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Editors: Brian Southworth
Henri-Luc Felder
Gordon Fraser

Advertisements: Micheline Falciola

Laboratory correspondents:
Argonne National Laboratory, USA
R. Arnold
Brookhaven National Laboratory, USA
Ph. Schewe
Cornell University, USA
N. Mistry
Daresbury Laboratory, UK
V. Suller
DESY Laboratory, Fed. Rep. of Germany
P. Waloschek
Fermi National Accelerator Laboratory, USA
R.A. Carrigan
KfK Karlsruhe, Fed. Rep. of Germany
M. Kuntze
GSI Darmstadt, Fed. Rep. of Germany
H. Prange
INFN, Italy
M. Gigliarelli Fiumi
Institute of High Energy Physics, Peking, China
Tu Tung-sheng
JINR Dubna, USSR
V. Sandukovsky
KEK National Laboratory, Japan
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Lawrence Berkeley Laboratory, USA
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Los Alamos Scientific Laboratory, USA
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A. Zylberstejn
SIN Villigen, Switzerland
G.H. Eaton
Stanford Linear Accelerator Center, USA
L. Keller
TRIUMF Laboratory, Canada
M.K. Craddock

Copies are available on request from:
Federal Republic of Germany
Frau G.V. Schlenther
DESY, Notkestr. 85, 2000 Hamburg 52
Italy —
INFN, Casella Postale 56,
00044 Frascati,
Roma
United Kingdom —
Elizabeth Marsh
Rutherford Laboratory, Chilton, Didcot
Oxfordshire OX11 0QX
USA/Canada —
Margaret Pearson
Fermilab, PO Box 500, Batavia
Illinois 60510
General distribution —
Monika Wilson
CERN 1211 Geneva 23, Switzerland

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CERN, 1211 Geneva 23, Switzerland
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(CERN COURIER only Tel. (022) 83 41 03)
USA: Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510
Tel. (312) 840 3000, Telex 910 230 3233

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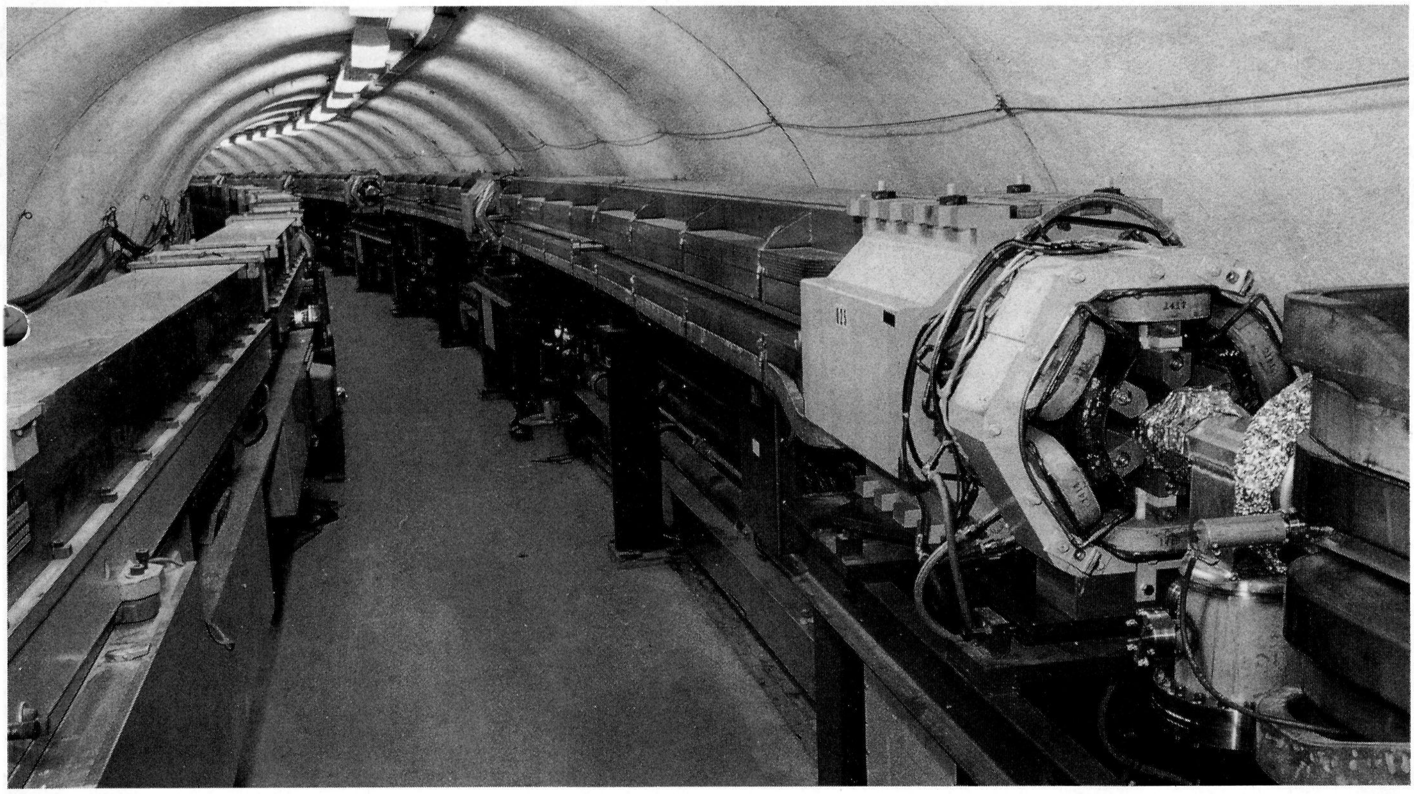
Cover photograph: Winter scene at the Wilson Synchrotron Laboratory at Cornell. This winter has seen the first physics results from Cornell's new CESR electron-positron storage ring, described in our lead article. (Photo Cornell)

We come to praise CESR

Now producing its first physics results is the CESR electron-positron ring at Cornell. The ring (right) is mounted in the same tunnel as the Cornell electron synchrotron (left), which acts as injector.

(Photo Cornell)



The end of 1979 saw a new high energy physics machine come smoothly into action as the electron-positron storage ring CESR at Cornell began operation and produced its first physics results.

During October, there was a period of nine days running for the two experiments — CLEO (a Cornell / Harvard / Rochester / Rutgers / Syracuse / Vanderbilt collaboration, see August 1978 issue, page 254) and CUSB (a Columbia / Stony Brook group). Although much of the time was spent tuning up the experiments and studying background and trigger rates, the final three days were devoted to a physics run in the upsilon region, near 9.5 GeV total energy.

The integrated luminosity during this three day period was approximately 30 nb^{-1} and about 20 nb^{-1} was clocked by the experiments during runs. The beams from the Cornell electron synchrotron are injected into CESR at 5.5 GeV, where most of the previous injection studies have been carried out, and the ring is ramped down to the operating energy. Peak luminosities of about 2×10^{30} per cm^2 per s were achieved, the average luminosity over a three to four hour period being as high as 5×10^{29}. Beam lifetimes range up to four hours at 5.5 GeV.

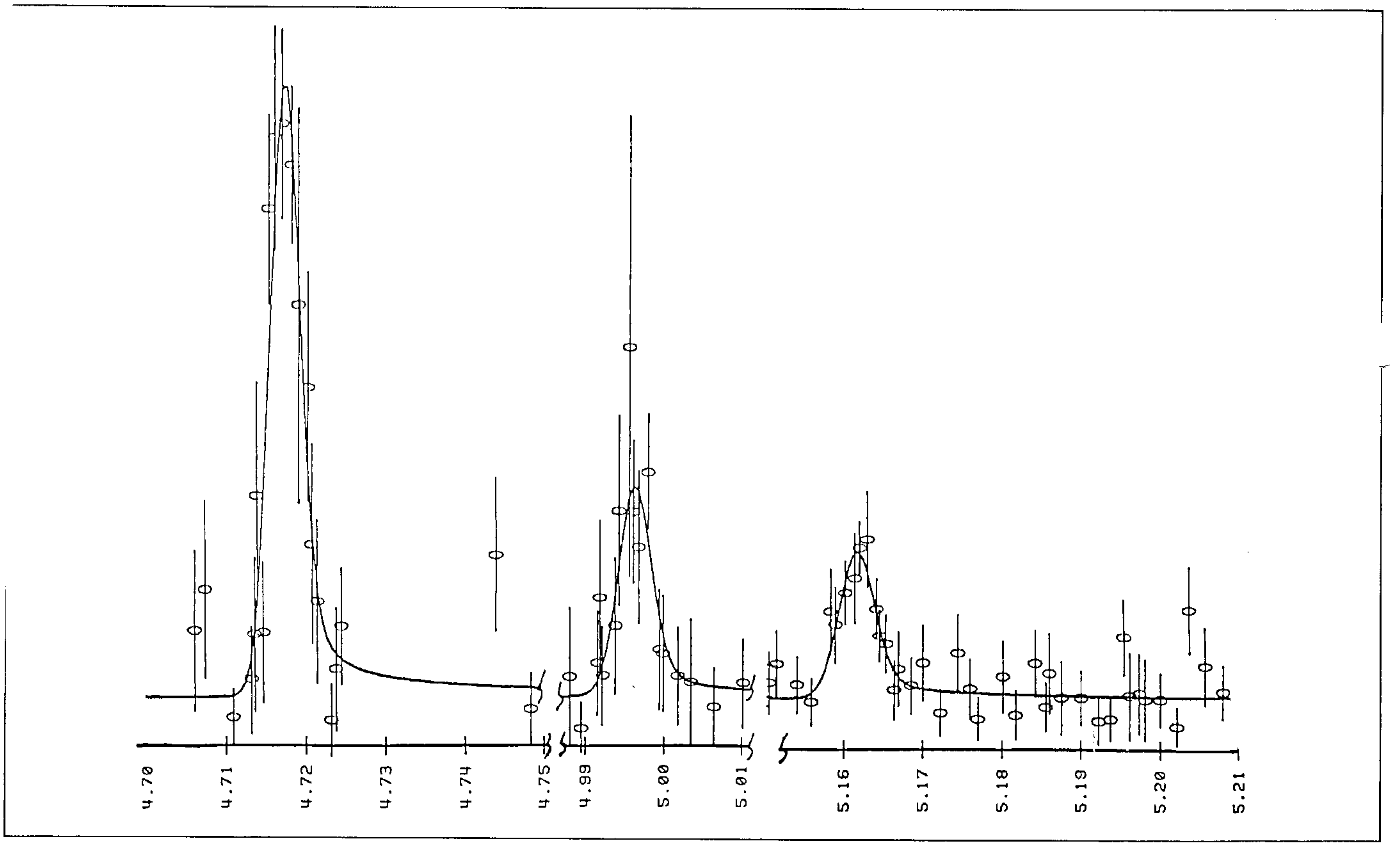
The CLEO detector was run with six of the eight octants installed, however particle identification systems in the octants were still being tuned up. Moving outward from the beam pipe, the apparatus consisted of beam pipe multiwire proportional chambers (with position measurement along the beam), cylindrical drift chamber, solenoid coil, outer drift chamber, time-of-flight counters, and finally proportional tube shower chambers. The muon chambers outside the iron magnet yoke were still being tested. The solenoid magnet was operated at 3.7 kilogauss.

The other experiment, CUSB, had about half its sodium iodide blocks installed during the October run and observed fifty electron-positron scattering events. More of the detector was soon installed, ready to catch some of the action in November, when CESR was largely devoted to a scan for the upsilon and upsilon prime resonances.

Both detectors observed the two resonances with excellent resolution. Results however are still preliminary, with cross-sections awaiting final efficiency corrections and with a 'local' energy scale being used which might need to be shifted by up to 20 MeV.

The observed energy resolution of approximately 3.6 MeV agrees well with the predicted value and is a significant improvement over pre-

The three upsilon resonances as seen by the CUSB (Columbia / Stony Brook) experiment at CESR. Similar results have been obtained by the CLEO group in the other intersection region. The results are preliminary, and the energy scale (energy per beam) has yet to be fixed absolutely.



vious results. There is general agreement with the integrated cross-sections previously observed at the DORIS electron-positron ring at DESY.

Encouraged by these nice resonances, the two experimental groups decided to skip a scheduled two week shutdown and scan the energy region around 10.4 GeV for the third member of the family, the upsilon double prime.

The storage ring ran beautifully, with the average luminosity increasing as the run progressed. Towards the end of December, the average luminosity registered by each experiment was over 40 nb^{-1} per day, the peak luminosity being about 2×10^{30} per cm^2 per s.

Within a few days the upsilon double prime was found, and during the following week it was carefully explored. Analysis is under way to compare the leptonic widths of the three upsilon resonances with each other and with theory.

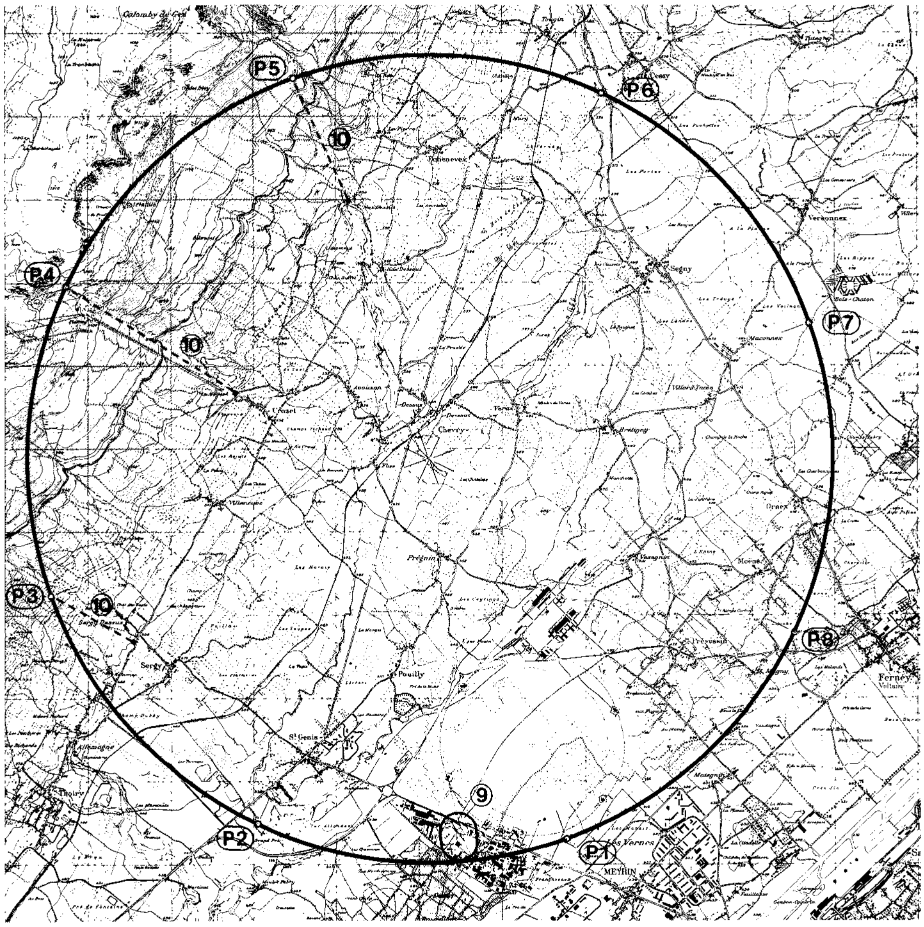
Meanwhile improvements are being made to CESR to increase the luminosity for the next running period. Electrostatic separator plates have been installed on either side of the two interaction regions to enable the electron and positron beams to be separated vertically so as not to influence each other during the critical phases of injection.

