CERN

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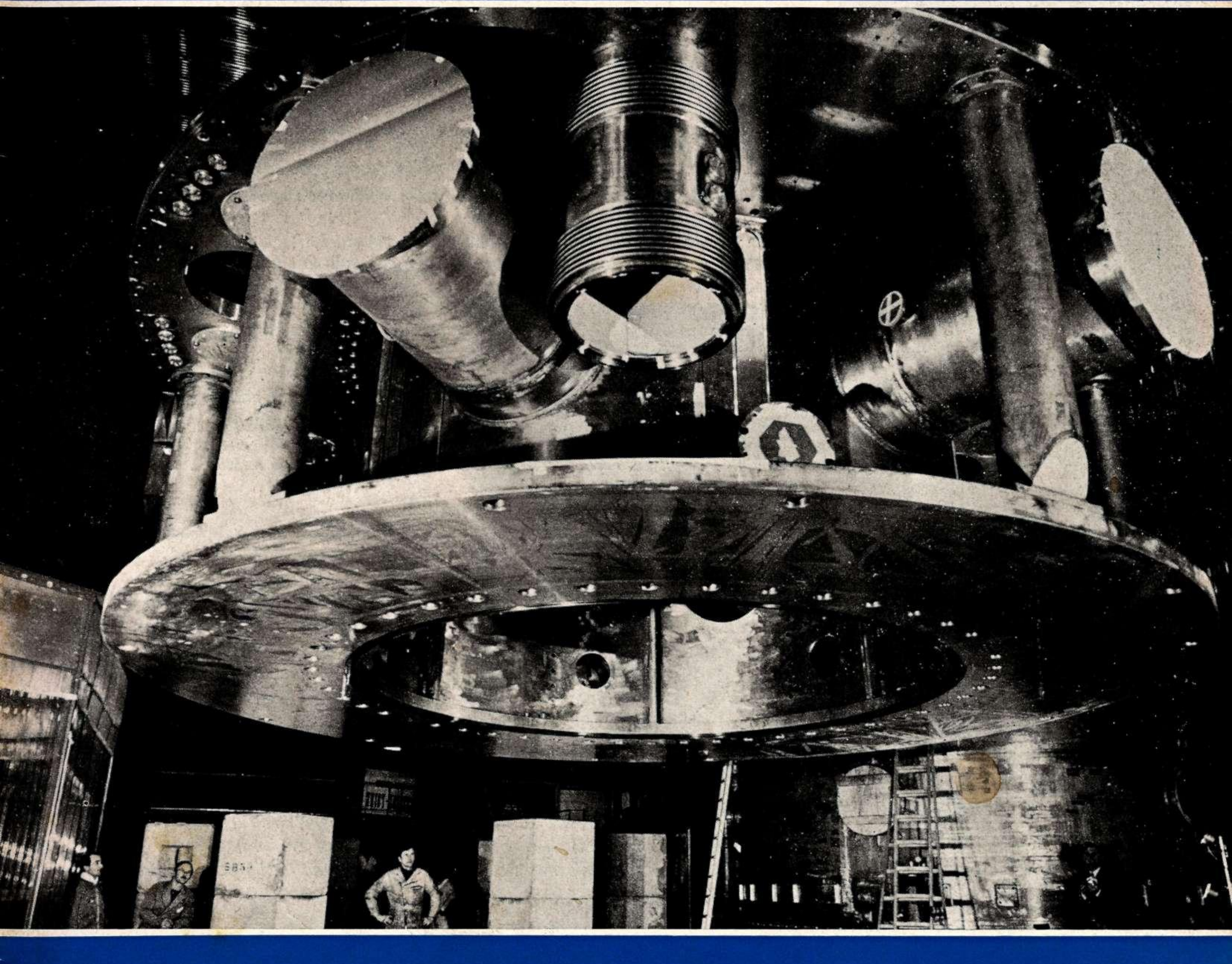
European Organization for Nuclear Research



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 I and CERN II.

CERN I has been in existence 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 1200 physicists draw research material from CERN.

The CERN I site covers approximately 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3000 people and, in addition, there are about 650 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN I budget, which totals 3[illegible]3.4 million Swiss francs in 1971.

The CERN II Laboratory was authorized by ten European countries in February 1971; it will house a proton synchrotron capable of a peak energy of hundreds of GeV (usually referred to as the 300 GeV machine). CERN II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1971 is 2[illegible].3 million Swiss francs.

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Contents

Cover photograph: The BEBC main support on which the whole chamber will be assembled and which will serve as a base for the chamber, the magnet and their respective vacuum tanks. This stainless steel component, which weighs 65 tons, was supplied by Mannesmann Röhrenwerke, Düsseldorf (Thyssen AG) the final machining being done by AEG in Berlin. The large horizontal pipes link up the diffusion pumps while the vertical pipes, equipped with bellows, allow the legs on which the magnet stands to pass through on to the base of the support and provide for the emergency evacuation of the helium used for cooling. The main support will be crossed from the top to bottom by almost all the power supply and control cables and by a mass of pipes. It was installed in February and the assembly of the body of the chamber, the vacuum tank and the magnet is scheduled in the coming months. (CERN 343.1.71)

CERN News

A2 splitting

Whether the A2 meson has a split personality has been a source of controversy for the past five years. (Enthusiasts who would like to go over the history could try vol. 10 page 272, vol. 9 page 233.)

A series of observations at CERN in missing mass experiments have indicated very clearly that the peak associated with the A2 meson at a mass of about 1300 MeV is split into two component parts suggesting that two particles of almost identical mass and identical quantum numbers are interfering with one another. This result has stimulated a variety of theoretical speculations and explanations — ranging from a freak accident of nature to fundamental new ideas on the scheme of elementary particles.

The missing mass experiment which produced the negative A2 meson, carried out with a low momentum pion beam on a hydrogen target, has been repeated several times with different experimental techniques and different apparatus. Each time the A2 has come up very clearly as split. This observation was supported for the neutral A2 meson in another experiment at CERN reported last autumn at the Kiev Conference.

Meanwhile, however a Berkeley bubble chamber experiment looking at the positive A2 meson has shown no sign of splitting over a similar momentum range. Two new experiments looking at the negative A2 at much higher momentum have now come down on the side of no splitting.

The first result came from a CERN-Munich team (G. Grayer, B. Hyams, C. Jones, P. Schlein, W. Blum, H. Dietl, W. Koch, H. Lippmann, E. Lorenz, G. Lütjens, W. Männer, J. Meissburger, U. Stierlin, P. Weilhammer). It was announced at a CERN seminar last December and was published in Physics Letters, 1 March. They used a negative pion beam of momentum 17.2 GeV/c from the proton synchrotron onto a hydrogen target 50 cm long to produce the A2

$$\pi^- + p \rightarrow A2^- + p$$

and detected the A2 through its decay into a negative and a neutral kaon

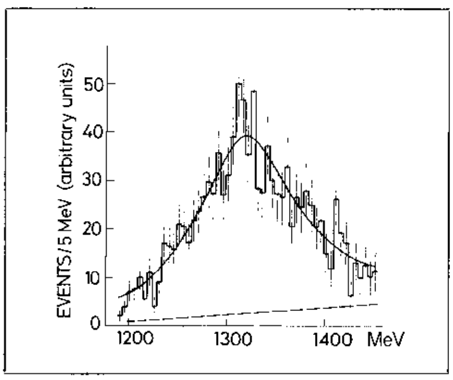
$$A2^- \rightarrow K^- + K_S^0$$

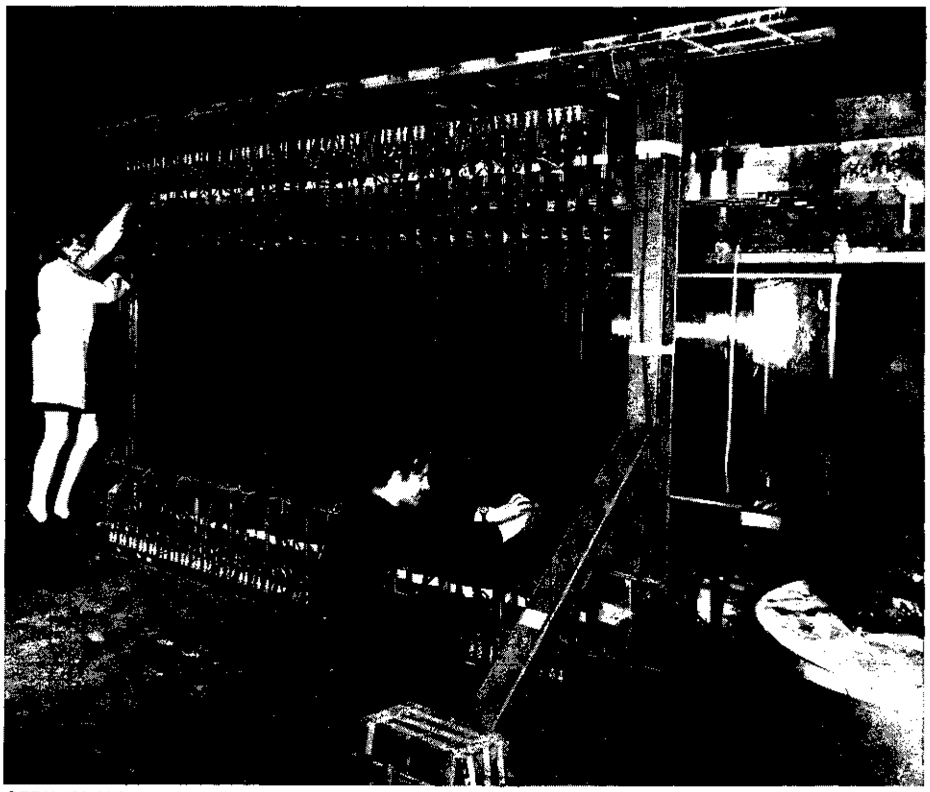
A total of 1934 events were counted in the mass range between 1000 and 2000 MeV with a mass resolution of $\pm$5.7 MeV at the position of the A2 meson around 1300 MeV.

The particles involved in the interactions were detected in wire spark chambers with magnetostrictive readout (24 planes identifying the incoming pion, 24 planes recording the charged particles emerging from the target), a spectrometer magnet with a 1.5 m wide aperture 0.5 m high and a bending power of 2 T m, and a further 24 wire planes recording trajectories

Right : The picket fence of scintillation counters used in the triggering system of the CERN-Munich experiment which has reported no splitting of the A2 meson. Behind the fence can be seen the last of the magnetostrictive wire chambers and behind the chamber is the large aperture spectrometer magnet.

