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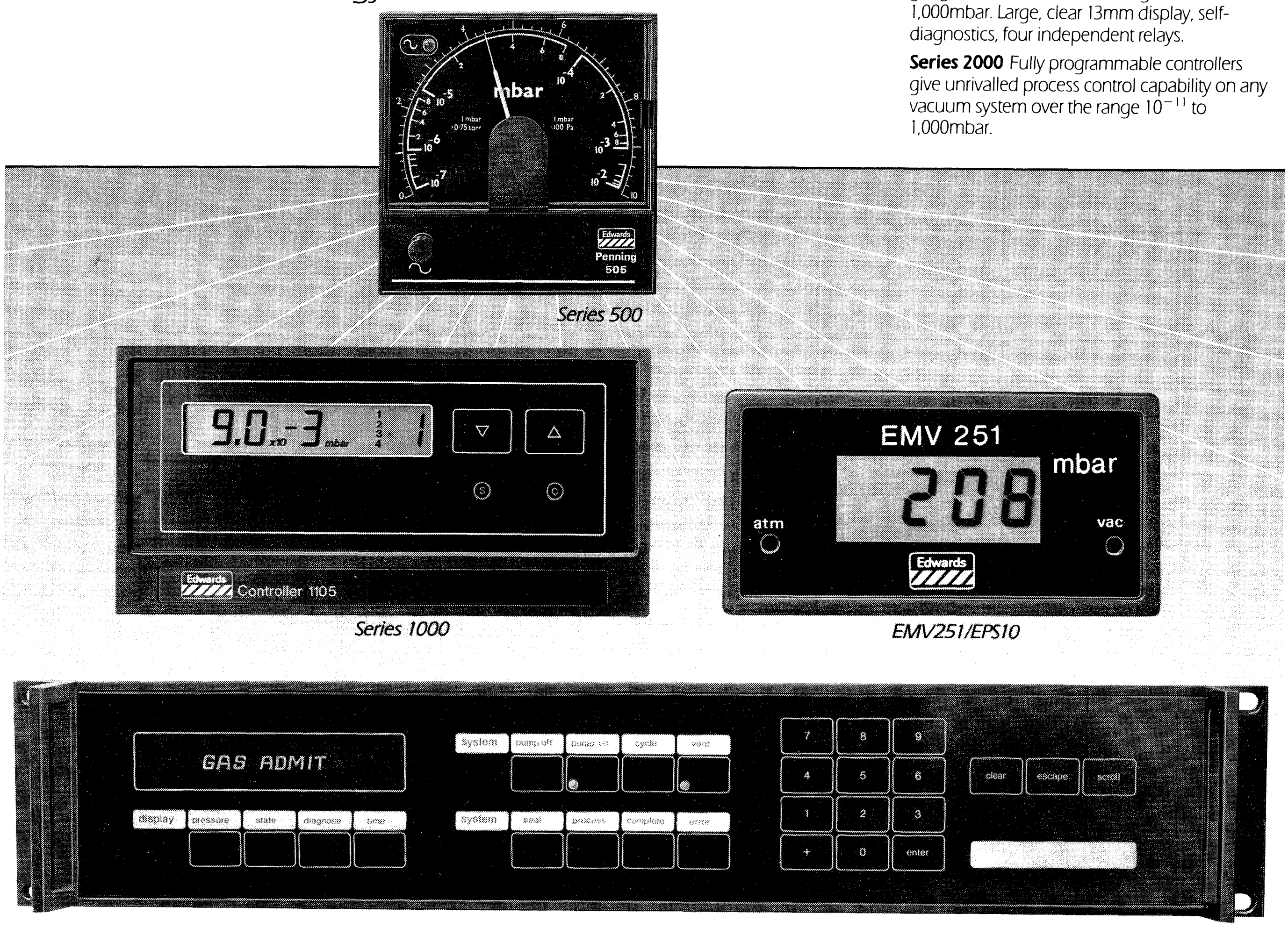

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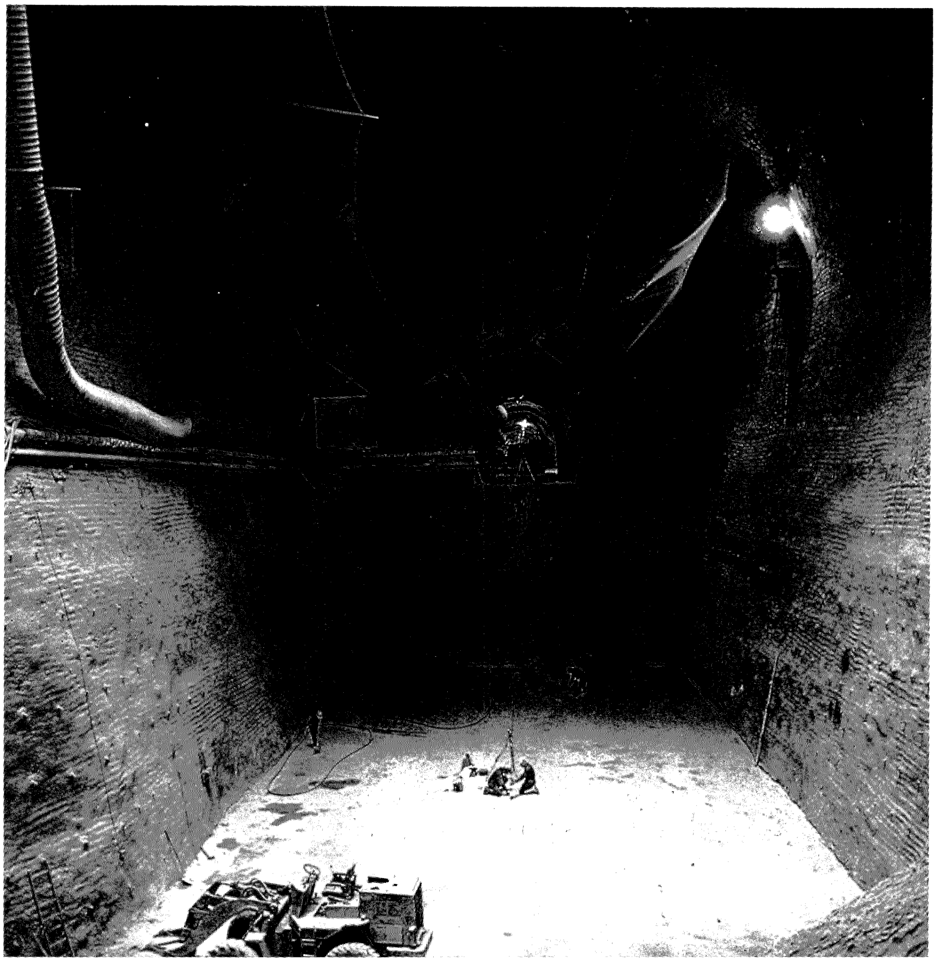
Cover photograph: The famous leaning tower of Pisa where Galileo conducted his famous experiments which showed that gravity cannot distinguish between different materials – as far he could tell. Some people say it is time for a rethink – see page 9. (Photo G. Claude)

A look at LEP

45 metres below ground, the LEP tunnel emerges into the vast underground cavern which will house the big L3 experiment.

(Photo CERN X809.11.85)



While work on the tunnel linking England and France under the English Channel has not yet begun, the 26.6 kilometre ring being built at CERN for the LEP electron-positron collider is one of Europe's major engineering projects.

Work began symbolically on 13 September 1983 when French President François Mitterrand and Swiss President Pierre Aubert gave the final touches to the LEP foundation stone. In a project of this size, problems and setbacks are only to be expected, but three years later the achievements are impressive and the project team is still confident that the gigantic machine can be finished on schedule towards the end of 1988.

With three big tunnelling machines now at work under the plain at the foot of the Jura mountains, over 10 kilometres of 3.8 metre diameter tunnel have been bored of the 23.3 required. In addition, 2.2 kilometres of tunnel have been blasted in a 3.3 kilometre stretch under the Jura, for which the tunnelling machines are not suited. Here special precautions are taken to avoid interfering with water courses which for centuries have served the towns and villages below.

February 5 saw one machine notch up a record of 58.7 metres of tunnel bored in one day, more than twice the average figure. As the machines move relentlessly forward, teams move in to line and concrete the completed tunnel sections.

Project Leader Emilio Picasso is always quick to point out that the status of the civil engineering work is even healthier than tunnelling progress alone would indicate. Before the machines could start work, huge shafts up to 150 metres deep had to be sunk and vast underground caverns excavated underneath. These are now 80 per cent complete, so that in total the underground operations are well past the half-way mark.

Over a million cubic metres of spoil will have to be removed, equivalent to digging a ditch several metres wide and several metres deep right round the urban sprawl of London!

But the tunnel is only the first step towards building a machine to accelerate and store beams of electrons and positrons (anti-electrons) initially at 50 GeV per beam, eventually higher.

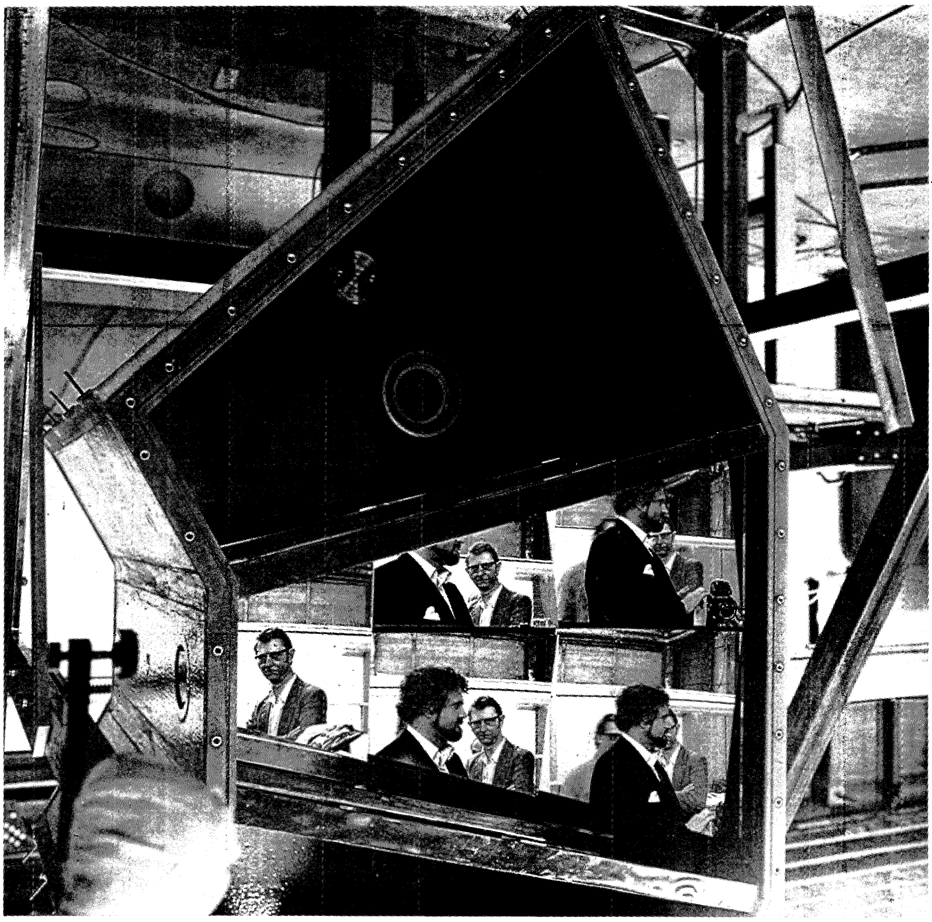
For this, a myriad of sophisticated components has to be designed and specified, ordered, manufactured and tested before installation work in the tunnel even begins.

