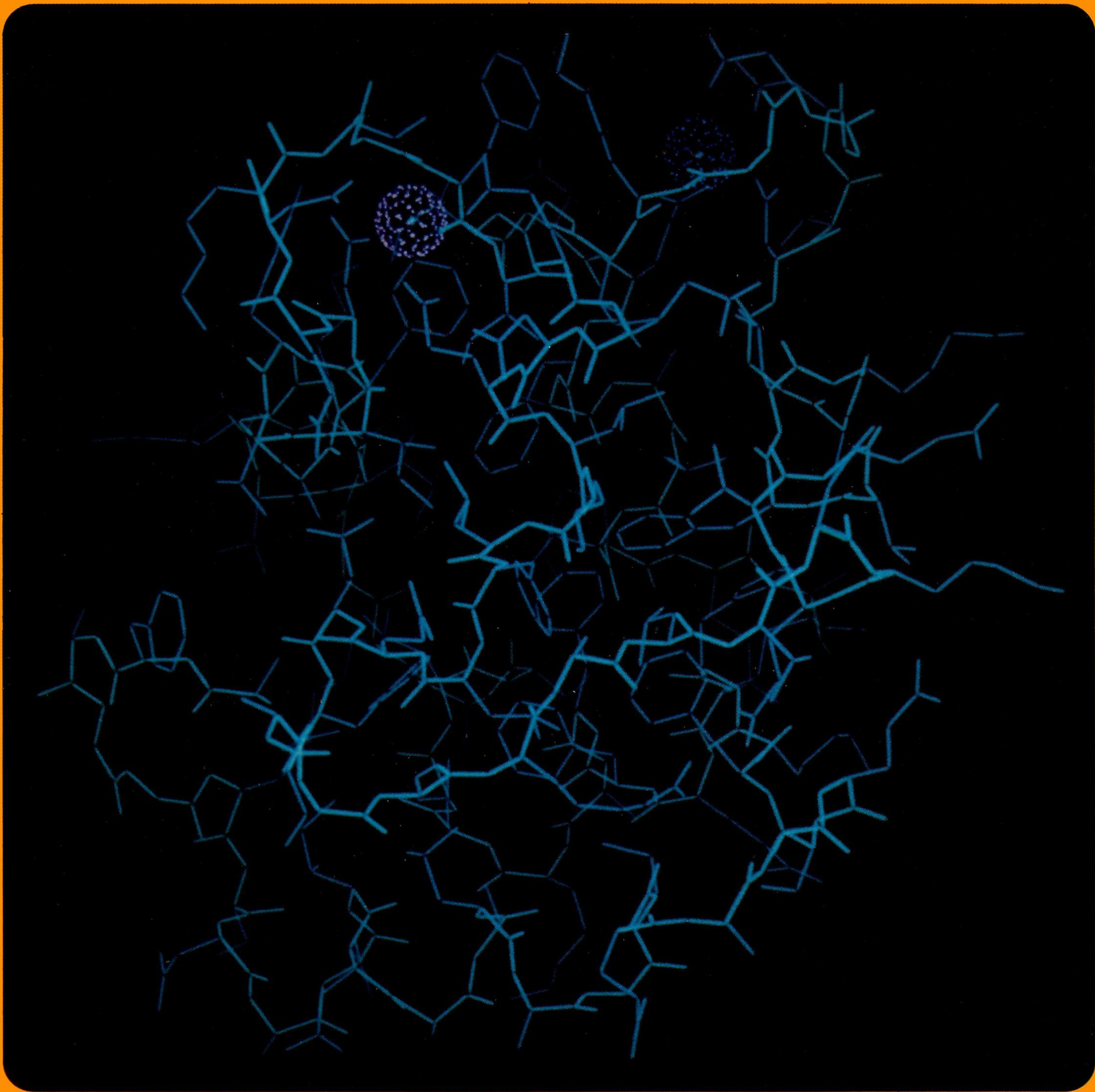
CERN COURIER

International Journal of High Energy Physics



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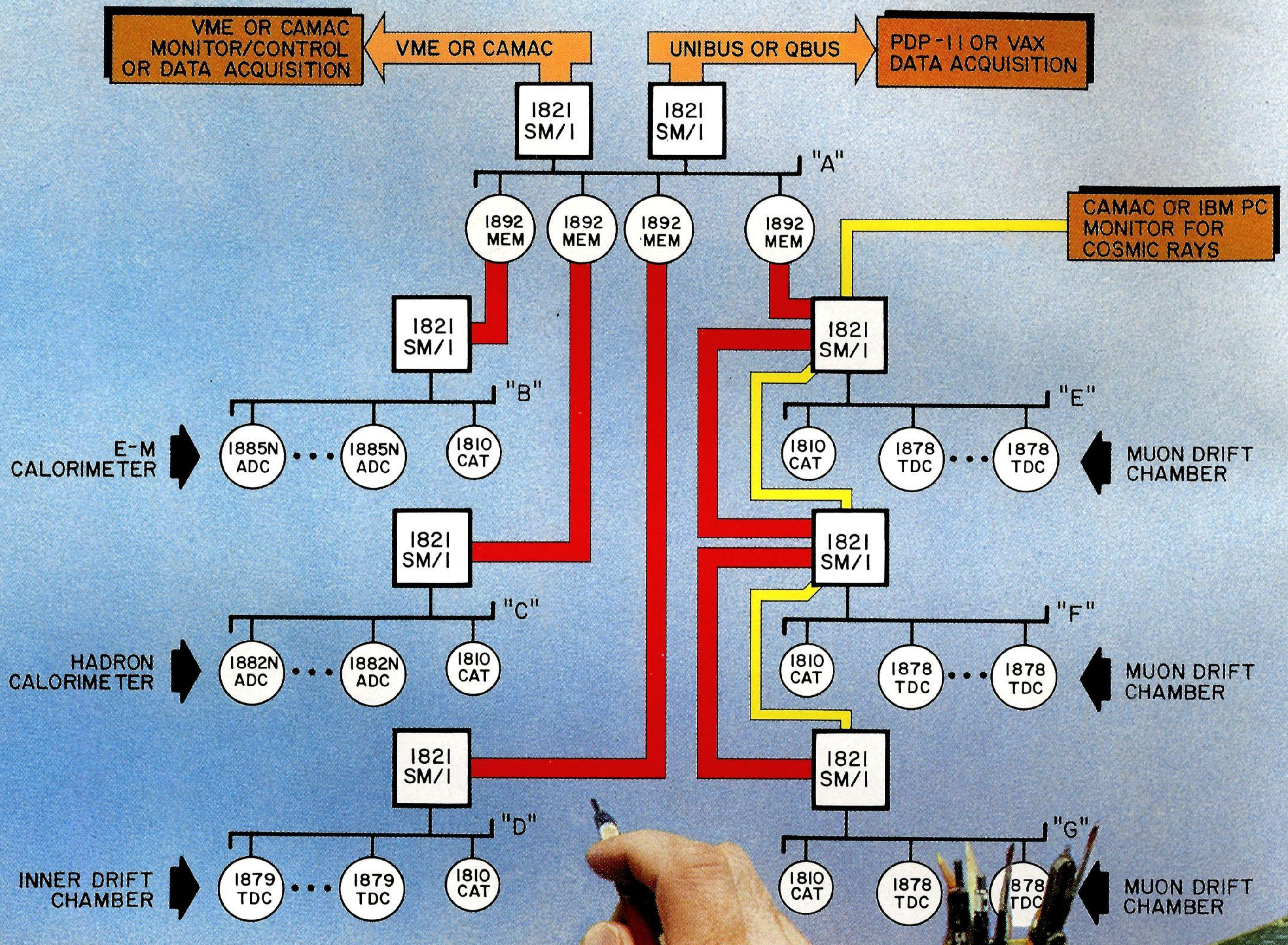

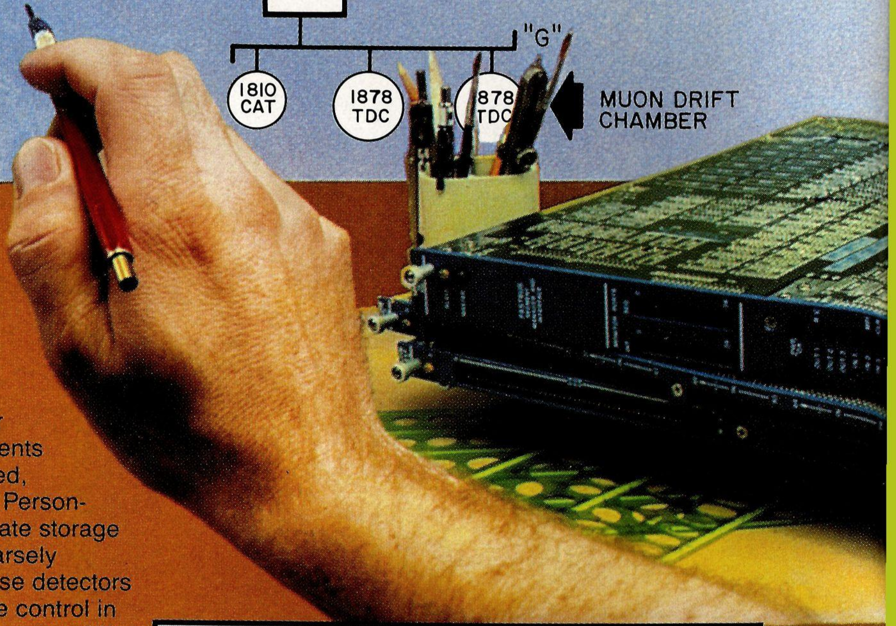

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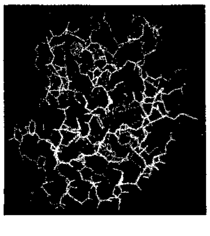

Cover photograph:
Structure of a complex protein molecule reconstructed from data recorded in a spherical drift chamber developed at CERN. The exposure to X-ray synchrotron radiation from the storage ring at Orsay, France, exploited the anomalous dispersion of terbium atoms (violet spheres) replacing the ordinary calcium. With the branches of the molecule only 1.5 angstrom units long, this demonstrates the considerable potential of this type of detector for imaging. Its principles will be described in a forthcoming article.

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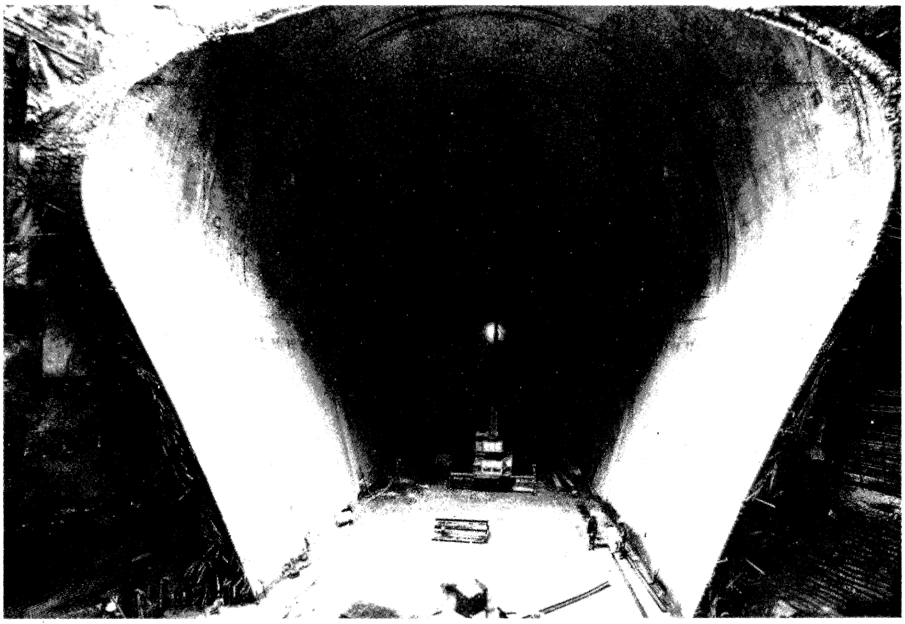
Focus on LEP

Now taking shape are the large underground caverns to house the four big experiments being assembled for CERN's new LEP electron-positron Collider. Seen here is the giant cave for the L3 experiment, some 45 metres below ground.



