CERN COURIER

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CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1500 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3200 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 410 million Swiss francs in 1975.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of 400 GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1975 is 237.9 million Swiss francs and the staff totals about 450.

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Cover photograph: The CERN Directors General are taken for a ride. J.B. Adams (left) of Laboratory II and W.K. Jentschke of Laboratory I enjoy a golf-cart tour of the SPS tunnel where installation of the 400 GeV proton synchrotron is well advanced (Photo B. Sagnell)

53rd Session of CERN Council

The Council met on 18, 19 December under the Presidency of Professor W. Gentner

The Council Session opened with the reports from the Directors General — W.K. Jentschke for Laboratory I and J.B. Adams for Laboratory II. Since we covered the construction of the 400 GeV synchrotron of Lab. II in the December issue, we concentrate here on an abridged version of the talk of Professor Jentschke mainly devoted to the developments in particle physics:

Performing an experiment is like opening a window looking out into the physical world. It brings new features into view and helps us to understand the nature of the world in which we live. In high energy physics, experiments are used to build a picture of the basic forms of matter and of the forces which determine the characteristic structure of the world. Just as the perception of beauty in a painting depends upon appreciation of the relationships between the colours and shapes in its composition, so our present understanding of Nature depends upon seeing relationships between the views offered by many different experiments. Over the ast few years, the view through our windows has been changing rapidly and 1974 may come to be seen as a landmark in our understanding of elementary particles.

The main topics of this survey are our present ideas on the possible internal structure of the nucleons (the proton and neutron) and the search for an underlying unity of the three forces in particle physics: the weak force (responsible for radioactive decay), the electromagnetic force (responsible for forming atoms and molecules) and the strong force (responsible for binding nucleons to form nuclei). Until recently, these forces have looked very different from one another but now, for the first time, we can see that they could be different facets of a single basic form of interaction.

25 years ago the term 'elementary particle' had a relatively simple meaning. Only a few particles were known; their roles seemed — with some exceptions — fairly evident and the task of the physicist was to understand the forces between them. We are now confronted with a tremendous proliferation of hadronic states (particles which interact via the strong force). A very important part of our research programme at CERN has been the study of these states. This careful and painstaking programme has assembled an impressive body of detailed information which is essential for complete tests of the theories which attempt to provide a framework for understanding such a complex array of particles.

This work is by no means over — a number of important questions remain to be answered but, nevertheless, a remarkable synthesis of all this information is provided by a theory which is extraordinarily successful even in its most naïve form. In this model, the observed hadronic states are assumed to be composed of three basic 'building blocks' called quarks. Putting these quarks together according to certain rules, the properties of the many different observed hadron states can be reproduced in remarkable agreement with the data. In particular the nucleons would contain three quarks, while mesons would be formed from quark and antiquark pairs.

There is a very good analogy with the atom, in which the study of atomic spectroscopy — the analysis of the light emitted by atoms changing from one state to another — revealed the detailed electronic structure of the atom. The spectroscopy of nuclear energy levels also told us about the composition of the nucleus. Similarly, by systematic studies of the states of hadronic matter, we gain clues about their internal structure. Also, another type of experiment has recently yielded striking discoveries which tell us about nucleon structure.

Results obtained a few years ago suggested that there are point-like constituents (partons) within the nucleon; these are required to explain the character and high occurrence of events in which the electron is deflected by a large angle on hitting the nucleon. These experiments probed the nucleon structure as revealed by the electromagnetic interaction. At CERN we have performed experiments in the heavy liquid bubble chamber, Gargamelle, using a beam of neutrinos which interact with the nucleon only via the weak force. The neutrino results are also most easily explained by the presence of partons within the nucleon, this time probing the structure as revealed by the weak interaction.

The data obtained in these electron and neutrino experiments can be interpreted in some detail since the forms of the electromagnetic and weak interactions are quite well understood. We are led to an extraordinary result: these two experiments, different in almost every respect except for the common target — the nucleon — can be explained with surprising success by a simple model in which the partons have just the same properties as the quarks proposed as nucleon components by the analysis of hadron spectroscopy. The results of the SLAC and CERN nucleon scattering experiments can be taken together to 'measure' the parton electric charge and the values agree with the presence of three quarks having the expected fractional charges (i.e. 1/3 or 2/3 of the charge on an electron).

Turning to high energy collisions between protons, experiments at the CERN Intersecting Storage Rings have shown that in the strong interactions also, effects occur which can be attributed to the presence of point-like constituents. This follows from the discovery of processes in which hadrons are emitted with high momentum at large angles to the line of collision over 10 000 times more frequently than expected. Studies of this phenomenon have continued, for example using the large Split Field Magnet where the momenta and charge of many of the accompanying particles has been measured. The first results show that a neutral pion of high transverse momentum is often accompanied by a positive particle, also of high momentum, going in approximatively the opposite direction. This is what would be expected from 'hard' collisions between point-like constituents of the quark type from which the proton could be built.

1974 brought confirmation of the discovery at CERN of the neutral current interaction. It is of the greatest importance in our understanding of one of the basic forces of nature and may lead us to a unification of the theories of the weak and electromagnetic interactions. This would be a synthesis as profound as that achieved by Maxwell when he united the phenomena of electricity and magnetism in one theoretical framework.

The result also comes from the experiment in which Gargamelle was exposed to a beam of neutrinos. Prior to this experiment, the weak interaction was believed to have only the charged current form — a neutrino (which carries no electric charge) would always change into a charged lepton when interacting with matter. The Gargamelle experiment saw interactions due to neutrinos in which a charged lepton was not created and the neutrino is presumed to remain unchanged.

The neutral current interaction has important implications in other areas of physics (for example, in astrophysics to explain the energy loss process and the collapse of stars to form supernovae) in addition to the possibility of a unified theory of the weak and electromagnetic forces. Attempts to find such a theory led to the suggestion that this form of interaction might exist. The discovery may also have implications for nucleon structure and be related to the existence of new forms of matter.

As with most discoveries it poses many new questions. Charm enters the field of particle physics for the first time! Before the discovery of neutral currents, it was thought that one of the best tests of the existence of this interaction was provided by the decay of neutral kaons into two muons. The search for this decay revealed that it occurs much less frequently than it should if the neutral current form of the weak interaction is important in Nature. We are thus faced immediately with a serious difficulty: Why does the kaon not decay more often to two muons?

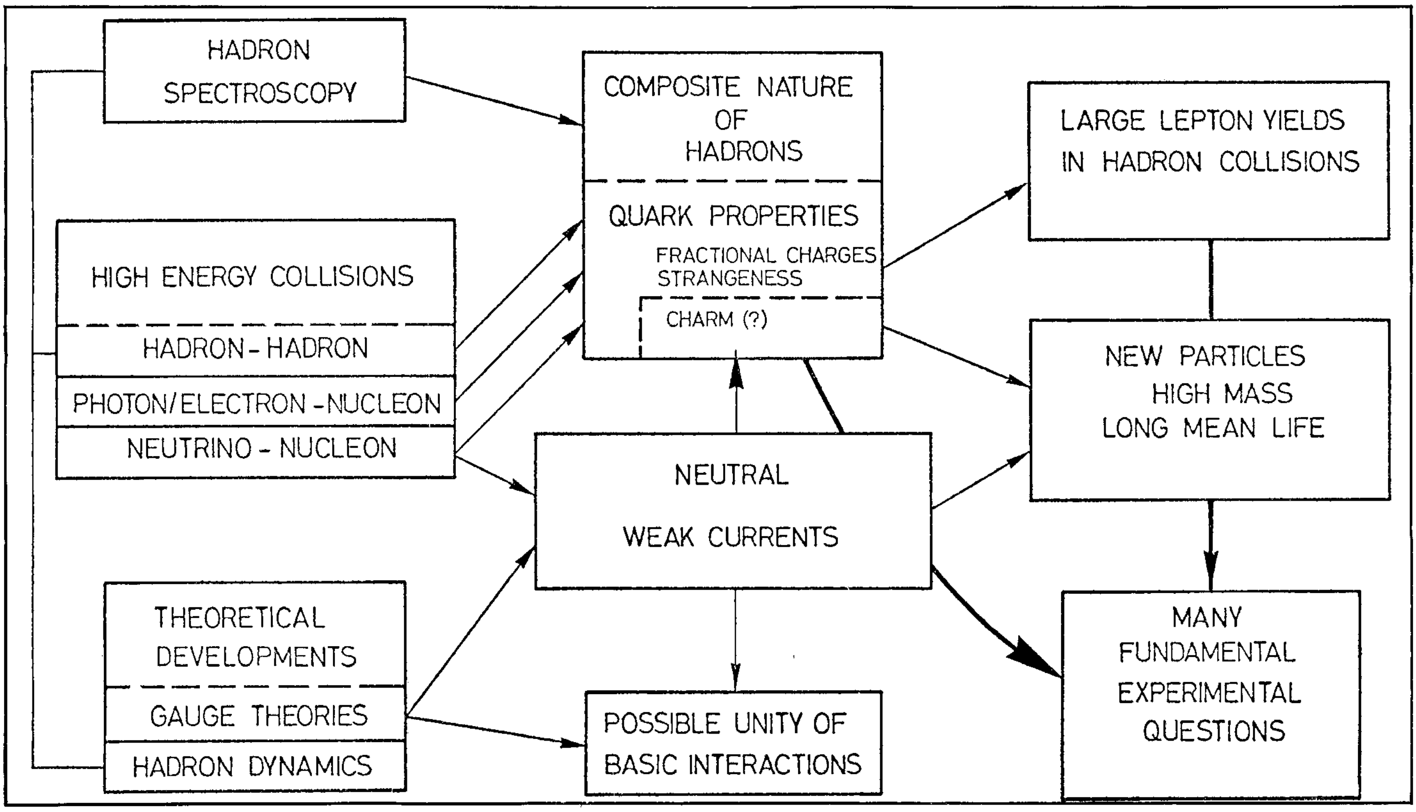
There is an important difference between the kaon decay process and the neutrino interactions. The kaon has an attribute, or quantum number, called strangeness — it carries one unit of strangeness while two muons have zero strangeness. In the decay, therefore, the strangeness changes by one unit. In the neutrino interactions, both the initial and final states have zero strangeness and there is no change in this number.