Supplies for the magnet system to guide the particles are well in hand. The old tunnel from the Intersecting Storage Rings is stacked with kilometres of dipole magnets ready to be lowered into position. 102 of the 524 quadrupole magnets and 144 of the 510 sextupoles have arrived from European industry. Supplies for the radiofrequency cavities and the klystrons to power LEP's beams are also beginning to build up.

Work on the other ancillary equipment — cooling and ventila-

While work for the LEP machines forges ahead, the four big experiments keep step with the demanding schedule to be ready to intercept the first electron-positron collisions towards the end of 1988. Here is a prototype module of the Ring Imaging Cherenkov counter (RICH) for the DELPHI experiment. The DELPHI RICH, the largest example of this relatively new detector technique, will surround the central tracking chamber and will identify charged hadrons.

(Photo CERN X 757.5.85)



tion, transport, cabling, power transmission, vacuum, control systems,... — is moving steadily ahead ready to lock into the intricate planning of the project.

While the tunnel progresses and the machine components begin to arrive, preparations unfold to supply particles for LEP. Near the valiant 27 year-old 'Proton' Synchrotron (PS) which gives all CERN's particle beams their initial kick of high energy, a 100 metre linear accelerator — the LEP Injector Linac — is being built. Just before Christmas one sector of this machine accelerated electrons to 4 MeV and accelerator physicists anxiously studied the behaviour of the beam.

In these tests, a number of important functions (vacuum, power supplies, beam position) were monitored and controlled by elements of the new computer control system. This gave confidence for the task of integrating the remaining controls and process elements.

In June, the linac is scheduled to inject the first electrons into the new Electron-Positron Accumulator (EPA), which will store the particles prior to injection into the PS. Injection into the PS is planned for the end of the year, providing a Christmas present for the stalwart team who are also looking forward this year to handling oxygen ions.

At CERN and the hundred or so research institutes across the world collaborating in the four big experiments to use LEP, an intricately dovetailed effort ensures that the four huge detectors will be ready to intercept LEPs first collisions of electrons and positrons, opening a new era of particle physics.

Neutrino masses

Postulated in the early days of quantum mechanics by Wolfgang Pauli to make energy-momentum conservation in nuclear beta decay come out right, the neutrino has never strayed far from physicists' attention. The Moriond Workshop on Massive Neutrinos in Particle Physics and Astrophysics held recently in the French Alps showed that more than half a century after Pauli's prediction, the neutrino stubbornly refuses to yield up all its secrets.

Peter Rosen (Los Alamos) began the Workshop with the charge that since 'no simple principle demands that the neutrino is massless, it's up to the people in this room to determine the mass', and the participants eagerly took up the challenge.

The possible role of neutrinos in cosmology was discussed by a

Moriond for physics

Twenty years ago, J. Tran Thanh Vanh from Orsay gathered together a group of fifteen physicists at a rented house in Moriond in the French Alps for a unique week's blend of informal physics discussion, skiing, cooking and housework.

The meeting was such a success that Tran's colleagues urged for a follow-up the following year — the Moriond tradition had started. An annual three-session format emerged, with a January meeting covering a special topic and two Spring meetings given over to strong and electroweak interactions. Cooking and housework have disappeared from the daily schedules, but the venue is always an alpine skiing resort, almost always in France.

The Moriond meetings are supported by the French CEA (Commissariat à l'Energie Atomique) and CNRS (Centre National de la Recherche Scientifique), but the workshop held in Tignes (France) from 25 January to 1 February this year was also sponsored (for the first time) by a US Laboratory — Lawrence Livermore. The topic was Massive Neutrinos in Particle Physics and Astrophysics.

number of theorists including Klinghammer, Schramm, and Steigman. Studies of galaxy formation indicate that neutrinos could contribute to the large scale structure of the universe but are not good candidates for galaxy formation. On a slightly different topic, Glashow and Haxton gave stimulating and timely talks on 'The Fifth Force' (see also page 9).

There was considerable speculation whether a neutrino beam passing through matter may grossly alter its content, which might explain the riddle of the missing solar neutrinos. (The neutrino signal picked up on Earth is less than what is expected from the sun's thermonuclear furnace.) Smirnov discussed the recent suggestion by Mikcheyev and himself that the process has a resonant character. He explained that if the electron density in the sun varies slowly with radius, then neutrinos born as electron-type neutrinos in the solar core can change into nearly pure muon-type neutrinos before leaving the sun. The electron neutrino flux on earth would then be severely suppressed. Detailed numerical analyses of this matter-induced suppression of solar electron neutrinos were reported by Gelb and Rosen, by Hampel, and by Mikcheyev and Smirnov. Forthcoming experiments using gallium detectors will sample a different part of the electron neutrino energy spectrum than the classic chlorine (dry cleaning fluid) experiment and could check this possible suppression mechanism.

A number of experiments were discussed which will attack the solar neutrino problem by looking directly at the neutrinos from fusion. Kirsten reported on the newly approved GALLEX experiment which is scheduled to receive its final delivery of gallium in late 1989 with data acquisition commencing in 1994. Pomansky commented on another approved effort, a sixty-ton Soviet experiment which hopes to have its gallium by late 1987. In addition, other proposals using gallium, boron, molybdenum, and heavy water were discussed.

Observations of the Cygnus X-3 binary star using the Mont Blanc, Frejus, and Baksan underground detectors disagreed as to whether any remarkable signal had actually been seen (see September 1985 issue, page 264). Since the output of Cygnus X-3 in the X-ray region is very time-dependent (October 1984 had two weeks of more than 10 times normal X-ray activity), correlations between experiments could help.

Coming back to Earth, searches for neutrino oscillations (transitions between neutrino types) at both accelerators and reactors were discussed. Accelerator experiments were reviewed and several new experiments at Brookhaven and Los Alamos in the US and Rutherford in the UK were summarized. No definitive evidence for neutrino oscillations has been seen in the accelerator experiments. Some disagreement exists between the reactor neutrino oscillation experiments. Vuilleumier presented the data from the group working at the Swiss Goesgen reactor. No evidence for oscillations is found with the detector at three different distances from the reactor core. He pointed out that the conclusions are independent of the particular neutrino energy spectrum emitted from the reactor. The group working at the French Bugey reactor presented previously announced evidence for oscillations (see July/August 1984 page 244). Sobel showed preliminary results from a new reactor experiment at Savannah River (US) which ruled out most of the region allowed by the Bugey experiment. Hopefully this dilemma will soon be clarified, possibly with new data from the Savannah River group or with a new experiment proposed by the Bugey group.

Several impressive limits from searches for neutrinoless double beta decay were presented by the Milan, Caltech and Osaka underground studies using germanium. The implications for neutrino mass was the subject of a debate among the nuclear theorists Klapdor and Vogel. Other searches for neutrinoless double beta decay were reported by Pomansky and by Fiorini, who was enjoying a welcome relief from his 21 000 hour germanium measurement in the Mont Blanc tunnel. Fiorini pointed out that progress may result from novel detection methods.

It remains a puzzle that double beta decay accompanied by two neutrinos (a rare but allowed process) seems be slower than calculations predict. On the other hand, Hahn pointed out that the two neutrino decay rate now observed in selenium 82 is no longer inconsistent with the geochemical value.

Daum reported on the muon-type neutrino mass limits, the lowest of which is now 270 keV, while Koltick reviewed the work on the tau neutrino mass, which now has to be lighter than 56 MeV.

In the continuing effort to weigh the electron neutrino, exciting new tritium beta decay results were presented. These discussions filled two sessions and were started by Lubimov presenting new ITEP (Moscow) data. Still using tritium bound in valine, the group has reduced backgrounds and made a considerable effort to better understand the spectrometer resolution. Many fits to the data over different energy intervals yielded results in agreement with previous work, though with a smaller electron neutrino mass range. The previous mass range of 9-46 eV was reduced, albeit with different assumptions about molecular effects, to 17-40 eV, giving an even stronger indication of a non-zero neutrino mass. Lubimov's talk was followed by a spirited discussion. Bergkvist, in a lively interchange with Lubimov, pointed out some possible subtle pitfalls.

Petersen presented tritium data taken by the Zurich group working at the Swiss SIN Laboratory. The group has been working for over a year with a magnetic spectrometer, observing electrons from tritium bound in a thin carbon substrate. Preliminary measurements indicate that the (electron) neutrino mass is less than 9 eV, but including a generous estimate of systematic errors extends the limit to 20 eV.

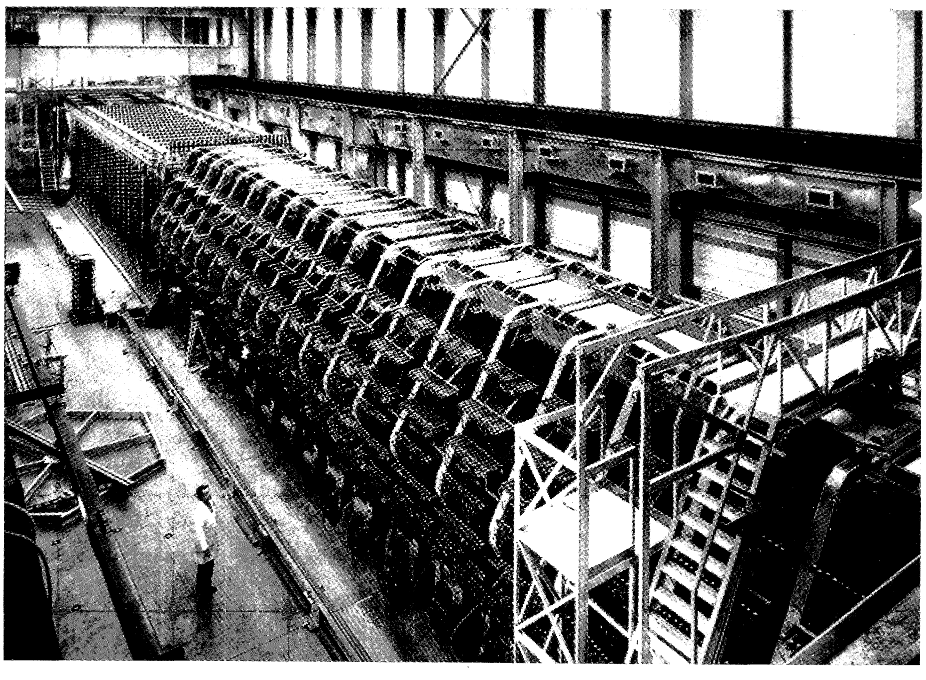
Two other groups also reported new data. Wilkerson presented Los Alamos data using gaseous tritium whose decay electrons were analysed in a magnetic spectrometer. Resolution was somewhat uncertain but a conservative choice gives a neutrino mass limit of 43 eV. Kawakami presented Tokyo data, preferring not to quote a preliminary result, but a comfortable limit could be drawn at 50 eV.