Below : The A2 peak as detected via the negative and neutral kaon decays of the meson. There is no sign of the two peak structure reported in previous experiments.





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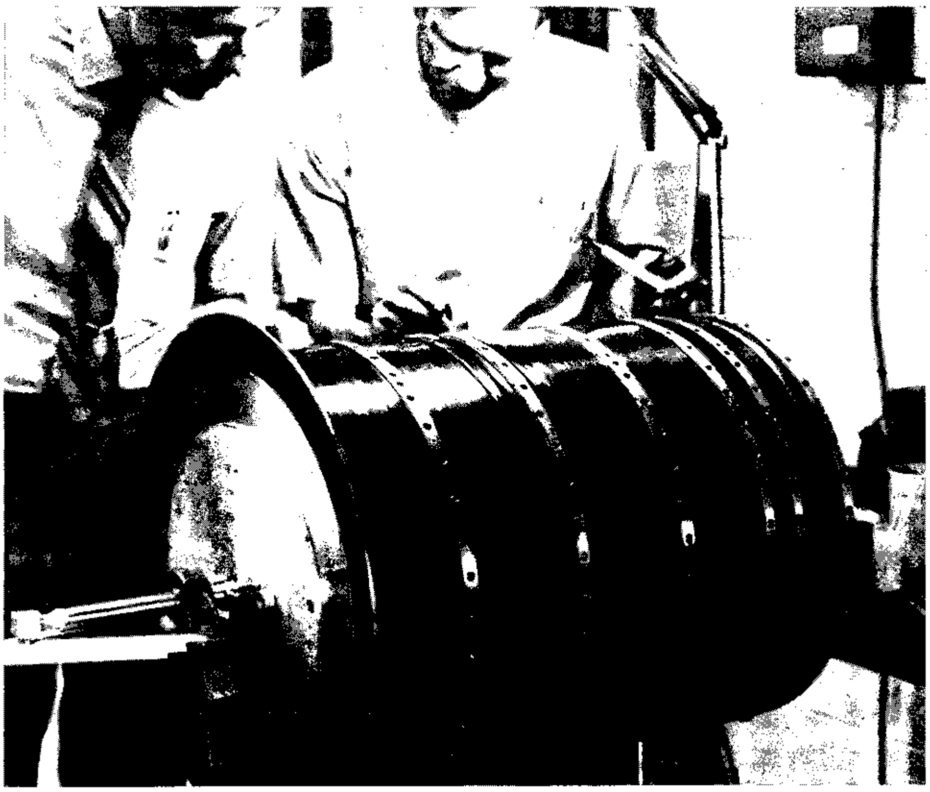
The niobium-titanium outer coil for the HYBUC bubble chamber photographed during the final stages of winding in the USA. The completed magnet has now been assembled and successfully tested at CERN.



after the magnet. Cherenkov and scintillation counters completed the particle identification system. With a pion beam of 4×10^4 particles an average of 2.5 events per PS pulse was recorded. No sign of A2 splitting emerged from the data and there was no sign of splitting dependence on momentum transfer which, at the time of the Kiev Conference, had seemed a possible way of reconciling the previous Berkeley and CERN results.

A result from Brookhaven emerged at the American Physical Society in February to support this conclusion (K.J. Foley, S.J. Lindenbaum, W.A. Love, S. Ozaki, E.D. Platner, A.C. Saulys, E.H. Willen published in Physical Review Letters, 15 February). They studied exactly the same interaction sequence with an incoming pion beam from the AGS at a momentum of 20.3 GeV/c. They also used a large aperture magnetic spectrometer and wire chambers as detection system. Their data (564 events) within the mass region 1200 to 1400 GeV, shows no sign of a splitting of the A2.

At the Kiev Conference the splitting of the A2 was taken as well backed by experimental evidence and the problem was to find the theoretical explanation. Now it looks probable that the A2 has returned to the fold of its brethren in the spin 2 multiplet as a single peak broad resonance. The problem is to understand the source of the narrow peaks in the A2 region found in the missing mass experiments.

HYBUC magnet success

The superconducting magnet for the hyperon bubble chamber, HYBUC, was taken above its design field of 11 T when it was tested at the end of February. The achievement of such a high field during the first complete test of the magnet could possibly hold a technological message of importance for the future of superconducting magnets.

The HYBUC story was told in vol. 10, page 353. Recaping briefly, it is a small hydrogen bubble chamber specifically designed for the measurement of the magnetic moments of hyperons (beginning with the sigma hyperon in an experiment to be carried out by a team from the Max-Planck-Institut für Physik, Munich, and members of the Niels Bohr Institute, Copenhagen, and Vanderbilt University, USA). Tests on the chamber itself yielded the first photographs of particle tracks at the end of last year (see vol. 11, page 15).

At the end of January the superconducting magnet, which has been built in the USA, arrived at CERN and was installed in the HYBUC vacuum tank. The magnet is technologically the most interesting feature of the chamber assembly. It is designed to produce a very high field (11 T) on the horizontal axis of the chamber — the higher the field the greater the effect on the hyperon via its magnetic moment.

The magnet consists of a set of outer coils, constructed using niobium-titanium as the superconductor, with 280 mm inner diameter, designed to give at least 7 T on the axis. Within the bore of these coils is another coil (178 mm inner diameter) using niobium-tin as the superconductor which is designed to add up to 5 T to the field on the axis. The useful chamber volume sits within the horizontal bore of the niobium-tin coil. (A further shorter niobium-titanium coil, which produces field in the opposite direction to the main magnet, serves to reduce the effect of the main magnet field on the incoming particle beam.)

The first time that the magnet was powered under conditions suitable for the experiment it climbed slowly during a 'charging' time of twenty hours to 11.3 T before the superconducting property was lost. Similar and even higher figures (11.8 T) were touched during a series of subsequent tests where the charging conditions were varied (the relative strength of the currents in the different coils being changed).

What is dramatic about this achievement is first that such a high field has been reached in a large volume (over 10 T in 6.6 litres) but, more importantly, that short-sample characteristics were closely approached right from the word go. Niobium-titanium, for example, can, when tested in 'short-sample' form, retain its superconducting property in a magnetic field up to a level of between 8 and 9 T. However, it is very difficult to avoid losing the superconducting property at field levels considerably below this when the niobium-titanium is wound into a large coil. The niobium-titanium coil of the HYBUC magnet was operating in a field level of over 8 T.

Obviously any source of heat which takes a region of the coil to a temperature above the temperature at which the coil material is superconducting can cause the superconducting property to be lost. For this reason the construction of such coils has to ensure efficient cooling of the superconductor and has to ensure a rigid mechanical structure so as to eliminate as far as possible mechanical movement of the superconductor which is a potential source of sudden flux jumps and hence of heat.

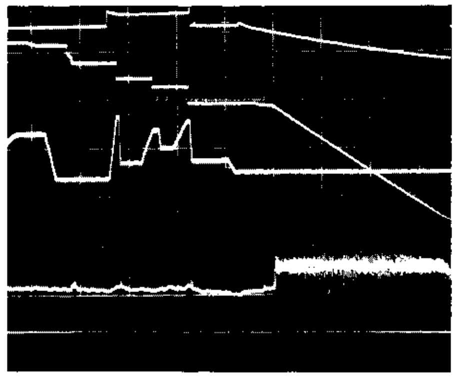
The magnet designers decided to lean particularly on the second of these considerations. They avoided a Gruyère cheese type of construction, where helium cooling channels are liberally sprinkled all over the coil cross-section to ensure efficient and even cooling, and instead packed conductor of rectangular cross-section (oxide coated for insulation between turns) close together to form a mechanically extremely rigid coil. This playing down of cooling and emphasizing of mechanical properties seems to have paid handsome dividends and may prove an important clue to developing superconducting magnets further.

A further observation which seems to confirm this interpretation of the success was that very little evidence of 'training' was seen when the magnet was first powered. Often a superconducting magnet only settles down at its peak field levels after being charged many times to lower field levels. This may well be due to the coil settling down mechanically and the relative unimportance of this in the HYBUC coil would thus confirm that exceptional mechanical rigidity has been achieved.

One further technical point — the niobium-titanium conductor is of the twisted filament type. There has been no sign of large scale parasitic magnetization current loops during the tests. Any sign of current loops in the niobium-tin coil disappeared at high field.

PS operation

Operation of the 28 GeV proton synchrotron is becoming more and more complex in the process of increasing the versatility of the machine to supply experiments with particles in a variety of combinations. For example, the protons were distributed during a recent machine cycle as follows : In succession, 1 % of the protons were used onto target No. 1 (providing test beams for counter experiments in the South Hall), 10 % onto target No. 6 (giving a beam to the 80 cm bubble chamber in the North Hall); 2 bunches were used for ejection 58 (providing beam for the first expansion of the 2 m bubble chamber), 1 bunch was used for ejection 74 (giving a test beam for the Gargamelle bubble chamber), 2 bunches were again used for ejection 58 (second expansion of the 2 m bubble chamber), and the remaining beam was used for slow ejection 62 (feeding counter experiments in the East Hall). It is possible to have three fast ejections in less than 150 μs by using the two fast kickers 13 (for ejection 74) and 97 (for the two ejections from straight section 58). In addition the slow ejection 62 pulse shape has been greatly improved by adding a filter in the sextupole power supply.



Signals from a PS operating cycle. Their significance is described in the text.

In the photograph the top trace comes from the main magnetic field cycle with two flat-tops. The second trace corresponds to the intensity of the protons beam circulating in the PS ring. The third trace shows some 'beam gymnastics' (radial shift) and the bottom trace the pulse shape in the slow ejected beam. (The horizontal scale is 100 ms/square.)

Large Telescope Conference

From 1 - 5 March CERN was host to a Conference on large telescopes organized by the European Southern Observatory, ESO. It brought together more than a hundred scientists and

1. One of the prototype multiwire proportional chambers for the ISR split field magnet detection system. The chamber is light enough to be elegantly carried, thanks to the use of plastic foam sandwich construction (which has reduced the weight from 60 to 6 kg). This method of construction increases the useful volume by about 15 %.

