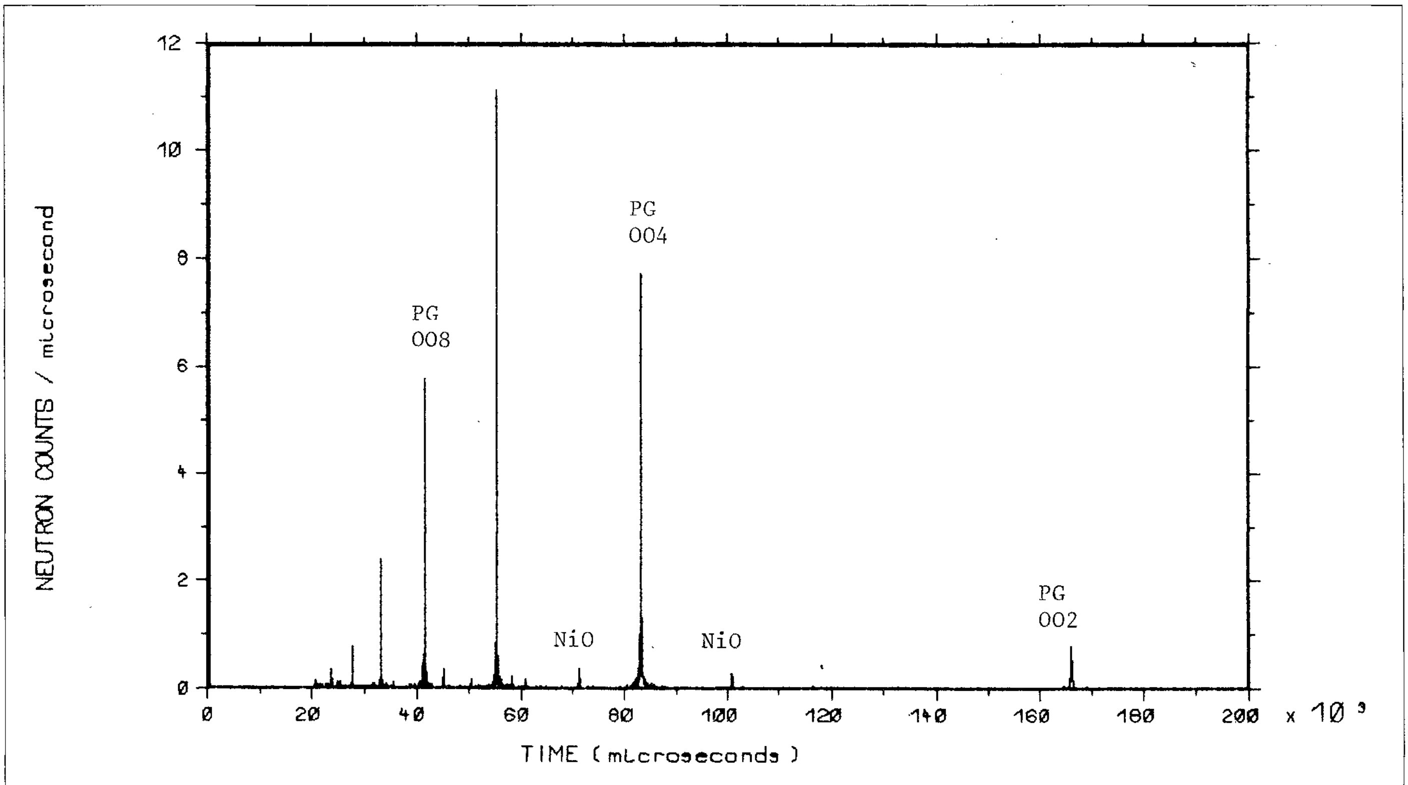
Nimrod, the last weak focusing proton machine to be built, provided its first 7 GeV proton beam in 1963 and provided the research fuel for several generations of UK particle physicists. With the decision to build the SNS, the task was to transform the existing facility into a high repetition rate, high intensity machine furnishing the protons to bombard a neutron production target. As well as equipment from Nimrod, the SNS synchrotron also makes use of components from the old NINA electron machine at Daresbury, closed down in 1977.

The SNS synchrotron reached 550 MeV last June using four of the eventual six radiofrequency cavities which will take the proton energy to 800 MeV (see September 1984 issue, page 289). During commissioning time, limited to a few days because construction is still proceeding, close to ten per cent of the final design performance of 2.5×10^{13} protons per pulse (ppp) has been accelerated

Goal! Rejoicing in the control room as the first protons hit the neutron production target of the UK Rutherford Appleton Laboratory's new Spallation Neutron Source — SNS.

(Photo Rutherford Appleton)

The shape of things to come. The neutron diffraction patterns of a pyrolytic single crystal and nickel oxide powder simultaneously measured on one of the 40 detector rings of the 96 m High Resolution Powder Diffractometer at the SNS, displaying the high resolution and low background given by this instrument.



to 550 MeV. 20 per cent of the design performance has been injected and circulated at 70 MeV. This should be sufficient to give a greater percentage of the design accelerated intensity.

At the end of September a further milestone was reached. Protons were extracted at the 10^{12} ppp level upwards into a beam dump in the synchrotron room. The extraction system uses three kicker magnets, all slightly different, but approximately 0.6 m long and having an aperture 170 mm square and giving a total vertical deflection of 14 mrad. The rise time is 200 ns, this being the time between the two bunches in the SNS. In the same straight section is a 1.8 m magnet with 10 mm septum giving 21° upward deflection. During the September run the beam also passed through the magnet which turns the beam horizontal above the synchrotron and through two horizontal bending magnets to a 2 m graphite beam stop. No beam loss was detected during this extraction process.

All commissioning work so far has been done at one pulse per second rather than the design figure of 50 Hz to minimize activation of components. The design performance of 800 MeV, 200 microamp mean current (160 kW of power in the beam) leads to the requirement for good diagnostics in the synchrotron to minimize beam loss to at most the one per cent level calculated to allow conventional maintenance techniques. A start has been made on commissioning the diagnostics. Beam intensity, beam profile, transversely and longitudinally, and closed orbit have been measured. It is noticeable that the 'raw' betatron Q-values coming from the main quadrupoles and dipoles being in series have given good injection and acceleration intensities at this early stage. Q-values have not been tuned using the trim quadrupoles — indeed they have not even been measured.

After commissioning the beam extraction system, the next task was installation of the extracted proton beam, the target station and the neutron beamlines. The extracted proton beam is about 150 m long and contains some 65 magnets — all except one, including their power supplies, being salvaged from the Nimrod and NINA installations, but requiring refurbishing. The extracted beam caters also for an intermediate transmission target 20 m upstream of the neutron target for producing muons for the first stage of the muon spin rotation and resonance project which will be funded by the

EEC, France and West Germany.

Early on Sunday 16 December, protons were taken to this intermediate target position into a 2 m graphite beam dump, and the very first pulse was seen on a scintillator on the target. Meanwhile the target station shielding had been completed to the stage where protons at low intensity could be focussed by the last six extraction line quadrupoles onto the neutron production target. This was the first of the full specification targets, with its uranium plates encased in zircaloy, together with all its cooling manifolds and connections and temperature monitoring. For the run the heavy water coolant was static, not circulating. The two ambient temperature moderators were installed and filled. In addition, the methane moderator was working with methane circulating at 100 K from its refrigerator through its 16 m-long transfer line, and the hydrogen moderator system, which previously had been successfully tested off-line, had been stripped and reinstalled in its final position. The moderator was filled and working at 25 K. This fed neutrons to the spectrometer built and installed by the Bhabha Institute of Trombay, India. The reflector vessels containing beryllium rods were filled with static heavy water. The 90-ton steel door, which completes the target shielding and is part of the train which carries all of the maze of room temperature and cryogenic cooling systems, was pushed into position. Six neutron holes in the 4.3 m thick shielding enclosure were open.