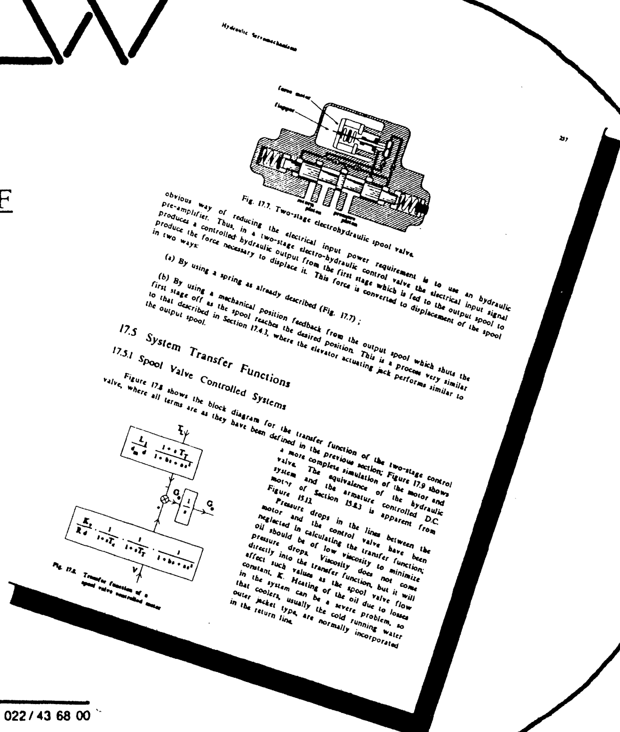
Several other groups expect to be taking data soon. Momentarily at least, the controversy surrounding the neutrino seems to be focused on the beta decay of tritium, and the excitement of the chase pervaded the whole Moriond meeting.

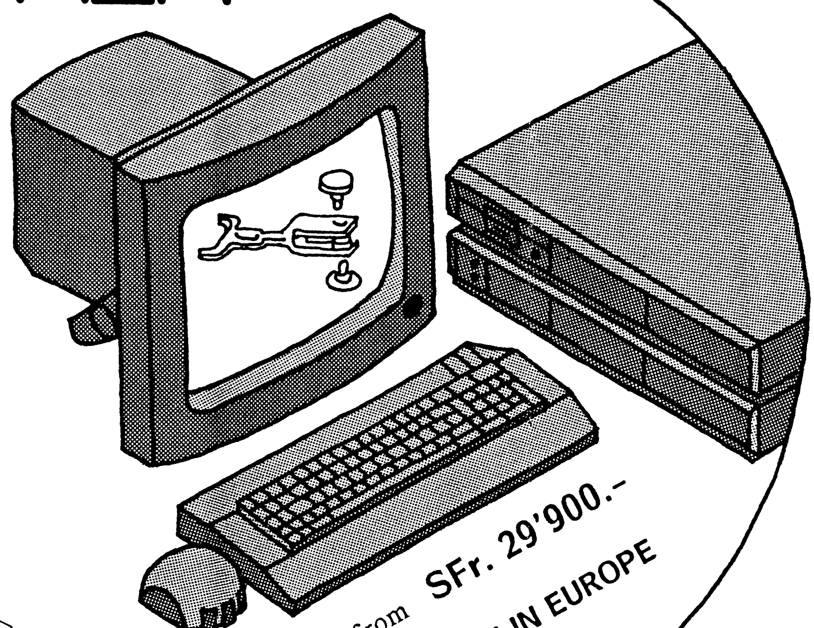
In his concluding remarks, Gary Steigman congratulated organizers Tran Thanh Van of Orsay and Orrin Fackler of the Lawrence Livermore Laboratory for a stimulating week of physics.

The original lineup of detectors in the CERN SPS neutrino beam. Accelerator experiments show no evidence for transitions between different types of neutrinos (neutrino oscillations), although results from studies at nuclear reactors do not entirely agree.

(Photo CERN 16.12.78)







A large-scale map of particle physics

Guido Altarelli — on closer inspection the Standard Model does not even look like an ultimate theory.

Most theorists will admit to being dissatisfied with the current 'textbook' picture of particle physics. Here Guido Altarelli explains why.

The so-called 'Standard Model' of particle interactions is a comprehensive and relatively simple way of describing the fundamental forces of Nature. It consists of quantum chromodynamics (QCD) — the theory of quarks and gluons interacting through the 'colour' force, and the 'electroweak' unification of electromagnetism and the weak nuclear force. Add Einstein's classical theory of gravity to complete the picture.

This Standard Model agrees with all the experimental information, and with the discovery of the W and Z carriers of the weak nuclear force at CERN in 1983, a chapter of physics closed.

Despite all the euphoria, the experimental evidence for the Standard Model is not complete. Not only has the sixth ('top') quark yet to be firmly established, but at a more fundamental level the so-called 'Higgs mechanism', which gives the weak force carriers their mass (see March issue, page 26) has not been tested at all. Even the widely-acclaimed electroweak sector has only been checked to within a few per cent, contrasting with the few parts per million precision of quantum electromagnetism.

On closer inspection, the Standard Model does not even look like an ultimate theory. Many questions emerge and a host of crucial problems appear. A large number of masses and coupling strengths have to be put in artificially. The pattern of masses and quantum numbers is full of intriguing features — the succession of three 'generations' each containing two kinds of quark plus one kind of lepton is impressive and unexplained. The quantization of electric charge is not implied by any Standard Model principle (although it does lead to useful cancellations in the theory).

Other features whose origins remain a mystery have to be fitted in. These include the violation of parity P (left-right symmetry) and charge conjugation C (particle-antiparticle symmetry), some aspects of the combined CP violation in the neutral kaon system, the conservation of baryon number and of the three distinct types of leptons (electron, muon and tauon), and the apparent masslessness of their associated neutrinos.

These conservation laws are not protected by a theoretical principle, in contrast to the conservation of electric charge which is guaranteed by having a massless photon. They might turn out to be violated by some as yet unknown interactions, but which would be an integral part of a more complete theory.

Another serious deficiency is the absence of any quantum picture of gravity. Although the force of gravity is extremely weak, it is still non-zero, so that as increasing energies probe deeper and deeper into matter, a level eventually should be reached where quantum gravitational effects should show up. This is the so-called 'Planck Mass' of about 10^{19} GeV - ten million times the energy of the Fermilab Tevatron.

The 'Grand Unified Theories' (GUT) which attempt to unify the colour force of quarks and gluons with the electroweak sector naturally involve very high energies at which the strengths of the colour and electroweak forces become comparable. These energies are intriguingly close to the Planck mass.

This enormous energy sets a new horizon for physics. Can the world remain basically the same all the way from the Tevatron to the Planck mass (the 'desert scenario')? The so-called 'Hierarchy Problem' suggests it cannot. To have a single field theory spanning such a wide energy range brings up technical difficulties.

These can be sidestepped by injecting new ideas, the chief current contender being 'supersymmetry', an elegant new classification of particles (see January/February 1983 issue, page 18). Supersymmetry is a vital ingredient of the 'string' models which have really caught on in recent months (see June 1985 issue, page 18), rating a two-page feature in 'Time' magazine earlier this year. These models provide a very promising framework for unifying gravity and particle interactions.

A number of clues hint that if the iteration of quark and lepton generations has not yet stopped at three, it should do so soon. However higher energies could well uncover the supersymmetric partners of these particles. To solve the hierarchy problem these new supersymmetric particles should be below a few thousand GeV. Other new physics could come from additional degrees of freedom (for example left-right symmetry, which could throw light on the origin of P and C symmetry violations), or from a deeper substructure within quarks and leptons.

Despite the apparent impregnability of the Standard Model so far, important new physics might be just over the horizon.

Polarized macromolecules

Interactions between protons and neutrons depend on the orientation of their intrinsic angular momentum (spin). Thus by lining up the spins of the particles (polarized targets and/or beams), increased information can be extracted.

Techniques for producing polarized targets and beams have made great progress in recent years, and now provide a powerful additional physics tool.

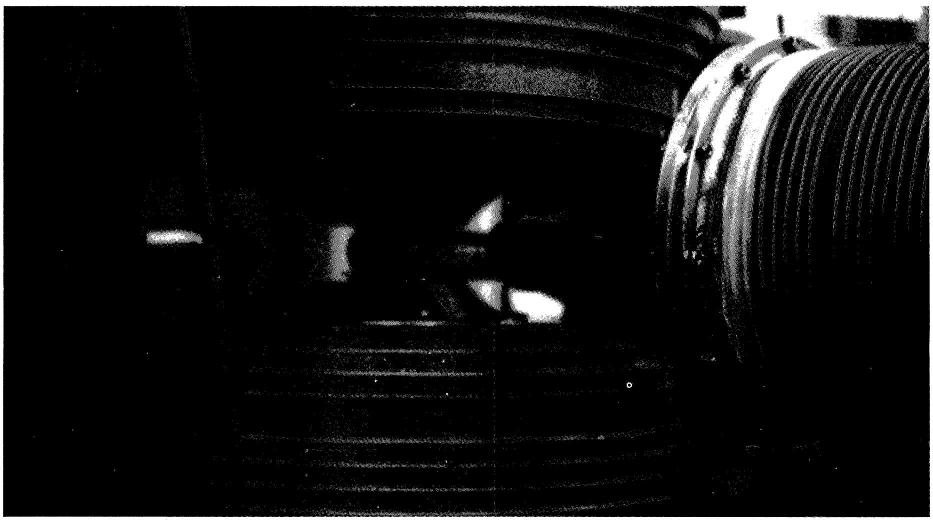
CERN's experience in producing polarized targets has found a new outlet in the study of biological macromolecules. Ingenious techniques developed for handling the spins of nuclear targets have been applied to gigantic molecules containing hundreds of thousands or even millions of nucleons.

The method is a direct extension of the dynamical nuclear polarization recipe developed at CERN. The specimen is dissolved in a mixture of heavy water and deuterated alcohol (e.g. propanediol) and doped with a deuterated metallo-organic complex. The nucleon spins, aligned by the combined action of a strong magnetic field (2.5 T) and microwave radiation (70 GHz), become 'frozen in' at temperatures of a fraction of a degree kelvin. In one hour, polarizations of up to 75 per cent have been achieved.

Their spins lined up in this way, molecules of proteins, enzymes, polymers and bacteria have been studied using beams of polarized thermal neutrons. The research involves an unusual collaboration between CERN, the Institut Laue-Langevin, Grenoble, the Max Planck Institute for Molecular Genetics, Berlin, the HASYLAB synchrotron radiation Laboratory at DESY, Hamburg, and the University of Mainz, under project leader Heinrich Stuhrmann.

Using neutron beams at the German GKSS research centre at Geesthacht, the results shed new light on the behaviour of these giant molecules and provide another important example of particle physics techniques paying dividends in another field of research.