2. A 'compressed-air loom' where wires are woven onto a chamber. A wire, secured to one of the pins on the right, passes around one on the left and returns to be secured to the next one on the right. The left-hand pins are fitted on ball bearings and those on the right on small compressed-air pistons ensuring uniform tension on all wires. Chambers of any desired length can be made on these portable looms.

3. and 4. Diagrams of how a chamber will wrap around the beam-pipe in the ISR and some of the detail of the proposed method of chamber construction. The wires can be seen bent over at the top where they are welded and the connectors are flexible printed circuits.

engineers who are involved in the design, construction and use of large optical telescopes.

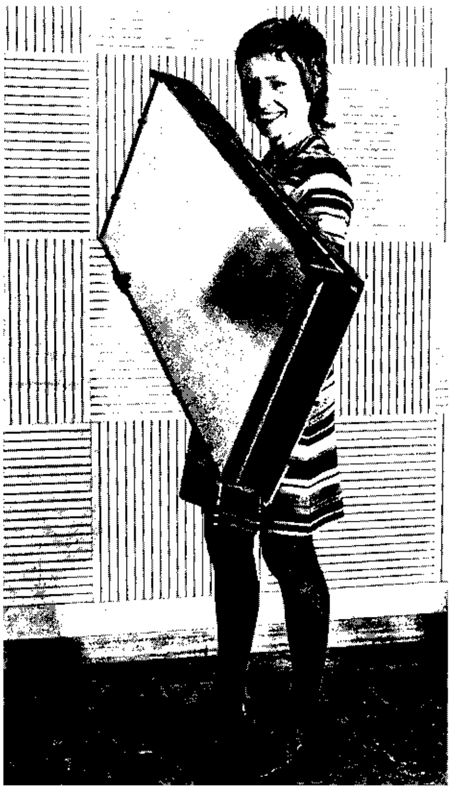
In recent years there has been a sudden new blaze of interest in the age-old occupation of looking at the stars. The discovery of the quasars, with their colossal energy output, and of the pulsars, with their intriguing mechanism of pulsating energy emission, the recent theories on the life cycle of the universe (and the related experimental evidence such as the 'three degree background radiation') and on the life cycles of individual stars (with the variety of states in which their corpses can eventually populate the sky)... these and many other observations and theories have brought astronomy and cosmology back to the forefront of scientific research. Paradoxically, a strong link with particle physics, at the opposite end of the distance scale, has developed since only at particle accelerators can conditions similar to those prevailing in the stars be produced and studied.

This resurgence of interest is reflected in a proliferation of projects to build new and better instruments for astronomical observations. Currently the largest optical telescope in action is the 5 m at Mount Palomar, USA. There are ten new ones with mirror diameter over 3 m being constructed or under study — two 3.8 m telescopes by the USA organization AURA, a 3.8 m Anglo-Australian telescope, a 3.8 m Canadian telescope, a 5 m telescope project initiated by the Carnegie Institution, three 3.55 m telescopes under study individually in the Federal Republic of Germany, France and Italy, a 6 m telescope project in the Soviet Union, and, of course, the 3.6 m telescope of ESO (in whose construction CERN is collaborating) to be installed at La Silla, Chile, to study the southern sky.

Despite, in most cases, their smaller diameter than the existing telescope at Mount Palomar, the improvements in mechanical construction techniques and in optical systems, combined with judicious selection of telescope site, make the new instruments capable of yielding better information.

The Conference was the largest of its type ever held and had representatives able to speak on the big projects listed above. The problems confronting designers and builders seem to be similar in all the projects and the usefulness of the discussions at the Conference came from hearing the variety of solutions proposed in the different design teams.

It is five years since a similar Conference was held on this subject and it is hoped that it will help develop closer collaboration between the interested countries where ESO is already showing the way. As astronomical instruments grow in size and



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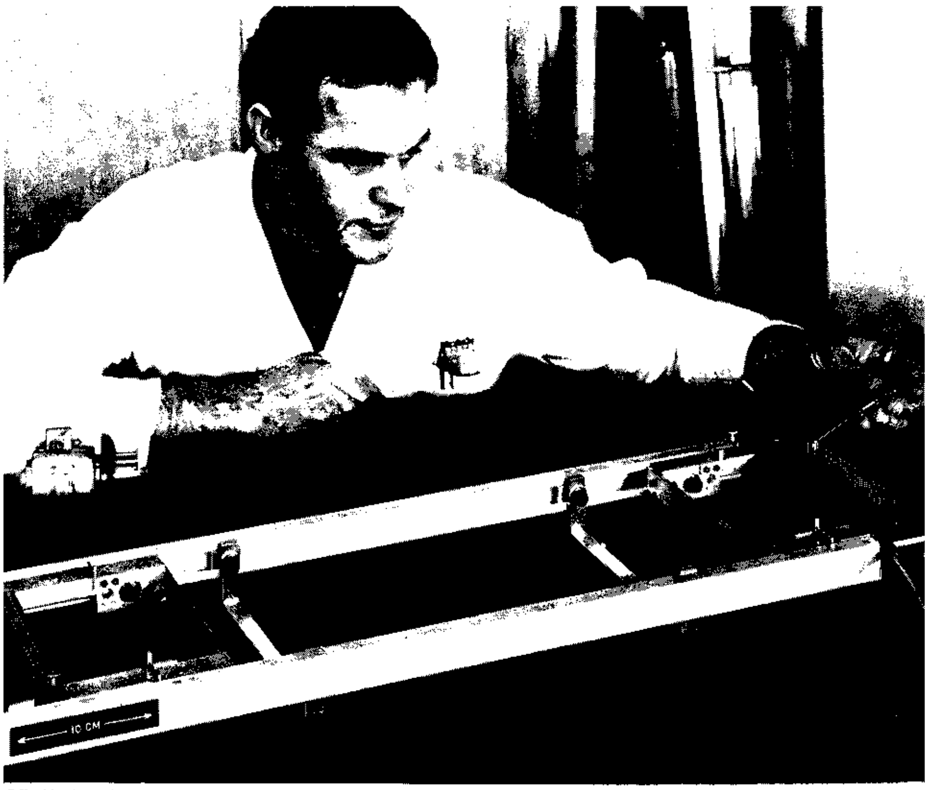

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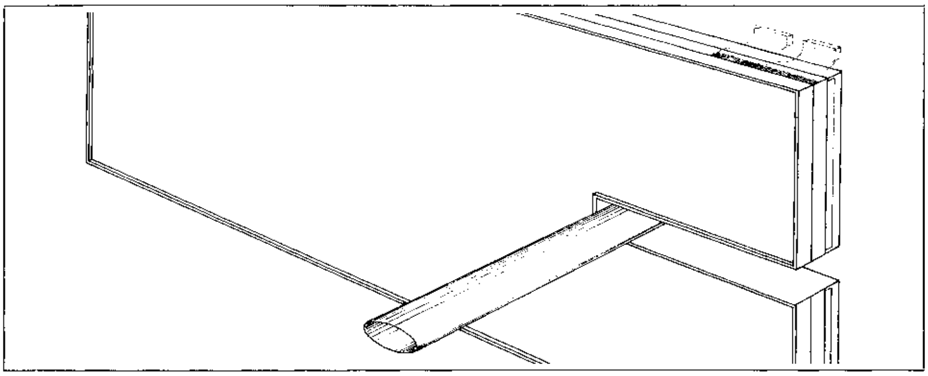

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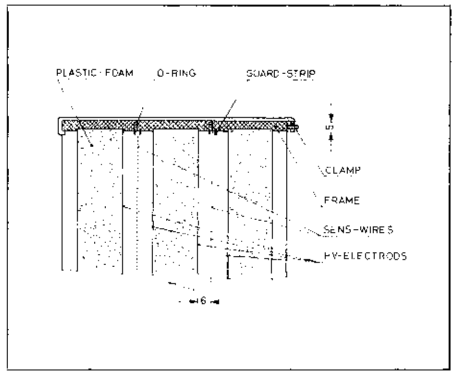

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cost such collaboration will be important to ensure that top quality equipment continues to be available.

MPC construction techniques

There have been further developments in construction techniques for multiwire proportional chambers (MPC) particularly in preparing them for specific applications.

In these chambers the wire tension is comparatively low : in general 50 g for the wires recording the signals and 100 g for the wires in the high voltage plane. However, by the time the tension on hundreds of wires has been added up, tensions like 85 kg for the measuring wire plane and 160 kg for the HT wire plane in a chamber measuring 1.8 × 0.5 m are recorded. In order to hold the wires in exact position it is then necessary to construct rigid and hence thick frames. In general this is no disadvantage, but when chambers are placed within the useful volume of a magnet, as for example that of the split field magnet of ISR intersection region I-4 (see vol. 10, page 148) or the Omega magnet (vol. 10, page 146), the frame can seriously reduce the volume available for particle detection.

The group responsible for constructing the MPCs to be placed in the split field magnet has just found a simple solution which eliminates the frame and has other advantages. The wires are supported not by a frame but by sandwiches of material (honeycomb, or very light, 30 kg/cm^3, polymethacrylimid plastic foam) which has great strength. The frame can be reduced to a simple surround. There is no longer any deformation of the frame and the wire tension remains uniform, eliminating errors in the parallelism of the wires. The weight of such a chamber has gone down from 60 to 6 kg.

Other developments have also changed the appearance of the chambers. MPCs have needed not only two planes of measuring wires (one horizontal and one vertical) but also a third oblique plane for cross-checking and two planes of high tension wires (five planes in all).

The first change consisted in plating the outside of the foam or honeycomb plates with silver (or gold) a few μm thick replacing the HT wire plane. The second change consisted in dividing the HT planes into oblique (15°) bands 20 mm wide, which make it possible to locate the particles with sufficient accuracy to replace the cross-check wires. This possibility is still being studied.

For the split field magnet detection system these developments will result on the one hand in increasing the useful detection volume inside the magnet by 15 % (a considerable saving if it is remembered that a m^3 of useful volume costs 750 000 SF), and on the other hand in increasing the uniformity of the medium crossed by the particles.

There are two other tricks of construction which will improve the assembly of MPCs. The first is to make the connections to the wires via printed circuits whose substratum consists of a very strong flexible material (capton). The connecting strips can then be turned at will in the desired direction. The second concerns the welding of the wires which was formerly done on printed circuits protruding from the frame taking up some space. Now the wires are fixed to the frame itself which has again increased the useful detection volume.