When it begins operations early in 1989, the LEP electron-positron Collider now being built at CERN will provide beams of some 60 GeV (120 GeV collision energy). However with superconducting radiofrequency acceleration equipment complementing the conventional units, the beam energy eventually could be boosted to about 100 GeV per beam. In parallel with LEP construction, a vigorous development programme for these superconducting cavities has been underway at CERN.

The physics objectives and experimental requirements for running LEP at these higher energies were examined in detail at a 'LEP 200' workshop held in Aachen, West Germany, from 29 September to 1 October, organized by the European Committee for Future Accelerators (ECFA) and the Rheinische-Westfaelische Technische Hochschule.

The consensus of the Aachen meeting was that the new physics available through higher energy LEP beams could be handled by the four experiments now being built, with only minor modifications.

CERN Scientific Policy Committee Chairman Don Perkins had been lined up to give the concluding talk at Aachen, but ended up giving it instead several weeks later at a LEP Experiments Committee session at CERN. Perkins split the LEP 200 physics into three areas: 'surefire bread and butter' — precision measurements of the properties of the W boson (the carrier of the beta decay force); 'probable jam' — searches for the Higgs mechanism or whatever is responsible for symmetry breaking in the electroweak picture; and 'possible cake' — new exotica, expected or not.

In conclusion, Perkins said that 200 GeV collision energies in LEP would provide a solid programme of physics for the years 1995-2000 which would not otherwise be accessible. He advocated 'getting on with it'.

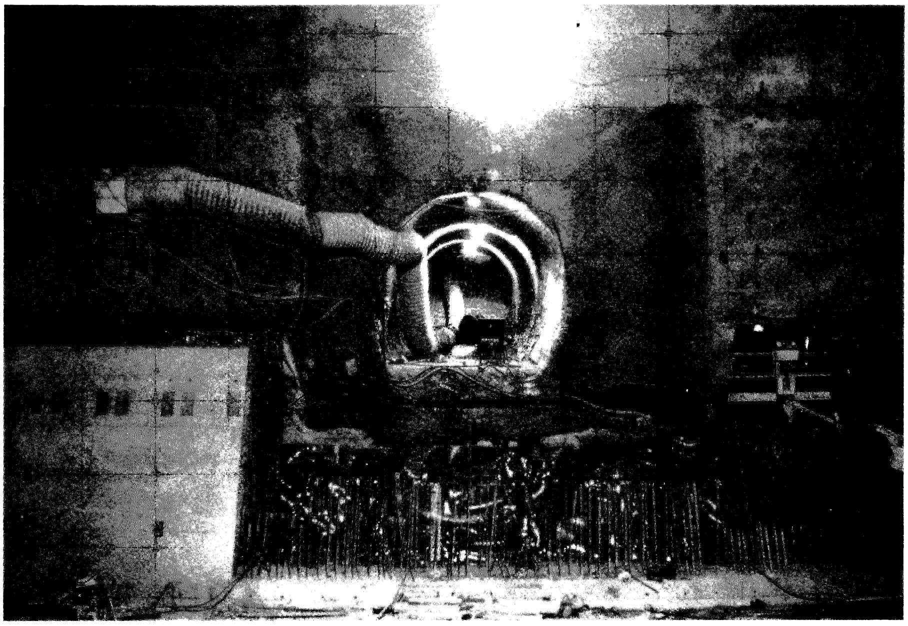
The LEP Experiments Committee meeting also provided a useful opportunity to review progress right across the LEP front.

Introducing the proceedings, CERN Director General Herwig Schopper reminded the audience that it was five years since CERN Council finally gave LEP the go-ahead, and recalled the motivation behind the decision.

The LEP machine is funded from CERN's normal annual budget of Member State contributions with no additional resources. For the experiments, most of the finance comes from the collaborating institutes. It was fairly certain at the outset that the new venture of building a machine costing at least 900 million Swiss francs with no special extra budget would require some belt-tightening, added to which there was the tightrope of coordinating the financing of the experiments. Nevertheless the courageous decision to embark on the mammoth project was taken in order to provide for CERN's long-term future.

With civil engineering for the 27 kilometre tunnel and its associated infrastructure now nearing completion, the total bill can be estimated with some confidence. A continual theme throughout LEP construction has been to use time as a contingency, so that unexpected costs could be offset by applying the brakes at the construction site. Following an appeal by Schopper, some CERN Member States are generously advancing future payments to cover a bulge of expenditure in the construction period. However despite all the difficulties and complications, the overall construction schedule is being largely respected. LEP start-up is now scheduled for early in 1989.

Some 150 metres below ground under the Jura mountains is this pit to house the ALEPH experiment. Although deep underground, this is in fact the highest point of the tilted LEP ring.



The status of construction was covered by Project Director Emilio Picasso. While the tunnelling machines have practically completed their allotted task and preparations for the four large underground experimental areas are well advanced, a major remaining preoccupation is the few hundred metres of tunnel still to be cut through difficult water-bearing layers under the Jura mountains.

This section of LEP tunnel is blasted out rather than cut by machine. Careful precautions have been taken from the outset, involving frequent stops. Some water seepage has been encountered, although nothing on the scale of the flooding during the construction of some major transportation tunnels. The final breakthrough for the LEP tunnel should occur early next year.

Picasso described how judicious modifications to the original construction schedule had enabled the overall timescale to be respected to within a few months. However, despite this rearrangement of strategies, repercussions in other areas could not be avoided, particularly the handover dates for some of the experimental zones.

With the end of civil engineering work in sight, attention turns to the myriad of components for the machine. The supply of LEP components has been 'a great success', said Schopper, indicating that careful design had enabled valuable savings to be made. Picasso proudly listed the material already at CERN, including 63 per cent of the main dipole magnets, 70 per cent of the radiofrequency acceleration equipment, and 90 per cent of the getter strip for vacuum pumping.

In parallel, the injection system for LEP is being prepared. The EPA electron-positron ring which takes particles from the new injection linac has achieved its design current, and the performance of the new electron beam in the downstream 'Proton' Synchrotron is being studied. One tunnel connecting LEP with the SPS synchrotron, the final link in the injector chain, has been cut, while another remains to be done. The SPS is being prepared for its new electron role.

Finally Picasso turned to the theme of the Aachen workshop, the use of superconducting radiofrequency cavities to boost the energy of LEP beams towards 100 GeV. Different scenarios are possible, each with its own price tag. Parallel installation of the two technologies would provide some increased energy, but further advances would follow either replacement of conventional r.f. by superconducting, or by building additional galleries to house the new equipment.

The detailed status of construction work for the four experimental areas and their infrastructure was covered by Franco Bonaudi. Nimble work will be required to install cranes, gangways, shielding, rails, pipework, power supplies, etc. as quickly as possible, with the eager experimentalists beating at the door.

Experiments

Progress for the OPAL detector is well advanced, declared Aldo Michelini and despite a few inevitable slippages no critical delays are foreseen. Advanced prototyping, module construction and calibration are proceeding in parallel.

Prototype tests have gauged performance and established realistic operating conditions for the inner portions of the detector, and a 'clean room' at CERN is now ready for assembly to start.

After delivery of components and coil winding at CERN, full coil tests are scheduled for next summer.

Another vital OPAL component is the large lead-glass electromagnetic calorimeter. Assembly and calibration are proceeding well, and already large modules are in principle ready for mounting in the main detector.

Acceptance testing of incoming hadron calorimeter modules is progressing well, while the general rhythm of component shipments is accelerating. The arrival of a VAX 8700 computer is an important milestone for the data acquisition system.

The installation schedule, revised to fit in with the latest LEP civil engineering news, looks a bit cramped at first glance, but careful modifications to a flexible plan should ensure that a workable detector will be ready on Day One.

Sam Ting described how the large octagonal elements for the L3 magnet are now taking shape near where eventually they will be lowered underground. The muon chambers to be installed inside the magnet are 'going quite well' and cosmic ray tests have performed (136 micron resolution) better than the design figure.

Components for the hadron calorimeter are arriving from all over the world (USSR, US, Switzerland, China, West Germany, India) albeit at different rates. Production in China of the famous BGO crystals for the electromagnetic calorimeter is well in hand. Under stringent testing, the acceptance rate for completed modules is nearing 100 per cent, testifying to mastery of this new technology. The design for the inner vertex chamber, based on the instrument developed for the Mark J experiment at the German DESY Laboratory, is being finalized in ETH Zurich.

Unlike the other three experiments, L3 will not be pushed in and out of the LEP beams and has no installation 'garage'. According to Ting, this means that the interplay between LEP infrastructure and L3 is 'very complicated'. An extra shaft will facilitate the task, but a substantial level of preinstallation on the surface is called for. Ting saw little room to manoeuvre.

Jack Steinberger admitted that building the ALEPH detector is 'more tedious and harder than we expected', however thanks to valiant efforts by the collaborating institutes there is every reason to be optimistic.

In a similar meeting earlier this year Steinberger had singled out the assembly of the electromagnetic calorimeter, with its mass of wiring, as a bottleneck. However the first module to be supplied had performed well under test. This had been good news, said Steinberger.

The magnet coil and cryostat is expected at CERN in April after preliminary testing at Saclay. Meanwhile the return yokes have been equipped for hadron calorimetry, the assembly taking place in the old BEBC bubble chamber hall at CERN, alongside OPAL's electromagnetic calorimeter.

A big effort is being made to coordinate the development of ALEPH software (for data management, data acquisition, simulation and event reconstruction) by the widely scattered collaborating institutes.

With a delayed handover date for the DELPHI experiment's pit, Ugo Amaldi voiced his concern about the tight installation schedule. Meanwhile the big superconducting solenoid will soon be finished and the complete magnet should arrive from the UK Rutherford Appleton Laboratory next September. Some delay in the availability of the pit could be clawed back by testing the magnet at CERN above ground prior to lowering it into place.

Delivery of hadron calorimeter components is proceeding 'routine-

Some 100 metres under the French-Swiss border is this cavern for the OPAL experiment.

At the lowest point of the LEP ring, but still some 100 metres below ground, is the cave for the DELPHI experiment.

(Photos R. Lewis)

ly' while the complement of inner muon chambers should be complete in May. Ingenious prototype machines developed for manufacturing the High Density Projection Chamber (electromagnetic calorimeter) have shown their worth and additional units are being constructed in Italy. The first production HPC module has reproduced the performance attained with the prototype. Construction of all track chambers is going according to schedule.