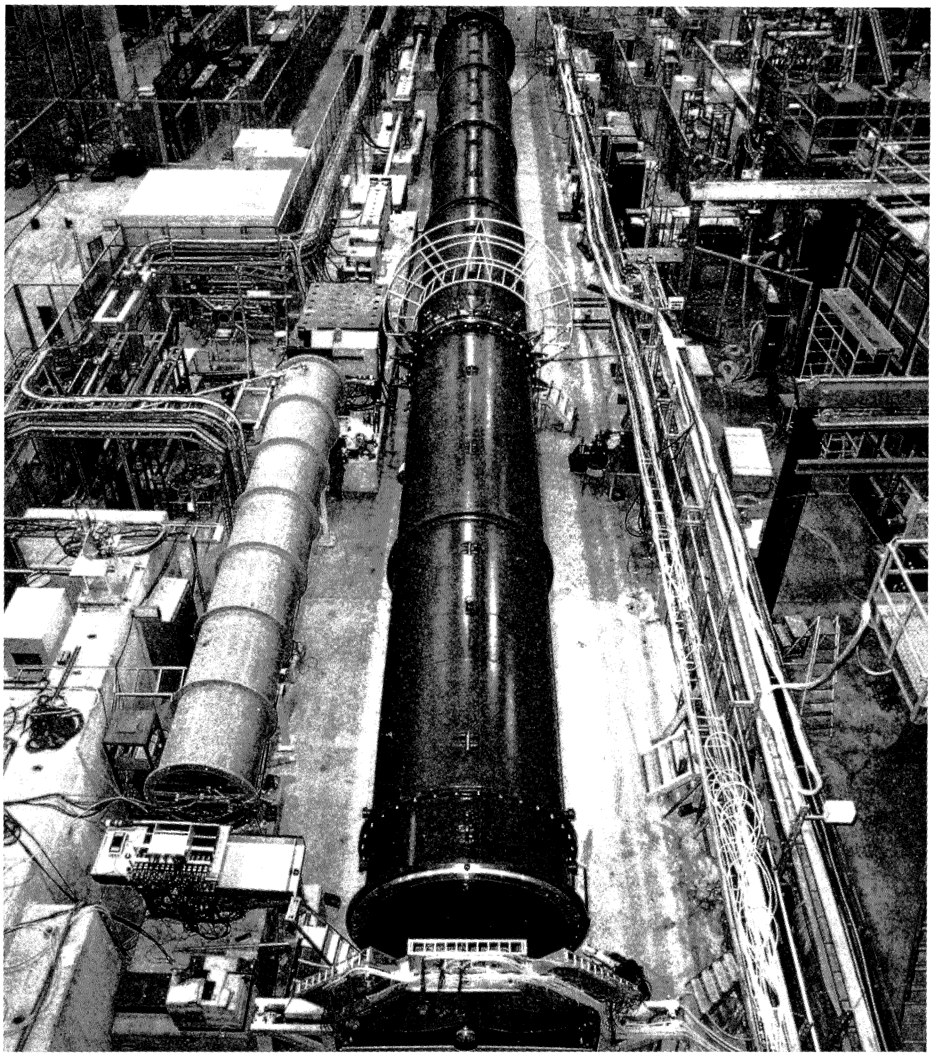
Applications can be foreseen in many areas of molecular biology and in the study of polymers, glasses, metals, alloys, etc.



At the heart of a new technique to study the structure of large molecules by lining up the spins of the component nucleons. The specimen is held in the small cryostat between the poles of the magnet. Right is the neutron beam used as a probe and left is the tube which picks up the scattered particles.

The 100 metre vacuum chamber of the CERN/Dortmund/Edinburgh/Orsay/Pisa /Siegen group studying neutral kaon decays. The neutral kaon might still have more surprises in store.

(Photo CERN 288.6.84)



Force apart?

Electromagnetism, the weak nuclear force and the strong nuclear force, plus gravity, together cover all the conventionally known forces at work in Nature. Even after the triumph of the electroweak unification, which effectively reduced the number of fundamental forces from four to three, the dream of many physicists remains to unify them into one single picture.

Since the time of Faraday in the middle of the 19th century, this goal has been elusive. While excitement runs high that 'superstrings' (see June 1985 issue, page 185) could finally do the trick, there could yet be major obstacles to be overcome. Just as Faraday and Einstein's efforts at unification were handicapped by an incomplete knowledge of the forces at work, the present picture might still be incomplete.

This has recently been suggested by a US (Brookhaven/Purdue/ Seattle) group, citing several clues. Firstly measurements of the strength of the gravity by geophysical (satellite, geological, marine, etc.) experiments give values consistently higher than those measured in the laboratory.

Secondly, the force of gravity should depend conventionally only on the mass and not the nature of a material, as Galileo demonstrated with the help of the leaning tower of Pisa. The classic (1922) studies by Eötvös using a precision torsion balance checked the uniformity of the gravitational pull on different materials to within a few parts per thousand million. However the idea now being put forward says that these tiny variations are in themselves significant.

One way to allow for the apparent variation of gravity is to introduce an additional force dependent on hypercharge (the sum of baryon quantum number and the strangeness quantum number), a quantity which plays a role in the symmetry of strong interactions. The force would be brought about by the exchange of 'hyperphotons'.

The US group has pointed to hints of subtle variations in the neutral kaon parameters measured in experiments running under different conditions and which could be due to such a force.

Several times in the short history of particle physics the neutral kaons have been the scene of dramatic new discoveries which led to rapid reappraisals of current thinking. In 1956 it was realized that decays of the neutral kaons violated left-right symmetry and the hitherto sacred invariance of parity was overthrown. In 1964, the replacement symmetry of charge conjugation and parity (particle/antiparticle and left/right) too toppled.

Could it be that the neutral kaons hold the key to still more mysteries?

Around the Laboratories

Construction work gets underway for the experimental area to house the DO detector for Fermilab's Tevatron proton-antiproton Collider.

(Photo Fermilab)

FERMILAB
How do you DO?

Late last year, the big CDF experiment at Fermilab's new Tevatron proton-antiproton Collider recorded the first 800 GeV protons and antiprotons smashing into each other (see December 1985 issue, page 419). Physicists now look forward eagerly to the first data-taking run later this year.

Waiting in the wings at Fermilab is another Tevatron Collider experiment, named DO from its position in the 2 km diameter ring, which hopes to get its first taste of physics in 1988.

The DO Detector has passed into its construction phase. Designed following initial experience from the CERN Collider experiments, DO is the first second-generation hadron collider detector. Its primary aim is the precision study of high mass, large transverse momentum phenomena with particular emphasis on measurements of jets (clusters of produced particles), leptons (electrons and muons) and the 'missing' transverse momentum indicative of penetrating particles.

The detector design stresses high quality measurement of energy deposition (calorimetry) and fine segmentation. Electron and muon measurements are made over nearly the full solid angle with good identification. The detector has no central magnetic field in order to keep it compact and to optimize the depths of calorimeter and muon absorber. Transition radiation detectors embedded in the inner tracking volume help to discriminate between electrons and hadrons.

The central feature is the excellent calorimeter system. Extensive tests and studies over the past few months have resulted in detailed decisions on the calorimeter design. After tests of uranium-liquid argon prototype calorimeters in electron, pion and muon beams of 10 to 150 GeV the collaboration has confirmed its choice of uranium as the primary absorber material.

Electrons and hadrons lose energy in different ways as they pass through material. Hadrons can produce low energy effects which go undetected, spoiling the energy measurement. To remedy this and bring the electron and hadron energy measurements back into line, the idea was put forward at CERN to use uranium absorber. This way the low energy particles would induce fission, compensating for energy lost in the calorimeter.

The test calorimeters were built using parallel plates of uranium and copper absorbers in various configurations.

The major finding of the DO tests was the near equality of response to electrons (2 or 4 mm plates) and hadrons (4 or 8 mm plates) over the full energy range and independent of the thickness of the uranium plates. This is important for minimizing the fluctuation in the observed energy of jets, whose particle content may fluctuate.

The total depth required for the calorimeter was also studied. Two independent studies lead to the conclusion that the DO calorimeter should have 7.5 absorption lengths at right angles to the beams, increasing to 9 at small angles. This is a confirmation that the absorption length for pions is about 15 per cent longer than for nucleons. Even after traversing 7.5 absorption lengths, a pion can still escape. Such occurrences need to be minimized so that the resulting undetected energy does not contribute significantly to the missing transverse momentum due to neutrinos or rare penetrating particles and simulate new physics.

The choice of high density uranium for DO also leads to space savings through increased stopping power. (The absorption lengths for iron, copper, lead and uranium are 16.8, 15.1, 17.1 and 10.5 cm respectively.)

The DO design now contains a central quasi-cylindrical device and two endcaps covering angles down to about 1.5° to the beams. Three separate cryostats for liquid argon containment nest together and contain the modules of absorber plates. Electromagnetic (3 mm plates) and the first part of the hadronic modules (6 mm plates) use depleted uranium; the latter (leakage) sections have thicker copper plates.

The designs of most other component systems have also firmed up following extensive tests. Beam tests at CERN by a Saclay group have shown that transition radiation detectors using lithium foils offer no appreciable advantage for the DO geometry. Good pion-electron differentiation was obtained.

Tests of muon proportional drift tubes have demonstrated excellent precision and accuracy. An important finding was that 8 bit, 100 MHz waveform digitization is sufficient to achieve 200 micron accuracy and efficient track resolution at 2 mm separation without separate time digitizations.

Construction of the transition radiation detector, muon proportional drift tubes and the tracking chamber have all begun.

Prototype DO electronics has now largely been tested and noise and stability were as expected and within specification. A small-scale test of the high level trigger and data acquisition system, based upon parallel MicroVAX-2 processor boards, was also successful. This system is now being fabricated for use in further tests of prototypes and assembly lines of detector elements.

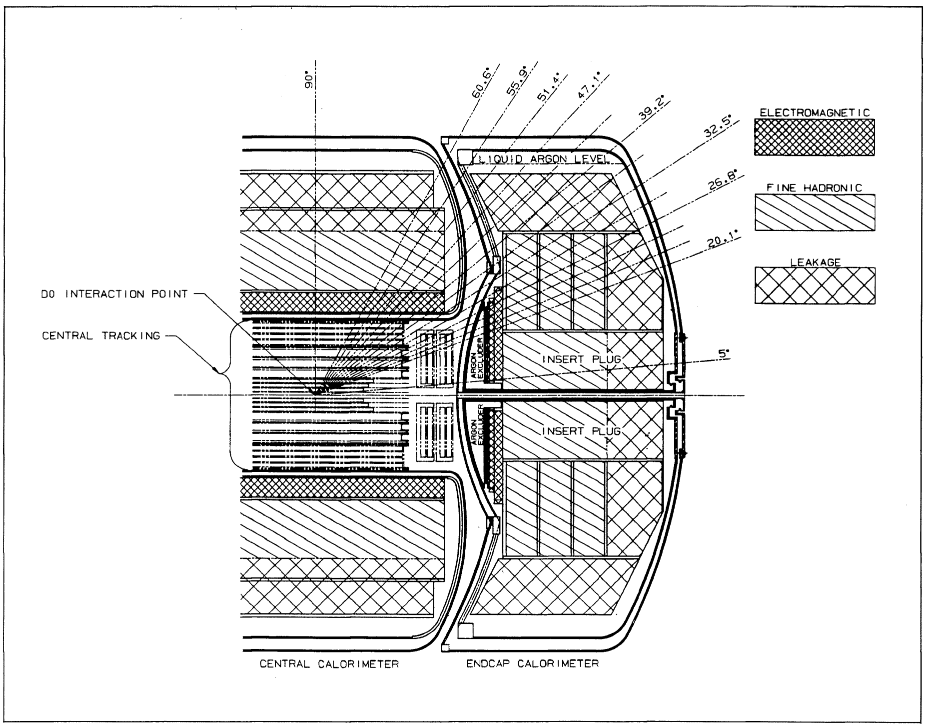
The overall collaboration has grown to include about 115 physicists from 18 institutions (Berkeley, Brookhaven, Brown, Columbia, Fermilab, Florida State, Indiana, Maryland, Michigan State, New York, Northwestern, Pennsylvania, Rio de Janeiro, Rochester, Saclay, Stony Brook, Virginia Polytechnic and Yale). A support team from Fermilab's Accelerator Division will provide technical and coordinating assistance.