Finally a new machine for weaving the wires onto the frame has been invented by one of the group's technicians. It ensures the right tension in the wires to within a gramme. Each wire is attached to a pneumatic piston and compressed air is used to standardize the tension with great accuracy. Moreover, the tension can be varied at will by adjusting the air pressure. The device has the additional advantage of being portable and it can be used for the construction of chambers with as many wires as required.

One last point, unrelated to actual construction — the 'magic gas' which gives a high power of amplification (see vol. 10, page 152) is now ready for use and deterioration in performance after long exposure to radiation has been eliminated by adding isopropyl alcohol or, better still, methylal to the gas.

Linac improvements

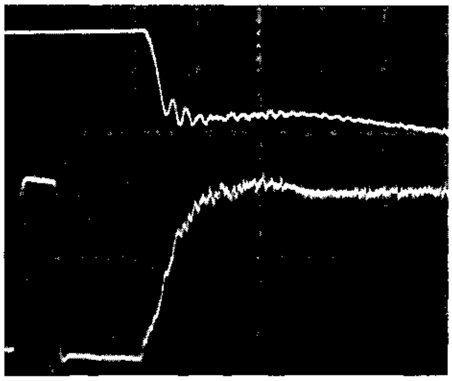
Part of the PS improvement programme involves modifications to the linac to increase its pulse length so as to have multi-turn injection into the 800 MeV Booster for 100 μs.

The necessary changes involve the source, the preinjector, the pulsed power supplies to the quadrupoles located in the drift tubes of cavity No. 1 and the quadrupole triplets positioned before cavity No. 1, and the compensation in the r.f. system to cope with beam loading in all three cavities.

In addition, the intention to use the PS complex to serve the 300 GeV machine, in addition to its own research programme and the filling of the ISR, makes it even more essential to have a 50 MeV injector which is very reliable and reproducible in its operation. It is intended to monitor and control the parameters, which most affect the beam quality, on the IBM 1800 computer with the aim of preselecting required beam characteristics and of speeding-up the

1. The voltage at the terminal electrode of the linac preinjector following the recent installation of a servo-system to compensate for beam loading. The horizontal scale is 20 μs per division and the vertical scale 1 kV per division. During a 100 μs pulse the voltage stability is thus better than 500 V peak to peak.

2. and 3. The pulse feeding the focusing quadrupoles in linac cavity No. 1. On the left is sketched the pulse form prior to the recent improvement ; the quadrupoles were powered for a very short time at the peak of the pulse. The new pulsed power supply provides a plateau, recorded on the right, to allow longer linac pulses.



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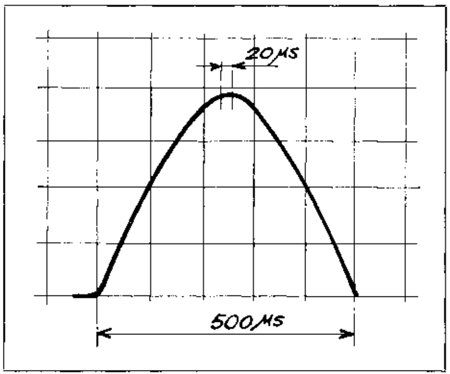

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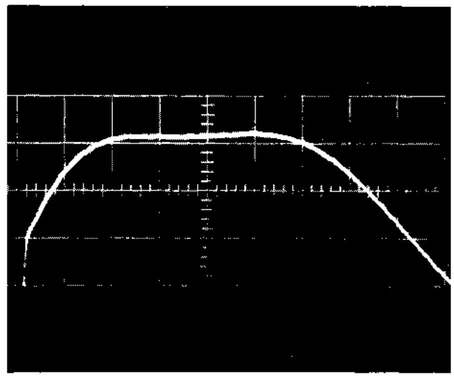

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diagnosis of faults and instabilities, as well as facilitating measurements.

Source : The main improvements relate to the arc current pulse supply, which is now capable of providing 100 A for 120 μs, the extraction pulse supply, the pulses of which have also been lengthened to 120 μs, and the position of the oxide cathode, which has made it possible to operate with one-sixth of the quantity of hydrogen previously needed. The new source, which had undergone lengthy testing on the experimental 3 MeV linac, has been in use on the PS since the machine restarted at the beginning of the year.

Accelerator column : A programmed circuit was previously used to compensate for the voltage drop occurring at the terminal electrode of the accelerator column during the passage of the beam. It was replaced in December last year by a servo-system which compensates for the beam loading as a function of the beam variations. Here also tests were carried out on the 3 MeV linac.

Quadrupoles : The quadrupole triplets, situated between the accelerator column and the first cavity of the linac, and the focusing quadrupoles located inside the forty-two drift tubes of the first cavity, are pulsed because of the intensity of the currents passing through them. (The focusing quadrupoles of cavities No. 2 and No. 3 are supplied with d.c. current.)

Because of the lengthening of these pulses to cope with the longer beam current duration, the pulsed power supplies (the power of which has been increased to allow the repetition rate to be increased and which must now provide pulses for at least 120 μs) have been changed.

The previous supplies provided a semi-sinusoidal pulse of 500 μs at the base, of which only a very small part (4 %) at the peak was used to power both the triplets and linac quadrupoles. The new system employs a circuit which, combining the third harmonic of the same wave, gives a very steady flat top (±0.15 %) for 100 μs, the precise shape of which may be modified to suit requirements.

Beam loading : In the three linac cavities the r.f. voltage has to be maintained constant for the duration of the pulse. Each cavity has two triodes, one of which brings the field to operating level while the other compensates for beam loading. The first will remain unchanged, while the peak power and gain of the second are doubled. Since the pulse lasts for 100 μs instead of 20 μs, the two anode pulse-shaping modulators are being changed.

Servo-controls : A phase servo-control acting on the tuning of the cavities has been used till now whereas the level was programmed. In future there will be two complete feed-back loops ; a slow one to match the cavity level with a reference level and readjust it from pulse to pulse, and a fast one to react to variations during the pulse by acting on the input of the triodes through a wide-band amplifier. In the new system the tuning servo-control will be completely separate from the phase control which will improve the phase stability between cavities and the voltage stability in the cavities.

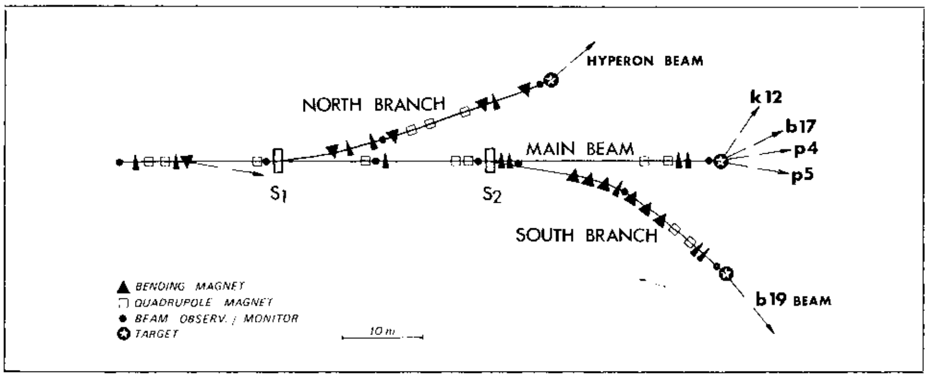
Data Acquisition and Controls : Data acquisition requires a large number of analog-digital converters. Since the commercially available converters are expensive, the linac group itself devised a series of units, most of which are accurate to within one part in a million. The system is connected to 'Star' linked to the control computer.

The linac has about 50 mechanical controls which are normally adjusted manually or by means of remote-controlled motors. When these are automated stepping motors will be used with an electronic system linking the computer and the motors. This electronic system is also expensive, so a single unit for every 8 motors will be used having a multiplex system and dealing with the motors in turn (both for acquiring position data and for transmitting control signals). The data acquisition system will be installed after the new units and should be completed by the end of 1971 ; the controls will be installed later as dictated by the needs of the whole installation.

1. The layout of the slow ejected beam at the PS in the East Hall with its three branches. S_1 and S_2 are the two splitter magnets which can slice the beam horizontally and deviate slices down the side branches.

2. A cross-section of the slow ejected beam taken a few metres downstream from the second splitter magnet (the first splitter magnet was not deviating beam). The beam sent down the South Branch is seen separated off to the right ; on the left the remainder of the beam can be seen 'sliced' due to the first magnet but with the slice still in the beam since it was not deviated.

3. Cross-section of an iron septum magnet used to split the slow ejected beam. The two septa (sketched in black) can be moved across the beam so as to pick out slices of any desired height. Application of field to the slice bends it off down one of the slow ejected beam branches.



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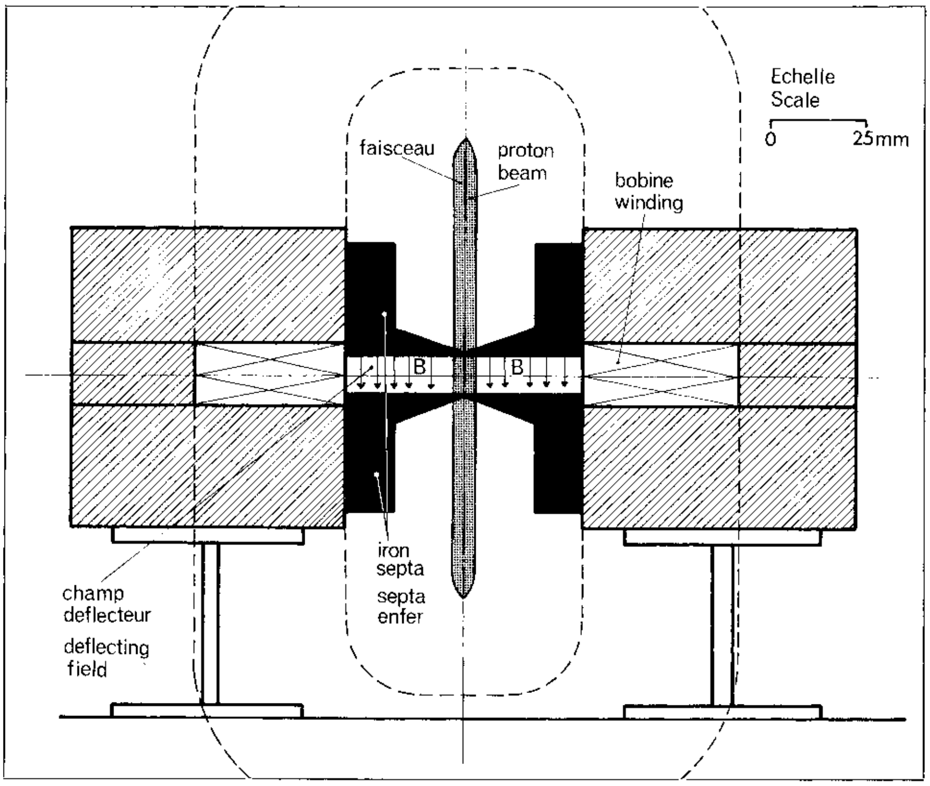

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Horizontal slices of the beam

Since the beginning of February a new, unique system for distributing the slow ejected beam in the East Hall has been in operation. The beam is divided twice to feed three different targets simultaneously giving rise to six secondary beam lines. The number of protons distributed to each target can be adjusted at will according to experimental requirements and what is new is that the duration and the shape of the proton burst to each target is now the same.