That evening, the beam dump at the intermediate target position was lowered and Laboratory Director Geoff Manning counted down to 'beam on'. Resounding cheers told that the operation was a success.

There was some checking and setting up of the equipment on the six neutron holes followed by a three-hour run. Neutron spectra and intensities were measured for each of the moderators. All were found to confirm the design performance. One of the spectrometers was 100 m away from the target, its particles coming through a neutron guide which also worked according to expectation. The time-of-flight and data collection electronics worked well together with the software, and a powder spectrum was taken as a demonstration that all was well.

Following this initial success, a scientific programme of neutron scattering at about ten per cent of the machine's ultimate performance level is scheduled for April. The Laboratory looks forward with pleasure to being once more the home of an accelerator-based research programme.

(From David A. Gray)

Around the Laboratories

FERMILAB
Accelerator back on

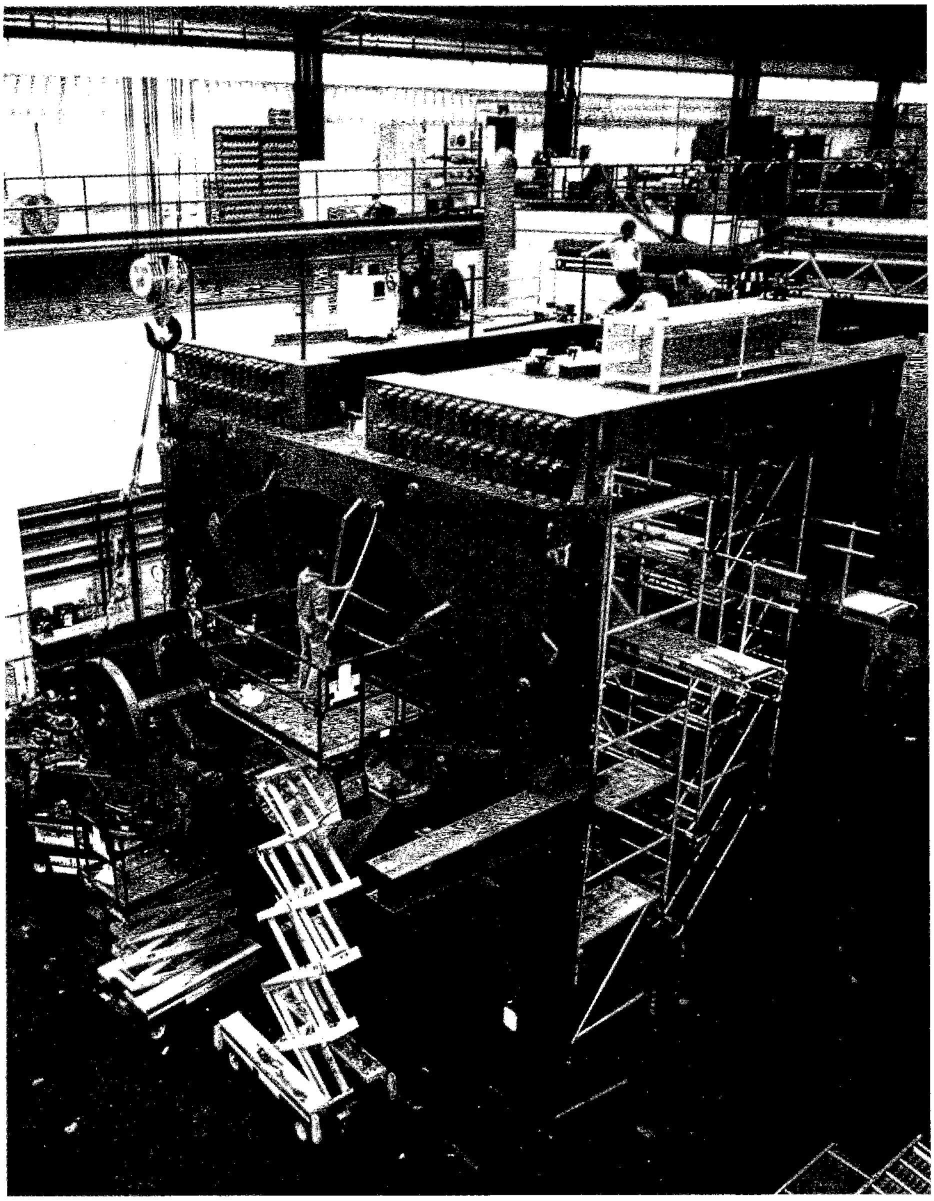
Throughout the end of last summer and the fall the Fermilab accelerator was down for improvement and maintenance. An enormous number of elements were installed and the accelerator has now operated once again at 800 GeV.

The most spectacular change involved the old Main Ring (conventional magnets) rather than the superconducting Doubler ring. There an overpass was installed at the DO straight section, raising the accelerator six feet above the median plane of the Tevatron and slightly inside the normal radius. This striking deformation to a conventional circular accelerator takes the main ring by the DO detector. Beam has now been accelerated to 150 GeV through the bypass. This success as part of the Tevatron project is reassuring, particularly in light of the large bypass that will be installed later near the BO Collider Detector. (The decision to go ahead with the DO detector was taken last year — see May 1984 issue, page 147. This will complement the big BO colliding beams detector — see January/February 1984 issue, page 11.)

Almost as spectacular was the operation to improve the lead restraints on a fair fraction of the Doubler magnets. A quarter of these magnets had to be moved into the tunnel aisle to carry out the operation. The smooth turn-on to 800 GeV attests to the effi-

Construction of the Fermilab collider detector at the BO pit. The superconducting solenoid (practically invisible) was placed between the magnet end walls several weeks before.

(Photos Fermilab)

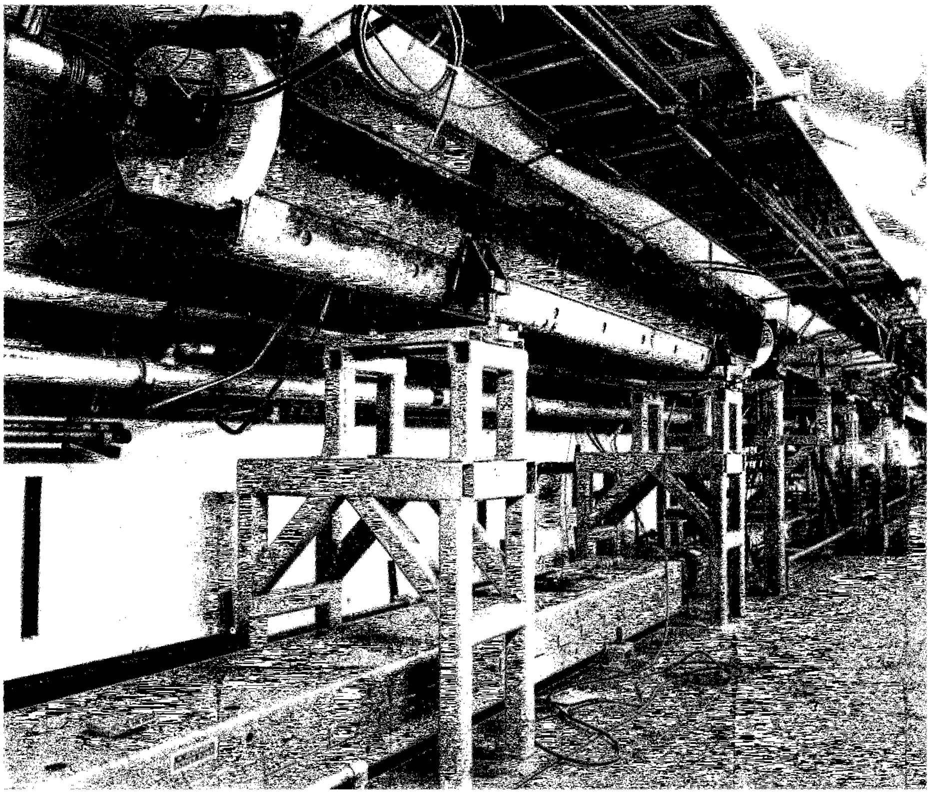


ciency of the modification.