An especially important milestone was the start of construction for the DO Experimental Area. Since the detector will sit in the DO long straight section needed for parts of the extraction system during fixed target running, it must roll in and out between the collision hall and the assembly area.

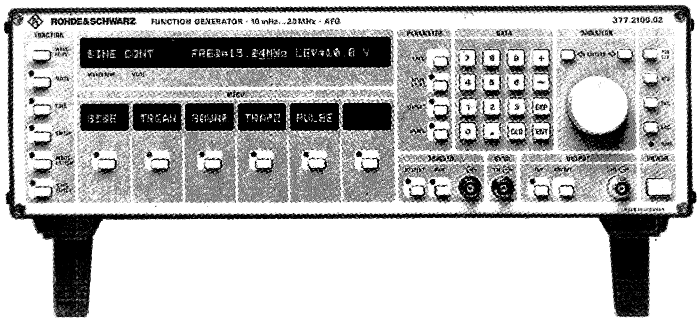
By late summer assembly of major detector components and support systems should begin.

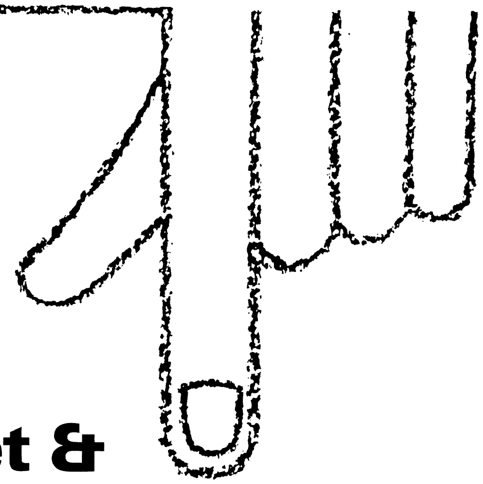
With the CDF team scheduled to take initial data later this year, the DO physicists are keen to follow suit and bring their detector on-line as quickly as possible.

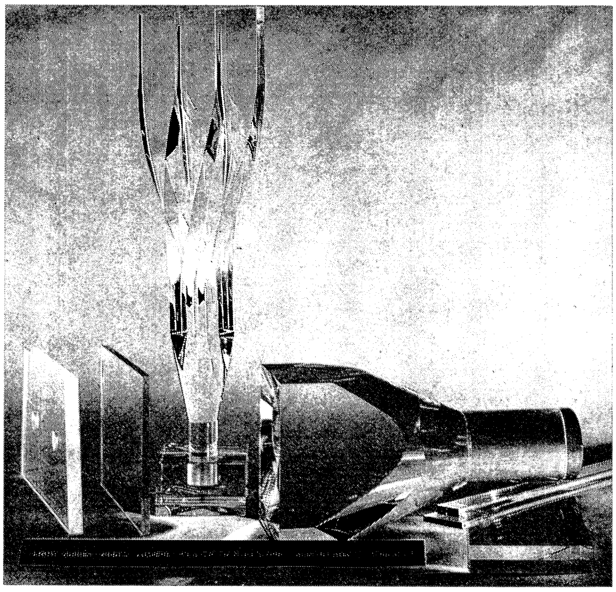
Much of the instrumentation should be complete by mid-1988 with a first checkout run in the fall. Completion of the calorimeter and full physics capability is expected by the middle of the following year.



Cross-section of half the DO detector. The central barrel calorimeter (left) encloses the tracking system and the transition radiation detectors. The endcap (right) covers down to 1.5° to the colliding beams. Modules containing uranium plates pick up energy in the first section (5 absorption lengths) of the calorimeter, while 'leakage' sections using thicker copper plates extend the coverage to between 7.5 and 9 radiation lengths, ensuring that a maximum of hadronic energy is intercepted.

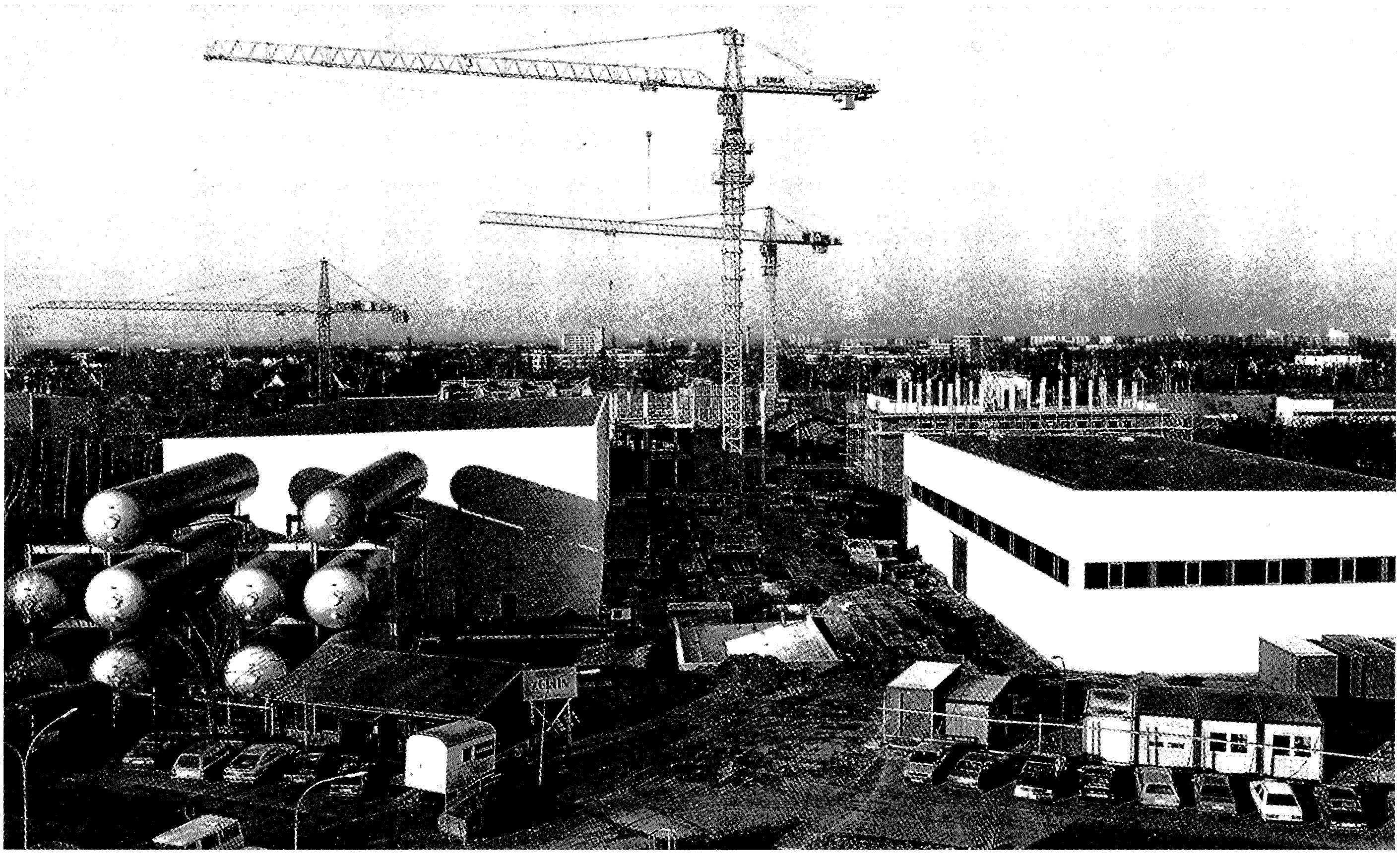






On 6 March, the German DESY Laboratory at Hamburg celebrated the completion of the Cryogenics Hall (left) and the Measurement Hall (right) for the new HERA electron-proton collider now under construction. The celebration also coincided with the completion of the first quadrant of the 6.3 kilometre HERA tunnel.

(Photo DESY)



DESY International participation

The HERA electron-proton collider now under construction at the German DESY Laboratory in Hamburg has a distinct international flavour with some 15 per cent of the investment coming from outside Germany.

Last year an agreement was signed between the Italian National Institute for Nuclear Physics (INFN) and DESY under which INFN will contribute to HERA construction, supplying half the superconducting magnets for the 6.3 kilometre proton ring. INFN has placed the necessary contracts with Italian firms Ansaldo, La Metalli Industriali and Zanon.

Italian physicists are also the major foreign contingent in the teams for experiments being proposed for HERA.

From Canada, the TRIUMF Laboratory in Vancouver is supplying beam transport elements while the Chalk River Laboratory will provide high frequency equipment for the PETRA ring, now an electron-positron collider but to be transformed into the HERA injector.

Warsaw and Cracow in Poland are supplying components for the HERA electron ring vacuum system, and the Swiss SIN Laboratory is developing the liquid helium distribution line.

From the Netherlands, NIKHEF, Amsterdam, is providing superconducting correction coils to be mounted in the proton ring, while the French Saclay Laboratory is furnishing superconducting quadrupoles.

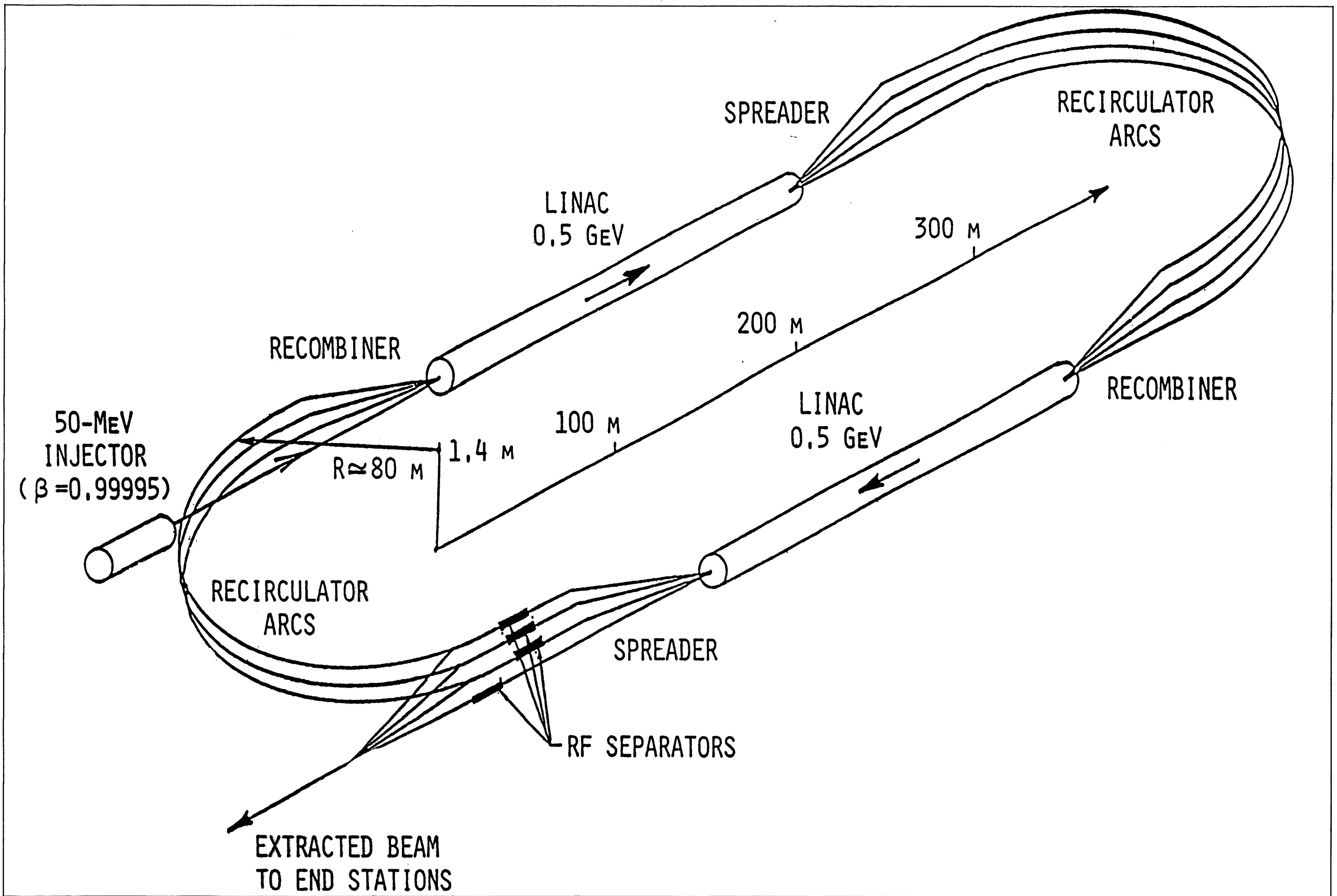
Under an agreement signed last year, the US Brookhaven Laboratory will assist in HERA cryogenics and in the quality control of the superconducting magnets.