This difference provides a clue to a mechanism which gets us out of the kaon decay difficulty but at the cost of introducing a new quantum number called 'charm'. In all strong and electromagnetic interactions, the total charm is presumed to be conserved (like electric charge or strangeness) but not in weak interactions. In terms of the quark model this introduces a fourth type of quark, one carrying charm to accompany the one carrying strangeness. Introducing such an additional 'building block' leads to a whole new set of possible particle states. Particles carrying charm have not been recognized so far, suggesting they may be heavy. However, the suppression mechanism in the kaon decay cannot work if they are more than about 2 GeV in mass.

In analogy to the production of strange particles in pairs, the charmed particles should also be produced in pairs by the strong interaction. The lowest mass particles carrying charm are expected to decay with a rather short life time (about 10^{-13} s) but via the weak interaction only; the products of decay will sometimes include an electron or muon and it is also expected that particles carrying strangeness would often occur. One possibility is a meson formed by a charmed quark plus a charmed antiquark; the meson itself would have no charm, but might reveal its hidden beauty only by the circumstances of its birth or death!

A second question raised by the discovery of neutral currents is that of the existence of the neutral intermediate vector boson. Most of our knowledge of the weak interaction has come from studying the decay of unstable particles and nuclei. In these processes the interaction seems to take place at a point in contrast to the case for the strong interaction, which has a characteristic range of about 10^{-13} cm and is mediated by the exchange of mesons between the interacting hadrons. However there are compelling reasons to believe that the weak interaction must also be mediated by the exchange of particles, called intermediate vector bosons. These would have high masses, corresponding to the very short range of the weak interaction and, so far, no evidence of the production of these bosons has been found.

The inter-related aspects of experiment and theory which are dominating high energy physics at the present time.



The existence of the neutral current implies a neutral intermediate vector boson to accompany the two charged ones required for the ordinary charged current interaction. In its simplest form one of the theories providing a unification of the weak and electromagnetic interactions predicts masses of about 75 GeV — well beyond the range of present accelerators.

Experiments looking for the direct production of electrons and muons in the collisions of high energy protons were among the earliest performed at the ISR. They discovered something else — the unexpectedly high frequency of emission of hadrons with large sideways momentum. With more sophisticated apparatus, and taking advantage of the new heights of performance reached by the ISR, the production of single electrons has been observed this year. The discovery was paralleled by similar observations on muons and electrons at the FermiLab.

There are two remarkable features of this observation: over the range of transverse momentum covered, the yield of single electrons follows the same law as that for hadrons (though at a level about 10 000 times smaller). Moreover, the ratio seems to be independant of the proton energy over a rather wide range, even though the total hadron yield changes by an order of magnitude. The experiment at the ISR is also able to show that these electrons do not arise as decay products of already known particle states. We are faced with a new phenomenon and one of the first speculations is that this may be related to the production of new forms of matter perhaps charmed particles or the intermediate vector boson.

Towards the end of the year we received news from Brookhaven and Stanford of the discovery of a new particle state with a mass of 3.1 GeV. At Stanford a second, even heavier, particle with a mass of 3.7 GeV was also found. The most outstanding property of the new particles is their lifetime which is exceptionally long for states of this mass; at 10^{-20} s it is about a thousand times longer than would be typical for hadronic states of 3 GeV mass. This presents a real stumbling block to all attempts to understand the new particles.

One possibility is that they are related to the neutral intermediate vector boson. If so, the mass is at least an order of magnitude smaller than expected and should show up in other properties of the neutral current interaction. On the other hand the observed coupling of the particle to electron-positron pairs has about the right strength. It is also very attractive to speculate that they are connected with charm. They may be examples of the meson state with hidden charm (composed of a charmed quark and charmed antiquark pair). The mass is reasonable but it is difficult to understand the long lifetime.

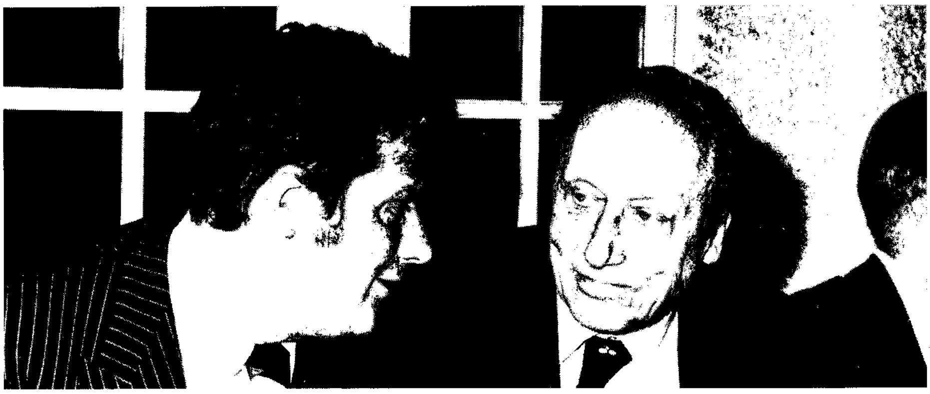
There will surely be other states to accompany these new forms of matter and many experiments will need to be done before we can place them in their proper context within the framework of our understanding of elementary particle physics.

CERN has already a very important programme of experiments searching for new particles. One, which is specially designed to look for charmed particles, is at present taking data at the ISR. At the PS, an experiment, which may be able to detect particles like those found at Brookhaven and Stanford, is scheduled to start in March 1975. Several groups with running experiments have switched their attention to search for effects related to the new particles and many proposals for experiments are being prepared.

This activity is a reflection of the excitement about the recent developments in the field of particle physics.

People in the news :

1. P. Levaux (left) in conversation with W. Gentner
2. A. G. Ekspong
3. W. Paul



1. *CERN 179.12.74*

2. *CERN 181.12.74*

3. *CERN 192.12.74*

Budgets for the coming year

As could be expected in the prevailing financial climate in Europe, the discussions on the budgets of CERN for the next few years were not easy and it was decided to postpone decisions on the longer term levels of expenditure.

CERN budgets are, in principle, set by the 'Bannier procedure'. At the December Council Session the figure for the next year is voted, with a firm estimate for the succeeding year (to be changed only under exceptional circumstances) and provisional determinations for the two years after that. This procedure enables CERN to plan its programme rationally over several years, with knowledge of the resources which will be made available, and enables Member States to plan their expenditure on science long-term with knowledge of the extent of their commitment to CERN. The figures are updated each year following an agreed 'cost variation index' which incorporates movements in salaries and materials costs in the CERN Member States.

The present high rate of inflation resulted in a high figure for the index to be applied to the firm estimate agreed the year before and, in view of the pressures on national budgets, the Council decided to establish a budget of 410 million Swiss francs for CERN Laboratory I for 1975. This implied a cut-back of about 10 MSF on the firm estimate. The figures for succeeding years remain to be further discussed in the course of 1975 together with the implications of budget cuts on the physics programme of CERN.

Several delegates and Professor Jentschke urged a return to the Bannier procedure as soon as possible so as to regain the ability to plan long term which has proved of such great benefit to the Member States and to CERN.

The budget for Laboratory II for 1975 was voted as 237.9 MSF which is in accordance with the budget profile agreed in 1971 for the construction years of the SPS.

The contributions (which are based on net national revenues) of the Member States are adjusted every three years on the basis on United Nations statistics. The figures for the Laboratory I budget, where all the Member States are involved, are given below. The contribution of the Federal Republic of Germany is limited to the maximum percentage (25 %) and that of Greece is set at a special rate (0.46 %) to take account of its economic situation. (The Laboratory II figures are slightly different since Greece does not take part and the

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maximum percentage paid by Germany is 25.4 %).

Austria	2.22
Belgium	4.01
Denmark	2.28
France	21.47
Germany (Fed. Rep. of)	25.00
Greece	0.46
Italy	13.33
Netherlands	5.30
Norway	1.60
Sweden	4.55
Switzerland	3.38
United Kingdom	16.40

Elections

With this Council Session, the three year term of office of W. Gentner (Federal Republic of Germany) as President of the Council came to an end. Warm tributes were paid to Professor Gentner's abilities and his efforts on behalf of CERN during those years. He is to be succeeded by P. Levaux (Belgium) who was elected President from 1 January 1975. Dr. Levaux has an impressive record in science administration in his own country and distinguished himself particularly in CERN affairs by his brilliant leadership of the work of the Finance Committee during three years as its Chairman.

The Vice-Presidents of the Council, T.G. Kouyoumzelis (Greece) and G.H. Stafford (UK) were re-elected as was the Chairman of the Finance Committee, M. Lemne (Sweden). A.G. Ekspong has completed a three year period as Chairman of the Scientific Policy Committee and will be succeeded by W. Paul.