A great deal of Tevatron progress has been made elsewhere. The Main Ring tunnel was enlarged at F18 and the pretarget hall was built to handle extraction and injection lines to the Antiproton Source. The radiofrequency building was also enlarged. The Booster complex was modified to install a beamline from the Booster tunnel to the Debuncher. Trim magnets for antiproton extraction and kicker magnets were also installed. More than 200 quadrupoles have been installed in the antiproton source. Recently the first dipole was installed in the debuncher.

Elsewhere, the Main Ring computer control system was switched to a VAX, the electronics for the entire Main Ring beam position monitoring system were replaced, and new magnets and power supplies were installed in the switchyard to prepare for fast extraction. The Main Ring cooling system was completely overhauled, including the replacement of 24 old 200-hp pumps with more efficient 50-hp ones.

Meanwhile the gigantic magnet end walls for the BO collider detector have been raised to an upright position in the BO assembly building pit, and the magnet yoke and some of the calorimetry modules have been assembled around them. Each end wall weighs 230 tons. The superconducting solenoid built by Hitachi has been placed in the interior of the detector.



Fermilab Main Ring bypass at DO, the eventual site of the second detector to monitor high energy proton-antiproton collisions. The Main Ring (conventional magnets — above) is elevated and slightly inside the ordinary ring configuration. The magnet in the photograph is also rotated to give both a horizontal and vertical deflection. Below are the superconducting magnets of the Doubler ring.

CONFERENCE
Electron cooling

ECOOL 84, held at the Kernforschungszentrum Karlsruhe (KfK) last year, was the first international meeting on electron cooling and related applications and reflected the increasing interest in this area of particle beam physics.

It is almost twenty years since the first ideas on electron cooling came from Gersh Budker's team at Novosibirsk in connection with a proposal for a proton-antiproton storage ring. The idea was to run an electron beam along the antiproton beam, continually refreshing the electrons so that the collisions between the particles in the two beams would reduce the momentum spread and divergence of the antiprotons, giving a tighter, better-defined beam.

In 1974, trials by the team of Budker and A. N. Skrinsky at Novosibirsk demonstrated electron cooling in the small NAP-M storage ring. The technique was subsequently tried out at CERN and Fermilab in the quest to develop high energy proton-antiproton colliders.

However attention turned to the technique of stochastic cooling invented by Simon van der Meer at CERN. This provided the crucial tool which made possible the CERN proton-antiproton Collider and the dramatic physics achievements which earned the 1984 Nobel Physics Prize for van der Meer and Carlo Rubbia.

As well as being used in generating the high energy beams of antiprotons for the CERN Collider, stochastic cooling also plays a vital role in providing the beams for CERN's LEAR Low Energy Antiproton Ring. After an initial deceleration to 600 MeV/c momentum in the Proton Synchrotron, the beams eventually can be taken down to 100 MeV/c (just 5 MeV antiproton kinetic energy!) by LEAR's own decelerating system.

However LEAR's physicists are looking for increased versatility, with internal targets and even lower antiproton energies, and electron cooling is seen as providing the ideal complement for the existing stochastic cooling system. LEAR's first electron cooling system, jointly developed by CERN and KfK, will soon be tested.

In addition to LEAR at CERN, small rings using electron cooling are planned or under construction at Indiana in the US, at Uppsala (the CELSIUS ring using magnets from the ICE — Initial Cooling Experiment — project at CERN) and possibly Stockholm in Sweden, at Jülich, Darmstadt and Heidelberg in West Germany, at Aarhus in Denmark, and at the Institute for Nuclear Studies (TARN II) in Tokyo. These projects cover devices operating from a few hundred eV to a few hundred keV to cool all manner of ions.

Thus ECOOL 84 attracted a wide audience and some hundred physicists participated. As well as summarizing the present status of the technique, the meeting went on to cover ongoing work — performance limits, new methods and applications in other fields of physics.

The scientific business started with an introduction to electron cooling theory by Alan Sorensen from Aarhus, followed by reviews of previous electron cooling experiments and talks on electron cooling applications at low and high (up to hundreds of GeV) energy.

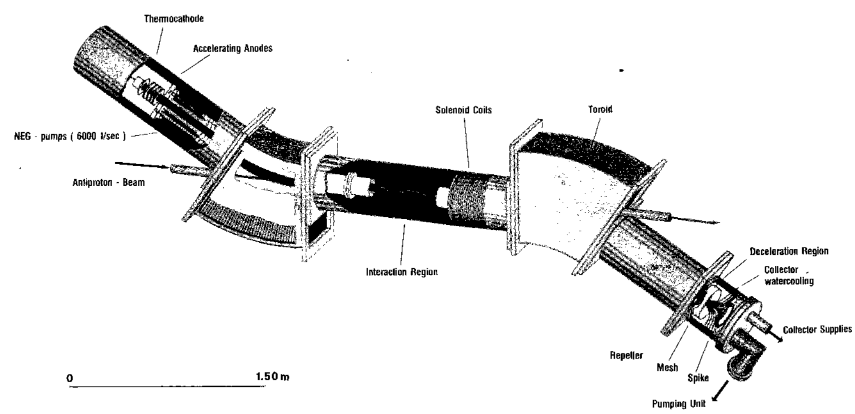


Diagram of the electron cooling system for the LEAR Low Energy Antiproton Ring at CERN.

Then came presentations on current projects in Europe, the US, the USSR and Japan. A topic of much discussion was the intrabeam scattering which counteracts cooling, especially for intense beams. This discussion was further stimulated by the news from Novosibirsk (presented by V. Parkhomchuk and D. Pestrikov) that cooling had been perfected to the extent that virtually all longitudinal momentum spread in a proton beam had been destroyed, thus suppressing intrabeam scattering. In such beams, the particles become strung out in an equally spaced (few microns) chain, like a row of beads.

Beams cooled by electrons offer interesting possibilities for atomic physics, exploiting for instance electron capture by very slowly moving ions and subsequent atomic effects.

All this and much more was covered in the meeting, which also featured a round-table discussion on controversial matters between F. Mills of Fermilab, H. Herr and J. S. Bell from CERN, Parkhomchuk and Pestrikov from Novosibirsk, and F. Krienen, now at Stanford. Fred Mills also gave the concluding talk, summarizing what had been covered in the previous three days.

Full marks to the Karslruhe organizing committee under the chairmanship of Helmut Poth for a timely meeting which provided a valuable impetus to electron cooling at a time when it is changing from a scientific curiosity to a widely exploited technique. The Proceedings will shortly appear as KfK Report 3846 (Documentation Office, KfK, Postfach 3640, 7500 Karlsruhe 1, West Germany). The next electron cooling conference will surely have many more working projects to review.