A septum magnet had been in use for the purpose of beam splitting during 1967 and 1968. It effectively cut the beam into vertical slices so that the right-hand slice went to the right, the centre slice straight ahead, and the left-hand slice to the left. However, on account of the variation of the proton momentum across the beam this system had the drawback of feeding the various targets with bursts of protons which did not have the same momentum spread and therefore not the same spill duration. This is because, during slow ejection, the protons with the highest energy (on the outer side of the vacuum chamber) are ejected first and those with the lowest energy last. In consequence the pulse duration in each vertical slice was not identical.

The new system cuts the beam into horizontal slices of variable thickness. The splitters (iron septum magnets) are placed at points where the height of the beam has been greatly increased by suitable optics whilst it is focused horizontally.

In the present layout two splitters are used in series ; each of them can pick out and deviate a slice of the beam. The proton bursts corresponding to the slices removed, or to the remainder of the beam, have exactly the same momentum spread, and therefore the same duration and the same structure.

Since the beam fed on to each target has momentum spread, the focusing onto the target is improved by using a pulsed magnet whose field may be programmed so that it matches the variation of the momentum with time. (The optics is designed to optimize the three branches independently.)

The idea of this method of sharing the slow ejected beam emerged from discussions between members of the Proton Synchrotron and Nuclear Physics Divisions. The beam layouts were designed by the MPS Division and several groups were involved in developing the equipment and building up the installation. The splitter magnets were designed and constructed by the NP and Synchro-Cyclotron Divisions.

Around the Laboratories

RUTHERFORD
Element 112

Following up a simple but ingenious idea, a team working at the Rutherford Laboratory has gathered some results which could be the first evidence for the existence of the element with atomic number 112. The team (A. Marinov, C.J. Batty, A.I. Kilvington, G.W.A. Newton, V.J. Robinson and J.D. Hemingway) presented the results in Nature, 12 February.

The elements which we find 'naturally occurring' in our environment stretch up to element 92, uranium. Since 1940, however, increasingly heavier ones have been artificially manufactured (the scientists at Berkeley being predominant in this work) up to as high as element 105 identified last year (see vol. 10, page 156). It is in understanding something of why uranium is the heaviest element found in Nature and of how we manufacture the heavier ones, that we can best interpret what the new results are about.

Generally speaking, the more protons there are crowded together in the tiny nucleus the more unstable the nucleus is likely to be, since the positive charges on the protons try to move away from one another. (This is not universally true as we shall see later, for there are some numbers of protons and neutrons which couple together in the nucleus in such a way as to give it exceptional stability.) Also, in general, the heavier the element the more neutrons, proportionally, it likes to have in its nucleus to ensure its stability. Thus the uranium nucleus is usually found with 146 neutrons added to its 92 protons.

The artificial manufacture of heavy elements means producing nuclei containing more protons and still more neutrons than uranium. Two techniques mainly have been used. The most fruitful has been to bombard heavy nuclei with heavy ions. If the heavy ion has sufficient energy to overcome the potential barrier due to the positive nucleus, it can enter the nucleus and add its particles to the nucleus. As an example the element 102, nobelium, was manufactured from element 96, curium, by bombarding curium with carbon ions carrying six protons. The second technique is to expose heavy nuclei to large doses of neutrons. Neutrons penetrate easier than protons since they do not feel the positive charge pushing them away and once installed a neutron can transform into a proton by emitting an electron (beta decay) converting the nucleus to that of a higher element. This was the mechanism preceding the first identification of element 93, neptunium, which was formed from the beta decay of the uranium isotope 239.

Because of the internal disruptive effect of their many protons, the 'transuranium' elements live for only a comparatively short time before decaying into the lower elements, usually either by emitting a clump of two protons and two neutrons (alpha decay) or by splitting in two (fission). There is every reason to believe that during the dramatic events which formed the universe there was enough energy around to form transuranium elements of all possible types but when we now look for them in Nature itself we do not find them because they have all long since broken up into the lower elements.

As mentioned above, there are some nuclei where the neutrons and protons pair-off so well together that the configuration is particularly stable. The numbers which give this stability are often called 'magic numbers' (2, 8, 28, 50, 82, 126). Thus, for example, the 'doubly magic' nucleus of lead which has 82 protons and 126 neutrons is exceptionally stable.

It was predicted about three years ago that the nucleus of element 114 with 114 protons and 184 neutrons might be another of high stability. The elements close to it are also expected to have some very stable isotopes, but up to now it has not been possible to reach this new transuranic 'island of stability' because of lack of ability to throw enough nucleons together. The Berkeley Super-Hilac (see below) and other heavy ion accelerator projects are designed to give us that ability.

There have, nevertheless, been some isolated pieces of evidence for the existence of very heavy elements — for example, from studies of spontaneous fission in lead at Dubna (see vol. 9, page 112), from cosmic ray photographs studied at Bristol University, from tracks left in meteorites and moon rocks studied at the Tata Institute. The Rutherford work has added itself to this list.

The bright idea came from A. Marinov (a physicist at the Rutherford Laboratory on leave from the Hebrew University, Jerusalem). He suggested that in the targets bombarded with protons at high energy accelerators we can have the conditions necessary for bringing many nucleons together. An incoming proton can bounce a nucleus in the target forward with high energy so that it crashes into another nucleus. The heavy ion accelerator situation on a small, not-controlable scale could thus be achieved inside the target and could produce nuclei of very heavy elements.

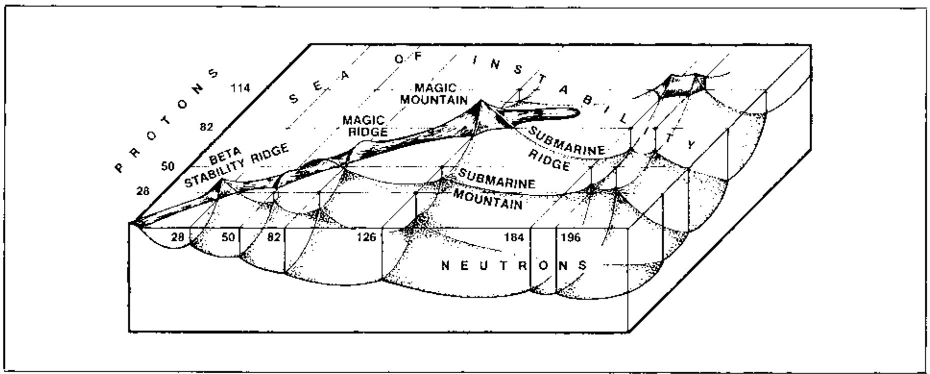
Step one was therefore to acquire targets which had been subject to long exposure in a proton beam at the CERN PS. Two tungsten targets which had been bombarded with 24 GeV protons in the neutrino beam-line were transported to Rutherford. It was calculated that the recoil tungsten (element 74) nuclei could have energies between 1 and 5.6 GeV and, since the potential barrier between two positively charged tungsten nuclei is about 1 GeV, it is likely that the nuclei often got in amongst one another. By spilling off particles a whole range of transuranic elements could be produced. The short-lived ones would obviously not be seen much later but the longer-lived, such as those around the element 114 island of stability, might still be there if in fact they were formed. The remaining question was whether they were there in sufficient quantity to be detected.

Step two was to attempt to pin down particularly element 112. Thanks to the nice orderly periodic table of the elements, it is possible to predict the chemical behaviour of elements which are not yet found. Mendeleev, who first shuffled the table together in 1869, knew only 63 elements but was able to predict others and describe their properties. Because the chemical properties depend only on how electrons are populating the outer fringe of the atom and not on the nucleus, we can have elements of radically different nuclear composition exhibiting similar chemical behaviour. Element 112, from the periodic table, is expected to behave chemically somewhat like mercury.

The two targets were therefore subjected to some intricate chemistry to isolate the mercury-like elements. The isolated samples were then studied for signs of spontaneous fission and for alpha emission. Spontaneous fission is characteristic of transuranic elements. Covering samples with polycarbonate films yielded, for example, about 90 detected fission fragments in 37 days. It is believed that the fission events are unlikely to be due to any contamination of the samples. (Similar samples drawn from the targets, for example of gold-like elements, showed no evidence of spontaneous fission, which strengthens the believe that mercury-like element 112 is being seen.)

There is further evidence in the alpha spectra observed from the samples. There are some predictions for element 112 of emission with characteristic alpha energy of between 6.5 and 7 MeV. Alphas of energy of 6.73 MeV were observed. These alphas have not been clearly associated with any other known decay.

Obviously these results will need amplifying and checking at Rutherford and elsewhere before the conclusion is completely accepted. It is nevertheless a thoughtful and provocative piece of research.



Swiatecki's allegory — an imaginative representation of nuclear stability. The peaks indicate the exceptionally stable nuclei and it is in the region of the 114 protons, 184 neutrons peak that the Rutherford team has searched for evidence of a new heavy element. (The 196 neutrons position, incidentally, is now no longer believed to correspond to a very stable configuration.)