Another DELPHI success story is the development of high density integrated circuitry for flash analog-digital converters (see May issue, page 17) by French industry which have now found extensive markets.

Albert Diddens of NIKHEF (Amsterdam) took over to describe the preparations for DELPHI's Ring Imaging Cherenkov (RICH) for particle identification. After extensive prototype tests giving satisfactory results, assembly should begin next summer.

Despite the nightmare risks at the outset, and all the ups and downs of a mammoth construction project, all is going remarkably well for LEP.

Around the Laboratories

FERMILAB
Proton synchrotron for cancer therapy

Fermilab has collaborated with the Loma Linda University Medical Center (LLUMC) in California to evolve the design of a small proton synchrotron appropriate for use in cancer therapy. The conceptual design for a 250 MeV synchrotron has been published and it is hoped that industry will pick up the technology and that many such facilities will eventually be built.

Radiation has been used for cancer therapy since Becquerel discovered radioactivity and Roentgen discovered X-rays. Before World War II, most radiation therapy used photons, although Ernest Lawrence and his collaborators made some tests with neutrons. The use of protons was originally proposed by Robert Wilson in 1946 as one of the uses of the cyclotron he built at Harvard. This cyclotron is still used for therapy and has pioneered treatment for many kinds of disease, both malignant and benign.

Work at Berkeley has used heavy ions and there has also been work at a cyclotron in Uppsala (Sweden), at KEK and Chiba in Japan, and particularly in the Soviet Union, using accelerators at ITEP in Moscow, Gatchina in Leningrad, and at JINR in Dubna. Pions have been used at Los Alamos and SIN. All these accelerators were originally built for physics and have been adapted with great ingenuity for therapy; there has never been an accelerator built specifically for proton therapy. Neutrons have been used in several centres, particularly the Hammersmith Hospital, London.

The primary advantage of protons is the unique ability for localizing the dose distribution. Cancer therapy is a competition between killing malignant cells and killing healthy cells in the body tissue near the tumour. The dose distributions from photons and neutrons cannot be precisely localized to the tumour site but, as Wilson pointed out in his first paper on the subject, the dose from protons can be localized to within a millimetre or so in depth because most of the proton energy is deposited in a sharp peak at the end of the range in matter. Heavy ions share this advantage and have greater biological effectiveness, but ion accelerators are substantially more costly.

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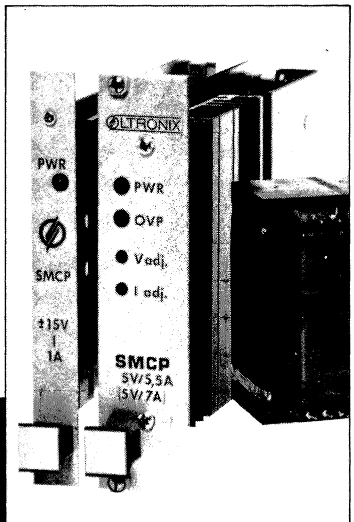

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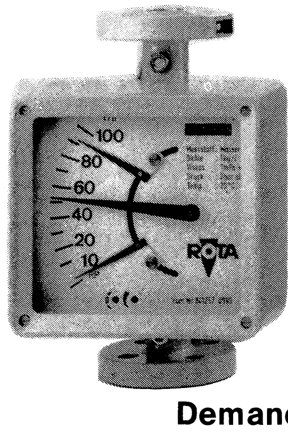

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Following an initial meeting at CERN in March, a group of medical practitioners, radiobiologists and accelerator engineers from various European countries met again at CERN in November to institute a feasibility study for EULIMA, a European Light Ion Medical Accelerator.

Groundbreaking ceremony for Fermilab's new Computing Centre, with Fermilab Director Leon Lederman (centre) leading the efforts. Helping are (left to right) Gordon Charlton of the US Department of Energy (DOE), Dave Mondo of Barcon Corp. Ed Temple of DOE and Jeffrey Appel of Fermilab.

Bob Wilson continued to be interested in protons for therapy and stimulated Don Young and Miguel Awschalom at Fermilab to consider therapy with the 200 MeV linac at the Lab. They put together a design, but devices such as CAT scanning and magnetic resonance imaging needed to locate the tumour boundaries precisely did not exist at that time and physicians were much more interested in neutrons because of the enhanced biological effectiveness. As a result, the Fermilab Neutron Therapy Facility was built and has been operating successfully for more than ten years, treating close to 1800 patients.

With some stimulus from Fermilab, PTCOG, a national Proton Therapy Coordination Group was formed and four workshops have been organized. At the second workshop, Phil Livdahl and Lee Teng presented some preliminary design thoughts on a synchrotron for proton therapy. Although a cyclotron produces far more intensity than a synchrotron, the intensity of the synchrotron appears to be adequate for treating all kinds of disease in a practical treatment time and has the advantage of easier variability of energy, so that different depths of tumour can be treated by varying the beam energy, rather than by using absorbers.

James Slater, head of the Radiation Sciences Department at LLUMC asked the Fermilab group to collaborate on the design and construction of an accelerator designed specifically for medical work. Loma Linda is sponsoring this work. Fermilab has agreed to design, construct and commission the accelerator then to move it to Loma Linda and put it into operation. The associated treatment facility is the responsibility of the Loma Linda staff. Fermilab does not plan to go beyond the prototype, but is assisting Loma Linda in finding industrial partners to build later accelerators.

A conceptual design was completed in June. It has since been modified to incorporate 'gantries', beam transport systems that rotate about the axis of the patient and bring beam to bear from many different angles. The use of superconducting magnets had been considered but it is very difficult to supply cryogens to the moving magnets of a gantry and there are therefore too few magnets to justify the development cost.

The main outlines of the design and many details are now firm. The accelerator will be a 250 MeV proton synchrotron with a 2 second cycle and an intensity of at least 2×10^{11} per pulse. Beam will be extracted over a 1 second flat top and transported to one of three gantry rooms or a fixed-beam room (for head and neck work). It is intended to complete the design early next year and to put the accelerator into operation at Fermilab early in 1988.

From Frank Cole and Phil Livdahl

New computer centre

During an auspicious break in the summer rains, ground was broken for the new Computer Centre at Fermilab. The groundbreaking, like the entire Central Computing Upgrade Project (CCUP), was a cooperative effort between Fermilab, the US Department of Energy and commercial contractors. At the groundbreaking ceremony, Fermilab Director Leon Lederman was accompanied by representatives of these three groups including Jeffrey A. Appel, CCUP Project Manager, Ed Temple and Gordon Charlton of DOE, and Dave Mondo of Barcon Corp., the contractor for the foundations of the new building.

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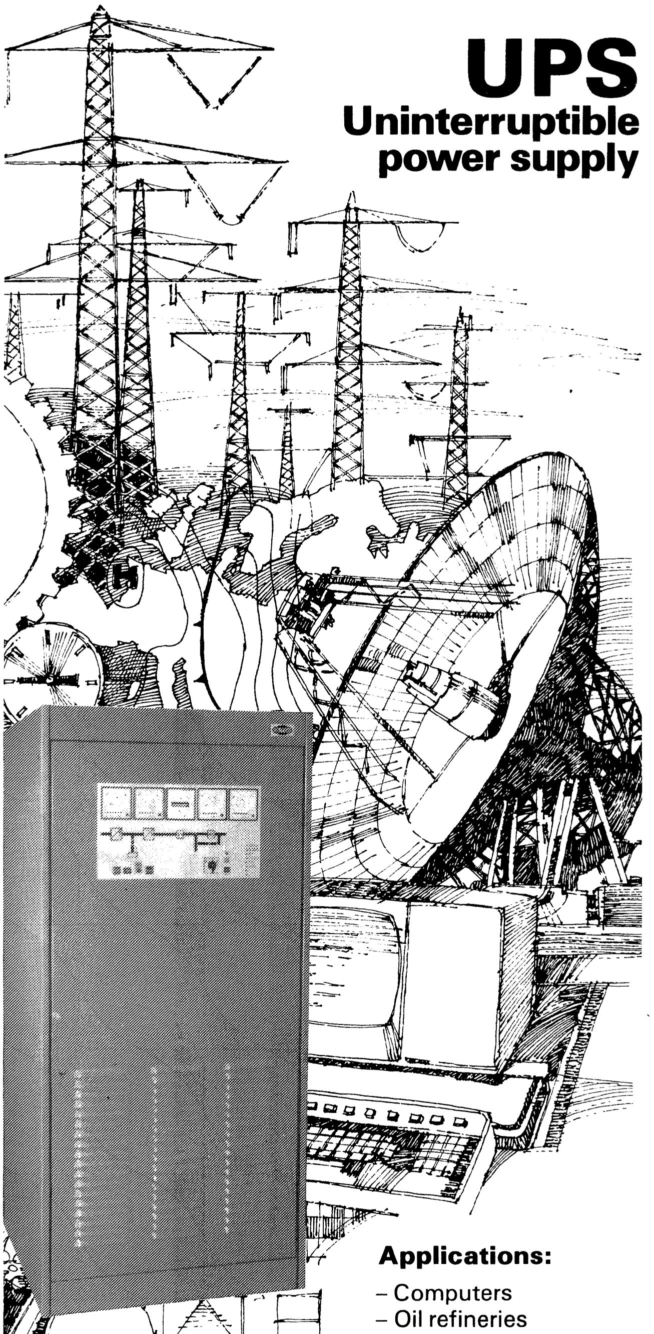

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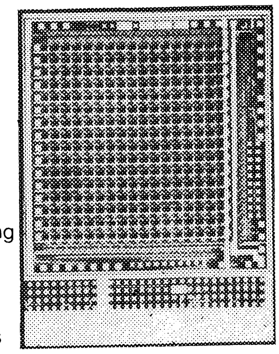

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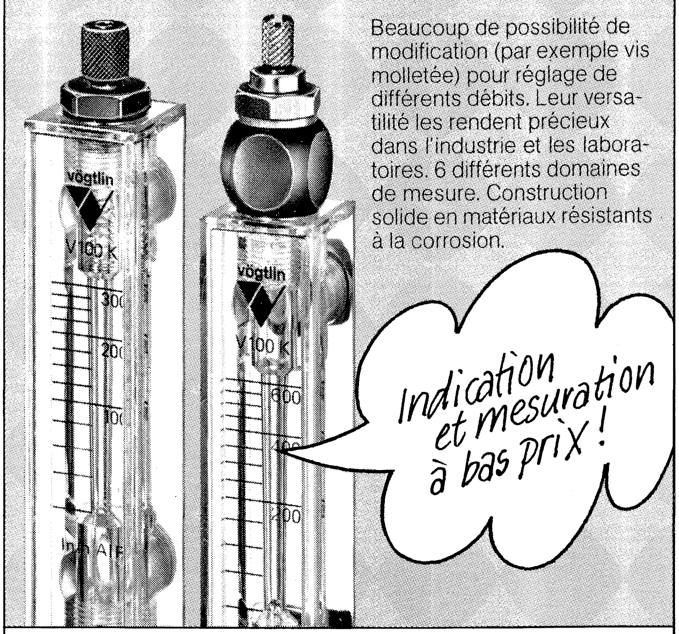