Another feature of CESR is the synchrotron radiation facility, CHESS, which also came into operation in October with one of the three high energy X-ray beamlines being used for two experiments. The first, a collaboration of Bell Laboratories, State University of New York at Albany, Princeton University and DESY, used an interferometer to study the location of atoms on a bromine monolayer in a crystal. The other spectrometer used a single crystal of silicon to obtain a tuned secondary beam. All three X-ray beamlines are now available for experiments by scheduled users.

The remarkably rapid construction and commissioning of this latest electron-positron ring is a credit to the Cornell group. With an energy falling between the SPEAR and DORIS rings and their PEP and PETRA successors, CESR will have an interesting physics region all to itself, and could reap a rich harvest of results.

The LEP project

The 30 km circumference LEP ring superimposed on a map of the CERN Laboratory region on the Franco-Swiss frontier near Geneva. This positioning is likely to be close to that finally selected if the project is authorized. The LEP ring passes alongside the existing SPS, so that it would not be difficult to connect the two rings at some future date, should the physics programme call for it. Eight experimental halls (PI-P8) are indicated, three of them (P3, 4, 5) being reached by tunnels into the Jura mountains.



At its 64th Session on 19-20 December, the CERN Council received a document from its Scientific Policy Committee entitled 'Proposal for the next major accelerator project at CERN'. Following the studies which have been carried out over the past few years, the SPC recommended that the 'Design study of a 22 to 130 GeV electron-positron colliding beam machine (LEP)' should be used as the basis for planning the next accelerator for CERN and recommended that the accelerator should be built adjacent to the existing Laboratory.

These recommendations were mostly favourably received by the delegates of the CERN Member States and the stage seems set for the formal presentation of the project in June of this year.

In this optimistic atmosphere we sketch again, in simplified form, the physics background against which the LEP project is being proposed and describe some of the features of the machine as drawn from the design study mentioned above (document CERN/ISR-LEP/79-33, more commonly known as the 'Pink Book').

Our present knowledge of the structure of matter

Rarely has the feeling been so strong that a clear understanding is emerging of the structure of matter and of the forces which govern its behaviour.

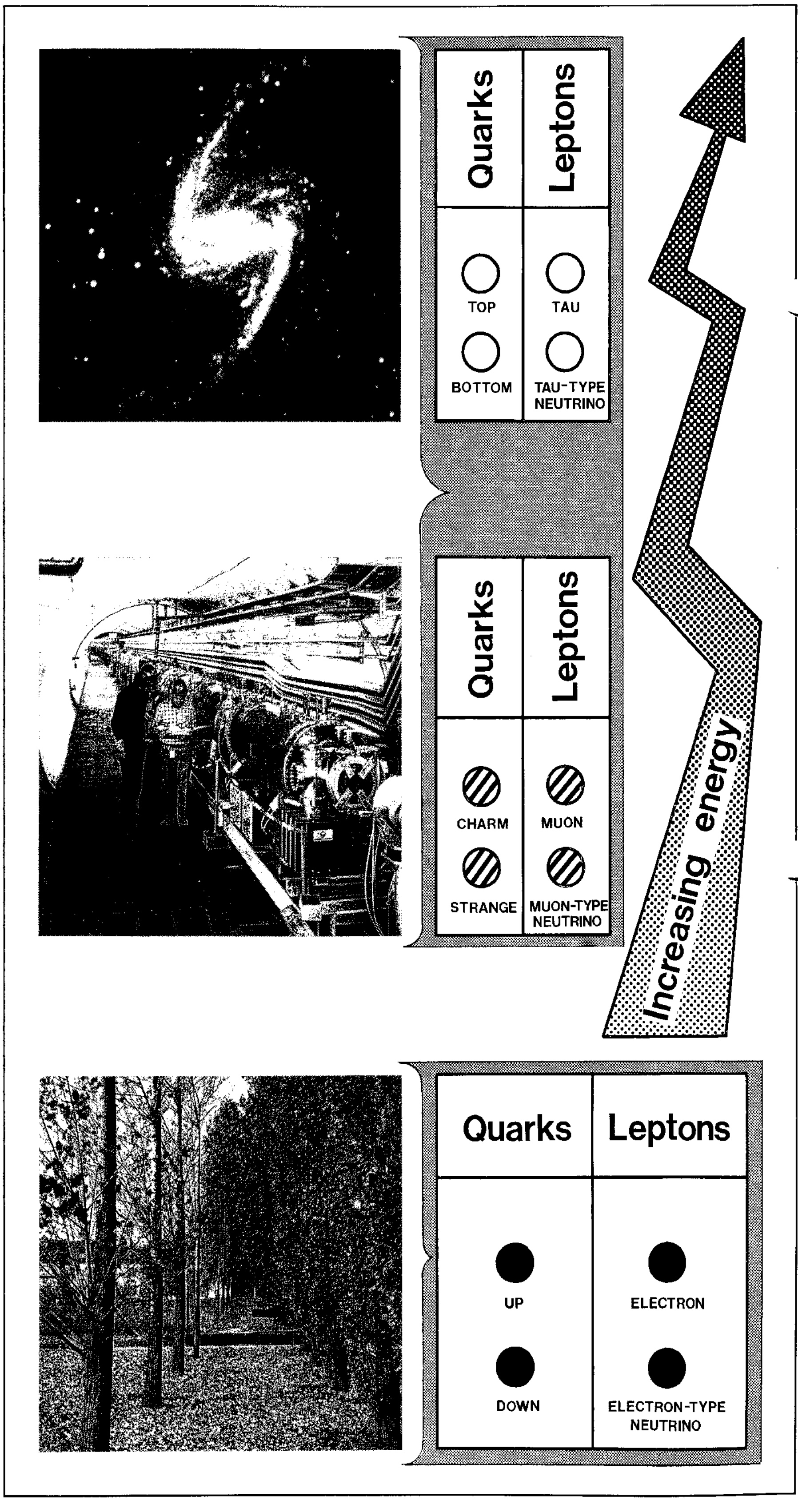
The list of what we believe to be the fundamental components of matter has shrunk to a handful of leptons and a handful of quarks. Our everyday world is built up essentially of just four particles — two quarks (the 'up' quark and the 'down' quark) and two leptons (the electron and the electron-type neutrino).

Two up quarks, with electric charge + 2/3 and a down quark with charge – 1/3, build a proton carrying a single positive charge. Two down quarks plus an up quark build a neutron carrying zero electric charge. Protons and neutrons build the hundreds of different types of nuclei. Together with electrons, these nuclei build the different types of atom. Electron-type neutrinos are needed in addition, to explain, for example, how some of the energy is carried away in radioactive decay. Thus with this handful of particles we can analyse the structure of our everyday world.

To be complete we should add that the quark comes in three variants each with a property given the name of 'colour' (for example, a red up quark, a blue up quark and a yellow up quark) though this nomenclature has nothing to do with our normal conception of colour. Also we have the antiparticle counterparts to our particles — for example, the positron which is the antielectron, carrying a positive rather than a negative charge. Nevertheless we can reasonably talk of our everyday world as being built up essentially of a quartet of particles.

But Nature does not stop there. When higher energies are in action further quartets of particles come into play; they are like carbon copies of the basic quartet but heavier. Thus at accelerators and storage rings we have discovered particles which fit in with the existence of a second heavier quartet — two quarks (strange

The constituents of matter as we now know them. A quartet of particles (two quarks and two leptons) explains how our everyday world is built up. Two additional quartets, like heavier carbon copies of the first, come into play at higher energies, such as exist on a galactic scale or are created in particle accelerators.



and charmed) and two leptons (the muon and muon-type neutrino). At still higher energies there is recent evidence for a third heavier quartet — two quarks (bottom and top, the second of which has not yet been observed) and two leptons (the tau and the tau-type neutrino, the second of which has yet to be seen).

How the particles behave

Given these sets of particles how do we explain their behaviour? Until very recently it was customary to divide particle behaviour into three categories because of the quite distinct relative strengths of the different effects — said to be controlled by the electromagnetic force, the strong force and the weak force.

The understanding of the electromagnetic force, first of all in the uniting of electric and magnetic phenomena and then in the formulation of the theory of quantum electrodynamics, is one of the crowning glories of physics. It is possible to calculate the behaviour of particles under the influence of this force with perfect precision.

The theory describes how the force acts in terms of the exchange of massless particles (photons) between the particles sensitive to the force. The photons can manifest themselves as radio waves, visible light, heat, X-radiation... If imitation is the sincerest form of flattery then the theory of quantum electrodynamics is highly regarded. The attempts to understand the other two forces follow the same pattern.

Present theory attempts to describe how the strong force acts by postulating other exchange particles, which have been given the name gluons since they stick the quarks together so well that they have not yet been observed in isolation. These gluons carry the strong force property of colour between the quarks.

The theory, because of having chosen the name colour for the strong force property, is known as quantum chromodynamics. It is far from being complete but it has a number of successes to its credit and last year received experimental support from results at the PETRA storage ring at the DESY Laboratory where indirect evidence of gluons was seen.

For the weak force, the present interpretation is so dependent on the electromagnetic force that it is no longer appropriate to speak of them separately and they are now combined in the so-called 'electroweak' theory.

The weak effects are explained by the existence of further exchange particles called intermediate bosons. For charged current interactions, where particles change electric charges, the carrier particles are named the W^+ and W^- bosons; for neutral current interactions, where charges are not changed, the carrier particle is named the Z^0 boson. It was the discovery at CERN in 1973 of neutral current interactions, predicted by the theory, which spurred the electroweak theory on its now very successful way.

The selection of an electron-positron ring

It is against this physics background that the European particle physics community made its choice of a high energy electron-positron storage ring as the machine most likely to contribute important new discoveries. This choice of LEP has involved, especially, discussions and work under the auspices of the European Committee for Future Accelerators (ECFA) and design studies at CERN with contributions from other Laboratories in the Member States.

There had previously been studies of the advantages of building a multi-TeV fixed target proton synchrotron or high energy proton-proton storage rings. Also developments of beam cooling techniques have enabled intense antiproton beams to be produced. This has led to proton-antiproton projects in the CERN SPS and at Fermilab to collide beams at several hundred GeV.

Experiments at such hadron machines should reveal, in particular, vital information about quark and gluon behaviour. For some other topics their data could be complicated to analyse because of the three quark structure of the colliding particles. To tackle many of the outstanding questions concerning the electroweak theory will not be easy on such machines because of the unavoidable dominance of the strong force. It is hoped that, when the proton-antiproton collider comes into operation at the SPS in 1981, it will produce evidence of the carriers of the weak force but it is unlikely that the complexities of the collisions will permit their detailed study.

A high energy electron-positron collider will provide cleaner conditions for the production and study of the Ws and Z^0. It could in addition be the scene of new particle discoveries (where its predecessors — SPEAR at the Stanford Linear Accelerator Center and DORIS at DESY — were so successful) filling in missing gaps in the quark/lepton quartets, revealing whether there are further quartets, discovering another type of particle known as the Higgs boson which is required by theory to give other particles their mass.

Also, when the storage ring is taken to 100 or 150 GeV collision energy, it should see the weak and electomagnetic effects become of comparable strength (since the weak becomes 'stronger' with energy). There are specific predictions about what should happen at these energies which it will be important to check.

LEP should be able to attack these problems and cover the many theoretical predictions which now exist. It would be even more dramatic if the predictions were not confirmed. We have always run into new phenomena when higher energy ranges became accessible and have to be open to new discoveries which could considerably modify our present theories.

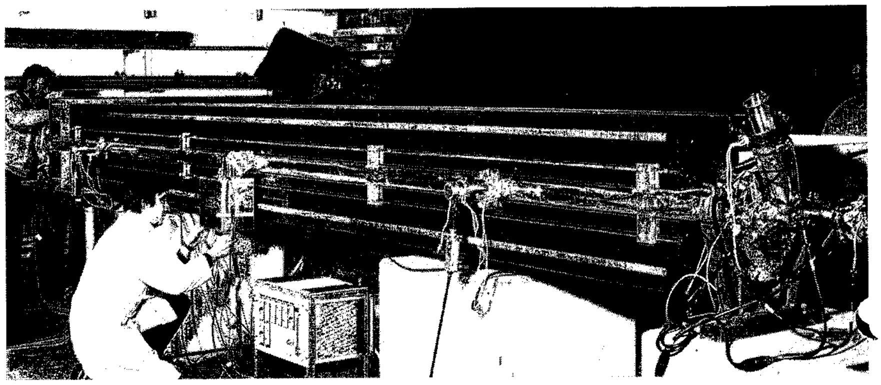
In addition to these physics reasons for the selection of LEP as Europe's machine for the future, there is a balance in the likely development of particle physics research facilities throughout the world. In the USA, Brookhaven is building 400 GeV proton-proton storage rings (ISABELLE) and Fermilab is building a 1 TeV proton synchrotron (Energy Doubler). In the USSR, a 3 TeV proton synchrotron is planned for Serpukhov. Further complementary facilities may emerge at DESY in Europe, at Stanford in the USA, at Tokyo in Japan and at Peking in China.

The design of LEP

The design of LEP has been through several iterations and has now settled on a ring of 30.6 km circumference with eight long straight sections (four with 10 m free space for the installation of experiments using full luminosity, four with 20 m and half luminosity)

A full scale 'concrete magnet' which uses the technique developed at CERN of filling the inter-lamination spaces with mortar. This can be done because of the low peak fields which are required. The technique has resulted in magnets of adequate quality with better mechanical properties and with about half the weight and at half the cost of conventional types.

(Photo CERN 3.1.80)



tunnelled adjacent to the existing SPS. This positioning could enable a link between the two machines at some later date, if there were good physics reasons for doing so, and several parameters have been set to keep such a possibility open.

The tunnelling technique was well mastered in the construction of the SPS and will ensure minimum disturbance to the environment. Some 40 test borings have been carried out over the proposed LEP site so as to determine the height of the stable molasse rock which will influence the precise position of the ring. The machine will require access shafts to the straight sections, or tunnels where the machine passes under the Jura mountains. By tilting the plane of the machine, excavation of one or more experimental halls may be possible.

The injector will be built under the existing Intersecting Storage Rings (and may use ISR magnets and vacuum chambers). It will involve a 200 MeV electron linac, a converter target for the production of the positrons, a positron linac and a 600 MeV accumulator ring, followed by a 22 GeV synchrotron. 22 GeV will be the injection energy into LEP, setting a lower energy limit for experiments which makes contact with the top energies of PETRA at DESY and PEP at Stanford.