Britain will assist with the radiofrequency for HERA itself and for the proton injector, while Oxford will assist with the injector linac.

The Weizmann Institute, Israel, is developing current carriers for the superconducting magnets.

Chinese physicists and engineers also help make up the HERA team. International participation could be even higher by the time the first colliding beams are achieved, scheduled for the beginning of 1990.

Schematic design of the Continuous Electron Beam Accelerator Facility, CEBAF, proposed for construction in the US for nuclear physics research. A new design involves recirculation through two 0.5 GeV sections of superconducting linear accelerator.



US nuclear physics: Some like it cold

A new US nuclear physics research tool will soon make its appearance. It is the Continuous Electron Beam Accelerator Facility, CEBAF, proposed for construction by the Southern Universities Research Association, SURA, at Newport News in Virginia. The latest plans aim for a superconducting linear accelerator which could be the first machine to use superconducting radiofrequency accelerating cavities on a large scale.

The potential of high energy electron beams with a high duty cycle to provide some unique insights into nuclear properties has been recognized for many years. Such a machine was given top priority in a 'Long range plan' for US nuclear physics prepared in 1983. Electrons of a few GeV are an ideal probe of the quark nature of the nucleus. They can penetrate deep into nuclei and their interactions with the nucleus should be relatively clean.

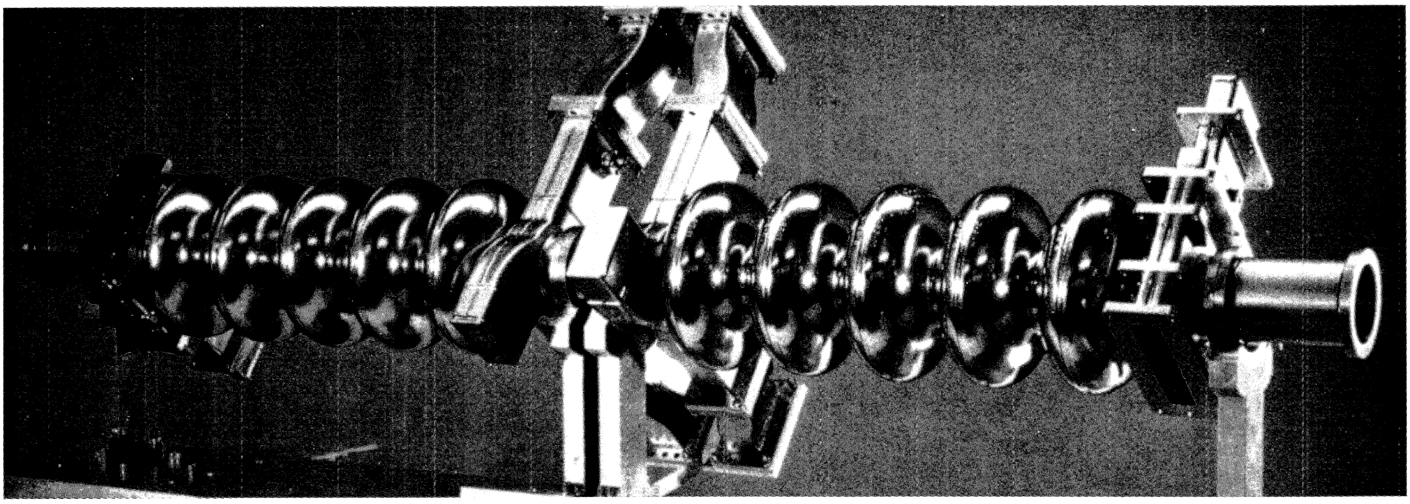
At the University of Virginia, James McCarthy was amongst the first to push for an electron machine and he initiated the creation of SURA in 1980 as an overseeing organization. The first proposal from SURA went to the US Department of Energy (DOE) at the end of that year.

This proposal, which of course had subsequent refinements, consisted of a 2 GeV electron linac with a recirculating loop to reach a peak energy of 4 GeV. Pulses from the linac were fed to a pulse stretcher ring from which continuous beam could be drawn. The design figure for the average current was 200 microamps. At this stage the proposal was known as NEAL (National Electron Accelerator Laboratory) but the name evolved to CEBAF when the proposal retained the attention of DOE from 1983.

Last Spring Herman Grunder, who had been prominent in the heavy ion accelerator work at Ber-

Two linked superconducting accelerating cavities, each of five cells, developed in a Cornell/CEBAF collaboration. It is the successful operation of a series of prototypes of this type, to performance levels beyond the linac specifications, that has given confidence in the superconducting option for CEBAF.

(Photo CEBAF)



keley, became Director of CEBAF with a first mission to re-examine the proposal to see whether appropriate technological developments could be incorporated into the scheme. In particular, superconducting radiofrequency technology had moved ahead rapidly and could pay important dividends.

The advantages of superconducting cavities over conventional copper cavities have been evident for a long time. The very small heating losses in superconducting cavities allow operation in a continuous rather than a pulsed mode. The accelerating gradients are higher and the beam quality can be greatly improved. The operating costs are lower, even allowing for the cryogenic system to maintain superconducting temperatures.

However, realizing these advantages has not been easy. There was pioneering work in centres such as Stanford (University) and Cornell in the US, and in DESY, Karlsruhe and Wuppertal in Germany. Addition impetus came with the advent of CERN'S LEP electron-positron collider, where energies much beyond the initial phase of 50 GeV per beam require superconducting cavities. European achievements have considerably boosted world confidence in this technology, leading to decisions to incorporate cryogenic cavities in projects at the Darmstadt and DESY Laboratories in Germany and at KEK in Japan, as well as at CERN. The CEBAF decision to go superconducting was also influenced by the progress in Europe.

The CEBAF design has been revamped to incorporate a superconducting linear accelerator. The linac will be in two sections, each capable of giving 0.5 GeV to the electrons. To achieve the design energy of 4 GeV the beam has to be recirculated four times through the linac and recirculating arcs are therefore needed at each end of the linac sections with different strength magnets to bend the different energy beams back into the next section. Beam spreaders at the linac exits split the beams vertically so that they enter the appropriate arc and a recombiner at the end of the arcs pulls the beams back onto the linac axis.

With superconducting linacs there is no longer any need for a pulse stretcher ring to provide continuous beam. Another useful feature is that at any one time electrons of different energies are moving through the linac and at the exit of the second section they can be drawn off to the experimental hall at energies of 1, 2, 3 or 4 GeV (any three energies being available simultaneously).

In the two sections there will be a total of 50 cryostats containing 400 superconducting cavities, each 0.5 m long, operating at 1500 MHz. The cavity design has been developed at Cornell where prototypes have all exceeded the design specification of an accelerating gradient of 5 MeV per metre with a quality factor Q of 3×10^9. Contacts with American and European industry for the manufacture of superconducting cavities are well advanced and the first cavities from industry are scheduled for test in the very near future.

It is hoped that construction of CEBAF will begin in Fiscal Year 1987 to produce first beams five years later. The cost estimate is $ 236 million. The DOE has encouraged the superconducting version and it is clear that, in addition to responding to the demands of the nuclear physics community for high energy continuous electron beams, the new design will provide an exciting technological challenge for the accelerator physicists.

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At the Kernfysisch Versneller Instituut (KVI) in Groningen (Netherlands), H. de Waard, chairman of the Dutch FOM foundation for fundamental research on matter, signs an agreement between FOM and the French Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) to build a superconducting cyclotron at Orsay for eventual installation at KVI. Looking on in the foreground is IN2P3 director P. Lehmann.

(Photo Nieuwsblad van het Noorden, Groningen)

GRONINGEN/ORSAY Superconducting collaboration

Last December a contract between the French Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) and the Dutch FOM foundation for fundamental research on matter was signed in a ceremony at the Kernfysisch Versneller Instituut (KVI) in Groningen in the presence of the representative of the Dutch Minister of Science and Education and of the French Ambassador to the Netherlands.

The agreement covers a collaboration between the Institut de Physique Nucléaire (IPN) in Orsay and KVI in Groningen in the design and construction of a superconducting cyclotron. While the capital funds required for the new machine will be furnished by the Dutch Government, the major part of the manpower needed to build it will be supplied by the French partner. The cyclotron will be built and tested in Orsay and subsequently (1991) installed at KVI replacing the present k = 160 MeV cyclotron. The accelerator will be jointly exploited with approximately 20 per cent of the beam time allocated to the French partner.

Called AGOR (Accelerateur Groningen ORsay), the new machine, based on an Orsay design, is a k = 600 MeV compact variable energy fixed frequency cyclotron with superconducting coils that will be capable of accelerating both light and heavy ions: protons to 200 MeV, deuterons to 190 MeV, and totally stripped heavy ions to 95 MeV/u. Moreover, it will be possible also to accelerate very heavy nuclei, and beams of polarized protons and deuterons will be available with an external source.

The scientific interest in AGOR is in the very broad range of particles it can accelerate and the wide energy range it covers. The international collaboration, at present restricted to France and the Netherlands, offers exciting new prospects.