PS: 10^{13} ppp

An intensity of 10^{13} protons per pulse was reached in the proton synchrotron (PS) in a test run held on 10 December. This test was a repeat of the one held on 7 November (see December COURIER, p. 423), finishing the year with a new record and achieving the required intensity set out in the PS improvement programme.

However, two incidents had troubled the days preceding the test: a small fire, fortunately put out very quickly, started in a transformer of a power supply of the Booster (PSB) and there was a water leak in part of the transfer line from the PSB to the PS. The damage was repaired rapidly and finally all was ready for 10 December.

The test began by adjusting the linac beam to produce long (100 μs) high intensity (85 mA) pulses which were then injected over 15 turns into the four rings of the PSB, where the energy was raised to 800 MeV. With dynamic programmation of the working point and compensation of both transverse and longitudinal instabilities, 1.4×10^{13} protons per pulse were ejected towards the PS. The transfer line had to be matched to 800 MeV for the protons to be injected into the PS. With experience gained during previous tests it proved possible to compensate more rapidly the resonances up to transition.

After a day of effort and a final run on each machine to obtain the best possible adjustments, the 10^{13} ppp barrier was finally broken, maximum intensity measured at transition reaching 1.019×10^{13} ppp.

However, this is only a beginning and much remains to be done before a beam of such intensity with the emittance required by users can be obtained under working conditions. The most difficult will be the development of a new ejection system (continuous transfer) for the 400 GeV proton synchrotron (SPS). This is being installed and tests at high intensity will be carried out during this year.

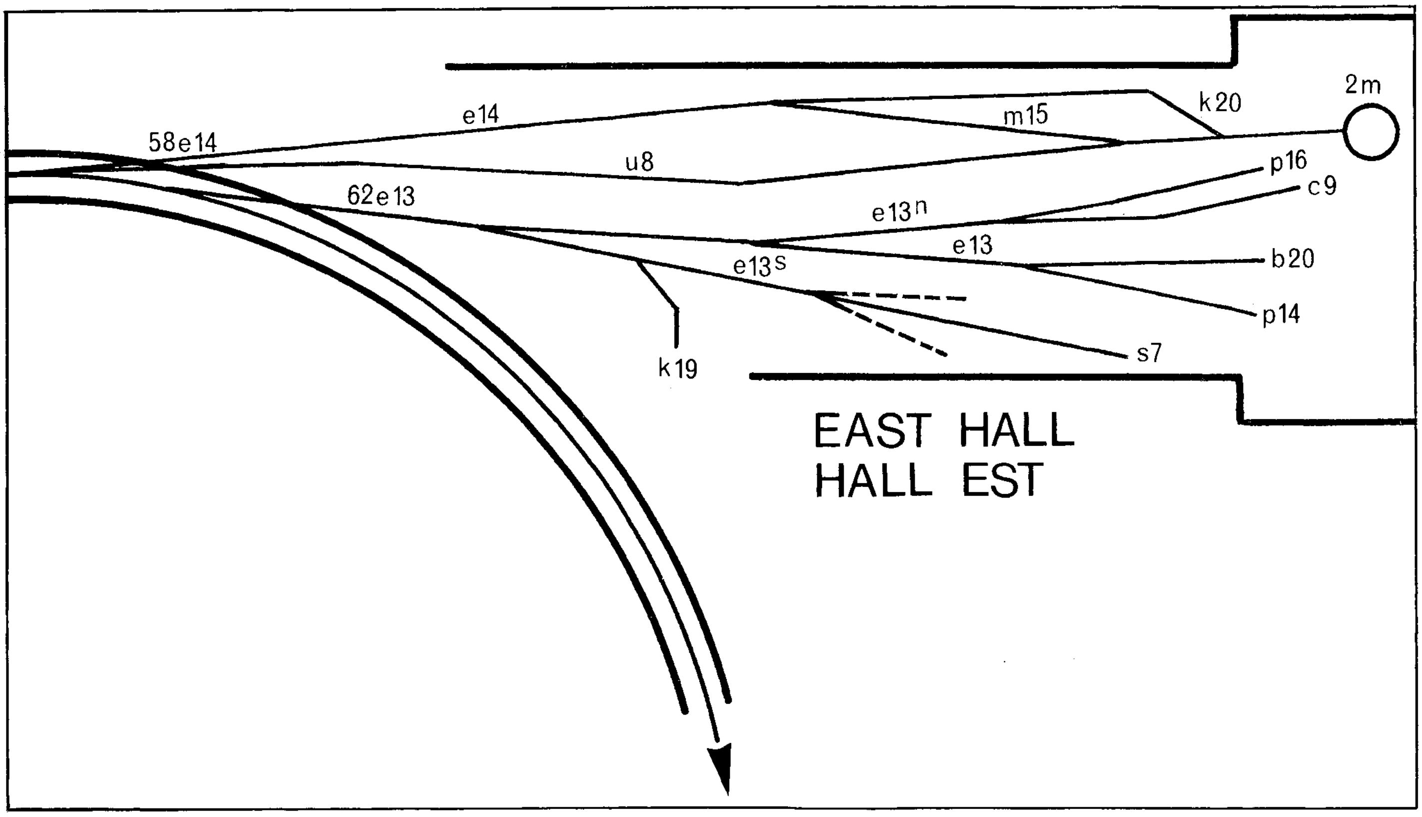
Annual shutdown

From 2 January to 19 February there is an overhaul of the Laboratory I machines — the 50 MeV Linac, the 800 MeV Booster, the Proton Synchrotron and the Intersecting Storage Rings plus beam-lines and the experimental halls. The PS accelerated its last 1974 protons on 21 December, to allow a fall in the levels of induced radioactivity during the end of year holidays before the shutdown work began. The shutdown is also being used for modifications and to install new apparatus. Some of the major operations are described here.

Now that construction of a new Linac has started, work on the existing machine is being kept to the minimum necessary to ensure that it does its job until its replacement comes into service. Diagnostic facilities are being improved by installing additional equipment to monitor the ion source parameters, the r.f. cavity phases and the beam energy spread in the 50 MeV spectrometer line. New units are being added to the r.f. amplifiers to allow the cavities to be decoupled one from another and thus be independently adjusted.

Preliminary work is being done on the injection line of the Booster (civil engineering, vacuum, laying of cables and cooling water piping) in preparation for the installation in 1975 of a new six-level beam distributor (four levels for the PSB rings and two for beam dumping). In the rings themselves: magnet positions are being realigned where necessary; a

The organized layout of beam-lines in the East Experimental Hall of the proton synchrotron. The 2 m bubble chamber (top right) is being moved by 13 m (taking its beam-lines with it) so as to clear more space for experiments with electronic detectors in the Hall. This more extensive use of the East Hall will enable the North and South Halls to be progressively closed down.



zero harmonic quadrupole correction system (using the correction windings of the quadrupoles and allowing individual operation on each ring) is being installed; the beam dump installation will be modified to enable beams from the four rings to be absorbed separately; a quadrupole pick-up electrode and a horizontal and vertical electrostatic deflector, are being installed for more precise monitoring of the transverse behaviour of the beam; glass dosimeters are being introduced to measure the radiation doses received by the installations and samples of the araldite insulation of the main magnet; the transfer line to the PS is receiving five new vertical dipoles and a correction dipole and the 800 MeV spectrometer line is being adjusted.

In the main PS ring, magnets are being realigned where necessary and, as usual, repairs are carried out on magnets at the 'hot' points of the machine where end laminations come adrift. Four magnets are being repaired by clamping plates on the end blocks and a fifth is being replaced by an overhauled unit. In the auxiliary magnet system, sixteen sextupoles are being replaced by compact versions, and nine injection skew quadrupoles installed to complete the skew quadrupole system.

Forty-five straight sections (nearly half the total) are to be dismantled and modified. A new beam loss monitoring system is being installed in all the straight sections, increasing the sensitivity in relation to the previous system by a factor of a hundred and allowing measurement of losses down to 50 MeV beams. The detectors are faster and give a resolution of 50 ns (an improvement by a factor of a thousand). They are moreover radiation resistant and calibration will be possible using a low intensity radioactive source.

To prepare for the continuous transfer system for injection into the SPS, enlarged vacuum chambers are being fitted in eight magnets. Th intermediate straight sections are also being replaced and the auxiliary magnets mounted there changed or moved. Also two r.f. cavities are being moved and a 200 MHz cavity installed for prebunching of the beam before its transfer to the SPS.

Damping resistors are being fitted in the 98 vacuum pump mainfolds to damp a resonance at about 1.5 GHz, which enlarges the beam longitudinally. The beam control system is being modified to give greater flexibility in cases where great variations in beam intensity are required from one cycle to the next.

There is a general overhaul of the main convertor in the power supply, which involves dismantling the rotor, the generator and the motor. The mercury rectifier protection system is

On 3 January, the Italian Minister for Education, F.M. Malfatti, visited the CERN Laboratories. He is seen here (centre of photograph), together with D. Amati (left) and F. Bonaudi being shown the Split Field Magnet detection system at Intersection I-4 of the ISR.

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being augmented by installing an auxiliary 100 kVA generator to ensure continuous excitation even when the local supply fails. Preparatory work is proceeding for the installation of four static power supplies in the auxiliary generator building in place of the rotary machines.