A total filling time of 15 minutes is foreseen to achieve about 6×10^{12} particles per beam, refilling every two hours to sustain an acceptable luminosity. Injection will be into four bunches of positrons orbiting in one direction and four bunches of electrons orbiting in the opposite direction so that collisions occur at the eight straight sections.

The design luminosity is 10^{32} per cm^2 per s at 86 GeV. It is not possible to sustain this luminosity over the whole energy range but it will be kept as high as possible (no worse than falling with the inverse square of the energy) by using a series of wiggler magnets.

The beam lifetime due to beam-gas bremsstrahlung will be 20 hours with a design pressure of 3×10^{9} torr in the main ring vacuum chamber. The chamber construction, using extruded aluminium, will follow principles developed when building lower energy machines. It needs to cope with power densities of 1–2 kW per m at 86 GeV, due to synchrotron radiation from the beams, and will have water-cooled walls plus 8 mm of lead shielding on the outside and 3 mm on the inside of the gaps of the magnets to avoid excessive radiation outside the chamber. A 7 m long test chamber has been built and installed in a prototype magnet.

It is to keep the synchrotron radiation emerging from the beams (and hence the energy which the radio-frequency has to supply to hold the particle energies constant) to an acceptable level that the radius of LEP is so big. The energy lost in synchrotron radiation increases as the fourth power of the beam energy but is inversely proportional to the radius.

Despite the large radius of LEP it will be necessary to make up some 25 MW of power loss when operating at 86 GeV. Energy consumption will thus be a significant burden on LEP operation. It is anticipated that the CERN Laboratory as a whole (following the close-down of other machines and further energy economies which are being made) may rise to about 800 GWh per year at the end of the 1980s with LEP in action. This compares with 660 GWh in 1978 which was then about 0.06 per cent of Europe's power consumption.

Some 22 km of the large circumference of the ring will be taken up by bending magnets. In addition there will be almost 2000 focusing and correction magnets (quadrupole' sextupoles, etc. . . .). The significant feature of the bending magnets compared with those in conventional accelerators and storage rings is that they need to produce only very low fields (0.123 T even at 130 GeV operation). This has led to a new idea in magnet construction which has had a major impact on reducing costs.

Instead of the magnet cores being built of closely packed steel laminations, the laminations are spaced out (1.5 mm thick at 5.5 mm pitch) and the gaps in between are filled with low-shrinkage, corrosion-inhibiting mortar. This results in magnets with excellent mechanical properties and satisfactory magnetic properties for a cost about half that of conventional types. A full-scale magnet, 5.68 m

A half-scale low loss cavity where preliminary tests have been carried out of the idea of transferring power from the LEP ring cavities when it is not needed for accelerating the particle bunches. This is an important idea to reduce the LEP energy burden. A full power low loss cavity is nearing completion.

(Photo CERN 338.4.79)

long, of this type was tested in December and met all the required parameters. Another cost-saving design decision concerning the bending magnets is to power them using water-cooled aluminium bars running in a two-turn circuit all around the ring connecting the magnets in series.

A crucial component of the machine, since it is here that the energy requirements have their important repercussions, is the radio-frequency accelerating system. It is intended to install copper cavities initially, operating at a frequency of 353 MHz. To reach 86 GeV will require 768 cavities, positioned either side of the long straight sections, over a total length of 1629 m.

A variety of measures are being pursued in an attempt to optimize the r.f. system. The first concerns r.f. power sources. Development programmes have started in collaboration with European industry to improve the efficiencies available from klystrons or tetrodes. A watch is being kept on progress with newer devices — the gyrocon and the trirotron (being investigated at Los Alamos and Stanford respectively).

Secondly a novel idea is being investigated involving transferring the r.f. power into low-loss storage cavities from the ring cavities, where considerable r.f. power is lost in heat, during the time intervals between the passage of the bunches of particles. Half-scale spherical storage cavities have been built of sheet copper at CERN and Q-factors 95 per cent of the theoretical value have been measured. A 500 MHz storage resonator for high power tests is under construction.

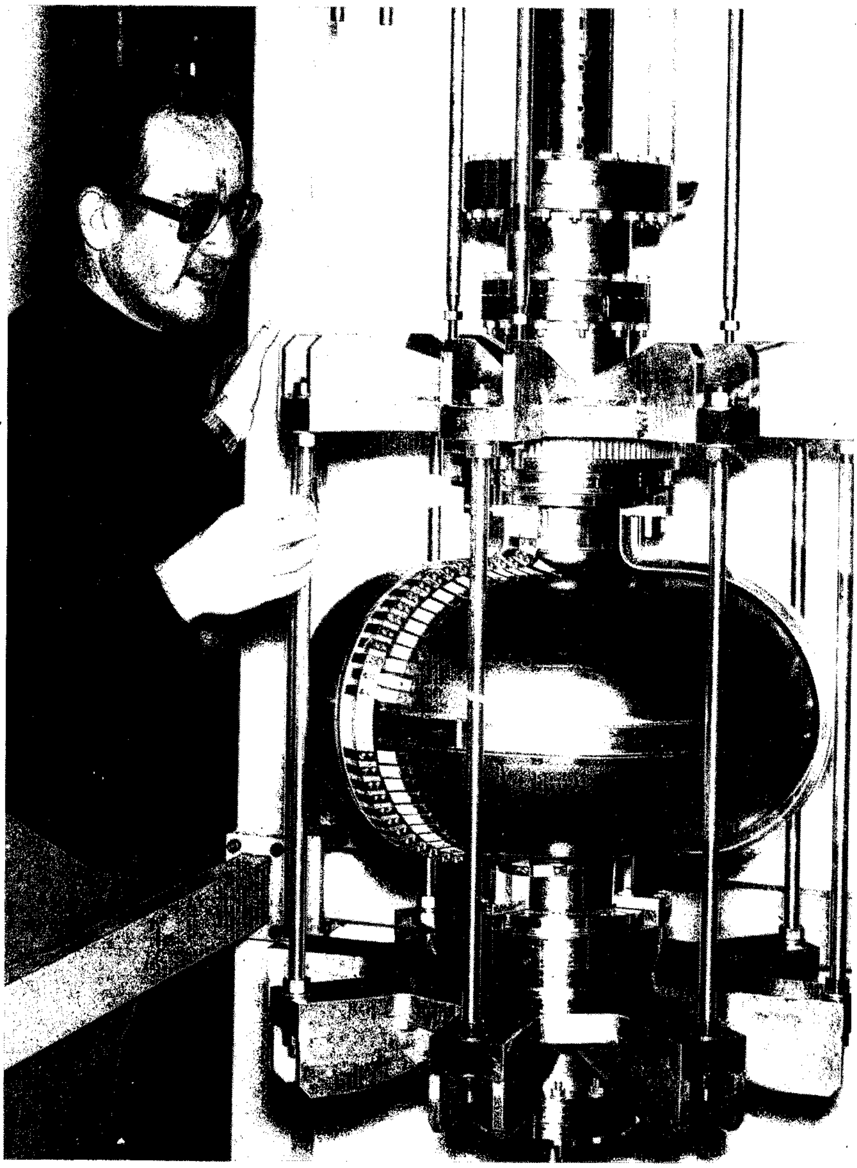
In the longer term, the most important contribution to the r.f. power problem would come from the development of superconducting cavities. With copper cavities it is difficult to envisage pushing the peak energy of LEP much beyond 90 GeV and the lower power consumption of superconducting cavities will certainly be needed to reach the peak design energy of 130 GeV.

This challenge is being tackled on two fronts. First of all a CERN / DESY / Karlsruhe collaboration has prepared two superconducting single cell cavities with the aim of operating them in actual storage ring conditions on the DORIS machine at DESY. The results of tests at Karlsruhe are reported on page 20.

Secondly, several European Universities (Genoa, Paris XI–Orsay, Wuppertal) are working with CERN to develop superconducting cavities. A single cell niobium cavity was operated recently at 500 MHz. It achieved Q values of 2.1×10^9 at low field gradients falling to 1.7×10^9 at an accelerating field gradient of 3 MV/m. A peak gradient of 4.6 MV/m was reached, limited by thermal breakdown at a welding seam. The next step will be to build multicell cavities and to attempt to reach similar figures in these structures.

Other systems for LEP will use the experience and facilities developed at CERN on the existing accelerators. In particular, the control system will follow the new philosophy developed so successfully during the construction of the 400 GeV SPS (see, for example, December issue 1973). The needs of the water cooling system and the electricity supply system can fortunately be met from the pipes and power lines which were brought to the CERN site for the SPS (from lac Léman and the French electricity grid at Génissiat respectively).

The experimental halls at the straight sections are each designed to accommodate detection systems



A single cell superconducting radio-frequency cavity which has recently been tested successfully at CERN. The development of superconducting cavities is vital if the peak design energies of LEP are to be achieved.

(Photo CERN 3.12.79)

which are not, in general, expected to grow much bigger than those currently installed at PETRA and PEP (given anticipated development in detection techniques). Five of the halls will have space for one detection system to be worked on while another is in place in the ring. A so-called push-pull arrangement will enable the two detectors to be exchanged. As yet there has been no need to think in much detail about particular systems but this will begin to get under way in June at a meeting in Uppsala (see page 24).

ECFA initiated an examination of the manpower and financial resources available to the high energy physics community in Europe (see the following article in this issue) to check that the advent of LEP would not perturb the present methods of collaboration in experiments at CERN from Europe's research centres. The indications are that, if present levels of support are maintained, an excellent programme of experiments can be mounted at LEP.

Costs and timescales

The design of LEP as laid down in the 'Pink Book' makes it possible to estimate construction costs and timescales. There is great concern in the high energy physics community to bring the machine into action as early as possible so as not to lose the very strong position which CERN has acquired amongst the world's high energy physics Laboratories.

By the mid-1980s, it is likely that the research potential of the excellent machines which are now in operation at CERN will be surpassed by the coming into operation of the Energy Doubler and ISABELLE. It is hoped that LEP's first beams will not be far behind.

However the speed with which LEP can come into operation will depend predominantly on the annual rate of expenditure which can be authorized by the CERN Member States. It is proposed that the LEP project will be financed from within present annual CERN budgets (600 million Swiss francs at 1978 prices) by closing down or reducing the research programmes on some of the existing CERN machines and by reducing further machine development. Thus it is planned to close down the Intersecting Storage Rings, and possibly the 600 MeV synchro-cyclotron, and to curtail the development of research on the SPS.

Almost all components of LEP will need to be in place in order to begin operation but two items could be built up to their full complement progressively. One is the amount of radio-frequency power installed; the other is the number of detection systems installed for the expe ments. Because of this, the physi programme will probably be co fronted in stages corresponding the progressive installation of radi frequency cavities, allowing pr gressively higher peak energies to l reached, and the progressive buil up of the experiments around tl collision regions.

The stage at which a full compl ment of copper cavities will installed is referred to as Stage 1. corresponds to an available radi frequency power of 96 MW givinç peak energy of about 90 GeV (a propriate for W particle productio It will, however, be possible to beç operation at a 1/6 stage w 16 MW of r.f. power giving energy of 50 GeV (appropriate foı particle production) or a 1/3 sta with 32 MW of r.f. power giving energy of 65 GeV.

The construction schedule pı

pared in the design study would allow the 1/3 stage to be reached in 1988 with four of the experimental areas in action, if authorization to build is given in 1981. The cost estimate for the 1/3 stage is 1065 million Swiss francs and a further 210 million Swiss francs would be needed to complete Stage 1.

The peak energy could be pushed little beyond 90 GeV with further copper cavities but significant advance to the Stage 2 aim of 130 GeV requires the installation of superconducting cavities. Until the development programme for the production of such cavities is much further advanced it is not reasonable to state costs or timescales to reach Stage 2.

The LEP project as described in the 'Pink Book' carries the very strong support of the European high energy physics community. In June of this year it is intended to present the project formally to the delegates of the twelve Member States of CERN. It is hoped that authorization for construction will be obtained a year later, in June 1981, and will have passed through all the necessary governmental approvals by the end of that year. If this is achieved, LEP could begin to take shape at the beginning of 1982.

High Energy Physics in Europe

A thorough survey of the present and possible future activities and resources in high energy physics in the CERN Member States has been carried out by a Working Group of ECFA (European Committee for Future Accelerators) under the Chairmanship of John Mulvey. The aim has been to obtain a view of the present European scene and to see whether it looks well adapted to the effective exploitation of possible future machines in Europe (particulary LEP) and the rest of the world. A report (ECFA/RC/79/47) has been presented to ECFA.

The high energy physics community in the twelve CERN Member States comprises about 2000 experimental and 1000 theoretical physicists centred in some 140 universities and research institutes. 88 per cent of the experimental physicists are spread around research centres in Europe while 12 per cent are employed at the two major accelerator Laboratories, CERN and DESY. Nearly a quarter of the physicists are research students of whom about 190 obtain their degrees each year. A half of this influx of young people moves to other work within three years of taking the degree.

A survey carried out a year ago revealed that between 50 and 60 per cent of the experimentalists utilized the 400 GeV proton synchrotron, the SPS, at CERN and that trend continues with the advent at the SPS of the proton-antiproton collider. The total number involved in the CERN research programme (not counting the synchro-cyclotron) was about 1350. About 320 physicists were using electron-positron machines with 230 of them on PETRA at DESY. Some 90 physicists based their main experimental activities at USA Laboratories (mainly Fermilab and SLAC) and 25 at Serpukhov (half of them on the Mirabelle bubble chamber). To balance this movement, some 70 American and 90 Soviet and Eastern European physicists came to CERN and another 20 American physicists to DESY. While mentioning bubble chambers, it is interesting to note that, since the previous survey in 1966, the number of experimenters using only the bubble chamber or emulsion techniques has fallen from 55 to 19 per cent.

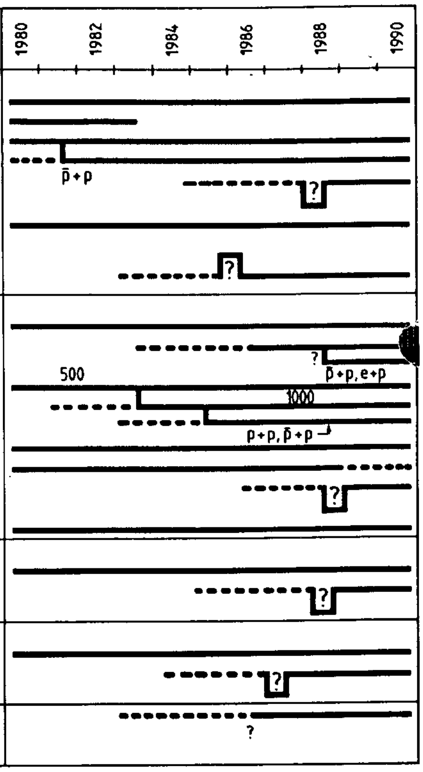
Direct financial support for the experimental programme (not including salaries, overheads and 'central' computing costs) is estimated at about 146 million Swiss francs in 1978. About half came from the two host Laboratories and some 13 MSF of the remaining University money was absorbed by travel and subsistence expenses. The manpower support (engineers, technicians, programmers) for the experimental programme involved some 2650 man-years in 1978, about one third being provided in the two host Laboratories.