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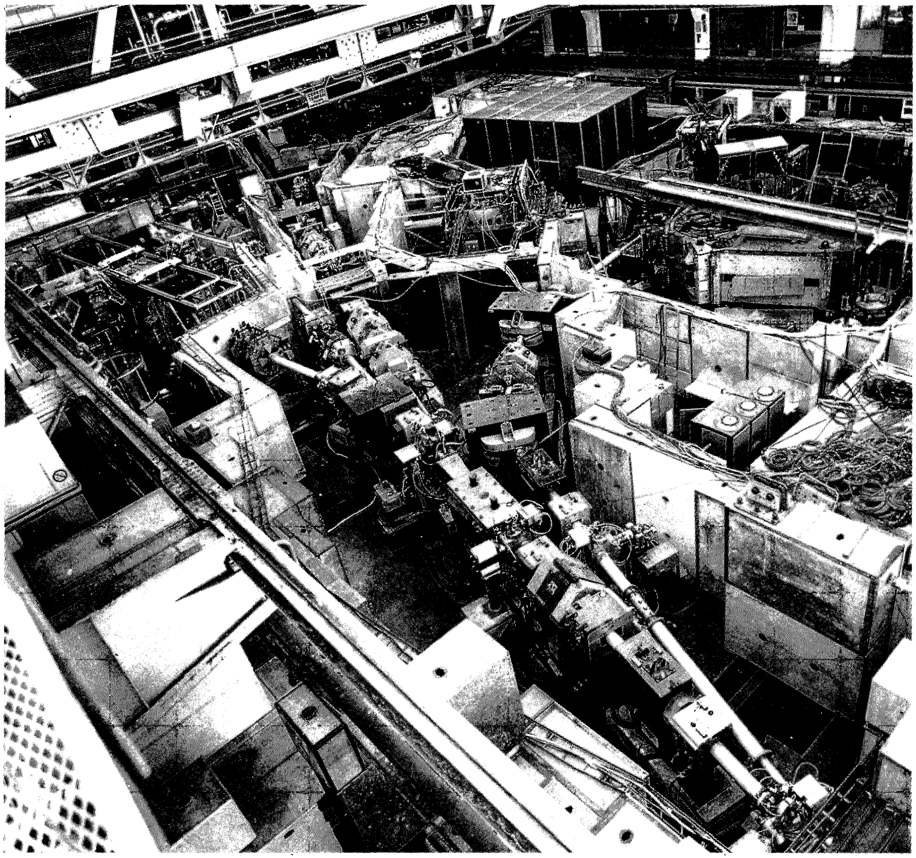
The new centre will be a three-storey building of approximately 72 000 sq. ft. with the new computing equipment located on the first two floors. The third floor will be home for the PREP (Physics Research Equipment Pool), the Instrument Repair Facility, the Data Acquisition Hardware Group, and the Evaluation Group, all of the Computing Department. While there will be a user area in the new building, there will be increasing use of distributed output devices.

In parallel with the civil construction work is the quest to purchase the new computing system. This involves the 'Next Computer Acquisition Committee', representing the broad range of Fermilab Central Computing users, the Computing Department and other Laboratory management. An Implementation Plan describing the new computing system has been submitted to DOE for review. Installation is scheduled for the end of 1988.

Experimental area at CERN's LEAR Low Energy Antiproton Ring, now undergoing a change of scenery as new experiments move in.

(Photo CERN 414.7.86)



CERN
New LEAR generation

CERN's antiproton operations have been shut down to allow construction of the new ACOL Antiproton Collector, designed to come into operation next year and significantly boost the antiproton supply rate.

During this time the big experiments at the SPS proton-antiproton Collider are undergoing major refits, while at the LEAR Low Energy Antiproton Ring the experimental programme is being reshaped.

Since the commissioning of LEAR in 1983, some 16 experiments involving more than 300 physicists have taken data. Only a few of these studies will spill over into the post-ACOL era.

In addition to the increased antiproton supply with ACOL, LEAR will undergo several improvements including the installation of electron cooling to further shape the beams. LEAR experiments will benefit from even longer spills (several hours at a time), smaller momentum spreads and continuously scannable momenta in the range 100-2000 MeV/c.

One of the outstanding unsolved problems of particle physics is the origin of so-called CP (combined particle/antiparticle and left/right symmetry) violation seen in the weak decays of the neutral kaons. Measurements by an Athens / Basle / CERN / Fribourg / Liverpool / Saclay / SIN (Switzerland) / Stockholm / Thessaloniki / Zurich group will provide a new handle on CP violation measurements, supplementing those obtained with proton beams.

Studying proton-antiproton annihilation at low energies is also an ideal way to look at exotic particle states and determine their content in terms of quarks and gluons. Much experimental effort has gone in recent years into searching for 'glueballs' — states built of gluons instead of or in addition to quarks — but the present situation is far from clear.

Two LEAR experiments will look at annihilations using an extracted antiproton beam —the aptly-named Crystal Barrel of caesium iodide (Berkeley / Irvine / Karlsruhe / London / Mainz / Munich / Penn State / Strasbourg / Surrey / Vienna / Zurich) and OBELIX (Brescia / Cagliari / CERN / Dubna / Fras-

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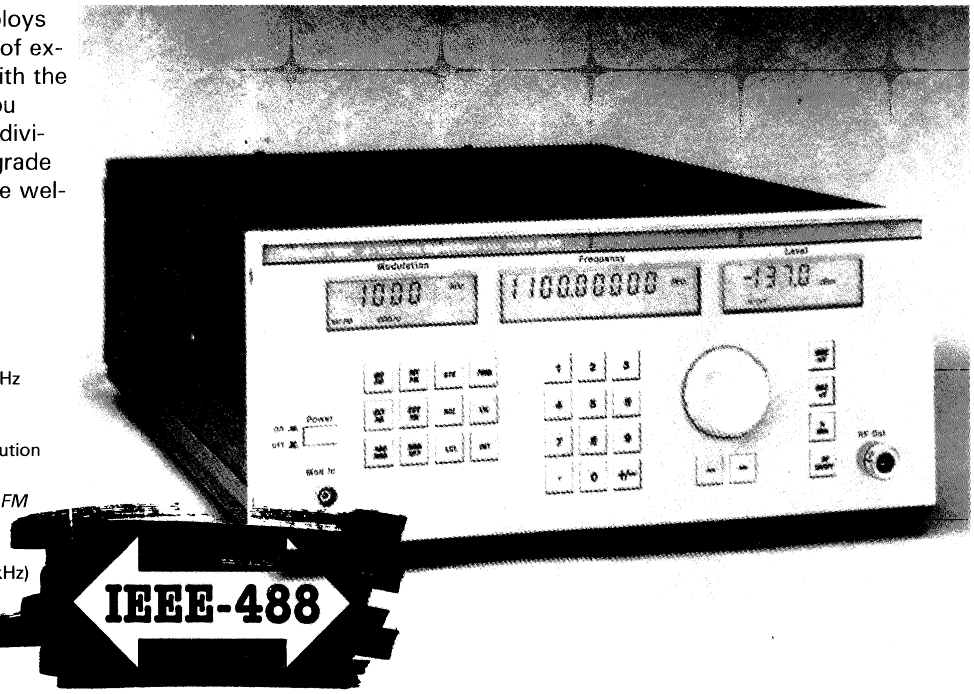

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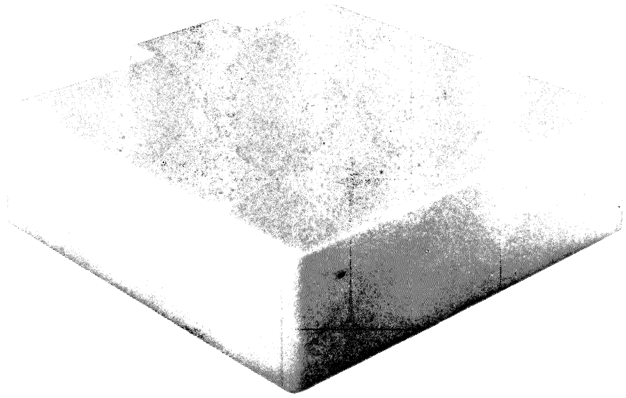

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cati / Geneva / Legnaro / Orsay / Padua / Pavia / Trieste / Turin / Udine / Vancouver) based on the Axial Field Spectrometer from the Intersecting Storage Rings, shut down in 1984.

Using polarized (spin oriented) targets, two experiments will try to clarify the spin dependence of nucleon interactions (a Karlsruhe / Lyon / Saclay / SIN group will look at proton-antiproton elastic scattering while a Cagliari / Geneva / Karlsruhe / Trieste / Turin collaboration will study the elastic scattering of neutrons and antineutrons).

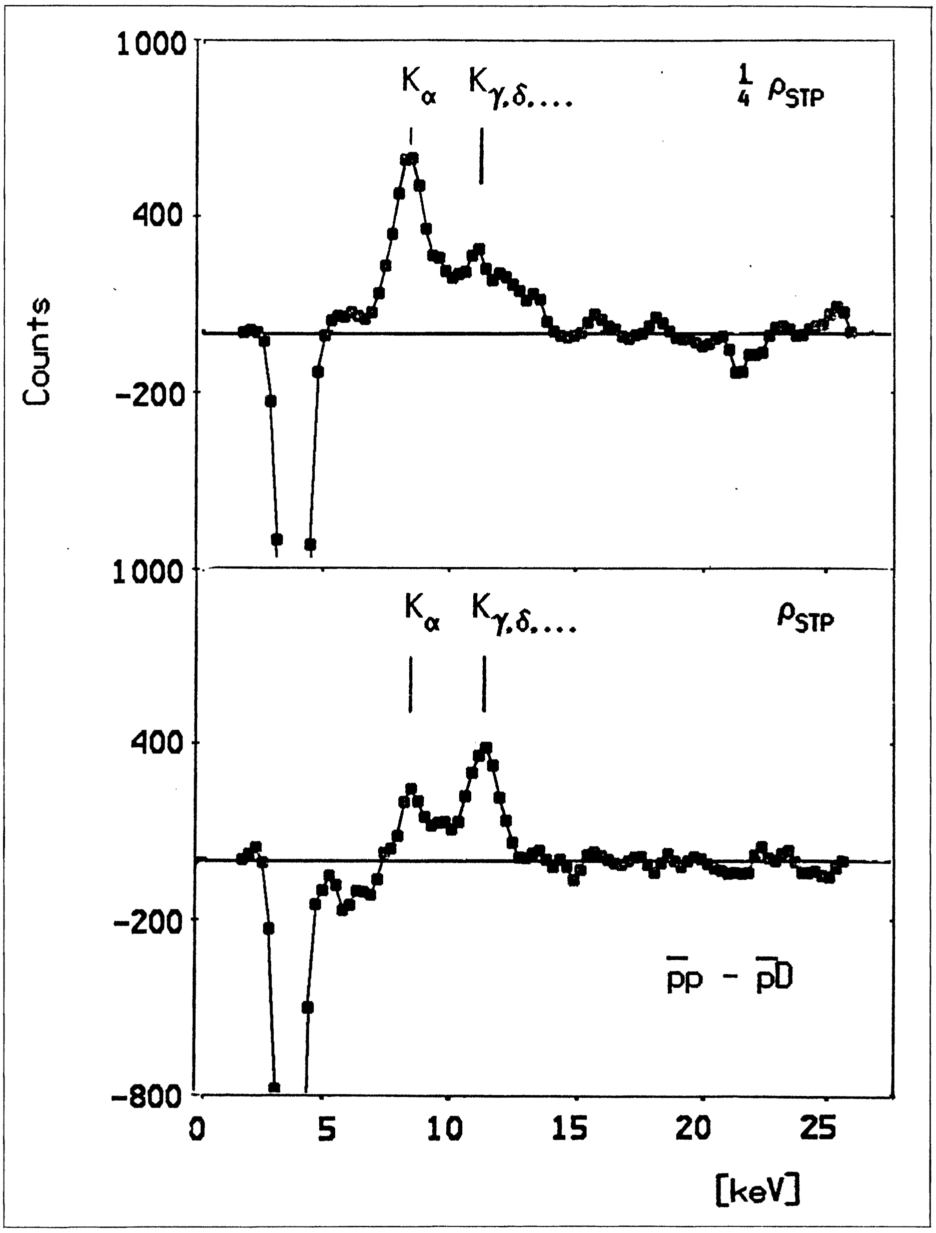
A largely unexplored area being attacked by the second generation of LEAR studies is the detailed comparison of proton and antiproton properties to test fundamental theorems of physics. Two experiments will look for any proton-antiproton mass difference (Orsay / CERN and Fermilab / Mainz / Washington — see November issue, page 25). A Case Western / CERN / Genoa / Houston / Kent State / Los Alamos / NASA / Pisa / Texas A and M group will look at the effect of gravity on antiprotons (do they fall down or up?).