Modifications are being made to the regulator of the 3 MW rectifier supplying the Gargamelle bubble chamber and the g –2 experiment and to twenty two regulators in the South generator building. Rectifiers and their auxiliary equipment are being installed in the new East rectifier building. The racks in the PS control room are being rearranged so as to free an opening to the future control room.

Although there are no major changes in the South-East experimental area and in the South and West Halls, the East Hall is seeing great upheavals. To make room for a larger number of electronic experiments, the 2 m bubble chamber (carrying beam-lines with it) is being moved about 13 m. This will take about five months, freeing space for electronic experiments. The resulting new layout of beam-lines and experiments is shown in the diagram.

At the ISR, the experimental programme is being reshaped with new experiments set up at intersections I-1, I-2, I-3, I-4, I-6 and I-8. The work-load is particularly heavy this year because twelve sectors of the machine have to be opened including three intersections: I-2 and I-8 for the installations of experiments, and I-3 to modify the bases of the beam dump targets. In this last intersection the radiation level is high and a large number of people will work there, each carrying an adjustable threshold radiation detector so that they can be under the surveillance of Health Physics group.

In the ISR, great importance is attached to the vacuum conditions which must be exceptionally good in order to maintain beam quality during operation. To increase the pumping speed, clarinet-shaped sublimation pumps are being installed in certain sectors. At intersection I-8 cryogenic pumps are being installed.

Work on beam measurement and control includes installing a new beam profile monitoring system in sector 62, two collimators in sectors 21 and 32 to reduce background for physics experiments, and standard ISR monitors at each intersection for luminosity measurements. It is also intended to install an experimental section of vacuum chamber made of titanium.

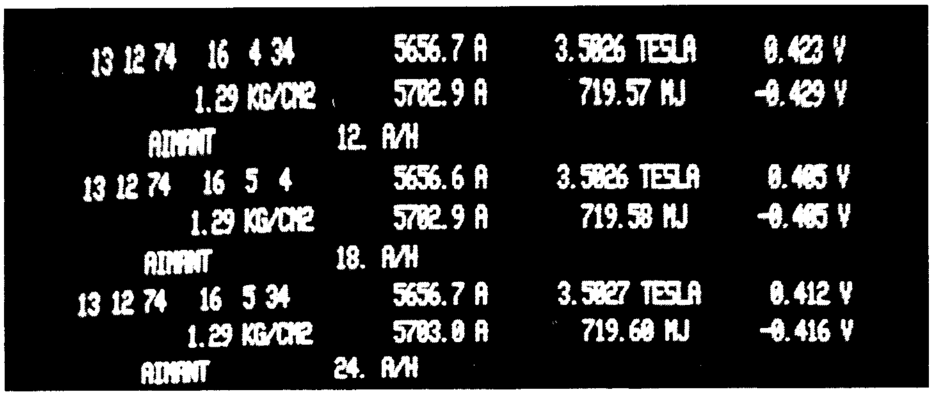
Major maintenance, checking and improvement work is being carried out on many the machine components such as the fast kicker magnets for injection and beam dumping and the r.f. cavities. Finally, the electronics in the ISR control room will be rearranged and maintenance work done on the refrigeration plant.

The shutdown is also being used to prepare the beam transfer line TT2 from the PS to the ISR for sending beam to the SPS. A satellite computer to control the equipment in TT2 will be installed and the beam-line will then be able to handle alternately pulses of protons destined for the ISR and for the SPS.

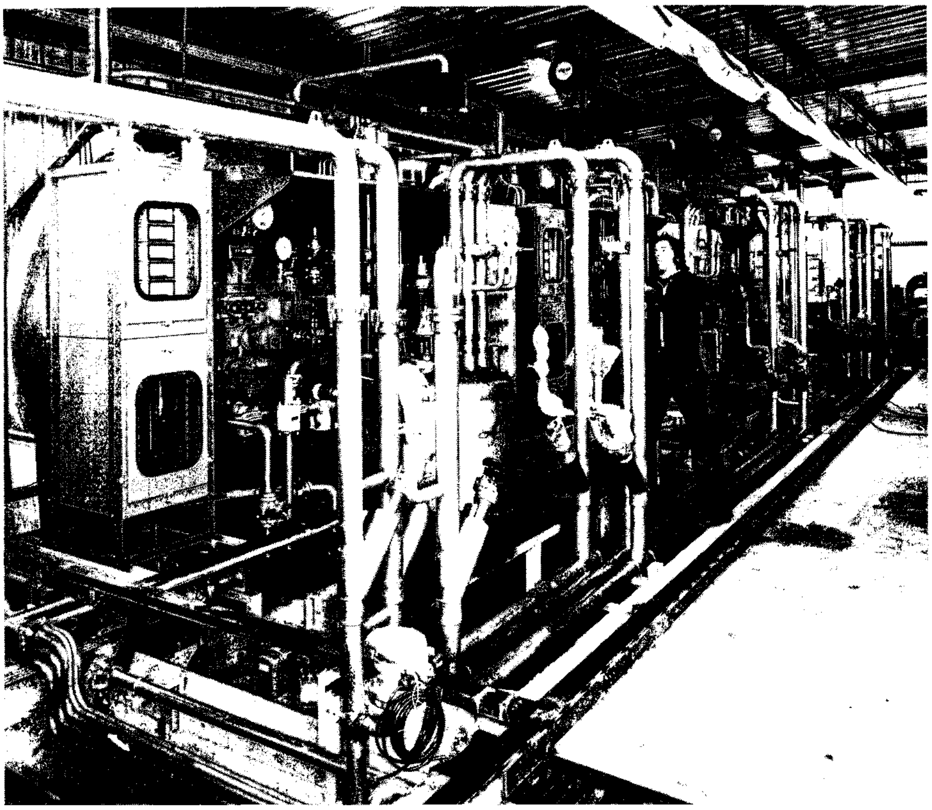
BEBC magnet operational again

Contrary to tradition, Friday 13 December was a lucky day for the 3.7 m European bubble chamber, BEBC. The large superconducting magnet was successfully powered at its design current of 5700 A.

The magnet had been dismantled for reasons which have already been explained in detail (see March issue



The state of the BEBC superconducting magnet captured on a television screen on 13 December. The date and time together with parameters such as the current in the coils, the field and the stored energy are recorded.



The four 50 000 litre dewars to be used for storing liquid deuterium, neon, hydrogen and neon-hydrogen mixture for use in the BEBC bubble chamber.

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1974, page 78). To summarise: the magnet, which had already given its design field of 3.7 T several times, was suffering from an intermittent fault — short-circuiting which disappeared at high field. All the signs pointed to a fault in the auxiliary circuits and not in the superconducting coil itself. This diagnosis proved correct and the way in which the results were interpreted was described in the September issue 1974, page 294.

Unfortunately, to determine and cure the fault required dismantling BEBC. The dismantling and reassembly involved the delicate handling of large metal structures. To limit the size of the bubble chamber, the clearances between the many tanks are very small indeed. Moreover, the strong mechanical forces existing when the magnet is powered (7000 ton attraction between the two coils) and the heat contraction on such large components, mean that very precise pre-stressed fixing methods have to be used. The work, therefore, threatened to take a very long time.

It was decided to start on repairs immediately in order to be sure to have BEBC operational for the start of experiments with the SPS. An eight-month schedule was drawn up, with most of the time being used for dismantling, reassembly and intermediate testing. This schedule was held and only ten weeks were needed for the reinforcement of the auxiliary circuit insulation.

The magnet was ready by the end of November. Cooling of the 350 ton mass took ten days, since the rate of cooling is limited by the allowable stresses in the coil cryostats. From 10 December, the magnet was powered in successive stages to allow checks to be made on all the sub-assemblies (including the instruments), the discharge system and the cryogenic components. A current of 4800 A was rapidly reached in steps of 500 and 1000 A; this level corresponds to 72 % of the maximum stresses. No faults were detected after careful examination of the connections between the pancakes and close inspection of the highly stressed components (supply cables and current inputs) after discharge. It was then decided to go to the design current of 5700 A. There were no problems in either the magnet or its sub-assemblies. From its recommissioning with beam in February, the chamber will be operated normally.

En route to multi-fluid operation

The storage area, hiding behind the walls of the West Hall, has been enlarged to take tanks for neon, neon-hydrogen mixtures and deuterium, all of which are important for the BEBC programme of experiments with the 400 GeV SPS. In addition, three new dewars have been added plus a huge assembly of piping and valves, forming a complex system of instrumentation. It will be possible to store these precious fluids in conditions in which the risk of losses is greatly reduced, even in the event of a breakdown in the cooling system. The chamber and its dewar will be supplied with the desired liquid without any risk of mixing the fluids as a result of an accidental operation or failure.

A tight schedule had to be observed for this work to take advantage of the absence of hydrogen in the storage area during the ten-month shutdown of BEBC. When the hydrogen safety regulations came back into force in January, it became impossible to perform much of the work such as welding close to tanks filled with hydrogen.