The size of collaborations has grown with the complexity of the experiments and a collaboration of about 40 physicists is now typical with some collaborations reaching 70 or 80. The average size of a team coming from a single institute is 6.5.

In looking towards the future, a scenario has been drawn up in

The future pattern of high energy physics research in terms of the main machines which could be available in the coming decade. The question marks indicate possible start-up dates for projects yet to be approved. Dotted lines indicate periods devoted to preparation of experiments.

Region and Laboratory	MACHINE	PARTICLE(S)	ENERGY (GeV)	POSSIBLE DEVELOPMENTS
EUROPE				
CERN	P.S.	p	26	LEAR: High intensity, low energy $\bar{p}$.
	I.S.R.	p+p	31+31	$\bar{p}$+p
	S.P.S.	p	450	
	S.P.S.	$\bar{p}$+p	270+270	
	L.E.P.	[?] e^++e^-	65+65 (1st phase)	e^++e^- 130+130; e+p ~100+270
DESY	PETRA	e^++e^-	19+19	
	(also	e^++e^-	5+5 DORIS)	
	DESY II	[?] e+p, e^++e^-		
USA				
B.N.L.	A.G.S.	p	33	
	ISABELLE	p+p	400+400	$\bar{p}$+p, e+p?
F.N.A.L.		p	500	
	Doubler / Saver	p	1000	p+p 250+1000, $\bar{p}$+p 1000+1000?
SLAC	SLAC	e	22	SLED, 40 GeV
	PEP	e^++e^-	18+18	
	PEP II	[?] ?	?	
CORNELL	CESR	e^++e^-	8+8	
USSR				
SERPUKHOV		p	76	
	UNK	[?] p	3000	p+p, $\bar{p}$+p, ?
JAPAN				
K.E.K.		p	12	
	TRISTAN	[?] p+p	200+200	e+p, e^++e^-, $\bar{p}$+p?
CHINA		p	50	



which obviously the large electron-positron storage ring LEP figures as first priority for Europe. The Working Group stressed that LEP should not be delayed. Operation is assumed to start in 1988 so as not to leave CERN too long with the SPS and the proton-antiproton collider as its front line machines since these are likely to be overtaken by machines in the USA by the mid-1980s. Too long a shift of balance to the USA would make it difficult for Europe to recover its present status. It is hoped that a new machine at DESY will do much to fill the gap from the mid-80s. (We hope to have more on the DESY plans in a forthcoming issue.)

The Working Group comments that the future scenario takes a significant step towards a situation where new facilities in the different regions of the world are complementary rather than duplicated, bringing economies while still allowing the

In the context of the sharing of facilities world-wide, the most positive recommendation we have yet seen came from the Fermilab Physics Advisory Committee last year concerning policy towards non-USA groups. Other similar statements are likely to appear in the final report from the ECFA Working Group and from the International Committee for Future Accelerators, ICFA. The Fermilab Committee said:

'The predominant considerations in accepting or rejecting any experimental proposal should continue to be the physics merit, the technical feasibility, the capability of the group and the resources required. The Laboratory should welcome outside money or equipment, but such opportunities should not have excessive weight in determining the choice among proposals. The national or institutional affiliations of proponents should not per se influence the acceptance or rejection of proposals. We expect that foreign groups would naturally want to team up with local experimenters, and the Laboratory should encourage this. However, we do not feel that it is in the interests of the Laboratory or of the field of particle physics to establish quotas or restrict the international character of the field. We hope that other major laboratories around the world would have similar policies'.

Numbers of people involved in high energy physics research in Europe

CERN Member State	Experimental Physicists			Total	Theoretical Physicists			Total
	Tenured	Fixed Term	Student		Tenured	Fixed Term	Student	
Austria	18	3	2	23	15	9	6	30
Belgium	26	12	10	48	28	18	19	65
Denmark	13	6	4	23	7	12	–	19
France	313	26	59	398	123	18	18	159
Germany	98	110	112	320	66	64	53	183
Greece	5	12	6	23	6	7	4	17
Italy	228	31	61	320	116	17	23	156
Netherlands	27	9	21	57	18	5	18	41
Norway	14	9	10	33	10	6	7	23
Sweden	4	26	21	51	4	11	12	27
Switzerland	20	21	23	64	10	12	10	32
United Kingdom	163	94	111	368	65	34	71	170
Total	929	359	440	1728	468	213	241	922
Based at DESY	38	33	–	71	6	6	–	12
Based at CERN	64	94	–	158	11	31	–	42
Total	1031	486	440	1957	485	250	241	976

research to advance on a broad front. This implies, however, that experimental physicists from any region should be allowed to have access to these facilities and be given the support necessary to use them.

The Working Group assumes some 200 European physicists will be drawn to use the Energy Doubler at Fermilab and the ISABELLE storage rings at Brookhaven and later in the decade some 80 being drawn to use UNK in the USSR. A return flow of physicists from the USA and USSR is anticipated for LEP and the new DESY machine.

If facilities in Europe develop as it is assumed, the number of users of fixed target facilities at the SPS would be likely to fall from 1000 to 500 while the users of colliding beam machines increase from 550 to 1000 mainly through the use of LEP and the new machine at DESY.

The initial LEP experimental programme is assumed to comprise six experiments at an average cost of 30 MSF involving some 450 physicists from the CERN Member States (later rising to 600). If the present pattern and levels of financial support are sustained and the experiments are carried out by large collaborations 50 to 100 (physicists), the necessary finance would be assured. It implies, however, that the host Laboratories must continue to have provision in their budgets to meet half the capital costs of the experiments. For CERN this would involve about 90 MSF over the three or four years prior to LEP start-up. The necessary technical support could also be found if present levels are sustained.

The Working Group was wary of the centralization of effort and resources implied by the size and complexity of the experiments and stressed the importance of providing resources to enable contributions to be made by physicists working in their home Laboratories. This would also strengthen the contribution made by high energy physicists to local academic life, improve the training of graduate students and lead to broader contact with a wider local community including local industries.

The 'concluding remarks' of the report the Working Group state 'Europe today possesses a broad range of front rank facilities for high energy physics research and the proposals under discussion would provide great opportunities for the future'.

Around the Laboratories

At the recent Fermilab Tevatron Neutrino Workshop Robert Shrock of Stony Brook discusses tests for tau neutrinos.

(Photo Fermilab)

FERMILAB
Tevatron Muon-Neutrino Workshop

Ideas! Big fat fuzzy ones — long skinny shiny ones... ideas of every kind flew through the air of the Fermilab auditorium (cafeteria, atrium, etc.) during four days of a Muon-Neutrino Workshop in January. It was the first public discussion of the plans of Fermilab users and staff for the physics and facilities that could happen with the advent of the Tevatron.

Tom Kirk, currently on leave from his position as Head of the Neutrino Department, organized the Workshop. More than 200 scientists attended, many from Europe, Russia and Japan, to discuss the coming era of 1 TeV lepton physics.

The Tevatron Neutrino Department construction and beam design plans were presented by Tom Kirk, Ray Stefanski, Dennis Theriot and Jim Walker. John Peoples, Research Division Head, outlined the time schedule for bringing on the Tevatron which calls for extraction of beam to the first experiments in 1982. The programme hits its full stride in 1983–84 with completion of a 750 GeV muon beam and other large-scale facilities.

With paper designs plastered across the auditorium walls, the experiments took over! New ways of detecting particle collisions and showers were presented by Bill Carithers (Berkeley) who described his recent interesting experiments on limited Geiger mode gas discharges, and Mikhail Kubantsev (ITEP) who described preliminary tests for a 100 ton high pressure argon gas detector for neutrino physics.

Enthusiasm for the new high energy, high intensity muon beam was strong as eleven speakers extolled the virtues of high precision experiments that may have the best chance to measure the parameters of the leading candidate theory of strong interactions (quantum chromodynamics, QCD) and the best weak interaction theory (Weinberg-Salam). The gains to be made with the new muon beam are probably the most dramatic at the Tevatron since it is here that the improvement over existing Fermilab facilities is greatest.

Pamela Surko (Princeton) showed how the natural polarization of the muons could be exploited to make a critical test of the Weinberg-Salam theory. Her ideas make use of an existing Fermilab apparatus, the multi-muon spectrometer, in a new way.

The remaining experimenters explored the interesting possibilities of neutrino physics as it will be extended with the Tevatron. Frank Taylor (North Illinois), Frank Sciulli (Cal. Tech) and others presented information on the two large neutrino detectors now at Fermilab, while Jack Steinberger (CERN) and his colleagues reviewed the Tevatron possibilities of the CERN WA1 detector. The plans concentrated on capabilities of existing neutrino detectors for the new energy regime and on the rewards that higher energy will bring.

Among the topics that will benefit from the neutrino beams are further study of nucleon structure functions with comparison to QCD and study of multimuon events as a probe of heavy quark production. A topic that should benefit significantly from the higher energies is that of neutrino-electron elastic scattering.

Experiments with 'prompt' neutrinos, obtained from burying a proton beam in a beam dump, came in for extensive discussion. Unfortunately, a muon or electron is born with each neutrino and the muons must b eliminated before the neutrinos can be used for experiments. Mike Peters (Hawaii) gave a useful talk on the tools for calculating an appropriate muon shield and both he and Richard Fine (Columbia) explained how such a shield might be constructed using magnets from the retiring Argonne ZGS accelerator.

Neutrino bubble chamber physics was reviewed in some detail. Horst Wachsmuth (CERN / Wisconsin) unveiled ideas for a new bubble chamber optimized for neutrino physics at Tevatron energies. It would be smaller than the existing Fermilab 15 foot Bubble Chamber, having a volume of only 10 cubic meters, and would be almost completely surrounded by electronic detectors for particle type and momentum measurements. The chamber could also function as a visible target spectrometer for hadron physics. Vincent Peterson, who organized the bubble chamber presentations, reported enthusiastic support for the project among bubble chamber aficionados.

The Workshop demonstrated a high level of user interest in lepton physics with the Tevatron with comparable interest in both muon and neutrino experiments.

Fermilab has requested that potential users submit Tevatron proposals for neutrino and muon physics by 25 April. Open presentations are scheduled for 15/16 May. The first consideration by the Physics Advisory Committee will be at its June meeting and, because the number of proposals is likely to be large and each requiring considerable scrutiny, it is not likely that final decisions will be made immediately after the June meeting.

Users interested in preparing proposals for the Tevatron are encouraged to contact Shigeki Mori, acting head of the Neutrino Department at Fermilab, for the latest description of beams and facilities which are expected to be available.

Emulsion hybrid spectrometer

Extending the Weinberg-Salam theory from leptons to quarks required the existence of a fourth quark carrying a new quantum number, 'charm'. Since charm should disappear only in weak decays, theorists have agreed for some time that the lifetime for the lightest charmed particle of each type should be relatively long, of the order of 10^{-13} s.

Initially, experimental results were in disarray indicating lifetimes either less than 10^{-14} or approaching 10^{-12} s. During 1979, data from several CERN and Fermilab experiments have favoured lifetimes in the 10^{-13} s range (see for example June 1979 issue, page 152 and September 1979 issue, page 253).

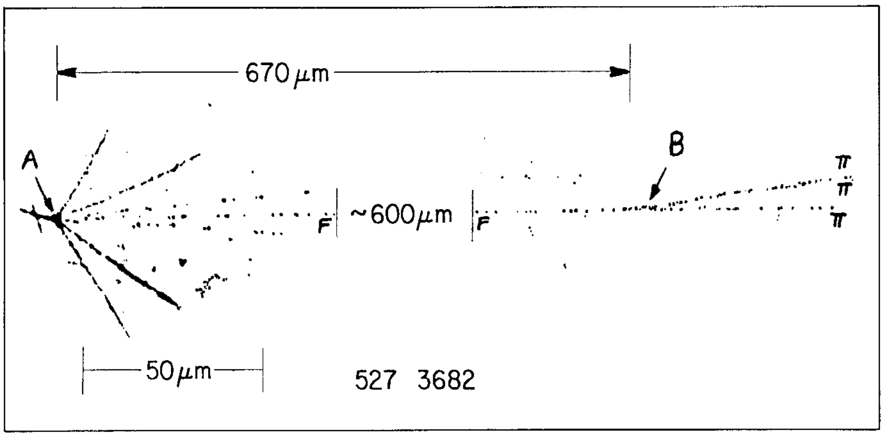
More data is now available thanks to a US/Canada/Japan collaboration which has carried out a run in the Fermilab single-horn neutrino beam with an emulsion hybrid spectrometer, using 24 litres of Fuji emulsion as the target.

A neutrino beam was chosen because the fraction of events with charm should be quite large (5 to 10 per cent). The spectrometer serves the double purpose of locating events in the emulsion and identifying the type of charmed particle through its decay kinematics. The spectrometer was operated with a low-bias trigger demanding only that more than two charged particles leave the target and that at least two of them appear downstream of the magnet.

Some 2200 charged and neutral current neutrino interactions have been reconstructed from the data. The emulsion has been scanned for about 40 per cent of these events of which 500 have been found. Of the tagged events not found, half were lost to fiducial volume cuts and the rest to scanning inefficiencies. The efficiency for finding tagged events is approximately twice that of previous hybrid experiments due to a new track follow-back technique used in conjunction with conventional volume scanning.

Twenty-two multiprong charm decays have been found in these 500 events, along with an additional dozen 'kink' tracks which exhibit a sudden large change in direction without evidence of interaction. Multiprong decay lengths range from 5 to 13 000 μm. Decay products have been identified in the large-aperture spectrometer by a variety of techniques - magnetic analysis, time-of-flight separation of charged pions, kaons and protons, lead glass identification of electrons, gamma rays and neutral pions, and muon identification by penetration through steel. A calorimeter measured total hadronic energy.

Of the multiprong decays, three have been identified as charmed lambdas, four as neutral D mesons, two as charged Ds and two as charged F mesons. One candidate for the weak decay of a charmed sigma has been found with a proper decay time of 0.5×10^{-13} s. If this identification is correct, the event is quite surprising because theorists



An example of a charmed particle decay as recorded in emulsion by a US / Canada / Japan collaboration at Fermilab. A neutrino interacts with a nucleus in the emulsion at point A. The central ongoing track is analysed as an F meson which decays at point B into four particles, three of which are identified in the spectrometer as pions.