DARESBURY Spectrometer system

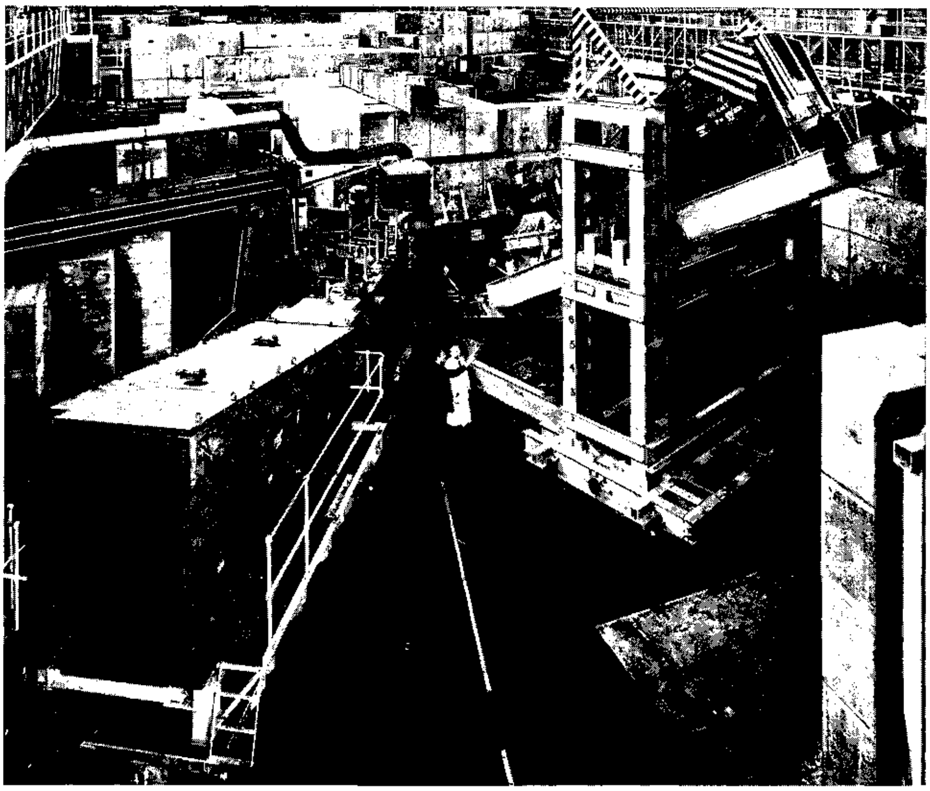
Using a unique spectrometer system, some very interesting and comprehensive data on photoproduction reactions have been obtained at the 4 GeV electron synchrotron at the Daresbury Nuclear Physics Laboratory by a Lancaster-Manchester team.

The system consists of a 120 ton electron spectrometer which can operate at angles from 9° to 30° to the incident electron beam and a 110 ton proton spectrometer which can operate at 19° to 65° in the horizontal plane and can tilt at angles up to 30° to the horizontal plane. Each of these spectrometers consists of two half quadrupoles and a vertical bending magnet with a momentum hodoscope and ancillary defining counters, the hodoscope being shielded by about 60 mm of steel. The liquid hydrogen target and its feeder system contain a very small volume of hydrogen, being cooled by a cryogenic refrigerator, and are inherently very safe.

The system is used to study photoproduction reactions with the virtual photons produced when the incident electron scatters into the electron spectrometer. The virtual photons are strongly polarized with the electric vector in the plane defined by the incident and scattered electron, which means that the production reactions have angular distributions which vary very strongly with $\emptyset$ as well as Θ (where Θ and $\emptyset$ are spherical polar co-ordinates with respect to the virtual photon direction).

The data already obtained forms part of an extensive programme of measurements on photoproduction reactions with virtual photons being carried out at Daresbury with the spectrometer system.

Technological footnote : To provide a flexible system for moving heavy equipment, such as spectrometer arms and magnets, with precision and repeatability a technique using re-



The two mighty arms of the spectrometer system used in a survey of photoproduction reactions at the Daresbury Laboratory. The proton arm on the right (weighing some 110 tons) can be moved with precision in both the horizontal and vertical directions.

(Photo DNPL)

circulating ball castors rolling on hardened steel plates backed by a precision laid concrete floor, is used at Daresbury. For example, during the past year the spectrometer used in the photoproduction measurements has been repositioned during running cycles some 650 times ; repeatability and accuracy of ±0.5 mm has been maintained over the 12.5 m length of each arm.

The castors are mounted in packs of twenty-five and preloaded to a load of about 600 kg; each castor is backed by a stack of Belleville washers. The overall height is restricted to about 20 cm. The plates are attached to the floor at the corners, bolted to inserts in the concrete which is laid to ±1 mm. Castors and plates were obtained from Autoset Ltd and Dunsford Hadfield.

At present 1000 tons of equipment is in use and is moved using this system. Most of the equipment has been in service for over two years and has proved trouble free. The system is also being used in a Rutherford / QMC / Daresbury / Liverpool experiment now on the floor at the CERN PS.

FRASCATI
Synchrotron future

The 1.1 GeV electron synchrotron at the Frascati Laboratory has now been in operation for twelve years (since the beginning of 1959) and there have recently been discussions to see what useful physics is still within the range of the machine. In November 1970 a meeting was held with scientists from Laboratories with related interests (Bonn, Daresbury, DESY, Saclay) to discuss research programmes and the possible modifications which might be made to the synchrotron and its experimental facilities to open up further experimental possibilities.

The subjects covered included photoproduction and electroproduction of mesons and invariance properties of electromagnetic interactions. Possible machine improvements are the acceleration of polarized electron beams to be used in conjunction with polarized proton or deuteron targets, or to be used on a target to yield circularly polarized photons, and the addition of photon tagging systems.

Meanwhile research at the 1.5 GeV electron-positron storage ring ADONE is yielding subjects of interest which were not anticipated. There is, at present, concentration on studying the surprisingly high rates of hadron production observed by teams at several of the intersection regions. More statistics are needed to find the mechanism behind these interactions, studying their energy dependence and angular correlations. Towards the end of this year it is hoped to have a large magnet installed over one of the intersection regions with optical spark chambers and possibly some multiwire proportional chambers for triggering. A Genoa, Padua, Frascati, Rome team will then study hadron production with higher solid angle for detection.

There is plenty to keep the ADONE team and experimenters occupied for some time. Possible short-term developments include a way to increase the luminosity by changing the magnet structure periodicity (doubling the number of groups of focusing quadrupoles supplied with different currents) thus changing the local betatron wavelength in the interaction regions. Longer term the experimental results obtained so far point to the need for higher energies. There is some very preliminary thinking about two higher energy intersecting rings. The construction costs would be absorbed predominantly by the r.f. accelerating systems and it would probably be necessary, in order to reach high energies within a reasonable budget, to accept lower currents in the rings and to use low beta regions to obtain high luminosities.

JAPAN
Construction of Laboratory begins

We already need to up-date the information we gave in the last issue (page 44) on the proton synchrotron to be built at Tsukuba near Tokyo. A budget of $ 4.2 million is assigned to the project in fiscal year 1971 and construction of the Laboratory on a 200 hectare site is authorized to begin next month (April). It is to be called the 'National Laboratory for High Energy Physics' and will be open to scientists from universities and research institutes throughout Japan. It will also be the centre promoting

The ADONE storage ring at the Frascati Laboratory with experiments in position around the intersection regions.

(Photo CNEN)

A map of the Tokyo region in Japan showing the location of the new 'National Laboratory for High Energy Physics' where a 8 GeV proton synchrotron is to be built.

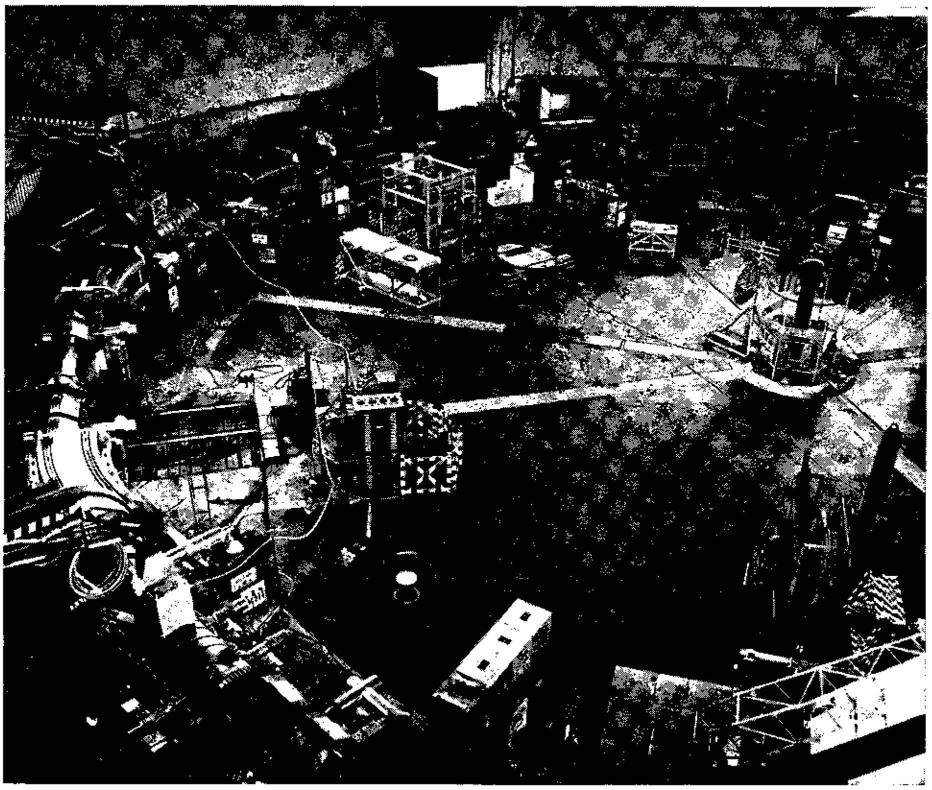
international collaboration in the field of particle physics on behalf of Japan.