(Information from Helmut Poth)

Together at last year's ECOOL electron cooling meeting at Kernforschungszentrum Karlsruhe (KfK), left to right H. Poth (KfK), F. Mills (Fermilab), A. Citron (head of KfK Nuclear Physics Institute), and D. Möhl of CERN. The ECOOL International Advisory Committee was made up of Poth, Mills and Möhl together with A.N. Skrinsky of Novosibirsk, who was not able to attend the meeting.

DESY Theory Workshop

Held during the 'Festwoche' which marked the 25th anniversary of the German DESY Laboratory last year, the traditional DESY Theory Workshop concentrated on weak interactions of heavy quarks and on non-standard models for weak interactions, together with a progress report on lattice gauge theories with fermions. The organizing committee (H. Fritzsch, F. Gutbrod, D. Haidt, H. Lehmann, D. Schildknecht) had invited eleven lecturers to present experiments and theoretical ideas in these fields. Also many short communications contributed interesting material.

After presentations of results on heavy particles (carrying the beauty quantum number), C. Jarlskog (Bergen / Stockholm) gave a comprehensive review of our present knowledge on the question of how the three known quark families mix. The pattern of quark mixing has been pinned down tightly. While the mixing of the first and second family is fixed by the sine of the famous Cabibbo angle (0.23), the mixing between the second and third family is of the order of its square and the mixing between the first and the third is at most of the order of its cube.

The weak decays provide a valuable filter for heavy quarks in electron-positron jets, especially when several jet variables are analysed in conjunction. As R. Marshall (Rutherford) showed, a consistent picture for heavy quark fragmentation has emerged. The axial charge of the b-quark can well be measured due to the asymmetric angular distribution with respect to the beam axis. It agrees with the standard model predictions.

The ARGUS Collaboration working at the DORIS II ring at DESY was represented by J. Stiewe (Heidelberg). He showed, among many other results, evidence for the F* (charmed, strange) meson at a mass of 2114 MeV. Also five good candidates for antideuterons have been observed, the rate being qualitatively in accordance with thermodynamic expectations.

B. Stech (Heidelberg) devoted the main part of his talk to weak decays of heavy mesons. He was able to describe successfully the bulk of non-leptonic two-body decay data. Furthermore he discussed possible relations between quark masses, mixing and charge conjugation/parity (CP) noninvariance.

S. Nussinov (Tel-Aviv) reviewed various methods to derive mass inequalities. Partially motivated by potential-like models, many mass inequalities have been obtained in lattice quantum chromodynamics, using various levels of rigour.

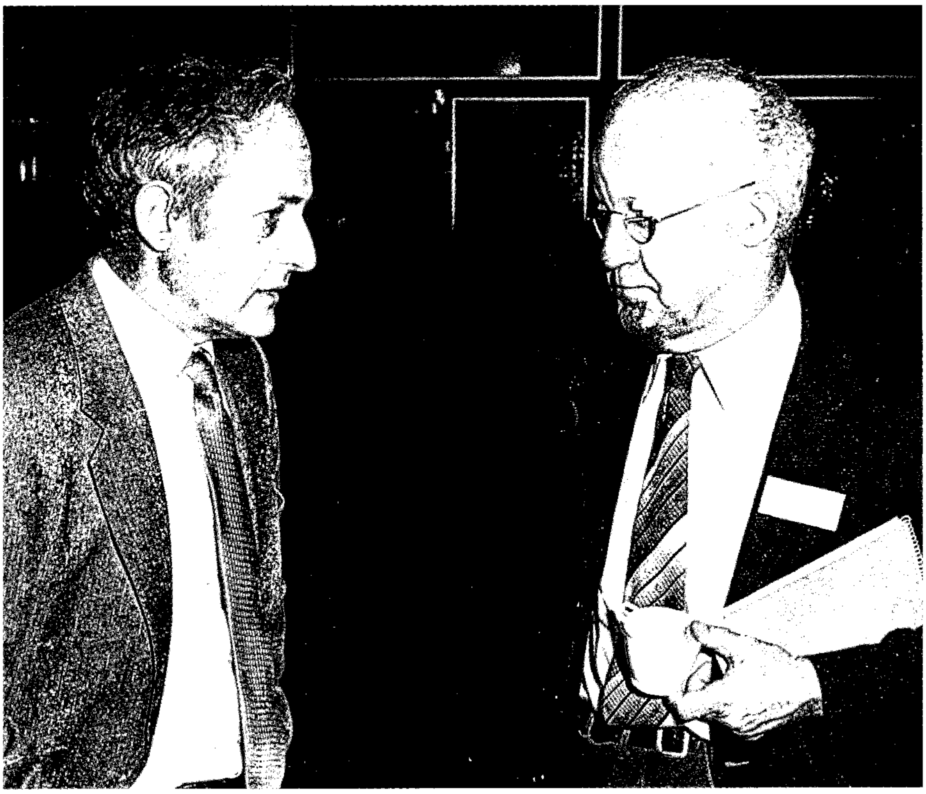
Although the standard electroweak model seems to work beautifully, there are good reasons to go beyond it, as D. Schildknecht (Bielefeld) emphasized. One way is to consider the W and Z particles as composites, which naturally leads to departures from the standard model. These ideas predict a rich spectrum of heavy particles in the 200 GeV range, and consequently many unusual events in high energy collisions.

J. Kogut (Urbana) reported on attempts to describe fermions by lattice theories, where progress is being made.

Several unexpected experimental findings were presented by T. Walsh (Minnesota) in his talk on exotic particles (with masses below 1 TeV), in particular Z decays accompanied by photons, anomalous jets from the CERN Collider, etc., which are the source of much speculation.

In the concluding lecture M. Peskin (SLAC) explained present thinking on the Higgs particle. Several ideas give limits or suggest ranges for its mass, giving many options for experimental searches. The zeta particle at 8.3 GeV (see September 1984 issue, page 266) did not fit easily into the expectations for a Higgs particle, and now is no longer healthy. Perhaps we will have to wait some time for the discovery of the Higgs particle, with its central role for mass generation.

(From Fritz Gutbrod and Harry Lehmann)



Left, E. Lohrmann (Hamburg) and R. Dalitz (Oxford) at last year's Theory Workshop at the German DESY Laboratory in Hamburg.

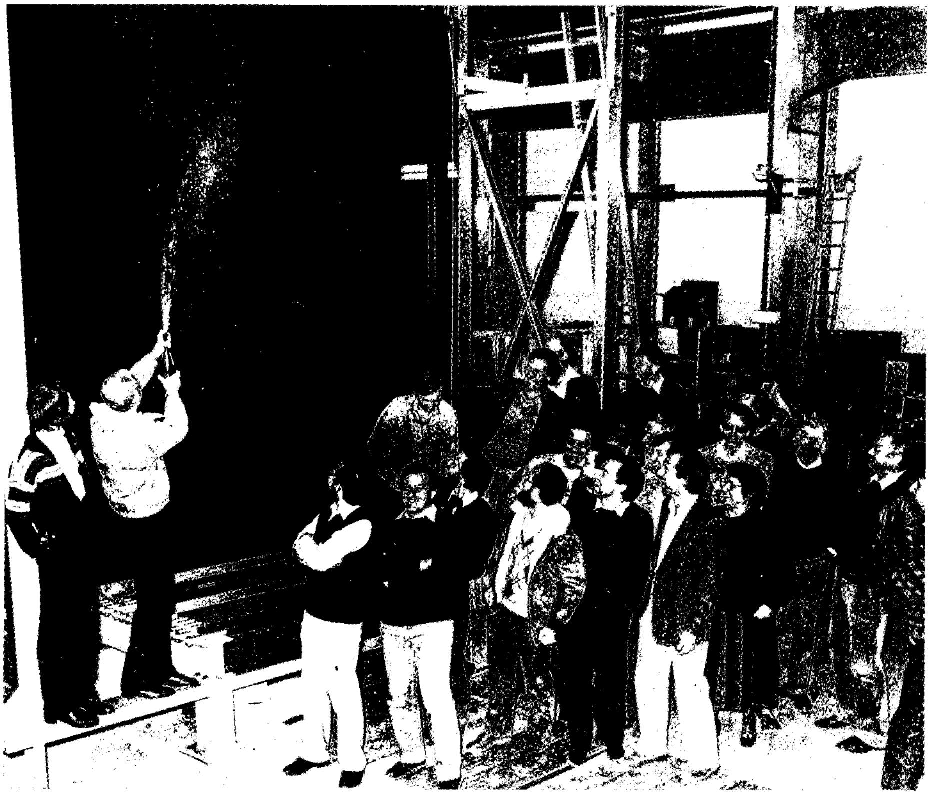
(Photo DESY)