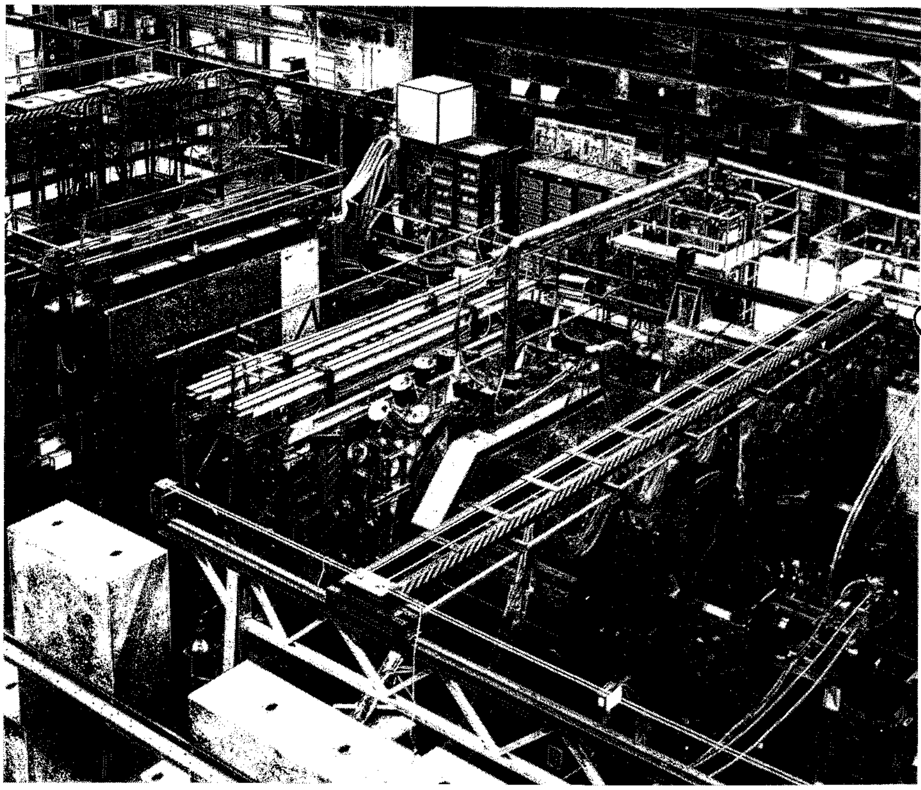
expected this particle to be massive enough to decay strongly. Five events could be attributed to either D or F mesons, and the remaining multiprong and kink events are still under study.

Based on these statistics, charmed sigmas and lambdas and neutral D mesons have lifetimes somewhat shorter than 10^{-13} s while charged D and F mesons live considerably longer than 10^{-13} s. A test based on this follow-back technique has been used to verify that the efficiency for finding neutral decays is high. The indication that the neutral D lifetime is an order of magnitude shorter than the charged D lifetime therefore appears to be real and not the result of scanning biases. (This is also supported by evidence that the neutral D has a higher level of non-leptonic decays.)

Production dynamics, such as the number of charmed particles coming from the strong decays of excited states and the fraction of the hadronic energy carried by the charmed particle, are being investigated. The experimenters expect to find about fifty charm decays in the complete data sample, and hope to identify two thirds of these unambiguously. Another run with improved apparatus is planned.

Apparatus used by a CERN / Collège de France / Ecole Polytechnique (Palaiseau) / Orsay / Saclay group studying the production of muon pairs by hadrons. The beam from the SPS first meets liquid hydrogen and platinum targets in series (bottom right) before passing into the hadron absorber. Immediately downstream is a large superconducting magnet. This magnet and the detectors further downstream contain a total of 26 000 sense wires mounted in 31 planes.

(Photo CERN 166.7.79)



CERN
Hadronic information from lepton pairs

Although the production rates of muons and electrons in hadronic experiments is relatively small compared with the production of hadrons, their properties are very different from the accompanying particles and they can be readily identified and measured. In particular, the study of lepton-antilepton pairs is now a powerful hadron physics tool.

Away from sharp resonances like the J/psi and the upsilon, the smoothly varying continuum production of lepton pairs provides information on the quarks inside the colliding hadrons.

This continuum dilepton production is understood to be due to the so-called 'Drell-Yan' mechanism in which a quark from one of the colliding hadrons annihilates electromagnetically with an antiquark from the other hadron to form a heavy photon, which subsequently decays into a lepton-antilepton pair. This means that while the experiments use hadron beams and hadron targets, the effects studied are not necessarily hadronic!

The continuum dimuons provide a valuable laboratory for the study of the inner constituents of hadrons which complements the information provided by deep inelastic lepton-nucleon scattering. Since the incident hadrons are not limited to protons, the Drell-Yan method can also probe the quark structure of unstable hadrons, such as pions, which cannot be used as targets for lepton beams.

The model has been successful in accounting for many of the observed features of the lepton-antilepton spectrum, such as the simple additive dependence on the mass number of the target material, the angular distribution of the outgoing dimuons, the different behaviour observed using positive and negative pion beams, and the variation of the dimuon levels with energy ('scaling').

Important new evidence from a CERN / Collège de France / Ecole Polytechnique (Palaiseau) / Orsay / Saclay group (NA3) in the North Area studying the production of muon pairs by different kinds of hadrons indicates that something else is going on.

Using high resolution differential DISC Cherenkov ('Cedar') counters, the experiment is able to identify the incoming hadrons in the intense (5×10^7 particles per second) secondary SPS hadron beam. This enables data to be collected simultaneously for negative pions, antiprotons and negative kaons (negatively-charged beam), and, using threshold Cherenkovs in addition, for protons and positive pions and kaons (positively-charged beam).

The NA3 group has measured the quark structure of the pion and has obtained the first evidence for production of upsilons using pion beams (see September 1979 issue, page 257). In this experiment, the copious production of J/psis is particularly useful for checking and correlating the continuum dimuon data.

The observed shape of the dimuon continuum spectrum, using the large angular acceptance of the apparatus, gives a handle on the 'structure functions' which describe the distribution of quarks inside hadrons, and the results are in good agreement with independent structure function measurements from high energy neutrino interactions. It is particularly encouraging that two very different types of experiment provide the same picture of the quarks inside nucleons.

These structure functions can then be used to calculate the expected overall magnitude of the dimuon continuum signal. However measurements are more than twice as large as the calculated levels.

In proton-nucleon collisions, each of the colliding particles contains three valence quarks, and the antiquarks for Drell-Yan processes have to be supplied by the 'sea' of virtual quarks and antiquarks which surrounds the valence quarks. The relative level of sea and valence quark contributions for input into the Drell-Yan calculation is obtained from neutrino scattering data.

However if instead of being bombarded with protons, the targets are bombarded with antiprotons, which contain three valence antiquarks, the dominant contribution to background dimuon production comes instead from interactions between pairs of valence quarks. Since the antiproton has the same structure function (for antiquarks) as that of the proton (for quarks), the calculations require a minimum of empirical input.

After their first antiproton data became available last summer, the group embarked on an intense period of data-taking which has produced some 350 antiproton events with muon pairs above the J/psi mass region. These show that the ratio of the observed and calculated levels of dimuon production using antiprotons is consistent with the result obtained using protons. This means that the high dimuon signal cannot be simply explained in terms of an increased contribution from sea quarks. The data also allows the first determination of the antiproton structure function.

Another possibility is that coherent nuclear effects in the target are responsible, which can be checked by using a hydrogen target. Using pion beams on hydrogen, the NA3 experiment still produces the same ratio of observed to calculated dimuon levels, so ruling out this explanation.

The use of a hydrogen target also provides data free of nuclear complications, and enables absolute cross-sections to be obtained. In practice, the experiment uses hydrogen and heavy (platinum) targets simultaneously, which enables the additive dependence on mass number to be checked.

Another suggestion is that the high dimuon yield could be hadronic, rather than electromagnetic, in origin. Such an effect would contribute equally to the results using positive and negative pion beams. However the difference between the NA3 results with positive and negative pion beams still yields the same high dimuon level as before.

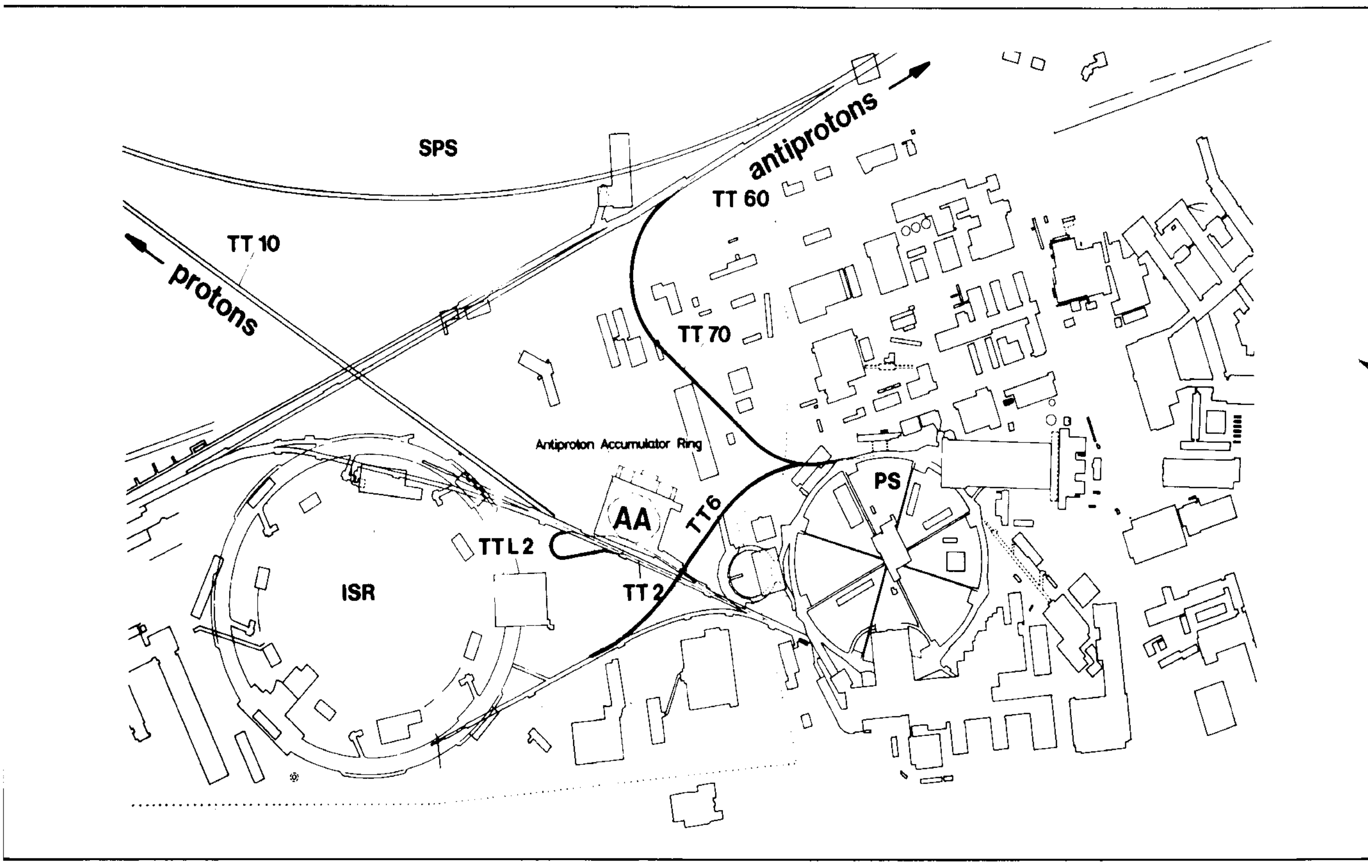
More evidence for a high dimuon cross-section comes from the Indiana / Imperial College London / Saclay / Southampton collaboration studying dimuon production by pion beams in the West Experimental Area of the SPS. This group has also seen a candidate for the beauty meson (see September 1979 issue, page 257).

Taken together, the evidence suggests that the Drell-Yan model for dimuon production needs to be modified. The disagreement could be due to the gluons responsible for the inter-quark forces, and this provides fuel for theoreticians developing field theories of quarks and gluons. The considerable difference between the observed and calculated dimuon levels means that the effects due to gluons must be large.

Digging for antiprotons

The CERN antiproton project is taking shape. The antiprotons, produced by the primary proton beam from the 28 GeV proton synchrotron (PS), will be stochastically cooled and stored in the new Antiproton Accumulator (AA) ring. From here, the low energy antiprotons will be fed to the PS (via TTL2) and accelerated to 26 GeV before being ejected

The intricate layout of beamlines for the CERN antiproton project: the new tunnels TT70 and TT6, to supply antiprotons to the SPS and ISR respectively, have now been excavated.

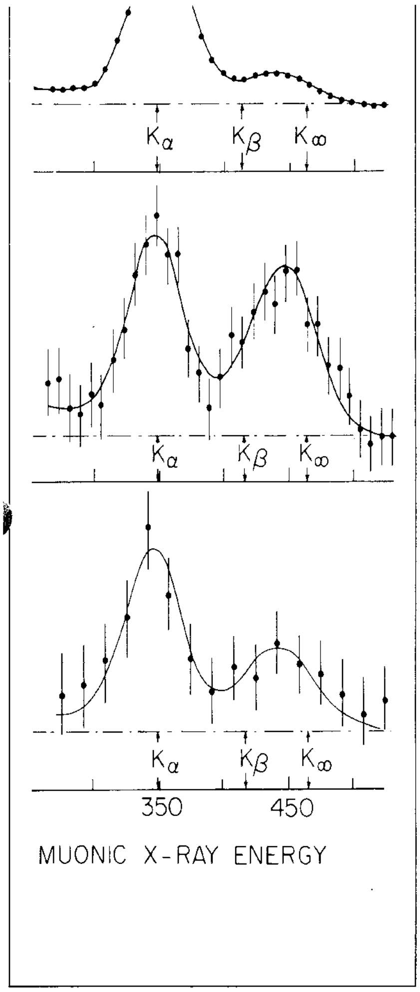


into a new tunnel (TT70) leading to the SPS, where they will be accelerated to 270 GeV (see September 1978 issue, page 291). Another new tunnel (TT6) will take antiprotons towards the Intersecting Storage Rings (ISR).

The 400 metre TT70 tunnel has how been excavated, the links with the existing SPS ejection tunnel (TT60) for the West Experimental Area, and with the PS tunnel having been made during the end-of-year shutdown.

The antiprotons will be injected into the SPS using the extraction channel normally used to supply protons to the West Experimental Area. Extracted protons can also be transported through TT70 back to the PS. This will allow the beamline to be tuned with protons and will

A pessimist's view of tunnelling operations, by Phil Bryant.



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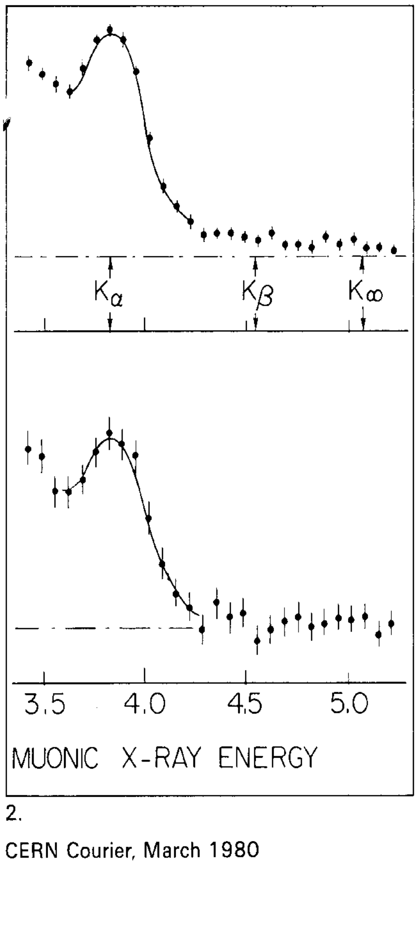

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1. X-ray spectra from muonic atoms formed in aluminium as observed by a Bologna group at the CERN synchro-cyclotron. The spectra are different depending on whether the atoms are formed by direct injection of muons into an aluminium target (top curve), by diffusion of muonic hydrogen (middle curve) or by diffusion of muonic deuterium (bottom curve).