A few proposals for second generation LEAR experiments are still in the pipeline, and the programme could be extended in the months to come.

Antiprotonic hydrogen

Most particle physics experiments rely on scattering — hurling a beam of particles against a target (either stationary or another beam) and collecting and analysing the bits flying off. According to a time-honoured (and fairly accurate) analogy, it is like trying to find out how a sealed watch works by smashing two of them together and looking at the fragments.

But particle physics has other methods, one being the manufacture of synthetic atoms with normal orbital electrons replaced by some other negatively charged particles (muons, pions, kaons or antiprotons). The study of these 'exotic' atoms has long been a



X-ray spectra at different gas densities from the rare ground state transitions of 'protonium' — an atom consisting of a bound proton and antiproton — as measured by an Amsterdam / Birmingham / Delft / Rutherford / William and Mary collaboration using antiprotons from CERN's LEAR low energy antiproton ring, and with a detector incorporating gas scintillation proportional counters. Background is reduced by subtracting the X-ray signal from antiproton-deuteron atomic states (which also causes the large dip on the left, due to a strong spectral line from these atoms).

CERN speciality, but the copious supply of antiprotons from the LEAR Low Energy Antiproton Ring opened up new possibilities.

Because the artificial orbiting particles are much heavier than electrons, they penetrate much nearer to the nucleus, getting so close that nuclear forces come into action. Measurements of the resulting deformations of the spectra thus provide information about nuclear behaviour to supplement what is learnt from scattering experiments.

The simplest exotic atom is 'protonium' — a proton and an antiproton locked together by their electromagnetic attraction. The innermost Bohr orbits are 2000 times smaller than those of the hydrogen atom and the corresponding X-ray spectra (K lines) are hard to see because the antiprotons are normally absorbed by interatomic effects before they can get near enough to the protons. However this absorption depends on the density of the targets, and the low energy and momentum spread of the LEAR antiprotons allowed low density gas targets to be used for the first time.

Even so, hunting the antiprotonic K lines was difficult, calling for ingenious experimental techniques. The 'ASTERIX' experiment by a CERN / Mainz / Munich /Orsay / TRIUMF / Zurich group (see November 1984 issue, page 386) used a 'Spiral Projection Chamber' — a drift chamber using a radially decreasing electric field providing energy measurement and localization of the produced X-rays.

An Amsterdam / Birmingham / Coimbra / Delft / Rutherford (UK) / William and Mary (US) group saw initial indications of the elusive K lines using a solid state X-ray detector. To boost the signal, gas scintillation proportional counters were developed at Delft University of Technology with support from the Dutch Foundation for Fundamental Research on Matter (FOM). Operating these chambers in a pre-scintillation mode gave a characteristic X-ray response with good suppression of charged particle background, providing fine examples of the protonium K lines.

Using a clever cyclotron trap to capture antiprotons, a Karlsruhe group has been able to use very low pressure gas targets (pressures down to 10 torr), extending the range of conditions under which protonium spectral lines can be studied.

Other LEAR experiments looked at the absorption of antiprotons measuring both atomic X-rays and gamma rays from nuclear transitions. One goal was to search for 'baryonium' — a predicted quasi-nuclear state containing a heavy particle and its antimatter counterpart tightly bound together by quark forces.

Over the years, baryonium sightings came and went, and one of the foundation stones of the original proposal to build LEAR at CERN was to provide at last the right conditions to manufacture baryonium.

Speaking on 'Future Prospects of Particle Physics' at the recent European Symposium on Nucleon-Antinucleon Interactions, held in Thessaloniki, Greece, former CERN Research Director General Leon Van Hove said — '(baryonium) attracted much attention in the last ten years and provided a strong motivation for LEAR. The lack of experimental evidence for these states, although very disappointing and a serious loss for the LEAR programme, does not create any difficulty for theory because of the highly uncertain character of the original predictions'.

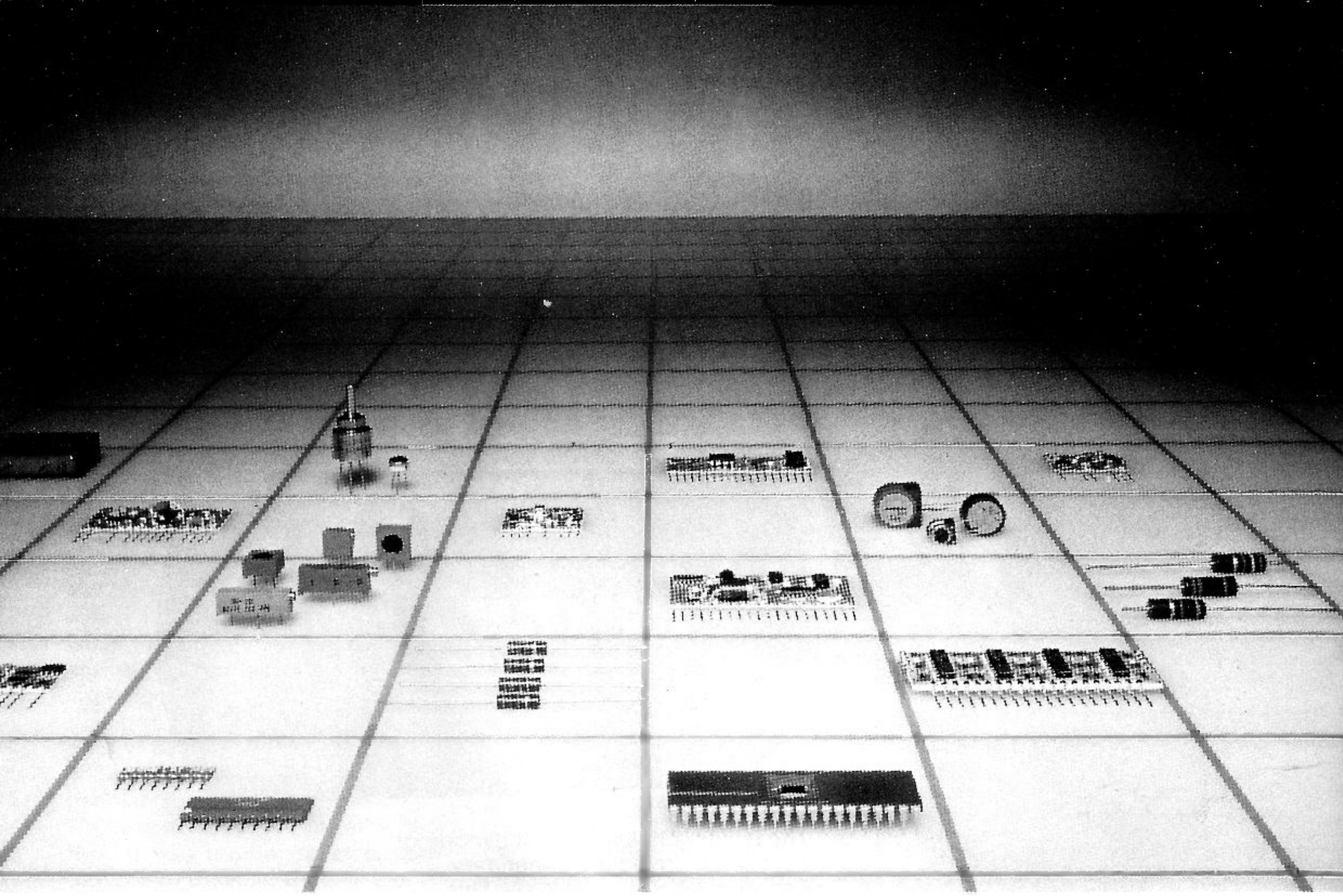
The search for nuclear exotica still continues, in particular the 'glueball' states containing gluons instead of, or as well as, the normal quark constituents of nucleons.

BROOKHAVEN Lattice gauge theory symposium

Originally introduced by Kenneth Wilson in the early 70s, the lattice formulation of a quantum gauge theory became a hot topic of investigation after Mike Creutz, Laurence Jacobs and Claudio Rebbi demonstrated in 1979 the feasibility of meaningful computer simulations. The initial enthusiasm led gradually to a mature research effort, with continual attempts to improve upon previous results, to develop better computational techniques and to find new domains of application.

For many questions falling outside the validity of conventional perturbation theory techniques, lattice numerical calculations remain the only method to make quantitative predictions using quark field theory.

The current interest in lattice gauge theories was demonstrated by the large attendance and packed programme at the International Symposium on Lattice Gauge Theories, held at Brookhaven from 15-19 September, at Brookhaven National Laboratory, with the sponsorship of NATO. During the past years similar meetings have been held on both sides of the Atlantic, with CERN hosting the conferences in 1983 and 1984. The very large number of contribu-



Lattice gauge theory pioneer Kenneth Wilson of Cornell (seated, right) with organizers of the recent lattice symposium at Brookhaven — (standing, from left) Michael Creutz, Sidney Kahana, Helmut Satz and (seated) Claudio Rebbi.

(Photo Mort Rosen)

tions drove the organizers to set up a few parallel sessions, a somewhat novel procedure for a topical meeting.

Lattices of up to 24 compartments in the three space dimensions and 48 in the fourth (time) dimension are currently used for deriving QCD results in the so-called quenched approximation (neglecting virtual quark-antiquark pairs). The accuracy is improving; the spectrum of heavy quark families can now be calculated from first principles, including spin-dependent effects. Agreement with the experimental data is rather satisfactory. However the emergence of strong fluctuations on the larger lattices, especially at the lowest quark masses, may signal the limit of applicability of the quenched approximation. The inclusion of dynamical fermions (effects from quark-antiquark pair creation and annihilation) remains one of the top priorities and one of the most debated subjects. Lattice investigations (of Higgs-gauge systems) indicate that the freedom of defining parameters present in the perturbative formulation of the models may actually be strongly constrained.

A substantial fraction of this research requires powerful supercomputers. One session looked at what the future may have in store for us, be it from established manufacturers or from enthusiastic groups of theorists who decide to build their own machine. However other presentations showed that there are also many very interesting problems which do not require large computers, or any computer at all.