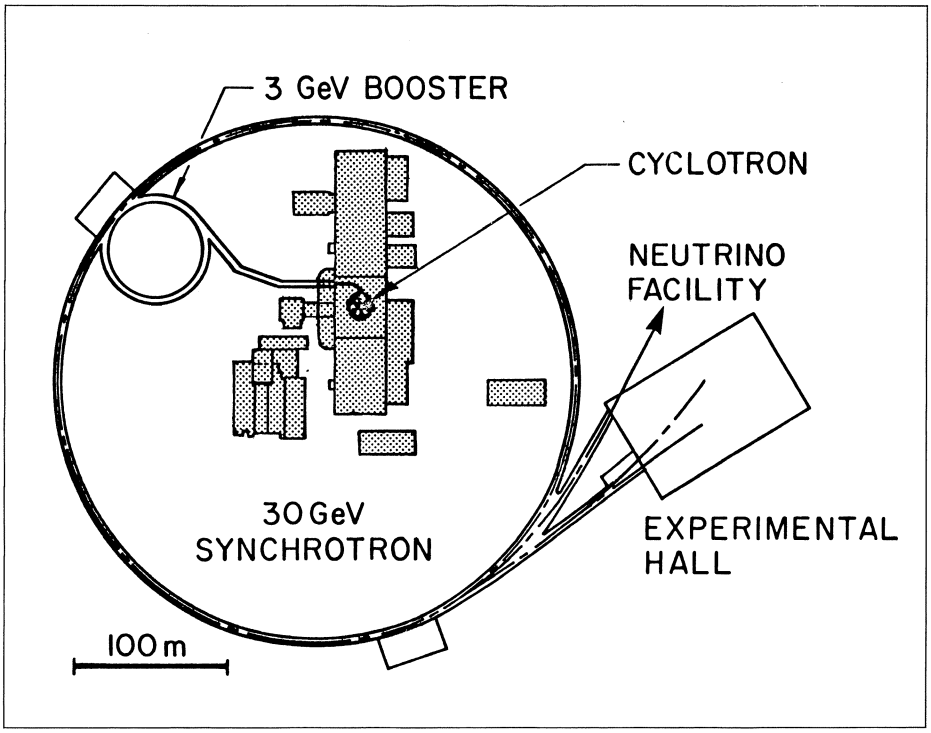
TRIUMF KAON factory proposal

The TRIUMF Laboratory at Vancouver in Canada has been operating a 500 MeV negative ion cyclotron since 1974 mainly for nuclear physics experiments. Together with the LAMPF proton linac at Los Alamos and the SIN cyclotron in Zurich, it is one of the world's 'meson factories', producing, in particular, exceptionally intense beams of pions.

In response to today's physics challenges, the TRIUMF staff (like those at LAMPF and SIN) have been studying a major improvement of their research facilities. All three centres are looking towards much more intense beams of hadrons. The Canadian proposal is for a KAON Factory, 'KAON' being an acronym for Kaon, Antiproton, Other hadron and Neutrino.

For nuclear physics, the aim is to have a variety of beams with energies ranging from several hundred MeV to a few GeV (the ideal range for studying most nuclear phenomena). Thus the nucleus could be studied with a variety of probes - pions, nucleons, kaons and hyperons. Despite the modest energies, the bigger part of the research programme at the KAON Factory could be for particle physics as the very high intensities would allow precision measurements. Thus the KAON Factory could have much to say in neutrino physics, in particle spectroscopy and especially concerning particle symmetry principles via the study of rare decays.

The accelerator scheme aims to provide a 100 microamp proton beam (6 x 10^{14} protons per sec-



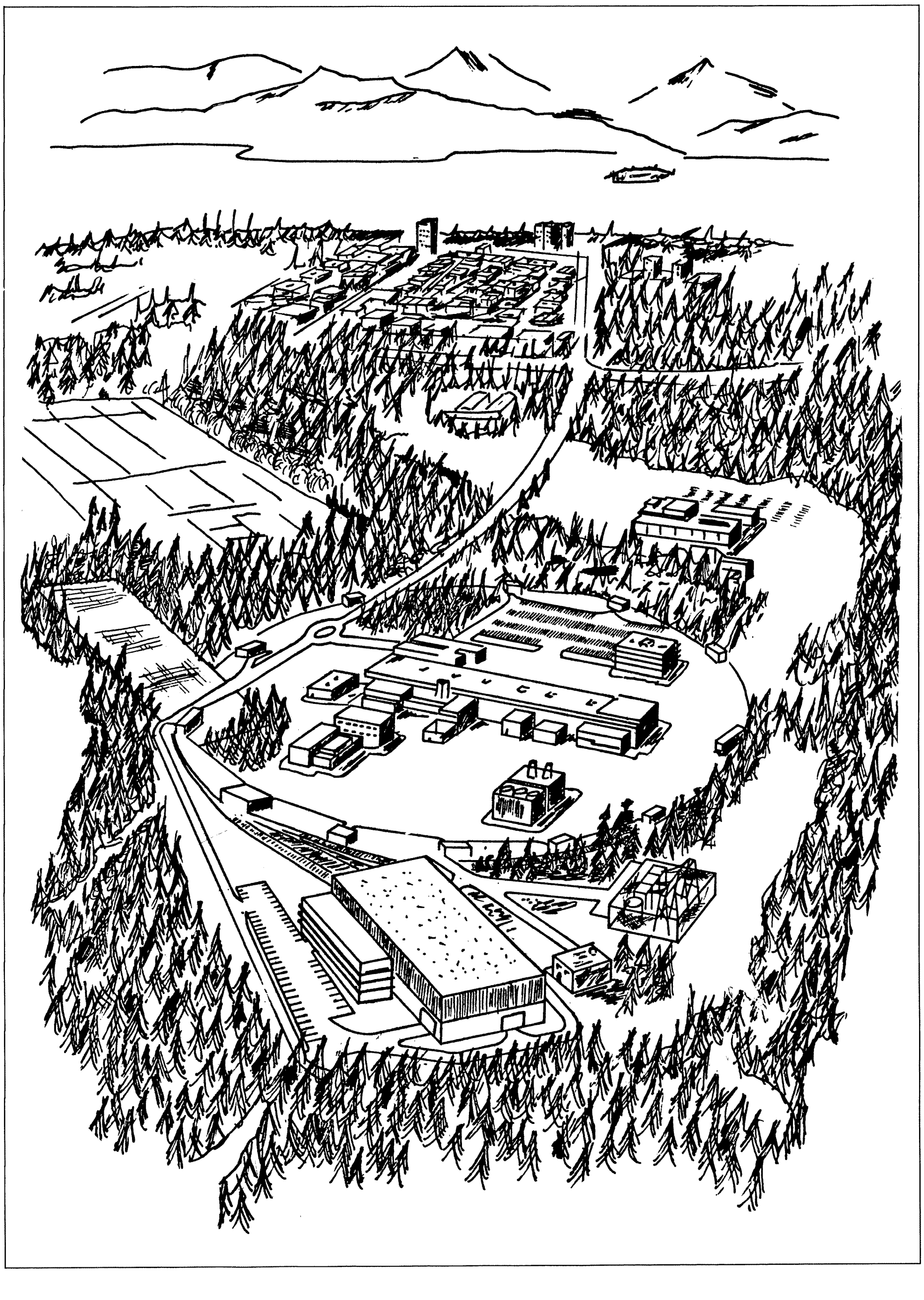
Layout of the proposed 'KAON' Factory at the Canadian TRIUMF Laboratory. The existing cyclotron would feed a 3 GeV fast cycling booster which in turn would feed the high intensity 30 GeV proton synchrotron built in an underground tunnel. The major visible sign of the new project would be the large experimental hall to receive the intense hadron beams.

ond) at 30 GeV; for comparison, the presently operating proton synchrotrons around that energy have intensities about fifty times lower. The scheme starts by using the existing cyclotron as a negative hydrogen ion injector into an accumulator ring where the ions are stripped to protons. Accumulation over 20 ms precedes transfer to a fast cycling (50 Hz) booster synchrotron, located in the same tunnel as the accumulator with a ring radius of 35 m, which accelerates the particles to 3 GeV.

The protons then pass to a collector ring which receives five pulses from the booster before transferring the beam to a 30 GeV synchrotron (10 Hz). Finally an extender ring receives the 30 GeV particles for slow resonant extraction. Collector, synchrotron and extender rings are in the same underground tunnel with a ring radius of 170 m. Obviously with such intense beams, many aspects of machine operation and component design are influenced by the need to keep beam losses down so as to have tolerable radiation levels.

A large experimental hall, 120 m x 75 m, would receive both slow and fast extracted beams. In addition there would be a conventional neutrino beam.

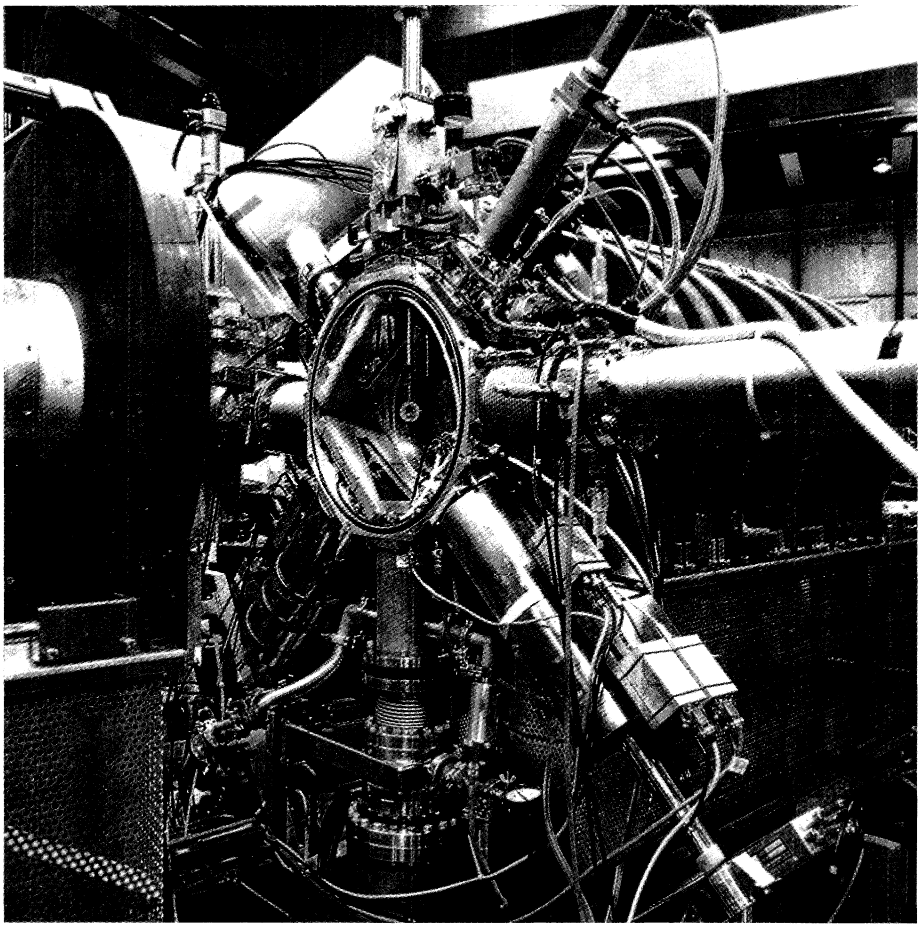
The cost estimates (1985 prices) are 260 million Canadian dollars for machine components and services and 80 million for construction. Experimental area facilities for some 66 million would be covered by the present level of contributions from the National



Sketch of the TRIUMF site as it would appear after construction of the proposed KAON factory. The large experimental hall is in the foreground. The undergroud synchrotron tunnel runs around the existing laboratory buildings.

The EPOS spectrometer at the German GSI Laboratory at Darmstadt has seen unexplained electron-positron signals in heavy nucleus collisions using the UNILAC linear accelerator.

(Photo GSI)



Research Council of Canada. The construction schedule is planned to cover six years for the accelerator systems plus an additional year for the experimental facilities which can be built up while the machine is being commissioned. The proposal has now been put before the Canadian Government.

DARMSTADT What is it?

For several years, experiments studying heavy nucleus collisions using the UNILAC machine at Darmstadt (GSI) have been seeing unexplained narrow peaks in the spectra of the emitted positrons.