2. The differences disappear for X-ray spectra from heavier elements. The top curve is obtained by direct injection of muons into a xenon target and the bottom curve by diffusion of atomic hydrogen.

provide a means of synchronizing the two accelerators.

Excavation is also complete for the TT6 tunnel to take the antiprotons from the PS towards the ISR. TT6 passes underneath the TT2 beam-line which takes protons from the PS towards the SPS and the ISR. This creates a potential radiation hazard, and to ensure that work in TT6 can continue while TT2 is in operation, special collimators have been installed in TT2 and shielding added to the tunnel floor.

Muons with memory

A Bologna team carrying out experiments at the CERN synchro-cyclotron have added more information concerning some intriguing observations on muonic atoms. It seems that, in certain circumstances, the atoms can remember in which way they have been formed and behave accordingly.

The effects were first seen at Dubna in 1967 when different spectra were observed from liquid argon depending upon whether the muon went into orbit in the argon atom via direct injection of a muon beam or via diffusion of muonic hydrogen through the liquid argon. It is thought that the different angular momenta involved in the formation of the atom by the two processes may be the reason for the atoms behaving as if they remembered how they had been created.

The Bologna team saw the effects for the first time in solids in 1978 using aluminium. They repeated the experiments using the diffusion of muonic deuterium. Again different behaviour of the resulting muonic atoms was observed. They then moved to atoms of higher atomic number since all previous work had been on light atoms. Measurements on liquid xenon did not show differences in behaviour depending on how the atom is formed.

Thus muonic atoms remember whether they have been formed by muon beams, muonic hydrogen diffusion or muonic deuterium diffusion but only with atoms of the lighter elements of the periodic table.

BROOKHAVEN
Hypernuclei

Hypernuclei are formed when the usual nucleon components of atomic nuclei are transformed into more exotic particles (hyperons) by bombarding them with a beam of kaons.

They were first seen in 1953, but systematic studies have only been possible in recent years, thanks to the availability of high flux kaon beams and precise spectrometers. They can be used to test nuclear theories in different systems and to discover processes and excited states not seen found in ordinary nuclei.

A programme of hypernuclear studies at Brookhaven is now well under way. First results confirm the existence of two states in carbon, first discovered at CERN, and extend the knowledge of their quantum numbers through measurements of angular distributions.

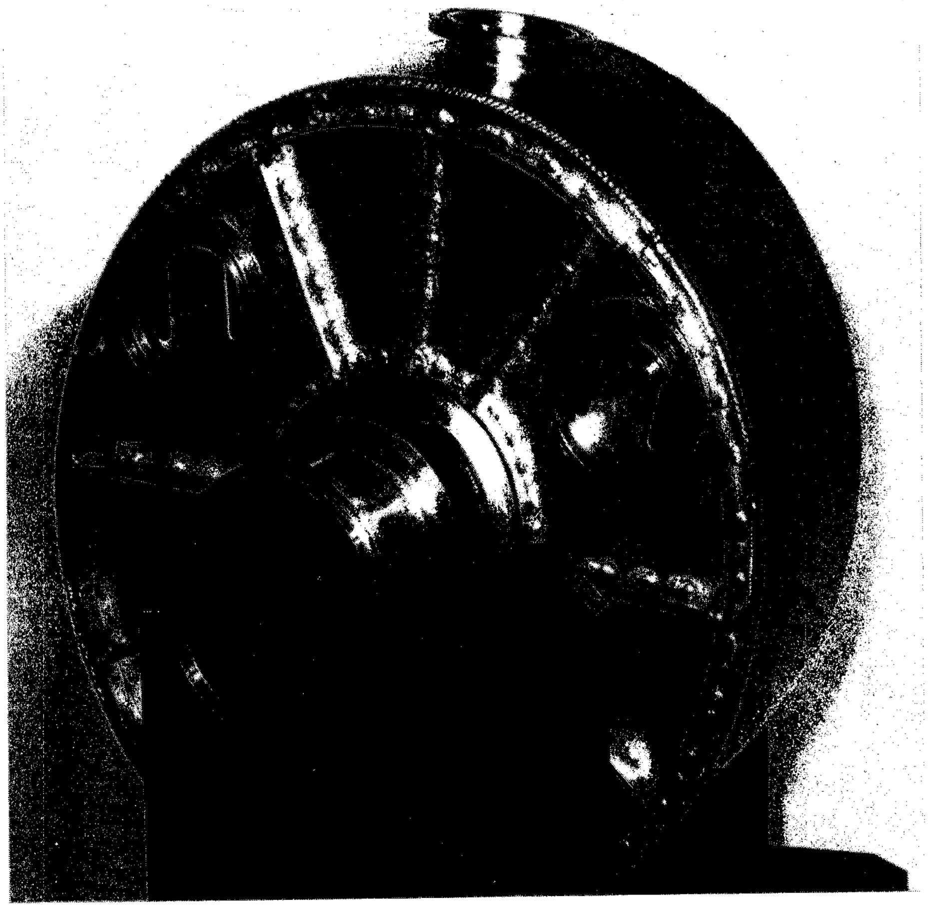
A novel feature of the experiment is the large range of momentum transfer covered — from 70–280 MeV. There are several classes of hypernuclei which require such large momentum transfers for their formation, and the experiment shows evidence for some of these states, while other expected states are not seen.

A Brookhaven / Princeton / MIT / Houston / Vassar / Carnegie-Mellon group used 800 MeV kaons to search for hypernuclei produced in carbon. States near threshold were detected by measuring the momenta of the incident kaon and the outgoing pion, the particles being identified by Cherenkov counters.

Detection of states of width 1–2 MeV required very precise momentum measurements, the resultant resolution varying between 2.5 and 4.5 MeV, depending on the thickness of the target. The AGS Low Energy Separated Beam I supplied 2×10^5 negative kaons per pulse, the kaons making up seven per cent of the total flux.

Two states were seen, one with a lambda binding energy of 10.79 ± 0.11 MeV, and another 11 MeV above. The angular distribution of the first bound state infers that it is the ground state of the carbon hypernucleus. The angular distribution of the 11 MeV excited state at small angles (less than 8°) indicates formation of a spin zero, positive parity (0^+) state, however the production level at 15° exceeds what could be expected from 0^+ states. This hints that a new state, possibly with spin two and positive parity, is being seen.

In the near future, the experimenters plan to study hypernuclear formation in other light nuclei in order to understand better the anomalously low lambda-nucleus spin orbit interaction discovered at CERN (see November 1978 issue, page 395). They then plan a search for hypernuclear gamma rays using apparatus modified for higher rates. Discussions have started on the design of a new, larger-acceptance beam and spectrometer.



A single cell niobium superconducting cavity built for tests in the DORIS electron-positron storage ring at DESY. The project involves a DESY / Karlsruhe / CERN collaboration and successful tests have been carried out at Karlsruhe.

(Photo Karlsruhe)

KARLSRUHE
New results with superconducting cavities

As a result of work by a CERN / DESY / KfK (Kernforschungszentrum Karlsruhe) collaboration on the development of superconducting cavities (see October 1978 issue, page 343), two single cell niobium cavities have been tested at Karlsruhe.

The cavities are designed for an acceleration test in the DORIS electron-positron storage ring at DESY and are therefore designed for operation at 500 MHz. They have a 100 kW input coupling and two higher mode output couplings, and the beam tubes are matched to the vacuum tube of DORIS. The principal dimensions of the two cylindrical cavities are: outer diameter 470 mm, beam tube radius 60 mm, length of cylinders 270 and 225 mm, wall thickness 4 mm, shunt impedance (Cu, 300 K) 22 MΩ/m, Q-value (Cu, 300 K) 4×10^4.

The ratio of the peak surface electric field and accelerating field is minimized to a value of about 2 by giving the transition from the beam tubes to the endplates of the cylinder an elliptical shape. The corners at the outer circumference of the cylinder are sharp.

Most parts of the cavity are made from 4 mm thick niobium sheet with only the coupling parts being machined from solid niobium. All parts were assembled by argon arc welding and the manufacturing carried out by two different industrial firms. Improvement of some welds and all surface treatments were done at Karlsruhe, including electropolishing and high vacuum firing at 1850°C.

For testing, the cavities were mounted in a laboratory cryostat with the future beam axis vertical. The coupling holes were closed with niobium blind flanges, which had to ensure a superconducting contact. A mu-metal screen reduced the earth's magnetic field. Input coupling was achieved by a movable coupling probe in one of the beam tubes. Twenty-six carbon resistance thermometers were distributed at critical points in order to detect heat pulses and thereby locate sources of loss.

After cooling to 4.2 K, which took about six hours, the surface was improved by r.f. conditioning at slowly increasing field levels. Finally a curve of Q-values versus peak electric field was measured up to the breakdown field. The breakdown was studied by looking at the oscilloscope picture of r.f. amplitude versus time and at signals from the carbon resistors. Also the d.c. component of electron current hitting the input coupling and X-ray production by electrons were observed.

After a series of measurements, the best values were obtained in the longer cavity. An accelerating field of 3.7 MV/m could be reached at 4.2 K (the intended operating temperature) at a Q-value of 10^9. The breakdown is magnetic (reducing the temperature to 2 K increases the limiting field to 4.1 MV/m) but electrons are present at this field level.

At 3 MV/m electron loading is unimportant and Q is up to nearly 2×10^9. If operation at 3 MV/m could be obtained in LEP, an energy in excess of 110 GeV could be reached and the dissipation would be less than 3 W per cavity. The shorter cavity reached lower fields (2.5 MV/m) but, in both cases, the limiting phenomenon was located near one of the output couplings. This is under investigation.

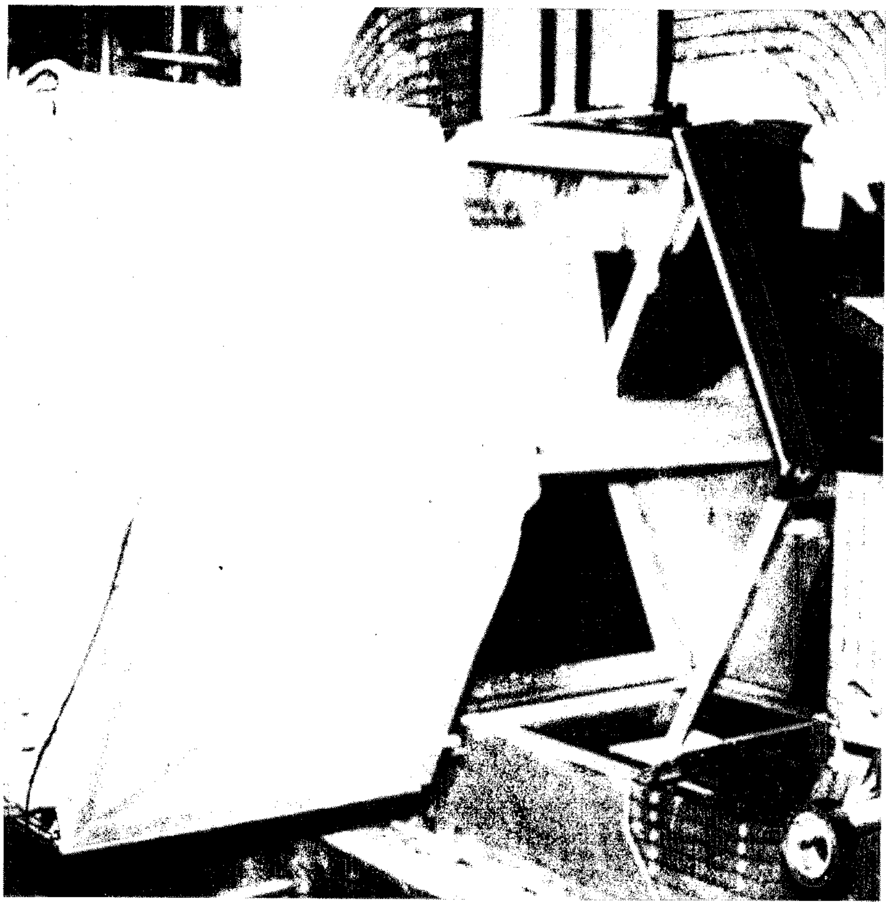
After the success of these tests, all r.f. and cryogenic components are now assembled for final tests at DORIS later this year.

TRIUMF Looking for muon-electron conversion

First tests of apparatus to look for muon-electron conversion were carried out at TRIUMF in December. Muon-electron conversion is a rare 'flavour-changing' interaction, and its branching ratio relative to muon capture has an upper limit of 7×10^{-11} (set by an experiment at SIN — see January/February 1978 issue, page 26).

The TRIUMF experiment aims to push this limit down by more than an order of magnitude to provide a stringent test of modern unified gauge theories. Various gauge theory models allow this conversion as well as other muon number violating processes (such as the decay of a muon into an electron and a photon) to occur at branching ratios down to 10^{-14}. In several models the conversion process is the most probable of the flavour-changing reactions.