A highlight was a talk by Kenneth Wilson on the future of lattice gauge computations. He sees the present computations as severely limited because the actual lattice sizes introduce too coarse a resolution in the space of momenta. Much larger lattices should be considered. This is impossible with present supercomputers, but may become feasible with the advent of new architectures and massive parallelism. However new algorithms will also have to be devised.

A useful piece of advice from Wilson to his audience — stay active in two different fields. Beyond the personal satisfaction this offers, it also generates a chain by which wisdom developed on widely different subjects gets communicated.

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Heavy ion research begins at the AGS

On Monday 20 October, oxygen ions from the Brookhaven Tandem Van de Graaf were transferred through the heavy ion transfer line to the Alternating Gradient Synchrotron (AGS) and for the first time accelerated to the full design energy of 14.6 GeV per nucleon. Four days later, ions were extracted and the first AGS heavy ion experiment was completed during the weekend. The beam intensity was about 4 x 10^8 ions per pulse. This milestone comes two years after the groundbreaking for the Tandem/AGS Heavy Ion Project.

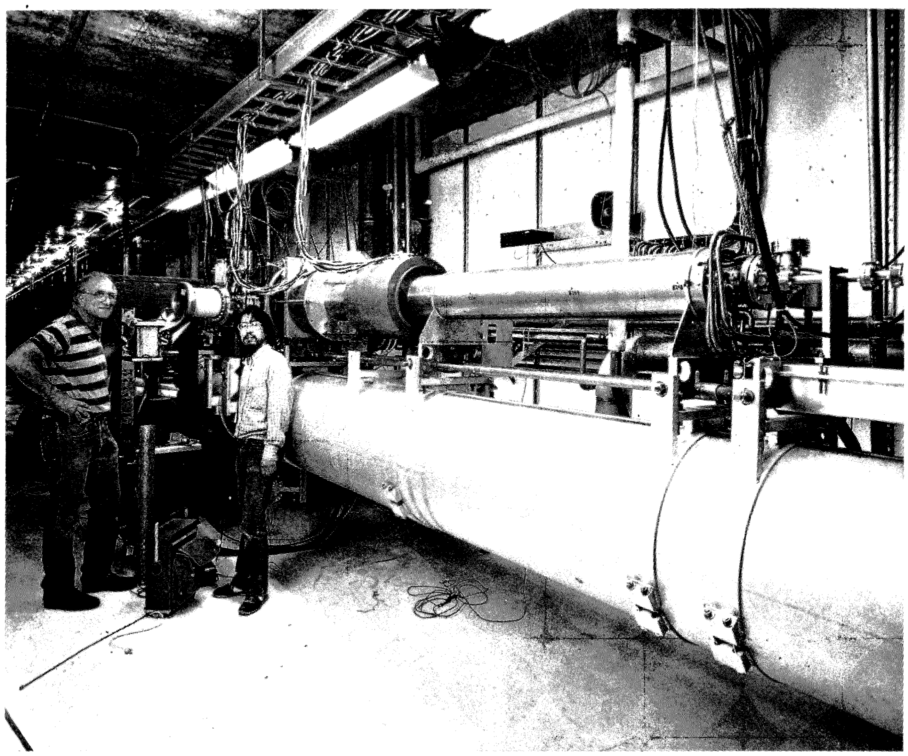
The first AGS experiment with the 14.6 GeV per nucleon beam of oxygen-16 (a collaboration of Oregon State, Brookhaven, Berkeley, Marburg, Oslo, Purdue and Studsvik) surveyed target fragmentation, looking for new features. Targets of various elements were exposed for periods ranging from 10 minutes to 36 hours. For the longest run, this amounted to an accumulated exposure of 10^{13} ions. Target fragmentation cross-sections and mean recoil properties of selected products are being determined by off-line gamma-ray spectroscopy.

A number of experiments will take data in subsequent ion beam runs. Efforts to accelerate and extract silicon or sulphur ions will begin soon. Ion species up to gold will be available when the booster ring, now approved for construction, is completed.

At CERN, ion beams of 200 GeV per nucleon were first delivered in September (see October issue, page 37), heralding a new programme of high energy studies.

This electron injector provides particles for the final stretch of the Stanford two-mile linac, producing lower energy but higher intensity beams for nuclear physics studies.

(Photo Joe Faust)



STANFORD Electrons for nuclei

Robert Hofstadter's work with electron beams at Stanford University showed that nucleons, as well as nuclei, had an inner structure. Subsequently the high energies available at the Stanford Linear Accelerator Center (SLAC) went on to probe deep inside the nucleons and show that they contained pointlike quark constituents.

Later came the discovery that the quark structure of nucleons also depended on the surrounding nuclear environment (the 'EMC Effect'), and particle-physics-type studies using nuclear targets received a major boost. Electron beams play a vital role in this work (see March 1984 issue, page 64).

In 1983, the US Department of Energy approved a proposal for a new 1.65 million-dollar injector to feed electrons into the final stretch of SLAC's two-mile linac to produce beams of up to about 6 GeV. Although the energy is lower than that supplied by the full linac (being upgraded to 50 GeV for the new Linear Collider — see November issue, page 11), the beam intensity is much higher because of the highly reduced beam breakup effects in the shorter length.

Construction and installation of the new injector went ahead so smoothly that the first beam was delivered ahead of schedule in October 1984. In the meantime a call for proposals had gone out, the idea being to make use of the big detectors in End Station A inherited from SLAC's programme of studies using high energy electron beams to probe the deep interior of nucleons.

A group of about 50 physicists now uses these electron beams to study the behaviour of nuclei, looking in particular for the onset of quark effects in nuclear behaviour.

The nuclear experiments are pushing out their kinematical coverage of light nuclear systems to uncover more details of nuclear matter and charge distributions.

This programme is coordinated by Ray Arnold of the American University, Washington DC, who asserts that the new community 'must grow', eventually doubling in size, to fully exploit the potential of the new facility.

One potentially new sphere would be provided by using internal targets in electron storage rings such as the PEP machine, now relatively undersubscribed after the completion of the first generation of experiments.

A test run was made using the TPC detector in the PEP ring, leaking in gas to provide a target for the circulating beams. In January a workshop is being organized to explore further these possibilities, including the use of polarized beams and/or targets. (Further information on the workshop is available from Ray Arnold at SLAC, Bin 43, PO Box 4349, Stanford, California 94305.)

PORTUGAL
Getting in the act

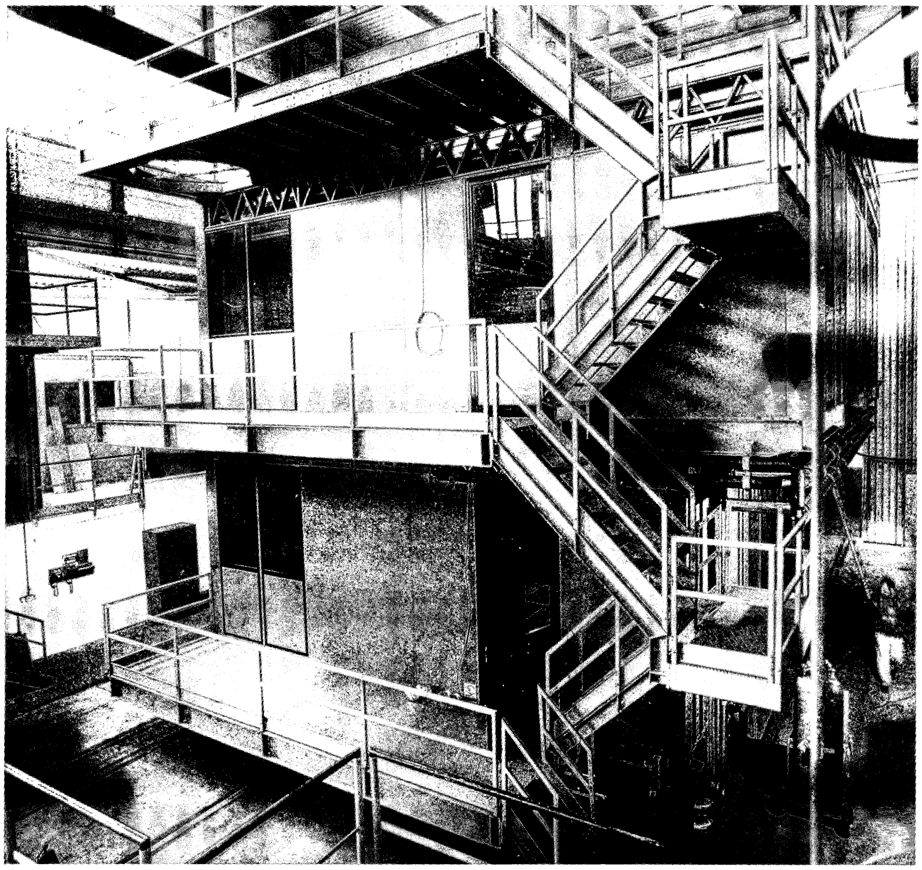
Portugal has been a CERN Member State for a full year and the results are already being felt both at CERN and in Portugal. Under the terms of the agreement between CERN and Portugal, 90 per cent of this year's Portuguese contribution (amounting to 0.8 per cent of the CERN budget) is being invested at home to develop high energy physics, set up infrastructures for experiments, initiate training schemes, and install computers. At the same time an effort is being made to develop contacts between Portuguese industry and CERN. The special 'CERN Fund', essential for the Portuguese particle physics community, is being administered by an inter-ministerial committee, advised by a 13-member scientific council, including five members from abroad.

The Lisbon and Coimbra groups have created LIP (Laboratory for Instrumentation and Particle Physics) to prepare for participation in LEP. Portuguese scientists are involved in the DELPHI experiment for CERN's new LEP electron-positron Collider, and in other areas of CERN research (heavy ions, low energy antiprotons at LEAR, rare isotope beams from ISOLDE). Theorists are expanding their contacts.

The CERN Fund allocation will decrease by ten per cent each year as more Portuguese funds go directly to CERN, but will continue to play a vital role in the development of particle physics in this enthusiastic new recruit to the CERN club.

Instrumentation for the DELPHI experiment at CERN's new LEP electron-positron Collider will be housed in this barrack. Portuguese scientists have joined the DELPHI team, where they are helping with the development of the data acquisition system.

(Photo CERN 525.9.86)



TRIUMF
Breakdown of charge symmetry

At the Canadian TRIUMF meson factory in Vancouver, an Alberta/Basel/Manitoba/TRIUMF collaboration has recently obtained the first evidence for deviations from charge symmetry in neutron-proton elastic scattering. Charge symmetry is a consequence of charge independence which considers the neutron and the proton as two manifestations of the same particle: the nucleon. In this picture the neutron and proton become indistinguishable if electromagnetic effects are switched off.

Charge independence implies that the neutron-neutron, neutron-proton, and proton-proton interactions are identical when these nucleons are under the same quantum conditions. The electromagnetic interaction, however, breaks the symmetry, giving effects of the order of one part in 137.

Charge symmetry is less restrictive, and compares nucleon systems where neutrons are replaced by protons and vice versa.