People and things

Friends and colleagues of theoretician Geoffrey Chew gathered at Berkeley recently for a 'Jubilee' honouring his 60th birthday. His name is intimately associated with the great advances in Regge pole theory and the 'bootstrap' idea in the sixties.

Klaus Winter extravagently baptizes a module for the new CHARM II neutrino experiment at the CERN 450 GeV Super Proton Synchrotron. Following the impressive contributions of the initial SPS neutrino experiments, CHARM II heralds a new generation of high energy neutrino studies.

(Photo CERN 439.11.84)



ICFA panels

The main decisions taken at the eleventh meeting of the International Committee for Future Accelerators (ICFA) — held last October at the Leningrad Institute of Nuclear Physics, Gatchina — concerned the setting up of the four international panels which were proposed and agreed at the ICFA Seminar held at the Japanese KEK Laboratory earlier in the year (see October 1984 issue, page 319).

The panels and their Chairmen are: Superconducting Magnets and Cryogenics (G. Brianti — CERN), Beam Dynamics (H. Dikansky — Novosibirsk), New Accelerator Schemes (A. Sessler — Berkeley), and Instrumentation (T. Ekelöf — Uppsala). The main task of these panels is to encourage the exchange of information and to coordinate activities such as the exchange of personnel and/or equipment amongst the various participating regions. They will meet at least once a year, and the Chairmen will report to ICFA once a year. It is hoped that the Chairmen will be able to submit preliminary draft programmes at the next ICFA meeting, to be held at the Tata Institute, Bombay, in April.

On people

In the UK New Year's Honours List, Chairman of the UK Science and Engineering Research Council Professor John Kingman received the accolade of Knight Bachelor, becoming Sir John Kingman.

At Brookhaven National Laboratory, the Accelerator Department was recently reorganized into the Alternating Gradient Synchrotron (AGS) Department and the Accelerator Development Branch. Derek I. Lowenstein, formerly Deputy Chairman of the Accelerator Department, was named as Chairman of the new AGS Department and Robert I. Louttit as Head of the Accelerator Development Branch. Within the AGS Department, Donald M. Lazarus has become the Head of the Experimental Planning and Support Division, Horst Foelsche is Head of the Accelerator Division, Alan Stevens is Head of the Accelerator Controls Section and Eric Forsyth is Head of the Advanced Technology Division.

Gösta Ekspong of Stockholm and the UA5 experiment at the CERN proton-antiproton Collider was the speaker at the latest Shulamit Goldhaber Memorial Lecture at Tel-Aviv University in January.

Album shot of the last of the 48 bending magnets for the new DESY-II electron/positron injection synchrotron in Hamburg. In front, covered in plastic sheet, is a quadrupole awaiting installation of the vacuum pipe.

(Photo Petra Harms)

Links to the DESY chain

On 14 January the last of the 48 bending magnets of DESY-II, the new 9 GeV injection synchrotron for electrons and positrons, was installed in the tunnel of the 20 year-old DESY synchrotron in Hamburg. The 48 quadrupoles and 16 sextupoles are also ready and the vacuum pipe follows. Everything is going according to schedule and the 93 metre-diameter machine will be operated for tests at 1 GeV from March until the next winter shutdown. Later, it will be run with 16 seven-cell cavities of the type already used at the PETRA electron-positron collider and with a peak radiofrequency power of 1.2 MWatt. The maximum beam energy will be 9.2 GeV.

In addition, the old synchrotron (now used to inject electrons and positrons into the DORIS-II and PETRA storage rings) must be transformed into a proton injector — DESY-III. Electrons from DESY-II and protons from DESY-III will then be injected into HERA via PETRA (see May 1984 issue, page 151).

The recent hard winter weather did not stop work at the HERA project. In January the big drilling machine for the HERA tunnel arrived at Hamburg by ship and was transported to the South Hall construction site, where the concrete ceiling is ready. Drilling for the 5.2 metre-diameter tunnel will start in April.

More news of HERA progress next month.

History symposium at Fermilab

An international history symposium on 'Particle Physics in the 1950s: pions to quarks,' will be held at Fermilab in Batavia, Illinois on 1-4 May 1985. The meeting will essentially cover the period of particle physics from the discoveries of the pion and strange particles and the building of the first large accelerators to the introduction of symmetry concepts and proposal of the quark. Speakers will include: physicists Murray Gell-Mann, Owen Chamberlain, Wolfgang Panofsky, W. Chinowsky, Jack Steinberger, Val Telegdi, Abraham Pais, George Rochester, Richard Dalitz, Matthew Sands, C. N. Yang, Edoardo Amaldi, Ugo Amaldi, Abdus Salam, Geoffrey Chew, Ernest Courant, Robert Hofstadter, Larry Jones, E. C. G. Sudarshan, Robert R. Wilson, Donald Kerst, Michiji Konuma, Louis Michel, Y. Nambu, Donald Perkins, Robert Marshak, Sidney Drell, Viktor Weisskopf, Gerson Goldhaber, Sam Treiman, Emilio Segre, Robert L. Walker; and historians Peter Galison, Silvan Schweber, Andy Pickering, Hywel White, Alan Franklin, Armin Hermann and John Heilbron. For information write to L. Hoddeson, Fermilab, P.O. Box 500, Batavia, Illinois 60510.

SLAC Summer Institute

The thirteenth SLAC Summer Institute will be held at SLAC, Stanford, from 29 July to 9 August. The topic will be supersymmetry, and a detailed programme will soon be announced.

Straightening the record

In our CERN Proton Synchrotron 25th anniversary article (December 1984 issue, page 421), we inadvertently made the error of stating

Fermilab Users Executive Committee members seated (left to right) are Ken Heller, Minnesota; Carol Wilkinson, Wisconsin; David Levinthal, Florida State; Robert McCarthy, Stony Brook; and Chuck Brown, Fermilab; standing (left to right) are Bill Reay, Ohio State; Carl Bromberg, Michigan State; Roger Dixon, Fermilab; Paul Grannis, Stony Brook; Alex Dzierba, Indiana; Stewart Loken, Berkeley; Phyllis Hale, Fermilab; and Frank Merritt, University of Chicago (not pictured is Ken Young, University of Washington). The Committee represents the broad interests of all Fermilab users.