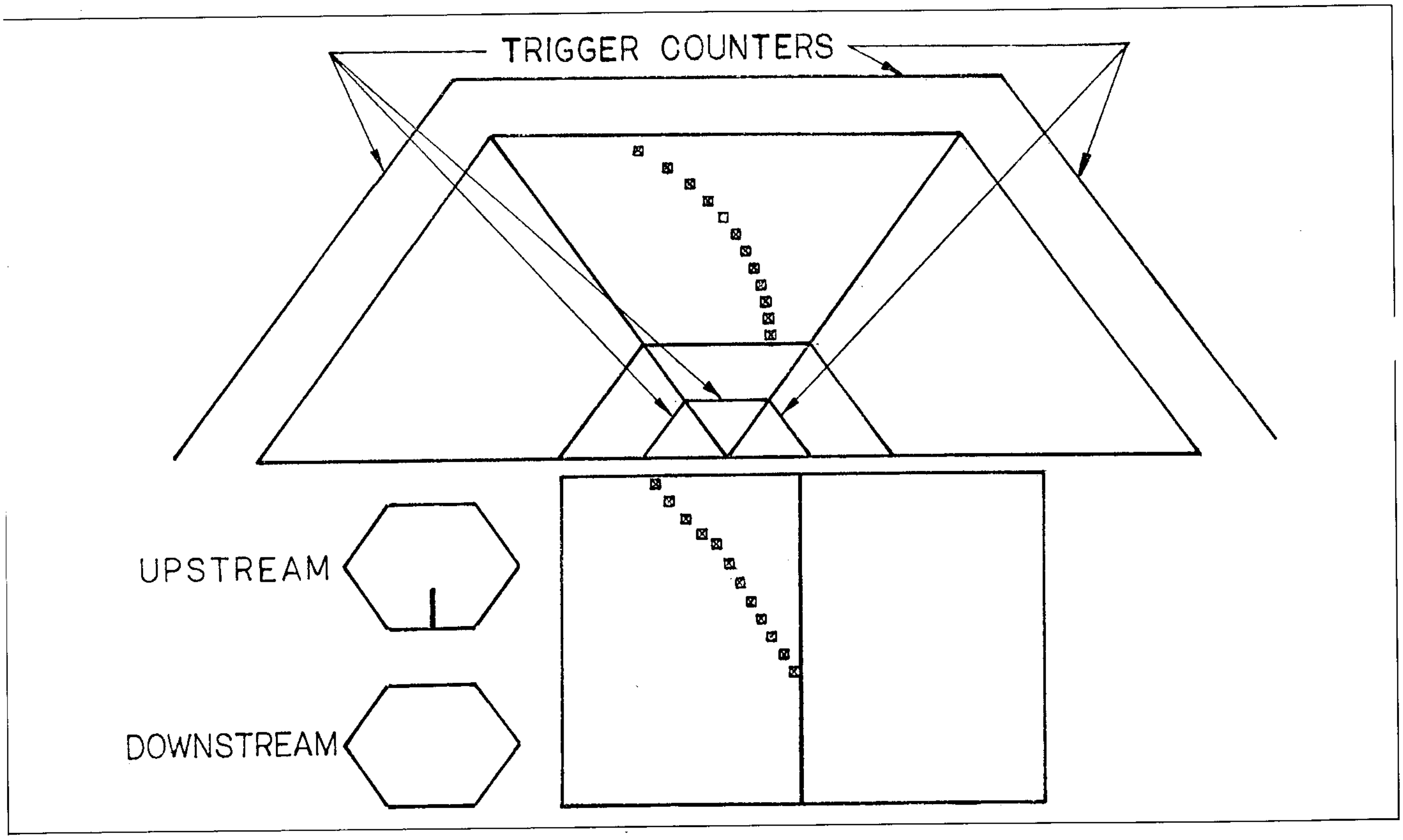
A collaboration from the National Research Council of Canada, the Universities of Victoria, British Columbia and Montreal, TRIUMF, Virginia Polytechnic Institute, the University of Chicago, Los Alamos and Carlton University, headed by D. A. Bryman and C. K. Hargrove, is



The drift chamber of the Time Projection Chamber at TRIUMF prior to its installation in the 'Chicago' magnet on the right. On the left is a hexagonal array of detector pads. The chamber is being used in an experiment looking for muon to electron conversion.

(Photo C. K. Hargrove)

A typical electron event seen in the TRIUMF Time Projection Chamber. The upper display shows three contiguous sectors of the chamber with a reconstructed track of an electron on a projection normal to the magnetic field. At the bottom, the orthogonal view of the track is reconstructed. The views at the lower left show in which sector of the array the event occurred.



doing the experiment. The apparatus is a simplified version of the Time Projection Chamber (TPC) developed by Dave Nygren and collaborators at Berkeley.

In the TRIUMF TPC a large volume atmospheric pressure drift chamber is placed in a uniform magnetic field. Electrons emitted following muon decay or capture are bent by the magnetic field as they pass through the chamber gas. The resulting ionization electrons are forced by an electric field onto proportional wire detectors at either end of the gas volume. The detectors measure the x-y positions of the ionization electrons directly, and their z positions are determined by time of drift. The large sensitive volume gives a solid angle of over 2π steradians. The drift system requires only two planes of wire detectors, leading to major simplifications in electronics and chamber hardware.

The drift chamber is 123 cm corner to corner with a drift region 68.5 cm long surrounded by field shaping wires 1.3 cm apart. It has a central high voltage wire plane requiring 6 kV when using a gas mixture of 80 per cent argon and 20 per cent methane. The magnet, provided by the University of Chicago, was originally designed by Val Telegdi. It has a field region 122 × 152 cm with a gap of 91.4 cm and the field uniformity is better than 0.5 per cent with 0.9 T at a current of 1.8 kA.

Preliminary tests were carried out in the December run. 70 MeV electrons from the decay of positive pions (branching ratio 1.2×10^{-4}) and 53 MeV electrons from the end point of the distribution from the decay of positive muons were used to study the performance characteristics. These measurements, together with estimates based on the performance of a small prototype chamber, indicate that the position resolution will be better than 225 μm in the x-y plane and better than 2mm in the drift direction, resulting in a momentum resolution of about 1 per cent.

People and things

Drasco Jovanovic

Willi Jentschke

On people

At the December meeting of the CERN Council, Jean Teillac was re-elected President with Paul Levaux and Günther Lehr re-elected Vice-Presidents. Karl Nielsen becomes Chairman of the Finance Committee in succession to M. Gigliarelli Fiumi. Godfrey Stafford remains as Chairman of the Scientific Policy Committee and Ingmar Bergström has been elected as a new member. Within CERN, the appointment of Fritz Ferger as Leader of the Intersecting Storage Rings Division has been extended for one year from 1 July. Giorgio Bellettini has succeeded Jean Perez-y-Jorba as Chairman of the ISR Experiments Committee.

A new Division has been set up for the ISABELLE project at Brookhaven. Called Magnet Construction and under the leadership of Edward Bleser, it has responsibility for the design and construction of the superconducting magnets for the storage rings. Mark Barton remains head of the Accelerator Division with responsibility for all other technical aspects of the machine. Kjell Johnsen, on leave from CERN, is acting as Deputy Project Head, assisting Jim Sanford.

On 20 December a ceremony was held at CERN in memory of Lew Kowarski. Jules Guéron, Charles Peyrou, Denis de Rougemont and Jean-Albert Mussard recalled different aspects of the career and personality of this remarkable man.

At Fermilab, Norman Ramsey has been elected President of Universities Research Association following the sad death of Milt White. The Physics Department at the Laboratory has been separated out from the Research Division. Drasco Jovanovic has been appointed Chairman of the Department with Tom Nash as Deputy. Shigeki Mori succeeds Tom Kirk as Head of the Neutrino Department and Marvin Johnson will head the Research Services.

On 4 February a ceremony was held at the DESY Laboratory to mark the honorary award of Professor Emeritus to Willi Jentschke by the University of Hamburg. Wilhelm Walcher and Karl Strauch were the main speakers at the ceremony.

Herman Feshbach from MIT became President of the American Physical Society in January. He is well known for his theoretical work in nuclear physics. He is a member of the National Academy of Sciences, the Nuclear Physics Commission of IUPAP and the Board of Trustees of AUI.

The 1980 Dannie Heinemann prize for Mathematical Physics has been awarded to James Glim of Rockefeller and Arthur Jaffe of Harvard for their contributions to quantum field theory.

New computer for CERN

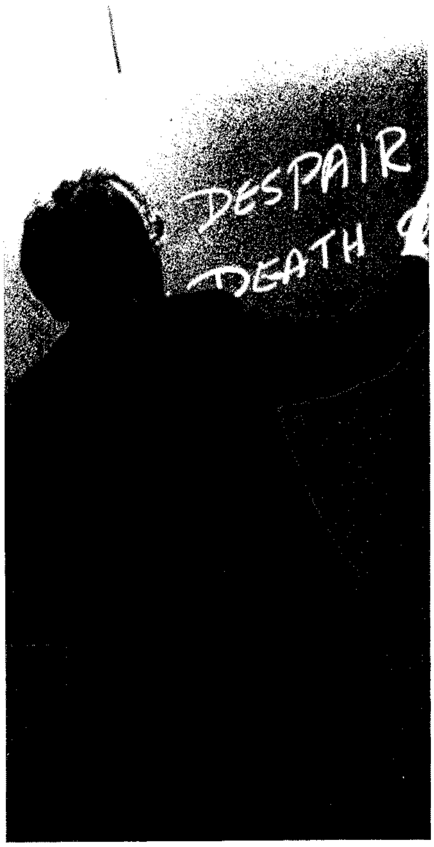
Now arrived at CERN is a new Control Data Corporation (CDC) Cyber 170 Model 720 computer, which will soon replace a CDC 6400 machine as one of the two front-end processors for the main 7600 computer. The second front-end processor is a CDC 6500.

Records

In December, both 'big machines' broke records for intensity of accelerated beam. The Fermilab main ring went to 2.562×10^{13} protons at 400 GeV (beating 2.528×10^{13}

1979 Nobel Prizewinner Sheldon Glashow caught in an apprehensive mood in a recent visit to CERN.

(Photo CERN 301.12.79)



achieved in 1977). Its record at 350 GeV is 3.703×10^{13} set in February 1979. The CERN SPS, thanks to magnificent performance from the PS, which supplies it with particles, reached 2.58×10^{13} protons at 200 GeV, but more is expected with the implementation of the Intensity Improvement Programme.

Conferences

From 17–24 March a Europhysics Study Conference on the Unification of Fundamental Interactions is being held at Erice in Sicily. It will cover present thinking on unified field theories with emphasis on schemes to unify the strong, electromagnetic and weak interactions and super-unification schemes to pull in gravity also. J. Ellis, S. Ferrara and P. Van Nieuwenhuizen are Conference Organizers.

The Second Novosibirsk/SLAC Conference on Storage Ring Instrumentation is taking place at the Stanford Linear Accelerator Center from 5–11 March. It will cover the latest developments in storage ring detector construction and performance. Pier Oddone at SLAC is Program Chairman.

An International Conference on Experimentation at LEP will be held at the University of Uppsala in Sweden from 16–20 June. It will review experimental techniques relevant to the proposed high energy electron-positron ring. It is planned that CERN will take this opportunity to initiate a LEP detector development programme by offering some technical and financial assistance to those people who wish to work on new and interesting detector developments. It is therefore important that all novel ideas, no matter how preliminary, be presented in the poster sessions of the Conference. Tord Ekelöf at CERN is Scientific Secretary. Sessions will cover particle identification, calorimetry, track chamber spectrometers, data handling, future developments and LEP detector set-ups.

On 2–13 July an Advanced Studies Institute on the Techniques and Concepts of High Energy Physics will be held at St. Croix in the Virgin Islands. The organization of the Institute involves NATO, the US Department of Energy, Fermilab and the University of Rochester. It is designed for advanced graduate students and recent Ph.D. experimentalists. Further information from Tom Ferbel, Fermilab, Mail Station 888, P.O. Box 500, Batavia, Illinois 60510.

On 28–31 May an International Symposium on the History of Particle Physics will be held at Fermilab covering elementary particles, cosmic rays and quantum field theory in the 1930s and 40s prior to the era of the great accelerators. An eminent gathering of physicists and historians will be present. Further information from L. Hoddeson, Fermilab, Mail Station 109, P.O. Box 500, Batavia, Illinois 60510.

On 11–15 August the Second International Topical Meeting on Muon Spin Rotation will be held at the University of British Columbia, Vancouver. Further information can be obtained from J.H. Brewer at TRIUMF.

The Proceedings of the International Conference on High Energy Physics organized by the European Physical Society in Geneva, Switzerland, from 27 June to 4 July 1979, are now available on order from Mrs. J. Lefley, Scientific Information Service, CERN, 1211 Geneva 23, Switzerland, price 30 Swiss francs for the two volumes, post free.

SLAC Single Pass Collider

It has been decided at the Stanford Linear Accelerator Center to put money into research and development for the Single Pass Collider Project (see December 1979 issue, page 404). The aim is to achieve 50 GeV colliding electron-positron beams with modest luminosity in a system capable of rapid construction at comparatively low cost. It is hoped to present a proposal to the Department of Energy in the next few months and the most rapid construction schedule envisages colliding beams by 1984.

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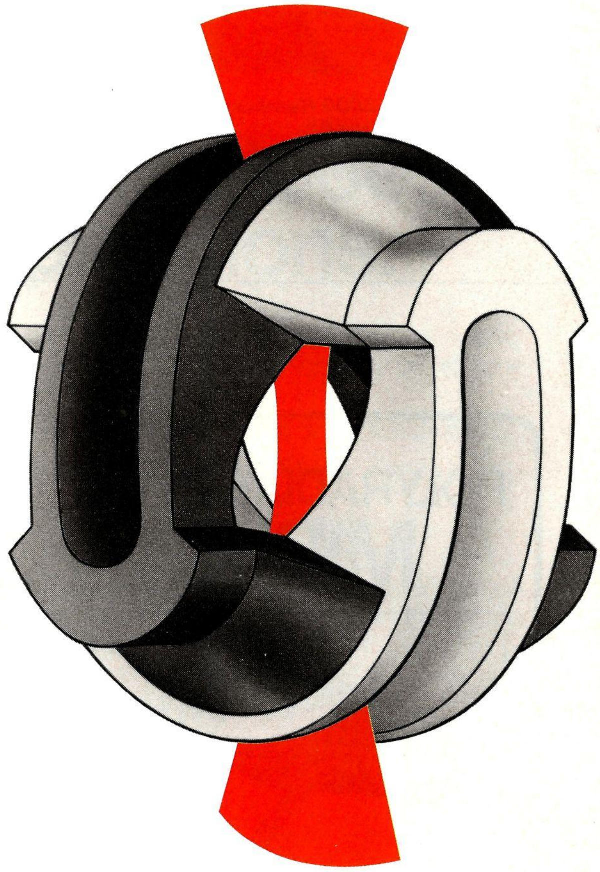