Applying charge symmetry to the neutron-proton system leads to equality of the left-right asymmetry, or analysing power, in two cases: when one scatters polarized (spin oriented) neutrons from unpolarized protons, or polarized protons from unpolarized neutrons (or, equivalent to the latter case, unpolarized neutrons from polarized protons after a 180° spatial rotation in the centre-of-mass system). Equalities involving more complicated spin-dependent effects can be derived theoretically, but experimental checks become increasingly difficult.

The Alberta-Basel-Manitoba-TRIUMF collaboration has performed a novel experiment at TRIUMF to measure precisely the difference of the two analysing powers in neutron-proton elastic scattering. A breaking of charge symmetry causes the neutron and proton analysing powers to cross zero at slightly different angles. The experiment determined the difference between the zero crossing angle of the neutron analysing power (when polarized neutrons were scattered from unpolarized protons) and the zero crossing angle of the proton analysing power (when unpolarized neutrons were scattered from polarized protons). The two interleaved phases of the experiment used identical experimental parameters, and differed only in the polarization of the beam and target. The angle at which the analysing power crosses zero can be measured without knowing the neutron or proton polarization and, as only a difference of crossing angles was determined, many other systematic errors were cancelled.

Planning for the experiment started in 1978. Much new equipment had to be built, including a 55 cm^3 polarized proton target of the frozen spin type. The 477 MeV polarized (unpolarized) neutron beam was produced from a 497 MeV polarized (unpolarized) proton beam hitting a liquid deuterium target. Data-taking was completed early last year. The result, in terms of the difference of the neutron and proton analysing powers at the zero crossing angle is 0.0037 $\pm$ 0.0017 $\pm$ 0.0008 (where the second uncertainty is the worst-case estimate of systematic error). It provides the first observation of charge symmetry breaking in the neutron-proton system.

Charge symmetry breaking can arise in several ways: direct electromagnetic effects (the magnetic moment of the neutron interacting with the proton); the mass difference of the neutron and proton affecting meson exchange mechanisms; meson mixing; and effects due to quark mass differences. The experimental result is in good agreement with recent theoretical calculations which include the most important of these effects.

BEIJING
Collider progress

While attention focuses on construction progress for big new machines at established particle physics research centres in Europe, the US, the USSR and Japan, work is well underway for a smaller particle physics project which despite its modest size is still a landmark achievement for national ambition.

In 1977, the People's Republic of China embarked on an adventurous multi-objective scientific plan, including the construction of a 50 GeV proton synchrotron. However the Chinese scientists realized this was perhaps a little too ambitious at the time, and the plan was modified into the Beijing Electron-Positron Collider (BEPC) to achieve beams of between 2.2 and 2.8 GeV. Chinese Premier Deng Xiaoping and other Chinese government leaders took part in the groundbreaking ceremony for the new project in October 1984, demonstrating their country's commitment.

The physics goals of the new machine are to study charmonium

(charmed quarks bound to antiquarks), charmed particles, and the tau lepton (heavy brother of the muon and the electron) at collision energies between 3 and 5.6 GeV.

Particles will be injected into the BEPC ring through a 200 metre linear accelerator to take electrons and positrons to between 1.1 and 1.4 GeV. The ultimate energy will depend on the power output of klystrons now being built in China. So far, output of more than 20 Megawatts has been obtained. A prototype section of the electron 90 MeV linac was completed at the end of 1984 and successfully tested. Maximum pulse is 500 mA: energy spread for 200 mA pulse current is less than one per cent. New innovations such as the energy 'doubler' with a quality factor of 10^5 and an energy multiplication factor of 1.4 have been used in the prototype.

The 240 metre circumference storage ring fed by the linac will contain 40 bending magnets and 60 quadrupole magnets. Electrons and positrons collide at two interaction points. Due to the tight budget, only one will be exploited at the first stage of the project.

The detector will be a general purpose magnetic spectrometer, consisting of a drift chamber, a time-of-flight counter, a shower counter, a muon identifier and a large magnetic coil of 4.5 kilogauss. The spectrometer will be about 5 m long and 6 m in diameter, with a total weight of about 350 tons. Prototypes of components have been built and online tests gave satisfactory results.

For the first phase of the project, synchrotron light beamlines and experimental stations will be built to study photoelectron spectra, extended X-ray absorption fine structure spectra (EXAFS), diffraction, small angle scattering, crystal topography, and X-ray lithography. These will be used to do solid state physics, surface physics, biology, medical science, semiconductor physics and other research and development.

The civil engineering work has progressed quite well. The 200 metre tunnel of the injector has been completed and the klystron gallery is near completion. All tunnels and buildings will soon be complete. Magnets, accelerating tubes of the linear accelerator, klystrons, etc., are now being built in batch. BEPC is scheduled to be completed at the end of 1988.

From an article by Minghan Ye, Director of the Institute of High Energy Physics, Academia Sinica, Beijing, which appeared in the first edition of a new publication, Asia-Pacific Physics News, supported by UNESCO and edited by S. C. Lim of Universiti Kebangsaan Malaysia, Selangor, Malaysia.

MICHIGAN
New ion beams

The K500 superconducting cyclotron at the National Superconducting Cyclotron Laboratory, Michigan State University, has recently accelerated a number of newly available ions to record high single cyclotron energies, thanks to a recently installed Electron Cyclotron Resonance (ECR) ion source and its associated axial injection system. The heaviest-ion, highest-total-energy beam so far has been 1720 MeV krypton 86 (20 MeV/nuc), which was requested for an experiment in June. Other new beams run for the first time this year include 1200 MeV argon 40 (30 MeV/nuc), 756 MeV nitrogen 14 (54 MeV/nuc), and 648 MeV carbon 12 (54 MeV/nuc).

The new ECR source was built at the Cyclotron Lab and is a large, 15 cm bore, permanent-magnet sextupole, room temperature solenoid, source. Injecting ECR beams into the cyclotron began in March and the source has been in use ever since.

Performance with the ECR has been so successful that the original plan for the K500 cyclotron to inject into the next machine, the K800, is being revised to allow the two cyclotrons to operate independently, each with its own ECR source. Construction of the second ECR has begun; this will use superconducting coils for both solenoid and sextupole so that the source can later be used at ultra-high microwave frequencies (around 30 GHz).

The past year has also seen much significant progress on constructing the superconducting K800 cyclotron. Landmarks were: trim coils (104 in all) custom-formed and fitted on the magnet pole tips; extensive field maps of the main magnet giving excellent results; the prototype radiofrequency final amplifier working in accord with design with all three final amplifiers complete and ready for testing; and the r.f. resonator assembly proceeding at a good rate. K800 beam tests should begin next spring with first experiments in the summer.

People and things

On people

Jan Kluyver has been appointed Knight of the Order of the Netherlands Lion on the occasion of his retirement as Professor at Amsterdam University. He is amongst the most prominent Netherlands physicists — member of the staff of NIKHEF, and long-time experimenter at CERN. He has also played many important management roles in the Netherlands. At CERN he has been Dutch delegate to Council for many years, serving most recently as the Council's Vice-President.

Godfrey Stafford, formerly Director of the UK Rutherford Laboratory and now Master of Saint Cross College, Oxford, has been elected President of the UK Institute of Physics.

At Fermilab, Daniel Green becomes Head of the Physics Department, succeeding Thomas Kirk who will be devoting more time to experimental physics. Charles N. Brown assumes Dan Green's former role as Physics Department Deputy Head.

Horst Foelsche has been appointed Deputy Chairman of Brookhaven's AGS Department. He will concentrate primarily on departmental interfaces between the AGS (Alternating Gradient Synchrotron) and the Booster, Tandem, and proposed Relativistic Heavy Ion Collider (RHIC). Theo Sluyters is the new Head of the Accelerator Division, where his responsibilities will include the ambitious AGS upgrade programme.

Jan Kluyver — Knight of the Order of the Netherlands Lion.

On 29 September Federal German Minister for Research and Technology Heinz Riesenhüber (on stairs, right) paid a lightning visit to the construction site of the HERA electron-proton Collider at the DESY Laboratory in Hamburg. With the Minister is DESY Director Volker Soergel, followed by Gustav-Adolf Voss, one of the two HERA Project Leaders. Behind him is Hartmut Perschau of the Hamburg City Parliament, followed by Herbert Oehlschläger of Frankfurt.

(Photo DESY)

ICFA Instrumentation School

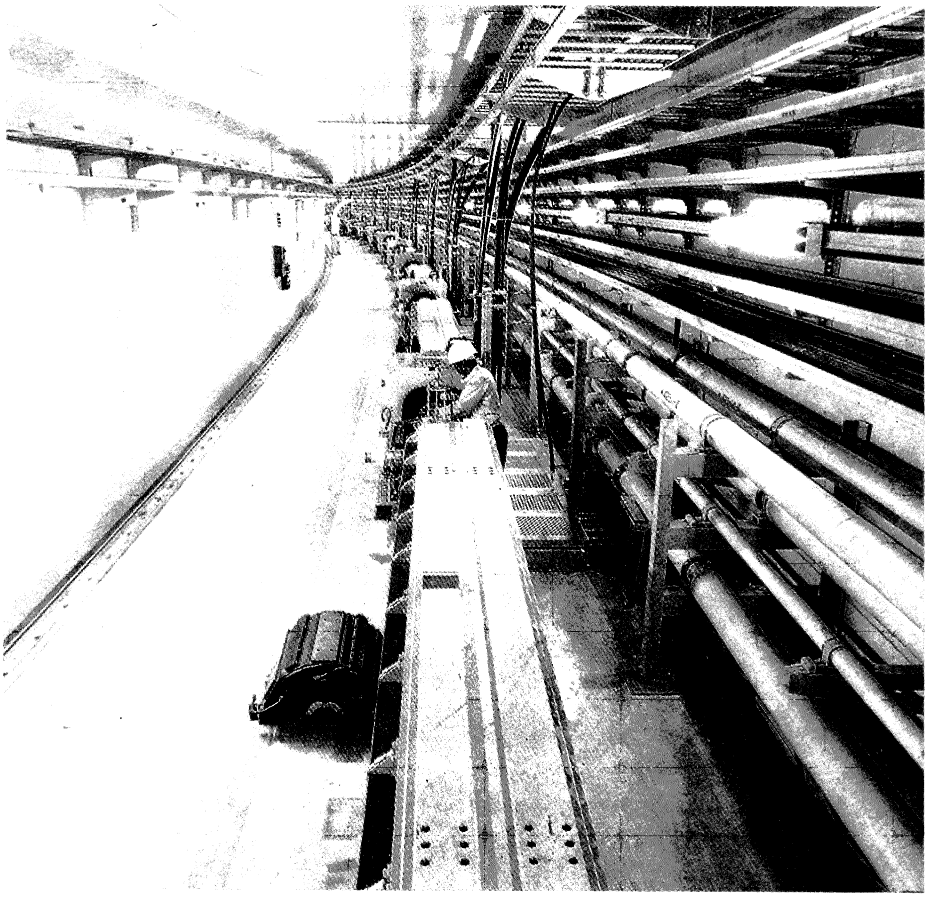
The recently-formed Instrumentation Panel of the International Committee for Future Accelerators (ICFA), together with the International Centre for Theoretical Physics, Trieste, is organizing a School on Instrumentation in Particle Physics, to be held in Trieste from 8-19 June.

The school aims to cover both the physics and the technology of modern detection techniques and to attract participants from all over

STOP PRESS — On 14 November the TRISTAN ring at the Japanese KEK Laboratory achieved electron-positron collisions at 50 GeV with a luminosity of about 2.6 x 10^{29} per cm^2 per s.