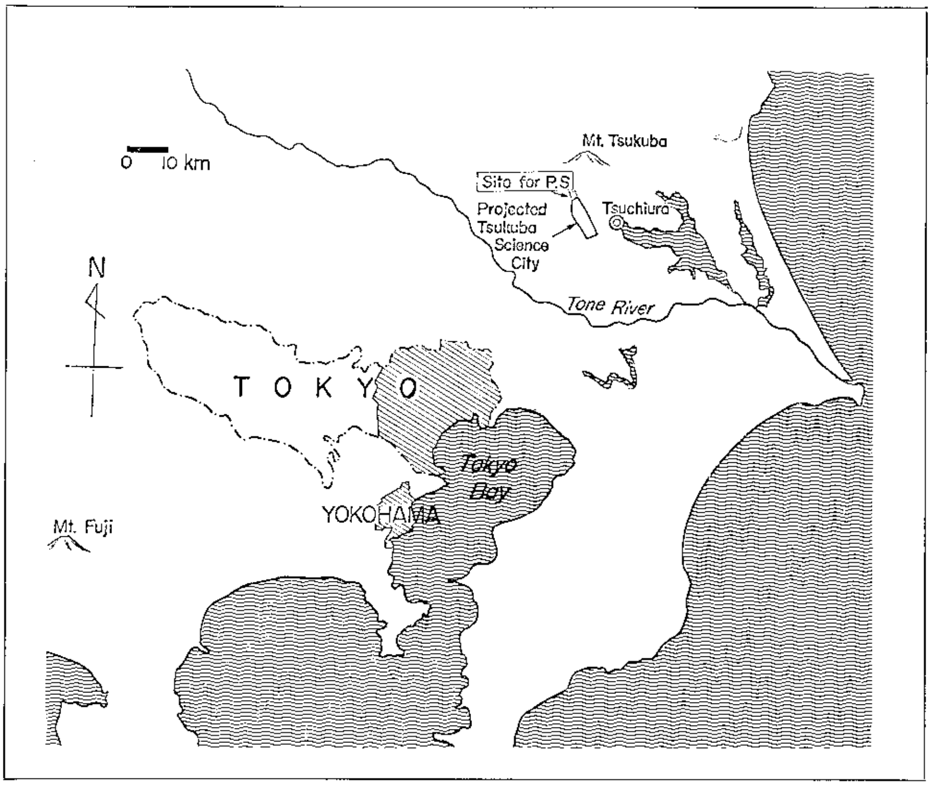
The total construction cost for the Laboratory is estimated at $ 24 million (including about $ 16 million for the accelerator, experimental facilities and support facilities, and about $ 7.5 million for buildings — including the accelerator enclosures — and utilities).

We will pick out a few design features of the accelerator which now differ from those listed in the last issue. The main magnet ring is to be separated-function with an initial peak energy of 8 GeV. The ring diameter will however be quite large (108 m) so that the peak energy could be taken to 12 GeV (with peak magnet fields of 1.9 T) given further investment. The 500 MeV booster diameter has been increased to 12 m and the peak field in its combined-function magnets reduced to 1.1 T.

The leaders of the various sections of the Laboratory, under the Director S. Suwa, are — T. Nishikawa (Director of the Accelerator Department), S. Yasumi (Director of the Physics Department), and I. Miura (Director of Scientific and Technical Services Department).

The machine is scheduled to begin operation in 1974. The budget does not make generous allowance for experimental facilities but it is hoped that sufficient beam transport equipment and detectors (including a hydrogen bubble chamber) will be in position for an experimental programme to begin as soon as the accelerator is completed.





BONN Machine operation and experiments

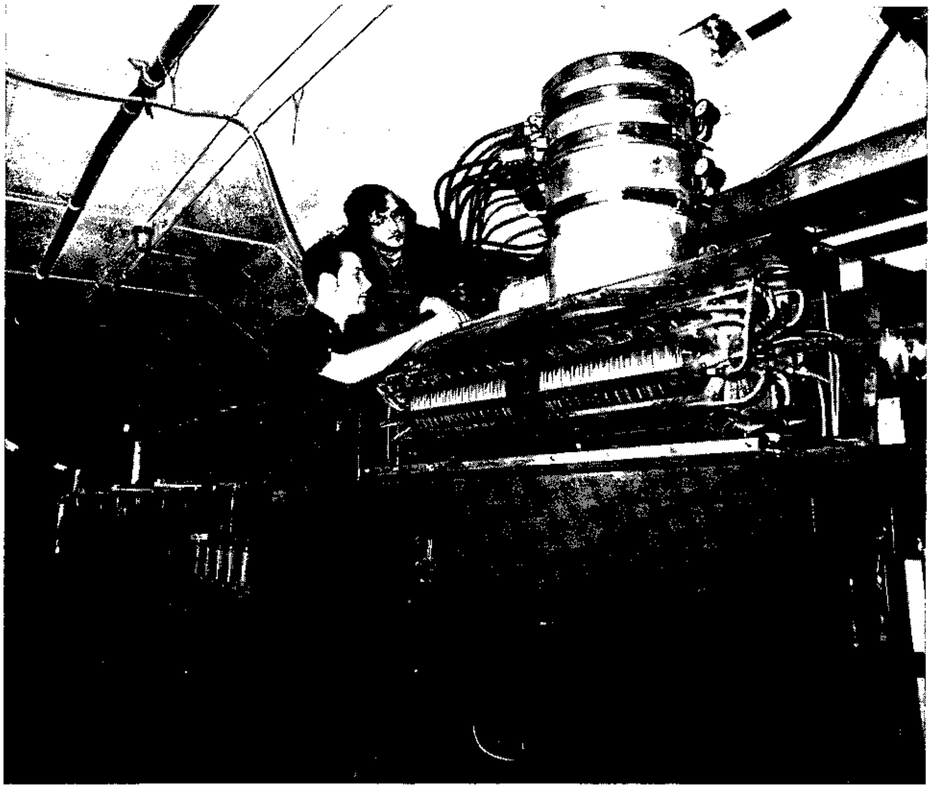
The 2.5 GeV electron synchrotron of the University of Bonn is now in its fourth year of operation. Its present performance yields about 5×10^{12} electrons per second, regardless of the energy at which the machine is operated (which can vary between 0.5 and 2.5 GeV). During the past year work on the machine has concentrated on improving the beam observation systems and on improving the stability of the injected beam.

New fixed targets have come into operation using a beam bump technique and they have been introduced to generate photon beams. Five different photon beams and one external electron beam are now being used. The power requirements of the experimental set-ups has increased considerably and during the past year the cooling system had to be extended.

Several experiments are now running. After completion of a positive kaon photoproduction measurement the kaon spectrometer is to be used to measure pion photoproduction with an unpolarized beam and a polarized proton target. The polarized target has already been tested in a photon beam. Measurements of the polarization of the recoil particle in pion photoproduction are continuing.

Differential cross-sections of eta photoproduction are being measured with the aid of total absorption Cherenkov counters. An experiment on positive kaon photoproduction in the backward direction has given preliminary results. An experiment on phi meson photoproduction between 1.6 and 2.5 GeV has just started taking data.

The external electron beam has been used for a single-arm measurement of inelastic electron-proton scattering in the region of the first resonance. The list of present experiments is completed by a coincidence experiment which has started to measure the differential cross-sections of pion electroproduction by observing the recoil proton in a spark chamber spectrometer in coincidence with the scattered electron.



BATAVIA Progress Report

The pressure is still on to bring the 200-500 GeV proton synchrotron being built at Batavia into action this summer. The present state of the three component accelerators is as follows: The 200 MeV linac is working very reliably and has been serving as injector for the Booster for many weeks. The fast-cycling 8 GeV Booster, which produced its first accelerated beams on 6 February, is operating stably at 1 GeV (the East Gallery r.f. systems are not yet in operation to take the beams to peak energy). Orbit corrections were not required for initial acceleration despite the small aperture (about half the size of any other proton synchrotron) and the r.f. programme was near enough to the optimum to achieve acceleration. Power supplies and magnets are working well but general tuning up is needed to approach the design figures and of course the remaining half of the r.f. cavities have to be brought in.

On 26 February a 1 GeV beam (about 1 mA) was ejected from the Booster and taken through a completed section (one sixth) of the main ring. The main ring magnets were powered for the first time by the permanent power lines from the master substation. Magnets for the ring are now being produced at the rate of about 60 per week and are being installed at the same speed. Over two-thirds of the ring is now complete. Pressure is now being brought to bear on the ejection system so as to be ready to send beams out

Left : Installation of magnet shields in an r.f. unit of the 8 GeV Booster at Batavia. One of the magnets is just about visible in the background on the left.

Below : A completed section of the main magnet ring. Magnet installation is going ahead at the rate of about 60 magnets per week.

(Photos NAL)

to the experimental areas when acceleration is achieved.

Experimental facilities will not then be in a polished state by any means — first of all because of the incredible speed at which the accelerator has been constructed, and secondly because the rate of funding has allowed only $ 13 million out of an anticipated $ 60 million to be spent on experimental equipment. (Up to the time the accelerator comes into action only $ 150 million of the projected $ 250 million construction funds will have been received. Only the most urgent construction could be tackled in these circumstances.)