The intensity and sharpness of these peaks are too high to be accounted for by conventional nuclear processes. The position of the positron peak moreover changed little with the type of nuclear beam or target (uranium, thorium, etc). This points to these peaks having a common origin, such as a neutral particle decaying into an electron-positron pair.

To check this out, experimenters embarked on a search for electrons and positrons diverging from a common point of formation, with the EPOS spectrometer used in the positron studies modified to pick up coincident electrons.

Electron-positron coincidence events show an electron peak similar to the positron signal, at an energy of 375 keV and with a width of 75 keV.

The effect is difficult to explain through internal pair conversion of gamma rays. Detailed analysis (correlated cancellation of Doppler shifts) suggests that the particles emerge back-to-back from a common slowly moving origin in the superheavy nuclear system produced in the collision.

Joint US-CERN Accelerator School

The 2nd Joint US-CERN School on Particle Accelerators is arranged for 23-29 October in South Padre Island, Texas, with the topic 'Frontiers of Particle Beams'. The course should be of interest to both accelerator physics beginners and experienced workers. Further information from either the US Particle Accelerator School, c/o Marliyn Paul, Fermilab MS 125, PO Box 500, Batavia, Illinois 60510, USA, or Suzanne von Wartburg, CERN Accelerator School, LEP Division, 1211 Geneva 23, Switzerland.

The first Joint US-CERN Accelerator School was held last year in Sardinia on the topic of Nonlinear Dynamics (see May 1985 issue, page 140). These regular joint schools supplement the separate programmes organized by the CERN and US Schools.

People and things

Meetings

A Summer Study to be held in Snowmass, Colorado, from 23 June to 11 July will allow the US particle physics community to critically evaluate all aspects of the proposed US Superconducting Super Collider (SSC) in the light of conceptual design, progress in accelerator technology, new developments in collider physics, and innovations in instrumentation. Further information from Joanne Day, Argonne National Laboratory, Building 362, Argonne, IL 60439, USA.

Organized jointly by the European Committee for Future Accelerators (ECFA) and the Rheinisch-Westfälische Technische Hochschule in Aachen, a 'LEP 200' Workshop is being arranged from 29 September to 1 October to work out the physics objectives and experimental requirements for running LEP at around 100 GeV per beam. Further information from Workshop LEP 200, III. Physikalisches Institut RWTH Aachen, Physikzentrum, Sommerfeldstrasse, D-5100 Aachen, West Germany.

A four-day practical course on microelectronics is being hosted by CERN and the International School of Geneva from 18-21

CERN Review Group

In the context of continued limitations in the amount of funding available for non-defence research in the UK, last year the 'Kendrew Committee' published its conclusions on Britain's future involvement in CERN.

After generally praising CERN's work and achievements, the report ended abruptly with the view that Britain's continued membership of CERN after 1989 was only possible at significantly lower cost (see November 1985 issue, page 375).

The UK government felt compelled to act, however under the CERN Convention, which has the status of a treaty, the fourteen Member States are not free to fix their own contributions. Further action can come only from the governing body of CERN, its Council. Thus after contacting other Member States the UK asked for a special Council session to be convened in February.

The UK proposed that a Review Group, composed of about half a dozen eminent people, should be set up to look at the way CERN runs and into the possible consequences of applying a range of alternative measures. This Group would complete its work this year and report back to CERN Council.

In the traditional CERN spirit of conciliation between Member States, a consensus resolution was unanimously adopted by the Council. Many delegates welcomed the setting up of such a review, and stressed that its aim should be to ensure the continued vitality of the Organization. However they warned against the dangers of trying to achieve 'unrealistic' savings which would prejudice CERN's future.

UK Under-Secretary for Education and Science George Walden (right) confers with Bill Mitchell, Chairman of the UK Science and Engineering Research Council, at the CERN Council meeting where the UK's resolution to set up a CERN Review Group was adopted.

(Photo CERN 311.2. 86)

June. It is aimed at teachers wishing to update their knowledge of this rapidly advancing field. Further details from P. J. Hayman, Department of Physics, University of Liverpool, Oxford Street, PO Box 147, Liverpool L69 3BX, UK.

▲ *Superconducting correction magnets for the HERA electron-proton collider at DESY will be built by Dutch industry. At the signing of the official agreement, Director of the Research Organization Division of the Dutch Ministry of Education and Science C.H. van Alderwegen (right) shakes hands with DESY Director Volker Soergel. Between them is General Director of Industry and Regional Policy of the Dutch Ministry of Economic Affairs H. Leliveld, while Bjorn Wiik, project leader of the HERA superconducting proton ring, looks on.*

(Photo DESY)

1966 — first steps towards building the Intersecting Storage Rings. ▼

Twenty years ago

Bulldozers moved in to start excavations for the Intersecting Storage Rings at CERN. At the Proton Synchrotron the new idea of slow cycling synchrotrons in injection systems was under study as part of the machine improvement programme. Links between CERN and Serpukhov were being strengthened with a view to obtain access to the Soviet 76 GeV proton synchrotron, then at an advanced stage of construction, for European experimentalists.

In the US the Atomic Energy Commission was pondering a site report from the National Academy of Sciences for what was then known as the 200 GeV accelerator. At the same time, it had asked the Berkeley design team to go back to the drawing board to see if it could chip costs down from the estimate of $ 348 million. The AEC did liberate money for the start of design work on a 'meson factory' at Los Alamos where an 800 MeV, 1 mA proton linac was already mooted.

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IUCF presently consists of a complex of two alternate 600-keV ion source terminals followed in sequence by two separated-sector cyclotrons which accelerate light ions to a maximum energy of 200 q^2/A MeV. In addition, the laboratory is now engaged in a major facility upgrade consisting of the construction of a storage ring which will have the capability both of synchrotron acceleration and electron cooling of the stored beams. There will also be an active program in design and construction of research instrumentation for research with the existing accelerators and with the cooled beams, as well as in planning for future accelerator upgrades.

This is a continuing full-time position funded by the office of the Dean of Research and Graduate Development, Indiana University. The salary will be competitive and is dependent upon training and experience. For a truly exceptional candidate, the possibility of an academic faculty appointment may also be explored.

Send resume and names of three references by June 30, 1986 to:

P. P. Singh, Co-Director
Indiana University Cyclotron Facility
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- a 800 meter circumference storage ring with a large number of straight sections to accommodate wiggler and undulator sources,
- a fast cycling synchrotron used as an injector for the storage ring.

The team that will be in charge of final design and construction of the ESRF is being appointed. Several employment opportunities at various levels are available immediately.

Successful candidates must have adequate knowledge of particle accelerator physics in general, relevant experience in hardware design and technology associated with the components of this type of machines.

Initial salary will depend upon qualifications.

Curriculum vitae, list of publications, resume of professional experience, brief description of field of interest, date of availability and names of three referees should be forwarded, before May 15, to:

The Director General
of European Synchrotron
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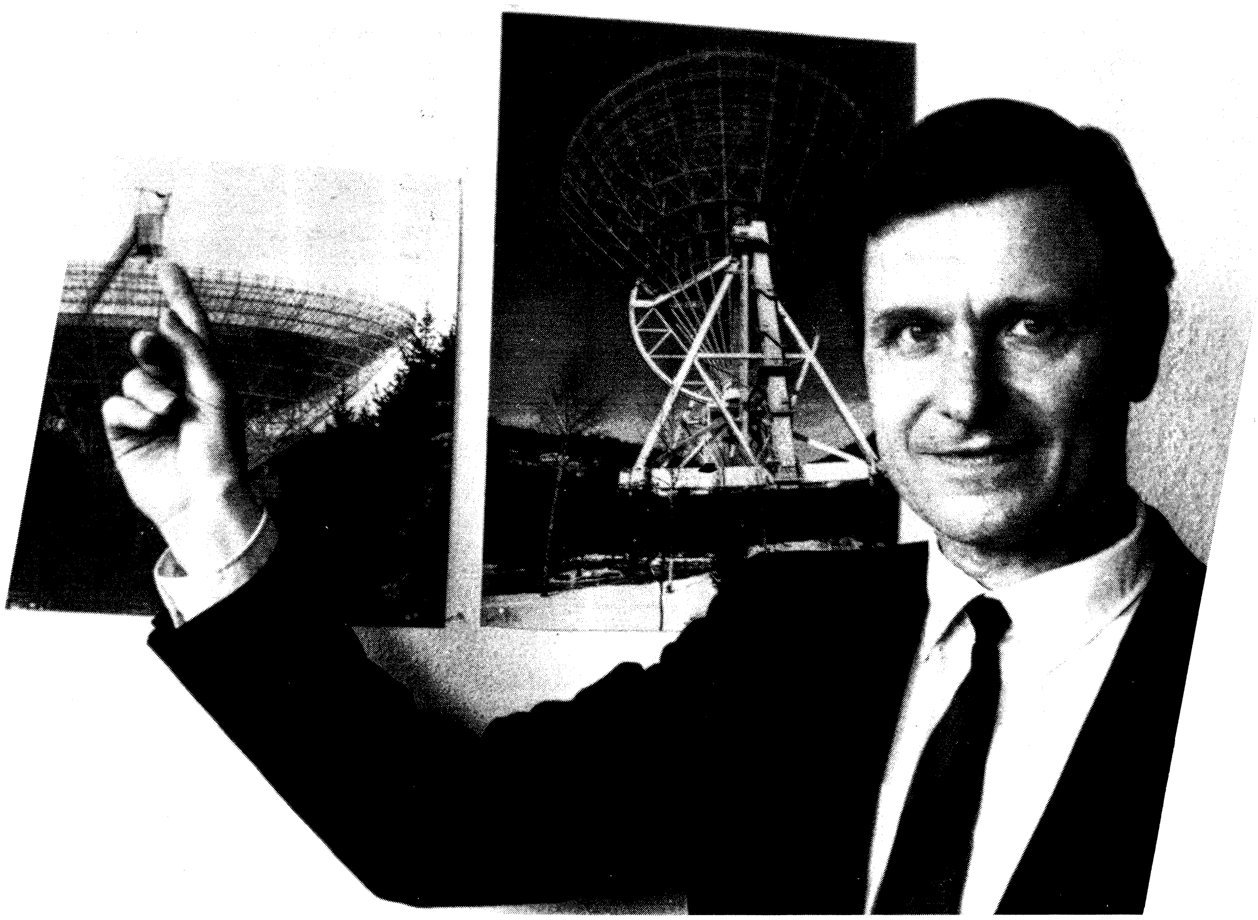

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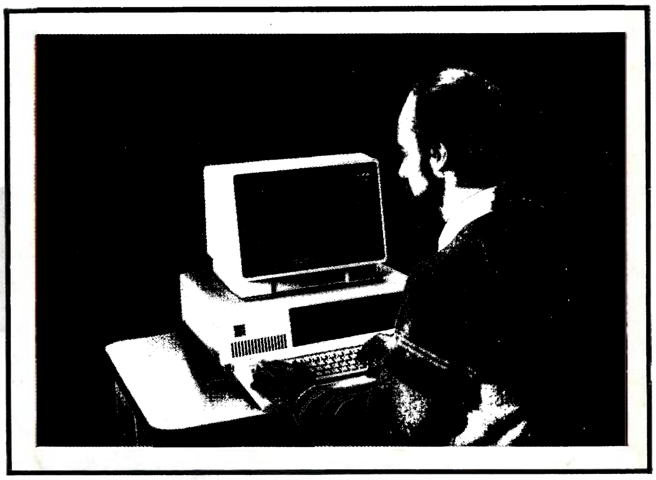

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