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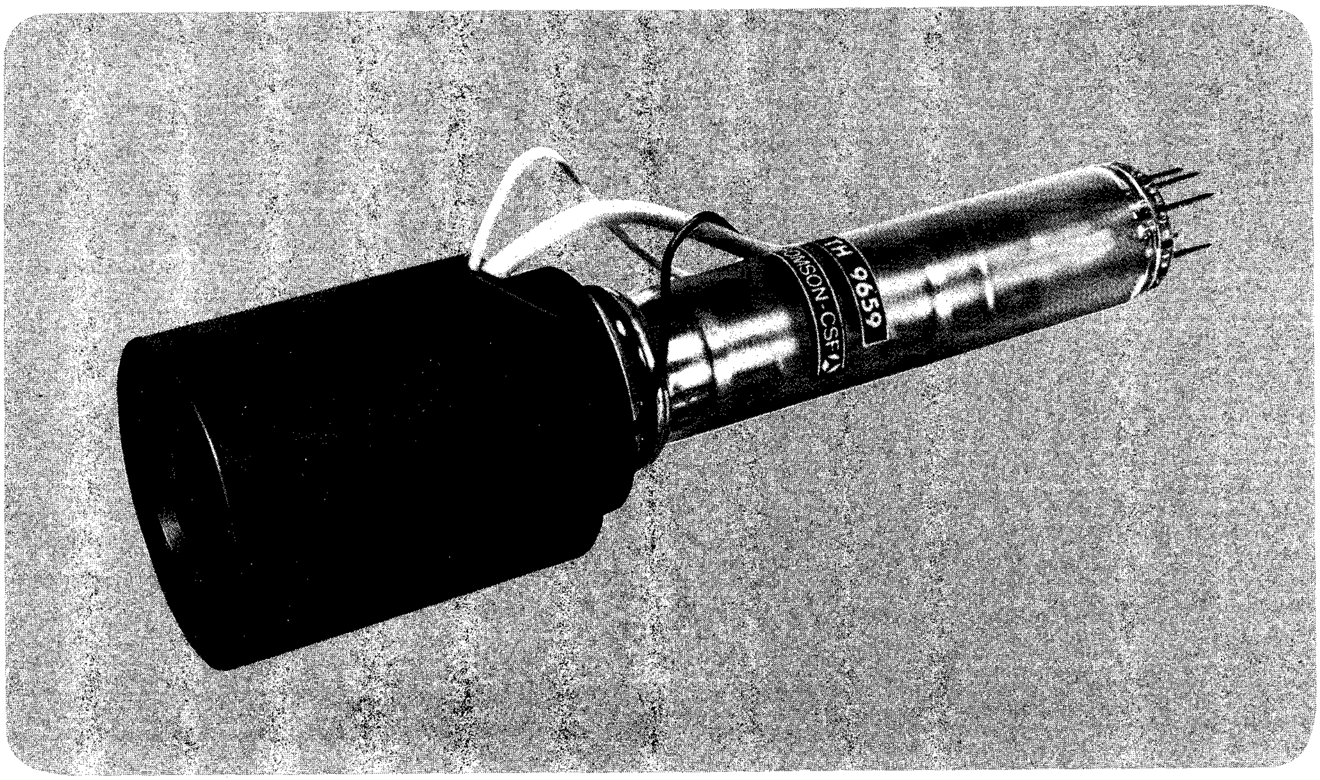

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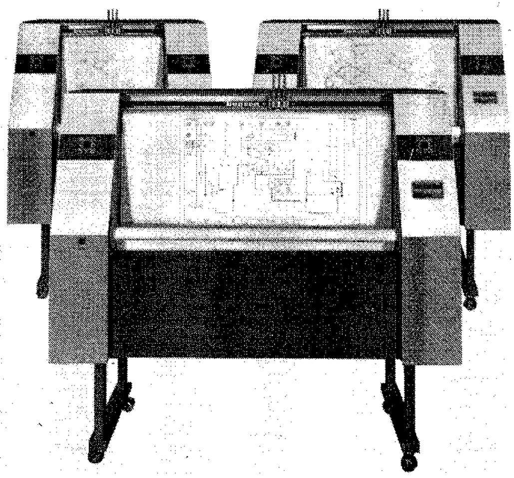

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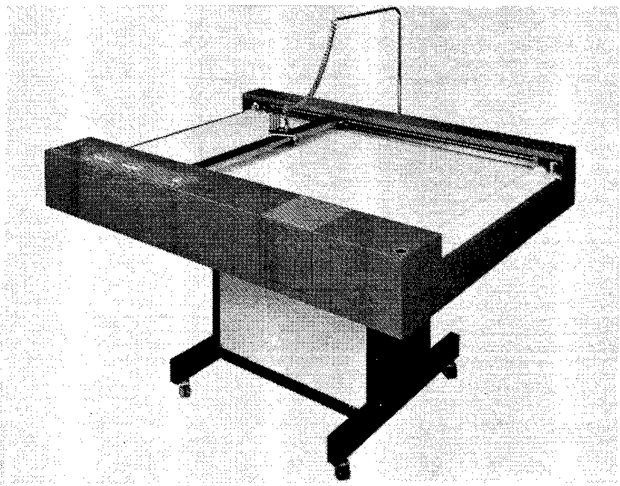

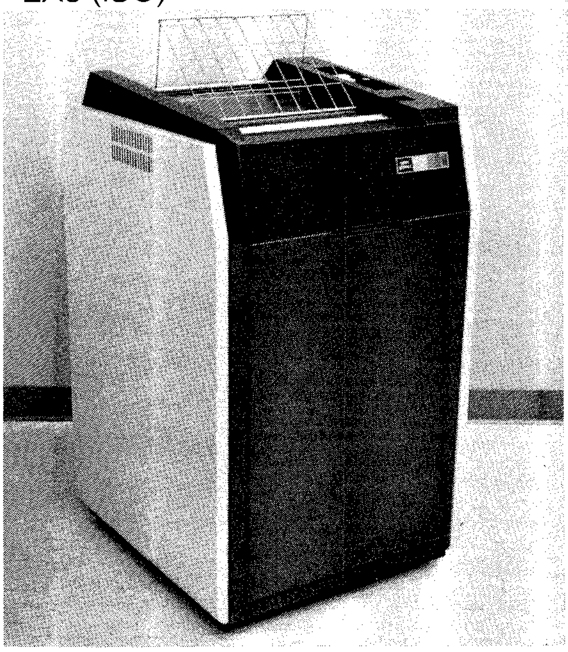

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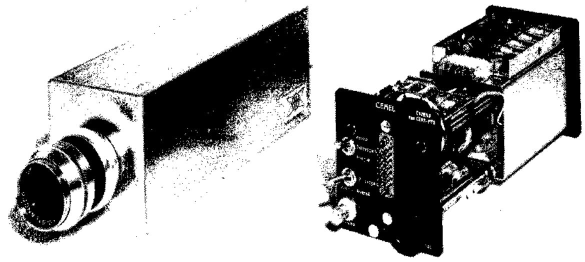

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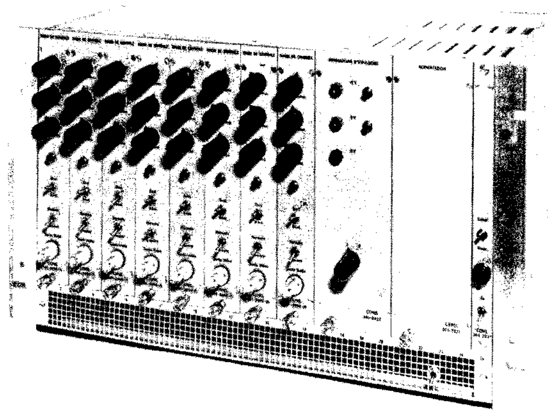

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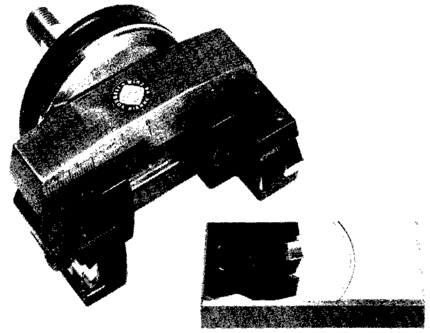

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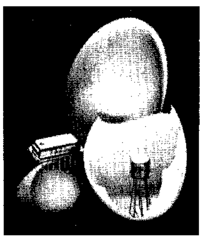

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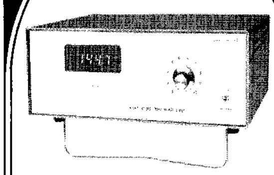

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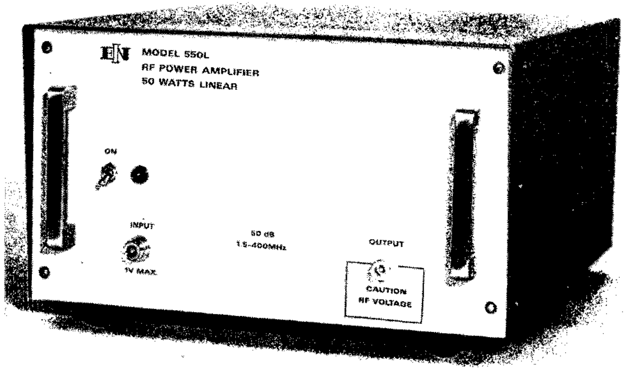

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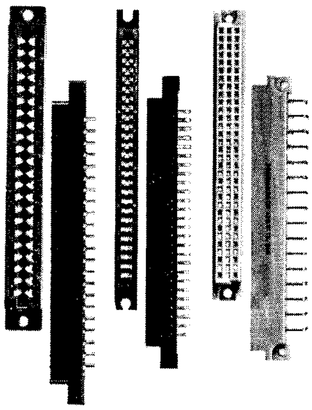

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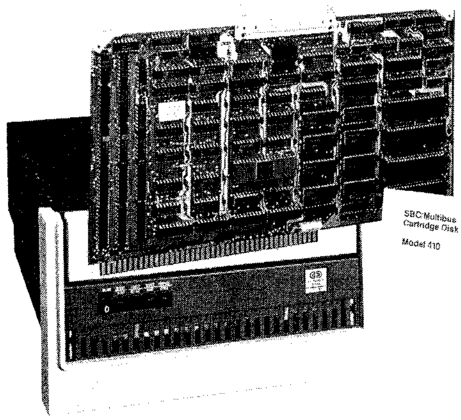

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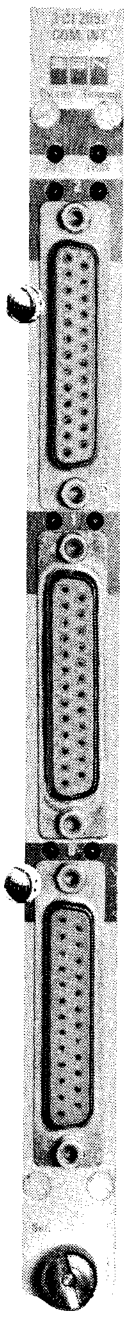

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— CAMAC/external devices interfacing

— Front-end I/O processor for Intelligent Crate Controllers
This unit is specifically useful when connected with our ACC 2099/ACC 2103 Auxilliary Crate Controllers to speed-up the I/O transfers when processing time is critical.

— main computer/Intelligent Crate Controller link, etc, etc.

France: ORTEC Sarl; 7, rue des Solets; Tel. (1) 6872571 - Tlx 202553F, F-94 RUNGIS – **Germany: SEN ELEKTRONIK GmbH**; Brandstücken 11; Tel. 041 802046 - Tlx 2163705d, D-2000 HAMBURG 53 – **DIDAS Digital System**; Radspielstrasse 8; Tel. 089 916710 - Tlx 529167d - D-8000 MÜNCHEN 81 – **Switzerland: SEN ELECTRONIQUE SA**; CP 39; Tel. (022) 442940 - Tlx 23359ch - CH-1211 GENÈVE 13 – **SEN ELEKTRONIK AG**; Austrasse 4; Tel. (01) 9455103; Tlx 58257ch - CH-8604 VOLKETSWIL – **United Kingdom: SEN ELECTRONICS LTD**; London Street; Chertsey; Tel. 9328.66744 - GB - KT168AP SURREY – **OFFICES THROUGHOUT THE WORLD.**

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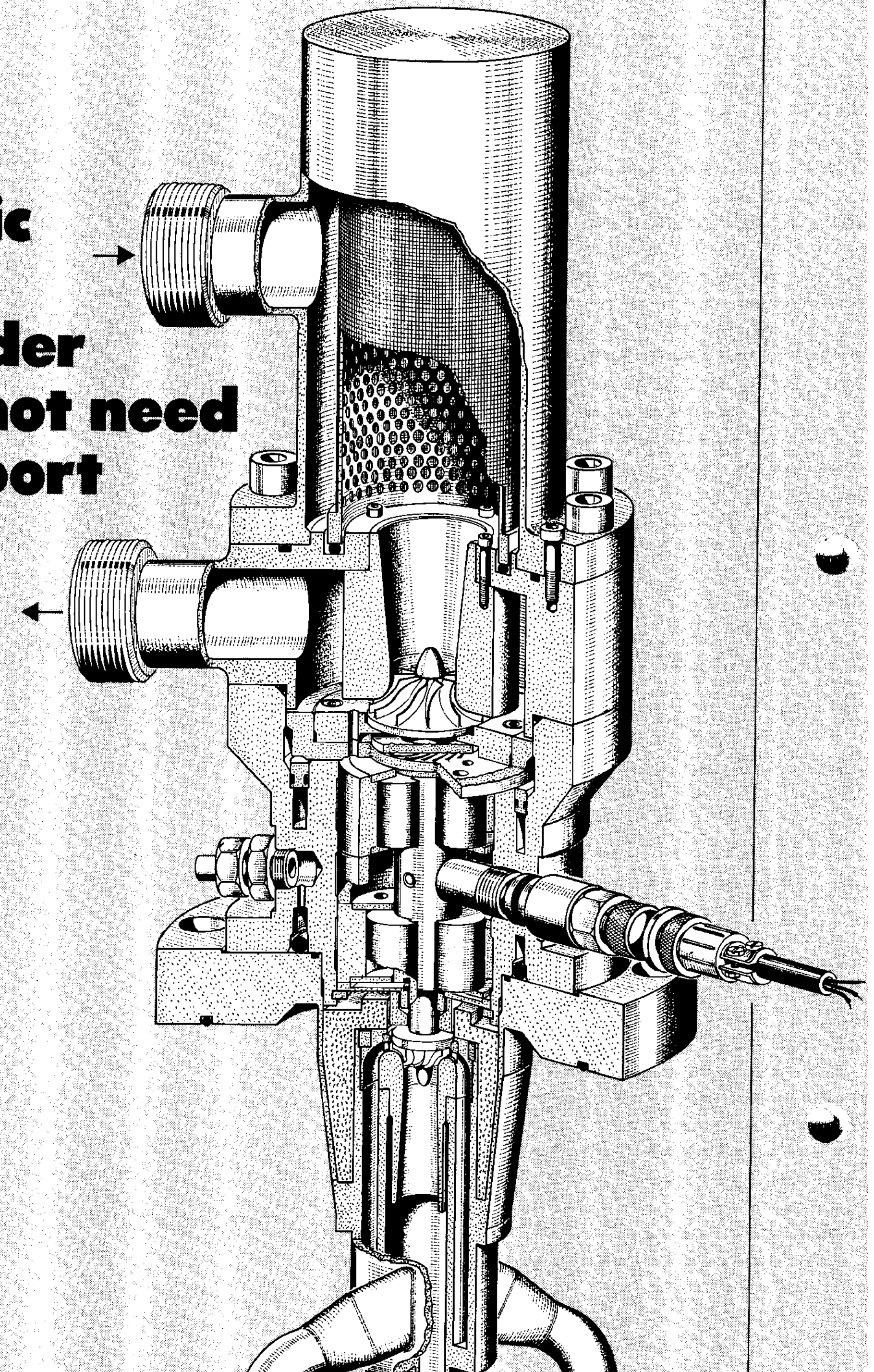
The cryogenic gas bearing turboexpander which does not need outside support

(unlike others...)



Usual gas bearing systems depend on an external source of pressurized gas. We have succeeded in developing a self-supporting autonomous system.
The shaft floats on gas cushions created by its own rotation. It spins—amazingly—at several hundred thousand rev/min without the slightest wear. Neither bearing gas nor seal gas have to be diverted from the process. Controls are fewer and simpler.
A story too fantastic to believe ... but true:
Our turboexpander is at the heart of dozens of cryogenic plants around the world.

Sulzer Brothers Limited
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Cryogenics Department
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