(Photo Fermilab)

that the PS was the first machine to come into operation using the alternating gradient focusing principle. To be precise the PS was the first proton machine to use the AG principle. Boyce McDaniel from Cornell reminded us that the Cornell 1.2 GeV electron synchrotron came into operation using strong focusing in 1954. Also, in Europe, the Bonn 500 MeV electron synchrotron beat the PS to it by a year.

The record of the Seventh Meeting of the US-USSR Joint Coordinating Committee for Research and the Fundamental Properties of Matter was signed at Fermilab on 6 December 1984. Signing was the Head of the US delegation, James E. Leiss (left), Director of High Energy and Nuclear Physics, US Department of Energy, and the Head of the USSR delegation, Ivan V. Chuvilo, Director, Institute of Theoretical and Experimental Physics, Moscow.

(Photo Fermilab)

POSTDOCTORAL POSITION IN EXPERIMENTAL INTERMEDIATE–ENERGY NUCLEAR PHYSICS

The Medium-Energy Physics Group of Los Alamos National Laboratory's Physics Division invites application for postdoctoral positions. The successful candidate will participate in an experiment at the LAMPF accelerator to measure the (π,η) reaction on nuclear targets and another experiment at AGS to study hypernuclei with the (π^+,K^+) reaction. Work could also include participation in the development of a high-energy gamma-ray spectrometer.

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The SNS is an 800 MeV, 200μA, 50Hz rapid cycling proton synchrotron scheduled to start operation in 1985. A major low energy neutrino facility is being constructed by KfK, Karlsruhe in association with RAL. An experimental team of German and UK physicists has been formed to exploit this facility. Initially the RA appointed would join this team in a study of neutrino oscillations, inelastic neutrino scattering from nuclei and inverse β-decay. The experiments will be carried out using a 50 ton segmented liquid scintillator detector which is scheduled to be completed and ready to detect neutrinos during 1986. In the longer term it is intended to study neutrino-electron scattering and it is hoped that the RA appointed would participate in the design study for a second 50 ton detector devoted to this interaction.

Research Associate appointments are made for 3 years in the first instance, with the possibility of extensions for a further 2 years.

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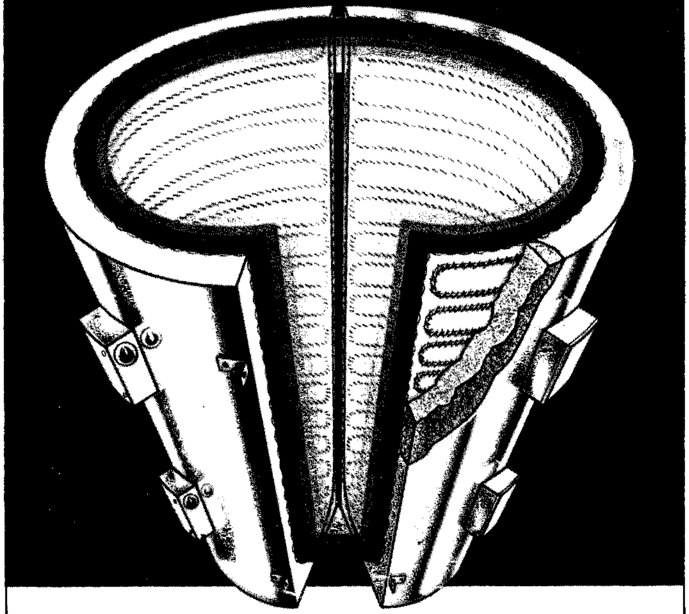

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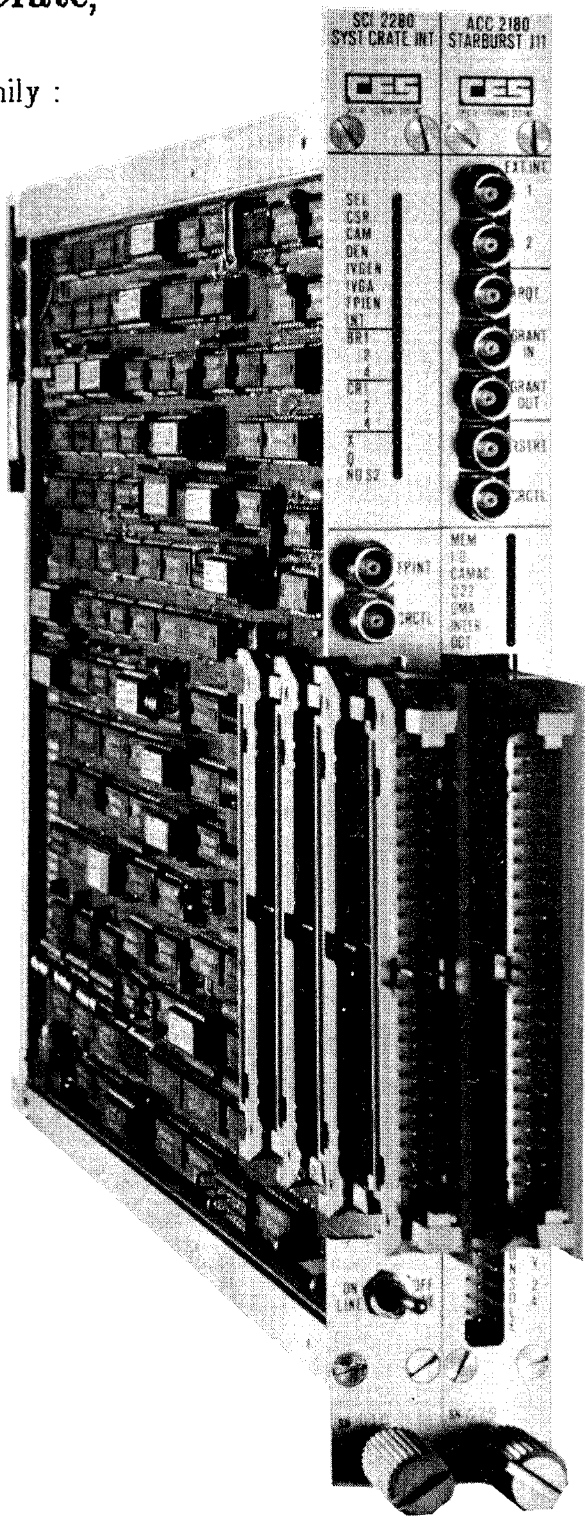

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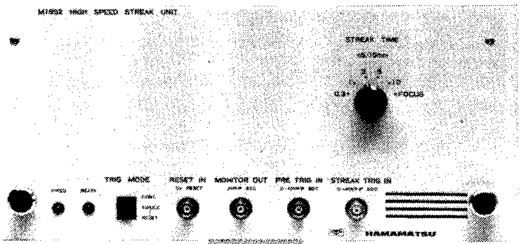