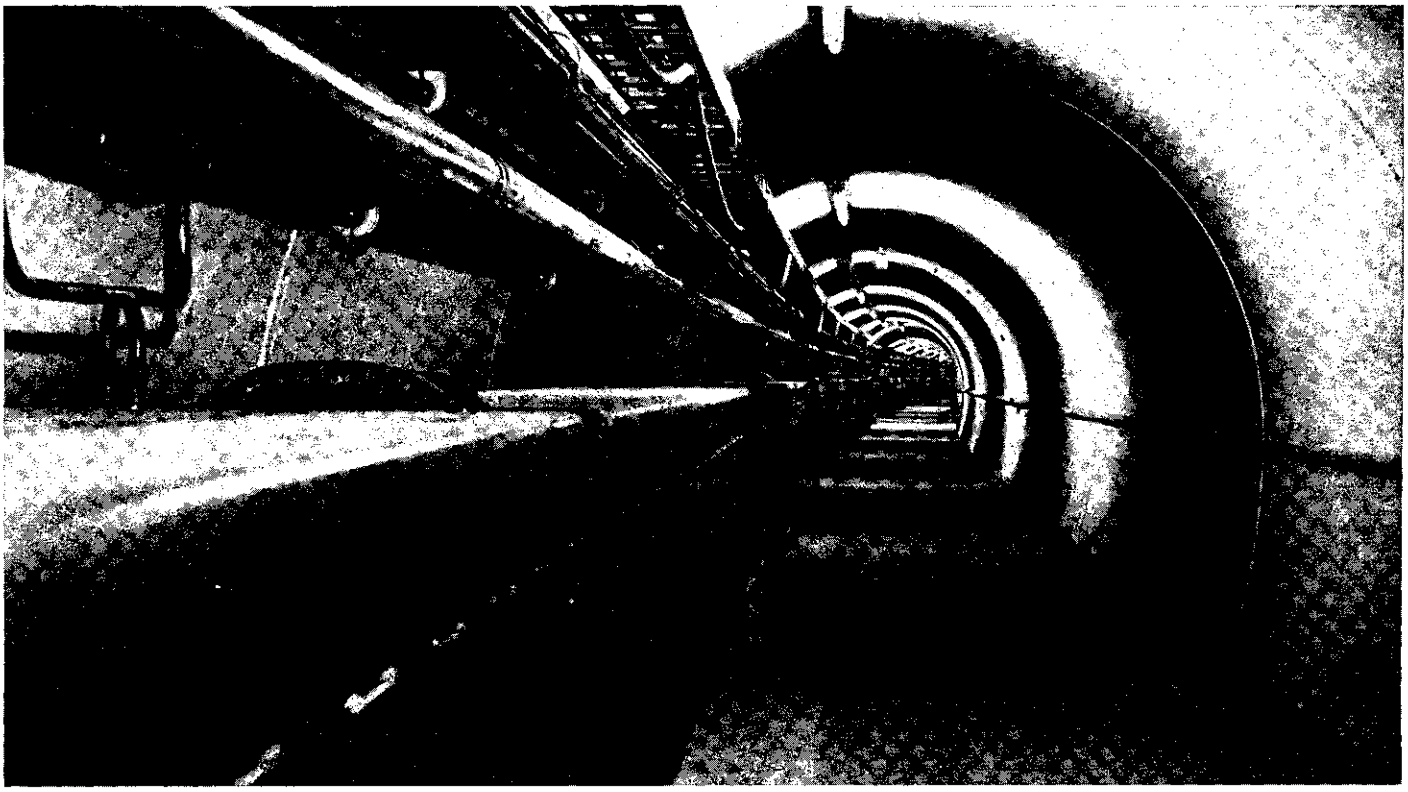
Two experimental areas (the meson area and the neutrino area) in their 'phase I' form are scheduled to be ready by late summer ; about six teams might then come into action. The 30 inch hydrogen bubble chamber from Argonne is being moved to Batavia to be ready for the start of the experimental programme but the major bubble chamber facility will, of course, be the 15 foot hydrogen chamber which is being built at a cracking pace. A first assembly of the vacuum tank was made at the end of February and the chamber is scheduled to begin physics mid-1972.

In a statement to the Joint Committee on Atomic Energy on 9 March the Director of the Laboratory, Professor R.R. Wilson, uncovered the latest idea for eventually pushing the energy of the accelerator higher. It is known as the 'energy doubler' and involves a small-bore (perhaps 3 cm) superconducting magnet ring mounted 'piggyback' on the existing main ring exactly repeating the main ring lattice.

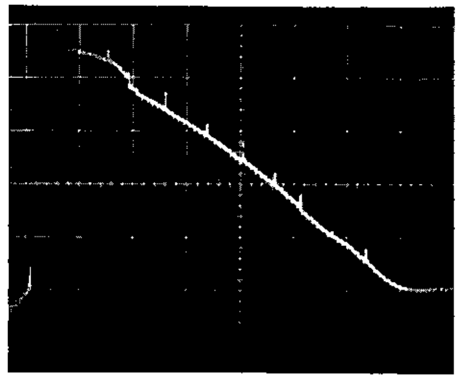
The main ring would be used as Booster No. 2 to feed the superconducting ring at very high energy. The superconducting magnets would not then have to swing their fields from very low levels to peak value but would need to double over a smaller range (for example 2 to 4 T) to double the energy of the accelerated protons. The ultimate peak energy could be around 1000 GeV but the energy doubler might prove an economic way of operating at much lower energy because of its low power consumption. A very preliminary cost estimate is less than $ 20 million. If the idea matures and the corresponding technology is mastered, the energy doubler is considered a possibility for about five years from now.

BERKELEY
Super-Hilac being prepared

Following on from the news of possible identification of element 112 at Rutherford is news of the final



Output signal of a dynamic phase meter monitoring the phase variation in an 'energy ramp' at the output end of the Saturne linac. The vertical scale is 20° square ; the horizontal scale is 100 μs/square. Achieving a linear phase variation over a time of 600 μs as shown makes it possible to achieve a similar linear rise in energy of the protons injected into a rising magnetic field in the synchrotron.



stage of preparation to convert the Heavy Ion Linear Accelerator (HILAC) at the Lawrence Radiation Laboratory, Berkeley, to a more powerful machine to be used particularly for the creation of very heavy elements. The converted machine will be known as Super-Hilac and will be the first to be capable of accelerating ions as heavy as uranium to energies high enough for them to penetrate into other heavy target nuclei. Modifications to HILAC began in February and the Super version is scheduled to begin operation in September. The research programme will open up again next January.

HILAC was capable of accelerating the lighter elements (up to argon) to sufficiently high energies for nuclear penetration and, since it first came into operation thirteen years ago, it has been the scene of the production and first identification of many new heavy elements. To extend beyond element 105 (identified at Berkeley last year — see vol. 10, page 156) it is necessary to bring more nucleons together than is possible with the argon nucleus as the heaviest projectile. One of the first experiments will be to bombard uranium nuclei with accelerated uranium ions in an attempt to find element 114.

Super-Hilac was proposed by A. Ghiorso and R. Main. The modifications will cost about $ 3 million. It will be capable of accelerating ions of all elements to energies ranging from 2.5 to 8.5 MeV per nucleon (HILAC was capable of 10.4 MeV per nucleon put only for ions with 40 nucleons or less).

Two new linac tanks, about 18 m and 30 m long, will replace the existing tanks and will have individually operable r.f. sections so that power can be fed to the appropriate number of sections to achieve a desired energy. The r.f. control system will allow different ions to be accelerated to different energies on alternate pulses so that several experiments can be set up at the same time to receive particles. Within the r.f. cavities a 4 T quadrupole magnet system will keep the ion beam focused.

A newly developed 'sputter source' will feed solid material into the plasma of the ion source. A 3 MeV Cockcroft-Walton injector will take the ions from the source to the first tank. Between the tanks a 'stripper' (a thin foil or a small volume of gas) will be installed to pull off more electrons from the ions so that they enter the second tank with higher charge and can be accelerated to higher energies.

Beam intensities are expected to range from 10^{11} ions per second, for heavy elements such as uranium, to 10^{16} ions per second, for light elements such as carbon.

In addition to the search for new heavy elements, mentioned above, a series of nuclear structure experiments and biomedical studies of the effects of particle radiation (both in relation to radiation hazards in space and to cancer therapy) are planned.

Summer Institute

An 'International Summer Institute on Duality in Elementary Particle Physics' is being organized by the University of Louvain (Belgium) and Technische Hochschule Aachen (Federal Republic of Germany). It will be held at Louvain from 30 August to 15 September. Further information can be obtained from D. Speiser, Institute for Theoretical Physics, Celestijnenlaan, 200 D, 3030, Heverlee, Belgium.

SACLAY
Variable energy Saturne injection

As recorded in CERN COURIER vol. 9 page 138, a special device has been installed at the output of the 20 MeV Saturne linac to allow injection to take place into the magnet ring of the 3 GeV proton synchrotron with increasing energy over a time interval of 600 μs. The excitation of betatron oscillations during injection into a rising magnet field in the synchrotron ring is thus avoided. The device which had not been in use because of technical difficulties, has just been successfully operated.

The energy increase is obtained by using an additional cavity called an energy ramp. Its power is provided via a fast-acting ferrite dephaser (specially designed for this application by the company LTT) capable of transmitting a power of 100 kW. A linear phase variation is applied which causes the phase of the r.f. wave in the energy ramp to vary during the passage of the particles from —45° at the beginning of the pulse to +45° at the end. This gives a linear increase in the beam energy around 20 MeV at a rate of 1 keV/μs, which exactly compensates for the rise in the magnetic field in the synchrotron.

The phase of the debuncher in relation to the linac must also vary to compensate for the reduction in the flight time of the particles during the beam pulse, and the debuncher therefore also receives its power supply via a ferrite dephaser. The phase shift is 150°.

The phase variation obtained is

monitored by means of dynamic phase meters designed by ALCATEL and capable of measuring up to 180° in 600 μs ; these instruments have, in fact, made it possible to operate the servo-system contains a digital memory which allows the results of one cycle to be taken into account in working out the following one.

Variable energy injection into Saturne has made it possible to increase the number of protons accelerated per cycle from 6×10^{11} to 10^{12} ; this latter level cannot be exceeded at the moment because of coherent beam oscillation in the synchrotron.

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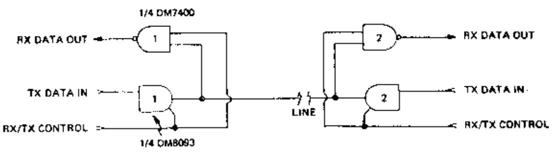

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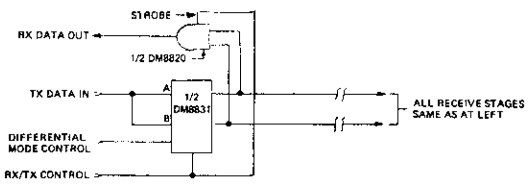

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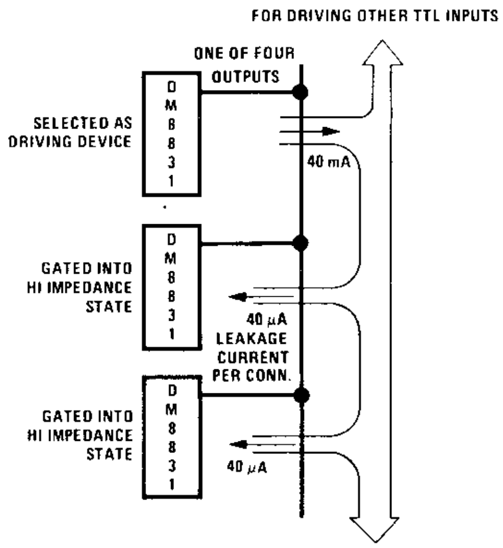

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