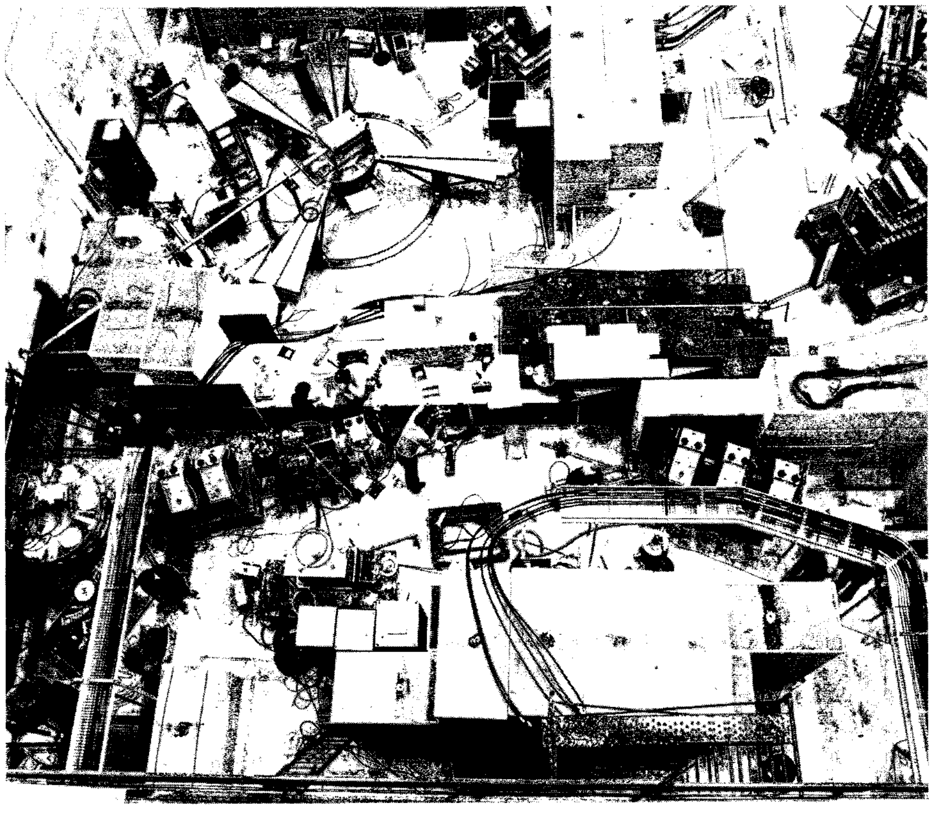
A first delivery of neon is expected in the spring and a start will be made on deuterium production towards the end of the year.

Around the Laboratories

Champagne flows in the TRIUMF control room at Vancouver on 15 December to celebrate first operation of the cyclotron at 500 MeV. Towards the right of the picture, E.W. Vogt (the present Chairman of the TRIUMF Board of Management), is congratulating the Laboratory Director, J.R. Richardson. The ship's wheel on the wall is not used to steer the beam — it was presented by Davie Shipbuilding of Quebec who built the magnet sectors.

One of the two experimental halls (the Proton Hall) at the cyclotron showing preparations under way for the start of the physics programme. Beam enters through the shield wall on the left and two beam-lines are seen being installed.

(Photos TRIUMF)



TRIUMF Triumph

On 15 December, the 500 MeV cyclotron at Vancouver produced its first full energy beams. After a month of gradually spiralling the beam further and further out in the machine, the success came precipitately. Within a couple of hours of the start of tests on the 15th, a beam was extracted from the machine and giving a neat spot in the external beam-line.

We last covered progress of the Canadian project in the June 1974 issue. At that time, the magnet had been tailored to the desired field configuration — the culmination of a hard year's work. The huge vacuum chamber was aligned and cleaned in May and in June the emphasis moved to the radiofrequency system. The eighty resonators were installed together with their water cooling headers.

About the same time, the polarized ion source produced 200 nA of negative hydrogen ions with good polarization. In the experimental areas installation of the beam-lines began. In August, the cryopumping system made its first impression on the machine vacuum — it took the pressure to 5×10^{-6} torr (the design value is 4×10^{-8} — an unusually low pressure for a cyclotron necessitated by the fact that negative hydrogen ions are accelerated).

In September, the pressure was a factor of ten lower but, when r.f. tests began, there were pressure surges limiting the peak accelerating voltage which could be obtained. The peak voltage was 58 kV. Meanwhile work on the injection system had brought 15 μA of hydrogen ions to a position vertically above the centre of the cyclotron with 80 % transmission efficiency.

The vacuum was attacked in October. Four diffusion pumps were added to help take care of the unexpectedly high outgassing of hydrogen from the resonators. The cryopumping was reinforced and the resonators were outgassed at 78°C. On 21 October, the first ions (6 μA) were dropped into the cyclotron and were detected on the low energy probe.

The first half of November concentrated on stepping up the r.f. performance after the repair of a water leak and by mid-month the sparking problem was considered under reasonable control. Tuning of the beam through the cyclotron began on 16 November when ions were detected out to a radius of 100 cm (equivalent to an energy of 6 MeV).

Progressively brushing aside pressure problems, deflector sparking, etc., the peak energy climbed steadily over the following month — 100 MeV (425 cm radius) on 23 November, 200 MeV (565 cm) on 28 November, 300 MeV (650 cm) at the beginning of December. At this stage the r.f. system was operated for a five hour period at 90 kV without sparking.

On 14 December an energy of 360 MeV (690 cm) was reached and beam transmission in the cyclotron out to this energy was looking good. By 12 noon on the following day, ions were again at 360 MeV. In the next hour, appropriately with the TRIUMF Director R. Richardson at the helm, the beam was taken to the design energy of 500 MeV by tuning the trim coils.

An hour later, extracted beam of 10 nA was detected and soon manoeuvred over 15 m to a beam dump. Using quadrupoles it could be focused on a 1 cm^2 spot. By 16.00 hours the champagne corks had been popped.

We congratulate Professor Richardson and his team on their success in bringing such an adventurous machine into action. They join Los Alamos and Villigen as the world's three major 'meson factories' and we wish them many years of good physics.

RUTHERFORD
The EPIC storage ring project

As mentioned in the December issue of 1974, a proposal to build a 14 GeV electron-positron colliding beam storage ring known as EPIC — Electron Positron Intersecting Complex — has been published (Rutherford Laboratory Report 74-100). This report and its companion document (Report 74-124 which concentrates on the physics case and experimental utilisation) demonstrate the considerable effort going towards re-equipping the UK Laboratories for high energy physics research from the 1980's onwards.

The first aim is to build an electron-positron machine with a luminosity (dictating the probability of collisions) which is at its maximum at 14 GeV.

However, the design is such that the basic machine could be developed to cater for further physics requirements. The tunnel cross-section (either 3.5 m square or 4 m diameter) is big enough for the installation of a proton machine above the electron-positron ring and the straight sections are long enough to bend both protons and electrons for collinear electron-proton collisions. This extra straight section length could also be used to add radiofrequency cavities for increasing the energy of the electrons and positrons. The depth of the machine below ground (chosen for stability reasons) provides a good thickness of earth for the relatively more severe shielding requirements for protons. The following is a description of the main design features of the proposed machine:

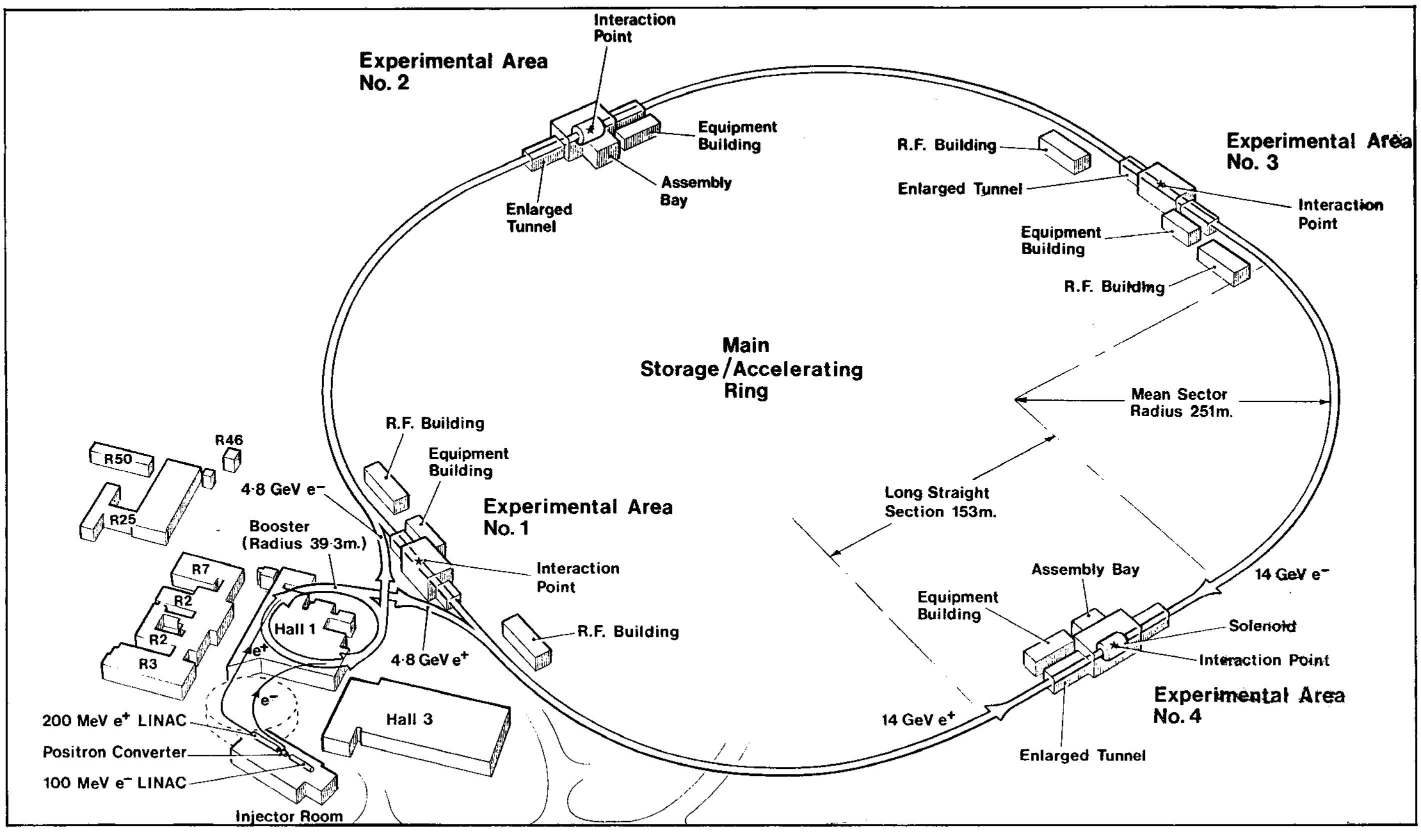
Electron-positron ring

Two very short symmetrically spaced bunches of electrons and two of positrons counter-rotate in a single magnet ring and collide head-on in four interaction regions. To achieve the design luminosity of 4×10^{31} cm^{-2}s^{-1}, the transverse dimensions of the bunches must be very small at the interaction points. This is achieved by using quadrupoles each side of the 17 m long interaction regions to produce a low beta (squeezing the appropriate beam dimension). This is at the cost of a high beta at these quadrupoles, which must have large apertures, and of effects on the beam dynamics which have needed careful study. The beta at the intersections cannot be decreased indefinitely since there comes a point when the force due to the effect of one beam on the other causes serious loss of particles. EPIC uses values based on experience at the existing smaller storage rings.

Electrons at EPIC energies are extremely relativistic and emit copious amounts of synchrotron radiation when following curved paths in the magnetic fields. The energy loss of an electron going round a machine is proportional to (energy)^3 × field. This loss must be made up by the radiofrequency system and there is every inducement to keep the field low to minimise cost even though this increases the ring diameter. The C-shaped dipoles are 4.5 m long with a 70 mm gap and a field of 0.272 T for 14 GeV. The mean ring radius in the normal lattice is 251 m and each of the insertions is 153 m long. The main quadrupoles are 1 m long with a field gradient of 5.5 T/m.

Radiofrequency system

The r.f. system must make up the energy lost by synchrotron radiation. For EPIC this is 20 MeV per turn



A schematic diagram of the proposed EPIC storage ring layout showing how components could be positioned relative to the existing Rutherford Laboratory installations.

which, for a total of 3.2×10^{12} particles in the machine, gives 1.4 MW of radiated power.

In addition, an 'overvoltage' is necessary because the emission of synchrotron radiation leads to a statistical variation in the energy of the particles. A large potential well must be formed so that particles at the edge of the energy distribution are still contained for a stored beam lifetime of, say, two hours. Phase stability is achieved for particles with an energy deviation of 6.5 times the r.m.s. energy spread in the beam by having an overvoltage of 10 MV.

The small number of very short bunches excites higher order modes of the resonant r.f. cavities leading to power dissipation and a modification of the accelerating voltage. A higher fundamental voltage is then needed to provide a given stable phase for the particles. For EPIC, a conservative design figure of 4 MW is used for the r.f. power requirement. The frequency is 402.7 MHz and the total cavity length is 42 m split into four equal sections placed symmetrically about two of the interaction regions. R.f. power is supplied by sixteen 250 kW klystrons each feeding 2.6 m of structure.

The structure is a scaled-up version of the side-coupled cavity used in the Los Alamos linear accelerator which achieves the necessary coupling from cell-to-cell but is expensive to make. More work will be carried out to try to arrive at a cavity with the advantages of the Los Alamos structure but at reduced cost.

Injection

Injection into the main ring is achieved via a 5.3 GeV booster running at 8 Hz. This will the electron synchrotron, NINA, brought down from the Daresbury Laboratory. The booster equipment and two-thirds of the ring can be housed in an Experimental Hall of the proton synchrotron, Nimrod. The NINA injector provides the electrons which either go straight to the booster or produce positrons in a converter which are then accelerated to 200 MeV in a new linac. Both linacs can be housed in the existing Nimrod 15 MeV injector building which becomes available when the new 70 MeV injector is commissioned.

The filling time for the main ring is minimised by making full use of the positrons. For the positron mode, the electron linac gives a burst of eight pulses, 10 ns long separated by 103 ns with 4 A intensity. The positrons have their energy spread reduced in an energy compression system similar to that used at the University of Mainz. The pulses are thus matched in time and properties to eight 'buckets' formed in the booster by a

A photograph of the Rutherford Laboratory site with an alternative location of the EPIC ring drawn in (the Nimrod ring building can be picked out bottom centre). This location gives a more compact site and involves only land already belonging to the UK Science Research Council or the Atomic Energy Authority.

(Photo Rutherford)

50 MHz r.f. system which accelerates the positrons to 2.25 GeV. At this energy a flat in the magnet waveform allows the energy spread to damp down under the influence of synchrotron radiation and the existing NINA high power r.f. system at 407.8 MHz can then take their energy to 5.3 GeV.

Each of the eight booster bunches is transferred to a given main ring bunch in a total time corresponding to seven turns of the main ring. The beam damps down under the effect of synchrotron radiation (with a time constant of 0.44 s) and further booster fills can be added to the bunch. The filling sequence will be electron bunch No. 1, positron bunch No. 1, electron bunch No. 2, positron bunch No. 2, etc. consistent with the booster cycling time of 8 Hz and the damping time of the main ring. It is hoped to achieve a booster fill of 3.6×10^9 positrons at 5.3 GeV in 4 minutes compared with a storage time of 2 hours. The time taken to accelerate the particles is 1 minute.

Vacuum system and controls

The vacuum system must achieve 5×10^{-9} torr in most of the machine with 10^{-10} to 10^{-11} torr in the intersection regions to ensure good beam lifetime and low background for the experiments. The vacuum system is all-metal with aluminium vessels in the normal sections and stainless steel in the insertions. The vessels in the dipoles are cooled to cope with the 1.4 MW of synchrotron radiation. Distributed ion pumps inside the vessel, using the magnetic field of the dipoles, are estimated to have a pumping speed of nearly 300 000 l/s. Holding ion pumps, installed between the magnets, are used when the dipoles are not powered and there are sublimation pumps in the insertions.

The control system is based on the SPS system with about twenty linked small computers. Apart from the usual functions, it must control the change from injection mode to storage mode. It must also respond to instructions, such as a call for altering the beta value at the insertions, changing the settings of the machine components in a manner that does not destroy the stored beam.

The required precision of the control system can be deduced from the need to ensure head-on collisions of bunches of electrons and positrons only 36 mm long with transverse dimensions 0.6 mm by 0.15 mm arriving every 2×10^{-6} seconds at an interaction point in a machine 2.2 km in circumference!

Site

The chalk site at the Rutherford Laboratory has the required stability and is suitable for tunelling which would be needed to clear existing buildings if the main ring is located as shown in the photograph. The rest of the ring would be constructed b the cut-and-fill method. The experimental areas are excavated to give a floor level of 6 m below beam height in two cases, and 3.5 m below beam height in the other two cases.

Cost and Programme

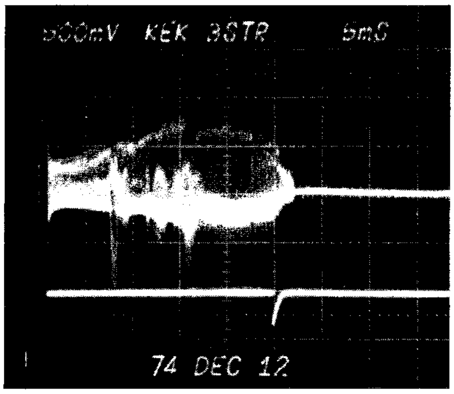
EPIC is estimated at £25.71 M for capital equipment at January 1975 price levels. 2166 man-years of effort would be required and there would be £1.4 M for research and development. The time-scale envisages a start on buying machine components in April 1976, with commissioning in October 1980.