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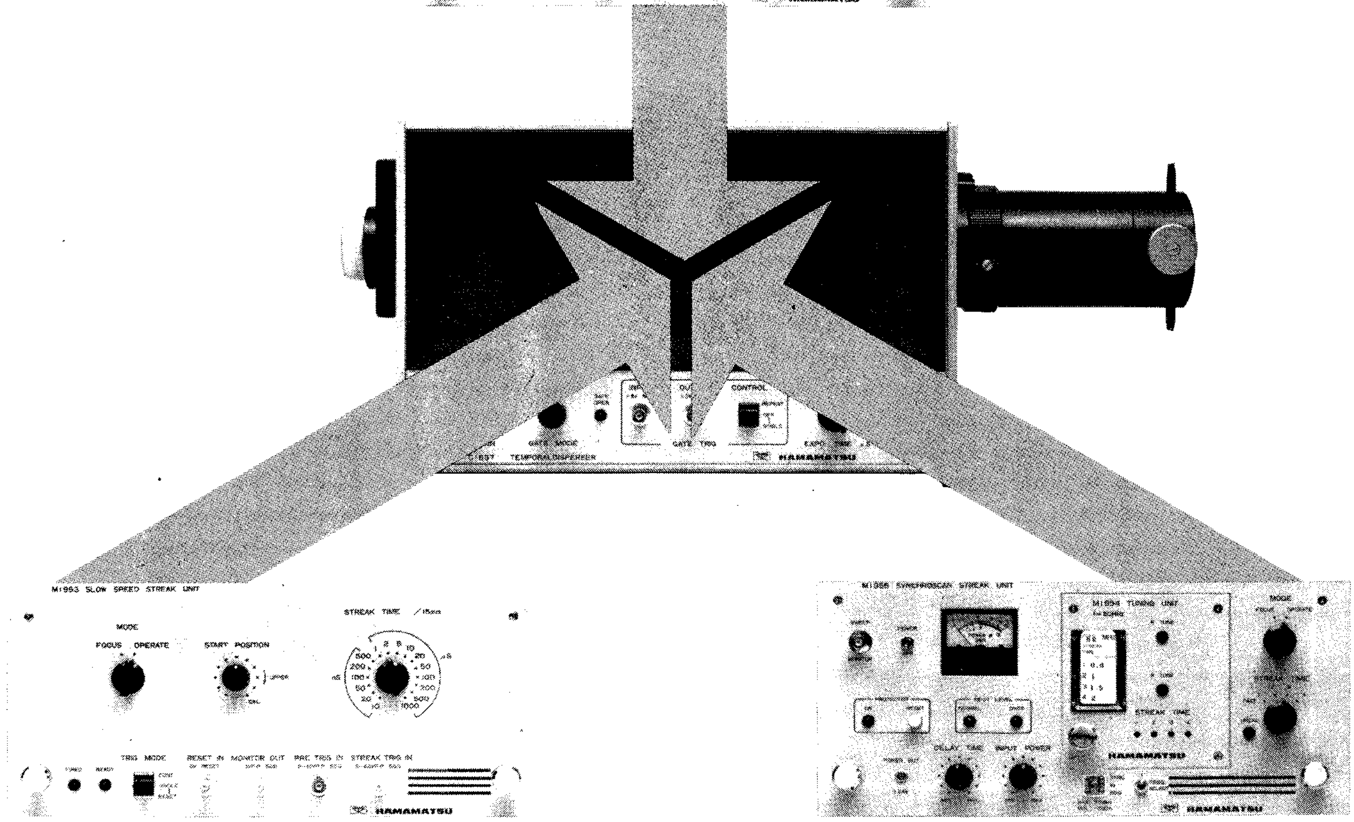

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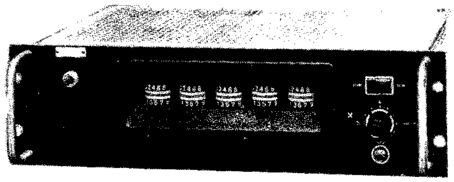

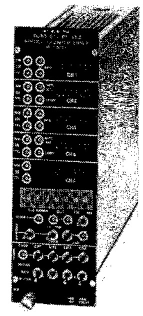

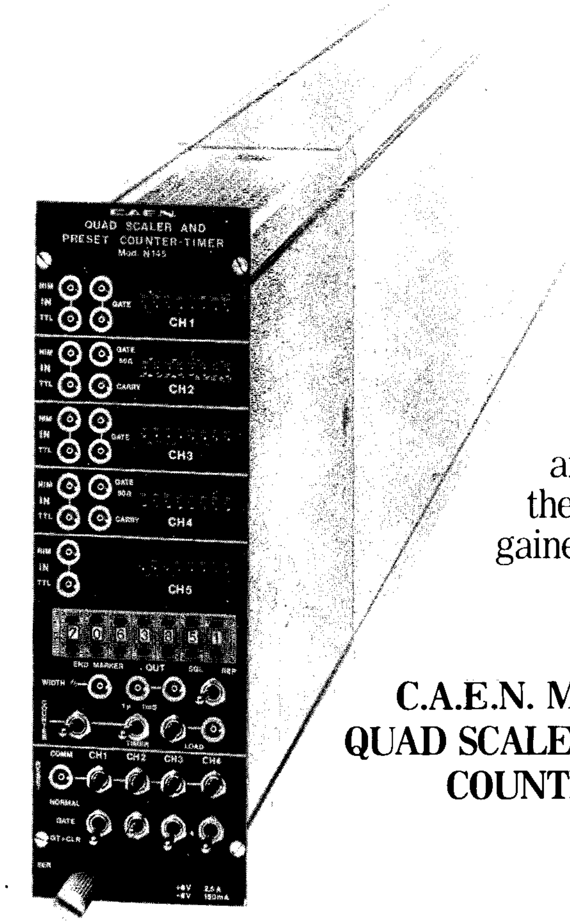

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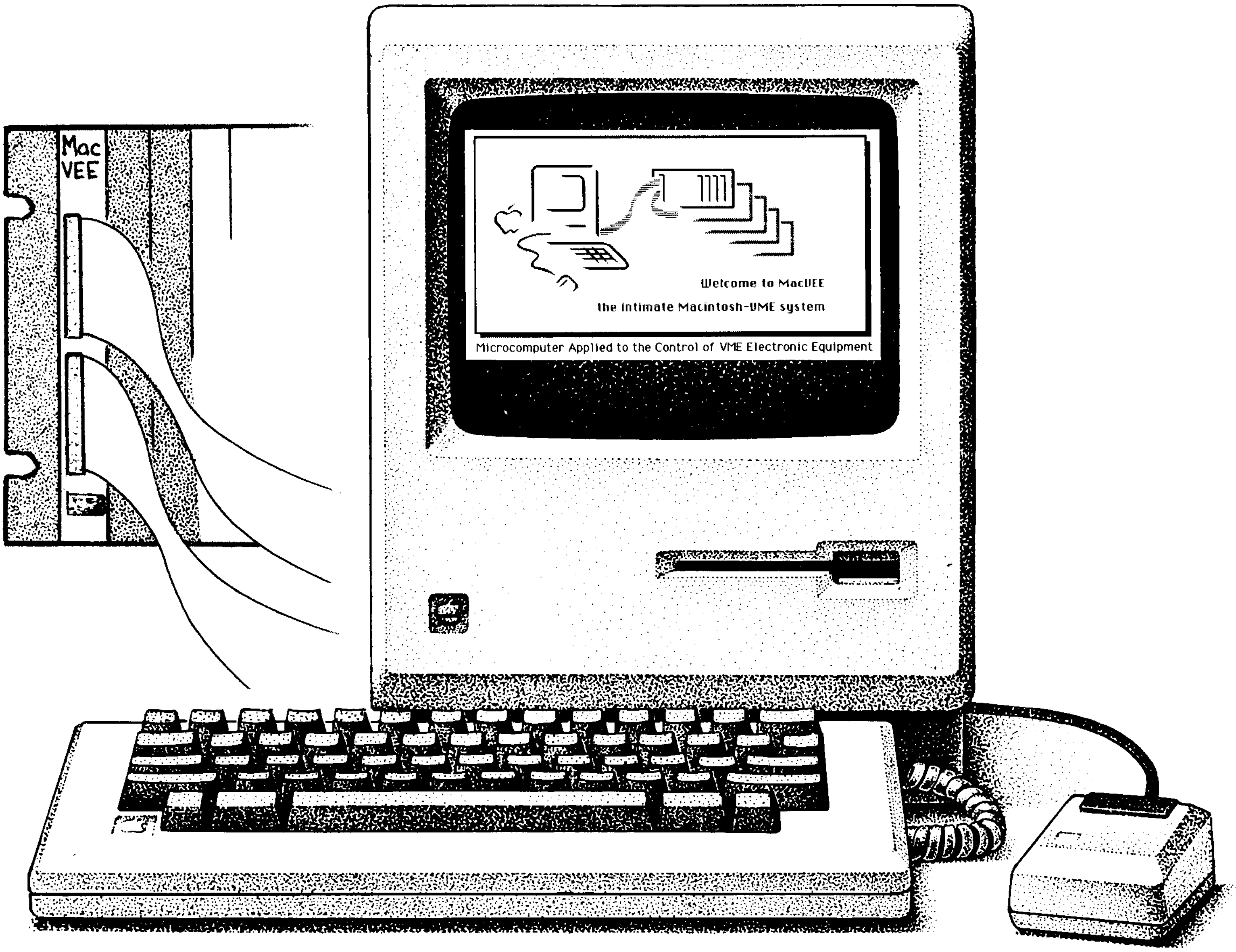
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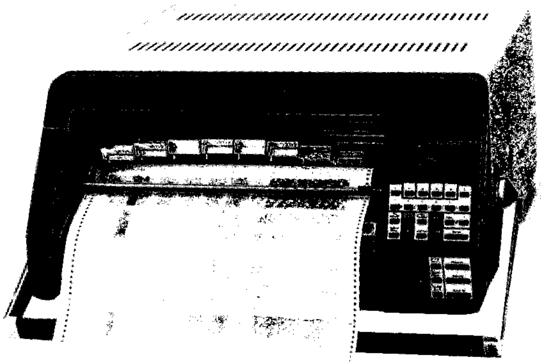