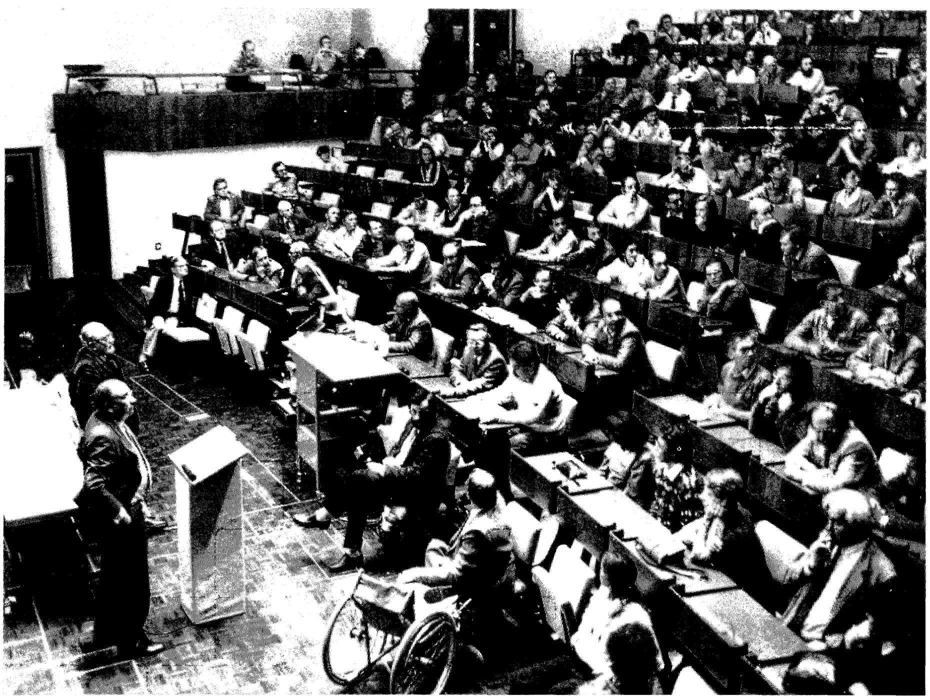
View of the now completed main ring of the TRISTAN electron-positron Collider at the Japanese KEK Laboratory. First electron beams were accelerated in October, and first electron-positron collisions should not be far away.

(Photo KEK)



the world, especially the developing countries. As well as formal lectures, the school will include hands-on practical work with 'table-top' experiments. Sponsors are the Dipartimento per la Cooperazione allo Sviluppo, Italy, the Trieste section of the Italian Istituto Nazionale di Fisica Nucleare (INFN), CERN and the US Department of Energy.

Further details from — International Centre for Theoretical Physics, ICFA School on Instrumentation in Particle Physics, PO Box 586, 34100 Trieste, Italy. Closing date for applications is 31 January.



On 20 October at CERN, a special colloquium was dedicated to the memory of Paul Musset, who died in an accident last year. André Rousset and Jean-Pierre Vialle first described Musset's contributions to physics, and Abdus Salam (standing, furthest from camera, with meeting chairman Charles Peyrou) took over for a personal overview of particle physics today.

(Photo CERN 357.10.86)

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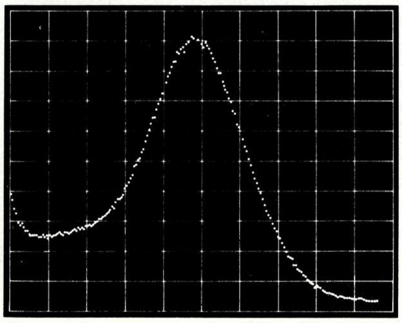

Single electron spectrum obtained with an XP2262 tube.

Our worldwide experience in high energy physics includes contributions to projects such as The Plastic Ball, The Mark II and III Detectors, BNL Neutrino Detector, Crystal Box, and in Europe, in the CERN Intermediate Vector Bosons Search. *COME, SEE THE LIGHT!* Contact us today, write for complete information to AMPEREX.

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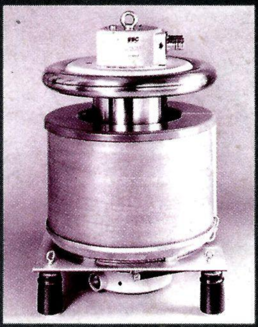
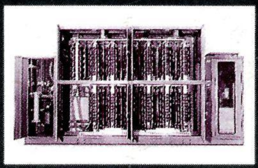
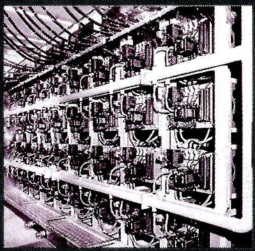
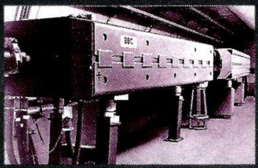
Brown Boveri Technology for High-Energy Physics and Fusion Research

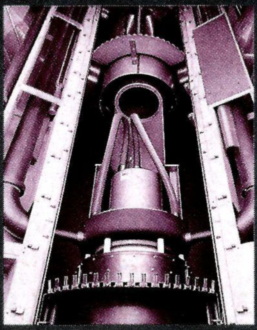
CERN, European Organization for Nuclear Research, Geneva: dipole and quadrupole magnets, spectrometer magnet 3 MW, superconductor and coils for Omega spark chamber magnet. DESY, Deutsches Elektronen-Synchrotron, Hamburg: bending and quadrupole magnets, exciting coils for PETRA bending magnets, super-conductor for HERA dipole magnets. Istituto Nazionale di Fisica Nucleare, Milano: 3 RF generators, 15 to 50 MHz, 90 kW. IREQ Varennes, Canada: 4 power supplies for Tokamak, 1 static bi-directional plasma start-up switch (20 kA/15 kV). Jet Joint Undertaking, Culham GB: poloidal and toroidal field coils, magnet core for Joint European Torus, switching and regulating tetrodes CQK 200-4. KFA Kernforschungsanlage Jülich, FRG: 2 neutral beam injection power supplies 55 kV, 100 A, switching and regulating tetrode CQK 400-1. Lawrence Livermore National Laboratory, Livermore USA: 2 RF generators, 6 to 20 MHz, 1 MW, switching and regulating tetrodes CQK 200-4. Max-Planck-Institut für Plasmaphysik, Garching/Munich: 2 RF generators, 30 to 115 MHz, 1,5 MW (tests up to 2 MW), poloidal and toroidal field coils for ASDEX and W VII, switching and regulating tetrodes, RF study for ASDEX upgrade. Oak Ridge National Laboratory, Oak Ridge, Tenn., USA: Superconducting toroidal field coil for Large Coil Task. Princeton Plasma Physics Laboratory, Princeton, NJ, USA: Poloidal field coils for TFTR Tokamak. SIN, Schweiz. Institut für Nuklearforschung, Villigen: 4 generator power supplies 16,5 kV, 80 A. Main magnets of isochron cyclotron (2000 tons), bending, quadrupole and experimental magnets. Superconducting coils for muon channel and bio-medical applicator PIOTRON. Switching and regulating tetrodes for Euratom-ENEA Rome, Euratom-CEA Fontenay-aux-Roses F, Fusion Research Center of Japan Atomic Energy Research Institute. High power RF triodes and tetrodes for CRPP, Association Euratom Suisse, Ecole Polytechnique Fédérale, Lausanne CH.

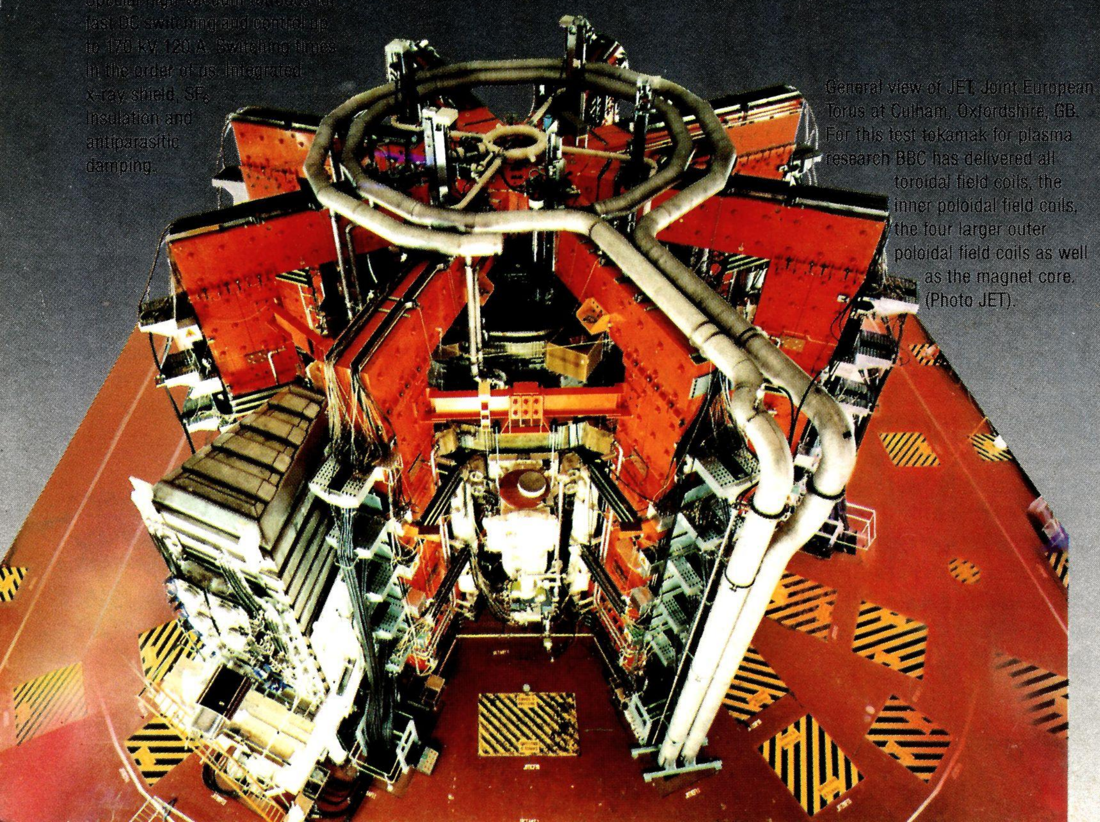

Special high-vacuum tetrodes for fast DC switching and control up to 170 kV, 120 A. Switching times in the order of µs. Integrated x-ray shield, SF_6 insulation and antiparasitic damping.


Toroidal field power supply for a Tokamak. Output current rating for pulses, continuous operation 100 kA (max. 120 kA/370 V DC), for 10 sec/900 sec pause.


Fast high-voltage power supply in pulse-step modulator technique.


B 340 type dipole magnets for beam transport of the Super Proton Synchrotron at CERN Geneva (Photo CERN).


ICRH-generator for plasma heating, 30 to 115 MHz, 1,5 MW, for pulses up to 10 s, equipped with BBC tetrode CQK 650-2.


General view of JET, Joint European Torus at Culham, Oxfordshire, GB. For this test tokamak for plasma research BBC has delivered all toroidal field coils, the inner poloidal field coils, the four larger outer poloidal field coils as well as the magnet core. (Photo JET).

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