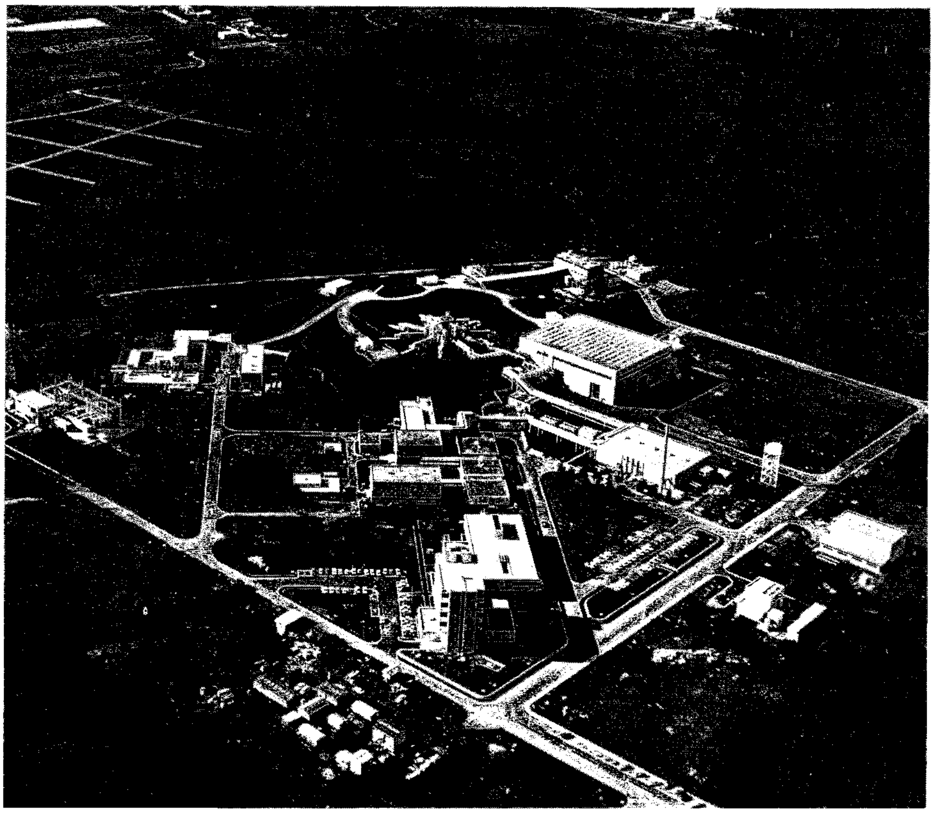
As indicated in the December issue of CERN COURIER, the Science Research Council has encouraged continued design work and inter-

The signal from the KEK booster on 12 December indicating that protons were being accelerated to the design energy of 500 MeV. The booster is operated at 20 Hz and the acceleration time is 25 ms. As can be seen, the monitor was picking up noise (mainly from the r.f.) and there was some loss of beam near full energy.

Aerial view of the KEK Laboratory. The main ring of the 10 GeV accelerator can be picked out at the centre of the photograph. The adjoining building, the largest on the site, is for counter experiments while the bubble chamber building is towards the top right. The linac and booster are central nearer the camera.

(Photo KEK)





national collaboration in the project. As well as continuing with theoretical aspects, the design work will involve a thorough survey of the site, building models of the dipoles and r.f. cavities and experimental work on vacuum and controls. There has been a great deal of interest from UK University engineering departments wishing to be involved in this programme.

Next month we shall be covering the proposed 19 GeV electron-positron storage ring known as PETRA. This was submitted by the DESY Laboratory to its Administrative Council in November.

KEK
Accelerated beam in the booster

On 12 December, the booster of the 10 GeV proton synchrotron being built at the National Laboratory for High Energy Physics (KEK) in Japan yielded its first design energy protons.

Since we last reported on construction progress in September of last year following successful operation of the 20 MeV linac, several months of effort went into polishing the performance of linac components (particularly on the r.f. power supply). In November, three further linac tests were made (a day at a time) and the accelerated intensity was increased progressively from 10 mA to 23 mA to 45 mA. In the third run, the pre-buncher was brought into action and improved capture of the protons by the linac r.f. fields by 50 % as designed.

The 500 MeV booster was largely complete by 4 December and a run on that day was scheduled mainly to tune the beam-line from the linac. This beam-line is 40 m long incorporating 20 quadrupoles and 8 steering magnets (plus a couple of pulsed bending magnets). The linac rapidly achieved a steady beam pulse of 40 mA and tuning of the beam-line went so smoothly that, about four hours later, protons were available for injection into the booster.

This was attempted somewhat hurriedly ahead of schedule and, following an hour spent sorting out timing errors, beam was detected on the monitor screen an octant around the ring. Playing with the injection septum and bump magnets soon had the intensity monitor recording circulating protons. The pulse width was 70 μs (the r.f. was not on) which corresponded to about 110 turns in the ring.

The r.f. was switched on and the pulse spanned out to 15 ms which, with the rising magnetic field, corresponds to protons surviving to an energy of 250 MeV. The radiation monitor near the booster was meanwhile clocking a rapid rise in the neutron flux. Before retiring to bed, one further fine adjustment to the phase of the magnetic field rise and the r.f. was made. Beam then survived for 22 ms (equivalent to 475 MeV) and the measured accelerated intensity was 10^{10} protons per pulse.

On 12 December, the booster was more ready for serious testing. A second run was tried. Beam was taken to the design energy of 500 MeV and the measured intensity was 4×10^{10} protons per pulse.

BROOKHAVEN
Superconducting magnet test

As described in the November issue of 1974, there is an extensive development programme on superconducting magnets under way at the Brookhaven National Laboratory. The main aim is to master the techniques to a sufficient extent to make it possible to build the magnets of ISABELLE — the proposed colliding beam machine for 200 GeV protons.

A series of ISA model magnets is being built and in December, ISA IV, was successfully tested. The magnet reached a field of 4.4 T in the aperture with the superconductor at a temperature of 4.6 K. The first quench (the superconductor going 'normal') at this temperature occurred at the comparatively high field of 4.1 T. When the temperature was taken lower to 4.2 K, the field in the aperture was nudged a little further to 4.5 T, corresponding to a field at the superconducting windings themselves of 4.8 T. The current density in the windings was 30 kA/cm^2 (160 kA/cm^2 in the superconducting filaments).

ISA IV is a dipole 1 m long with an inner winding diameter of 8 cm. It differs from its predecessors in using a conductor which has been simplified to make fabrication easier. The new conductor is a metal filled flat braid of the same dimensions as used previously (19 mm wide; 0.6 mm thick) but contains only half as many individual multifilamentary wires which have double the cross-sectional area. In addition to simplifying the manufacture, the new conductor reduces the time dependent effects observed in models I and II by a factor of six.

Since the construction of ISA IV further improvements in conductor configuration have been made which should allow an improvement in current density of 20 % and an additional reduction in time dependent effects by a factor of four. To sustain the optimistic note, somewhat further off is a conductor of similar type using niobium-tin multifilamentary wire rather than niobium-titanium. This should make it possible to achieve 6 T with coils of the same dimensions.

Readership survey

In the course of 1974, a survey was made of the external (or non-CERN) readership of the COURIER. The aims were to 'spring clean' the distribution list (removing people who are no longer interested in receiving the journal), to gather information on the interests of the readers and to have reaction on the journal content. The results of the survey were as follows:

From the number of readers who did not reply, it is possible to reduce the number of copies produced by about 17 % (from 11 500 to 9500). The activities of readers who did reply (not including journalists who were contacted separately) were divided — 28 % high energy physics, 10 % accelerator design and operation, 6 % component manufacture and supply, 7 % administration, 19 % other scientific research, 20 % education, 10 % other. The readers are based — 40 % university, 27 % research centre, 14 % industry, 4 % information centre, 5 % government science administration, 10 % other. On average five people read each copy of the COURIER — 37 % are cover to cover readers, 60 % read selectively and 3 % are just glancers. Over 90 % find the level 'about right'.

These figures remain rather close to those obtained in the previous survey in 1968. From the point of view of the editorial staff, some of them are very satisfying to learn. However, there are always many improvements which can be made. Some of these are comparatively small-scale — for example, several readers pointed out the tendencies to slip into the 'jargon' of high energy physics without preliminary explanation, to use abbreviations or acronyms familiar in the field without spelling them out, and so on. When trying to communicate to a wide audience, even within the field, we should try to avoid this as much as is reasonable.

In broader terms, a lively journal should try to evolve as the field itself evolves. One direction, particularly in recent years, is towards greater integration of the various components in high energy physics research. The COURIER has tried to follow this and is already reporting news of events in high energy physics no matter where they occur. Now the trends in the research itself, and in the social and financial climate in which it is carried out, point to an even closer working together of the various centres of research. We shall attempt to reflect this in developing the journal in the course of the coming year.

The close contact which it has been possible to maintain with other Laboratories during 1974 was greatly helped by the co-operation of correspondents and this gives us another opportunity to thank them for their efforts —

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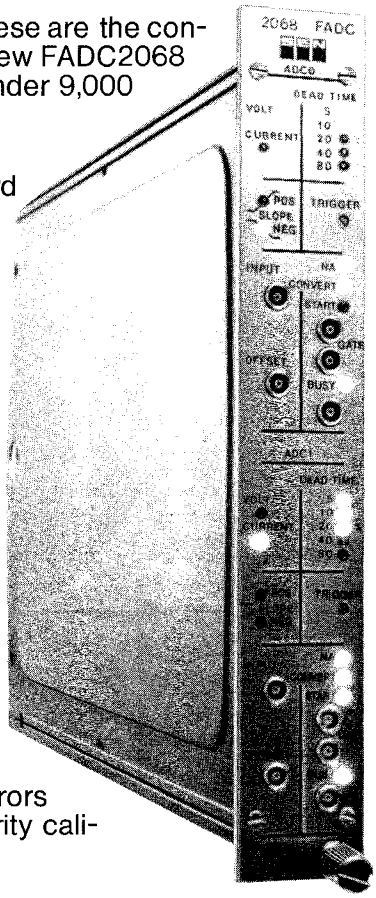