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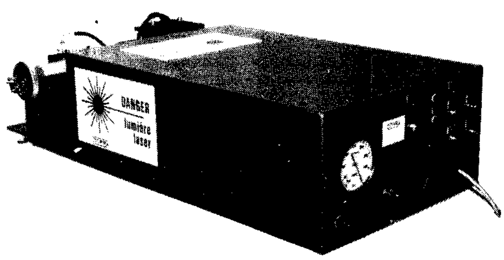

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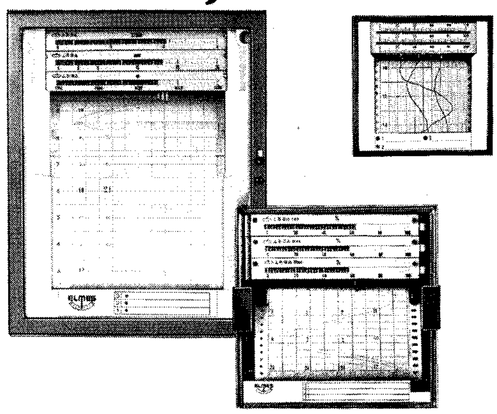

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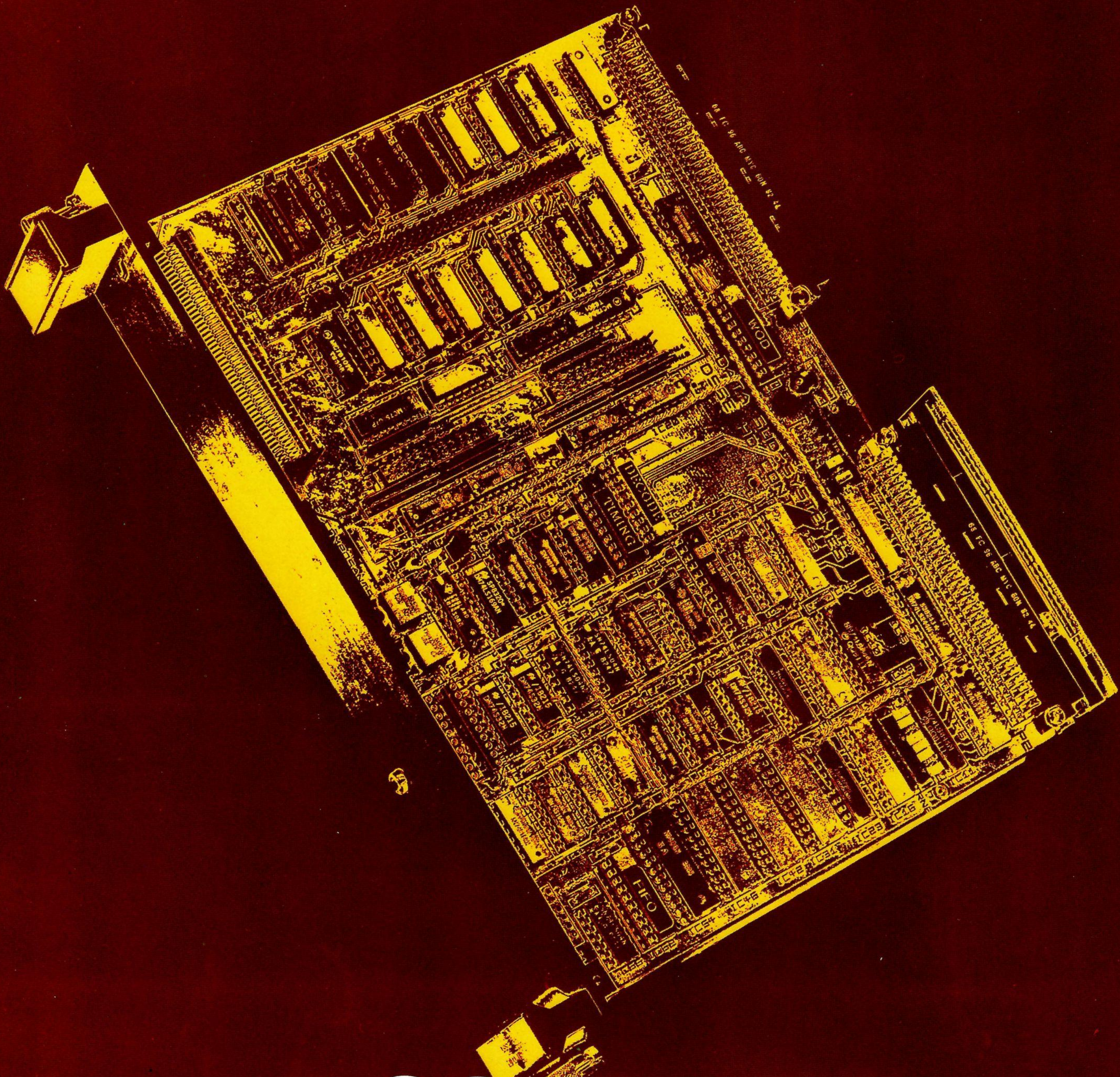

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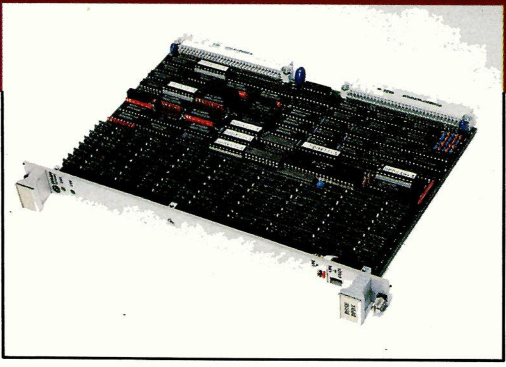

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