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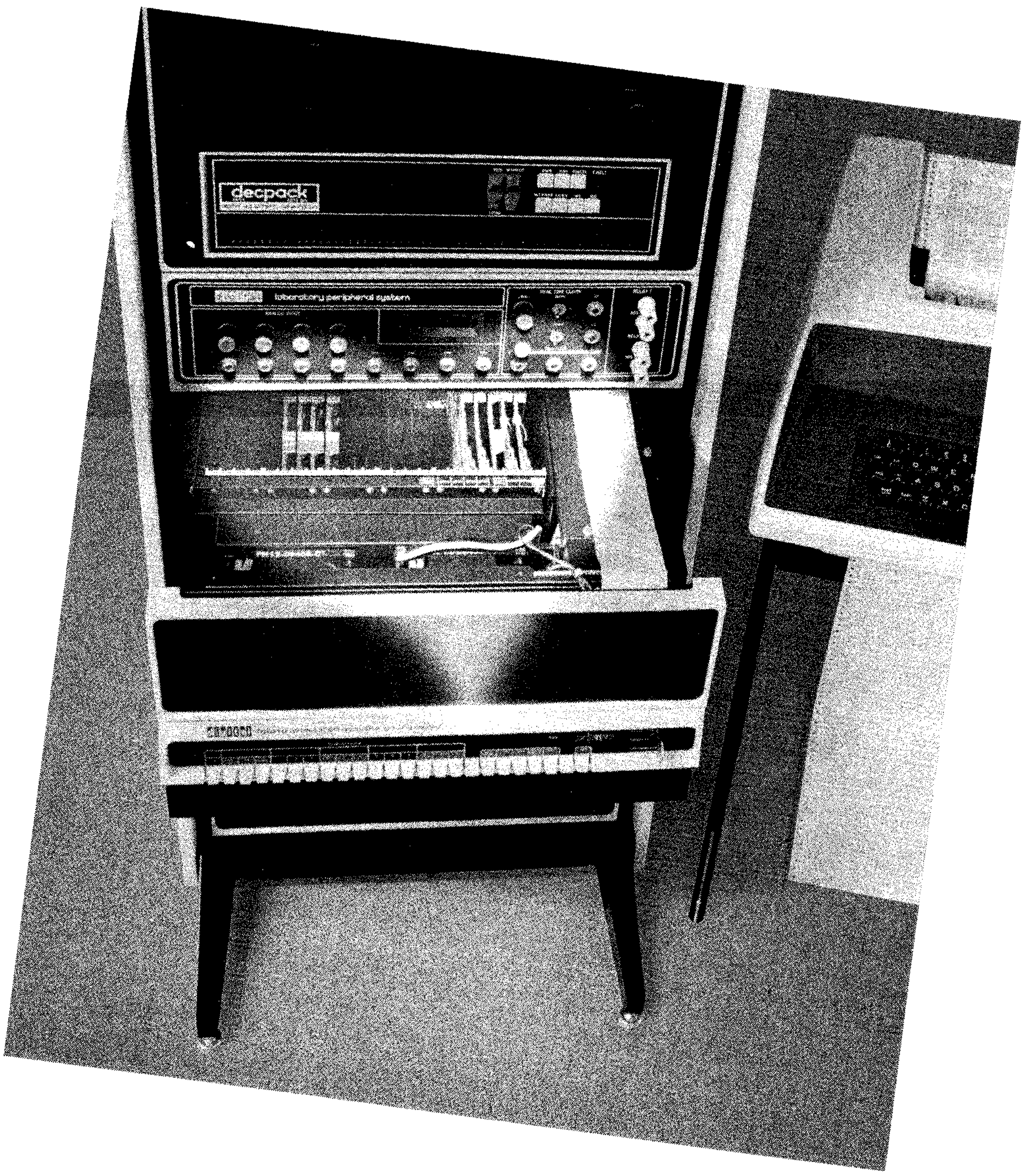

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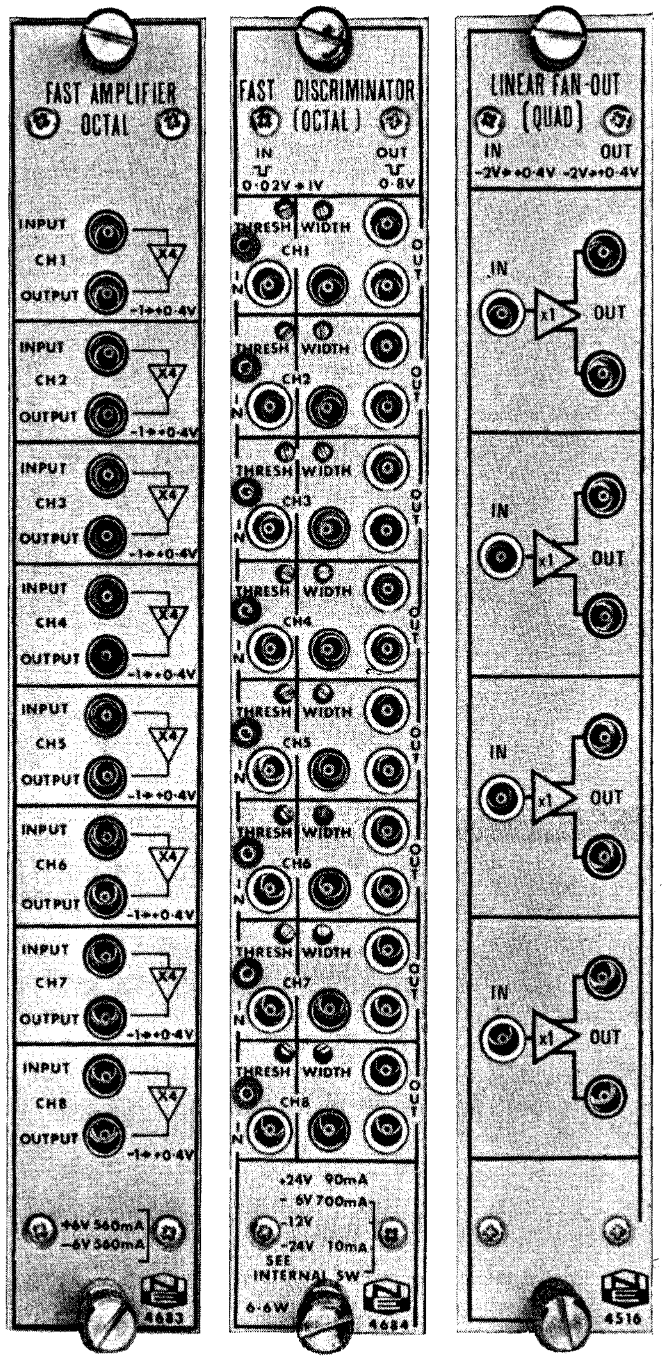

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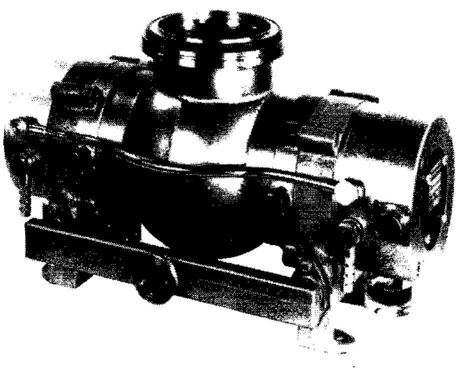

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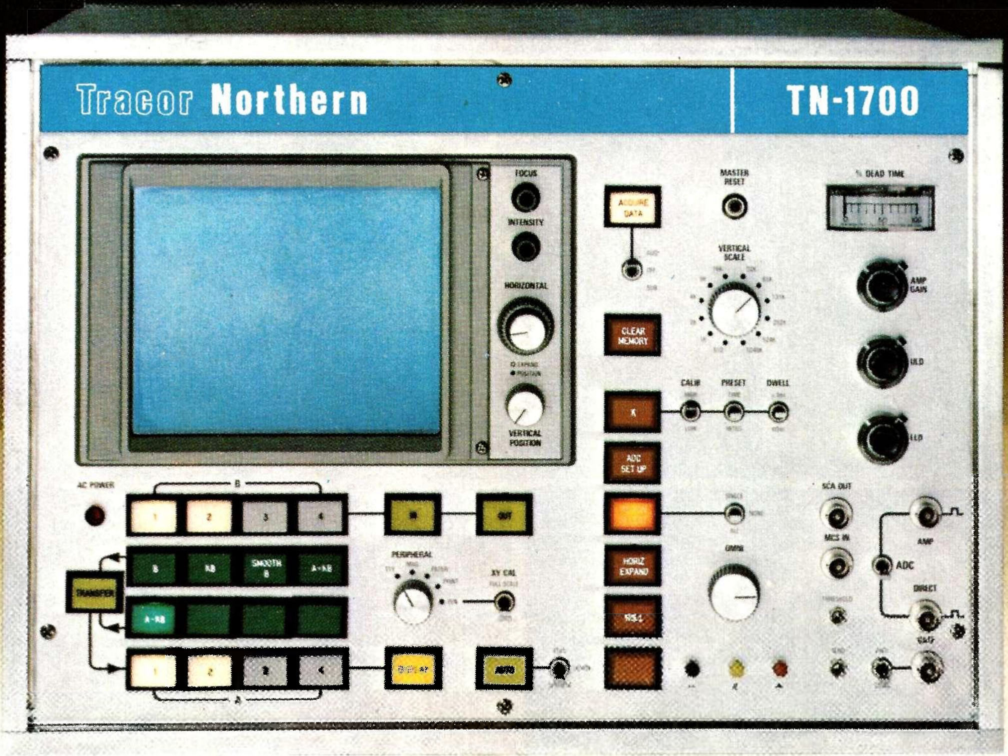

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