CERN COURIER

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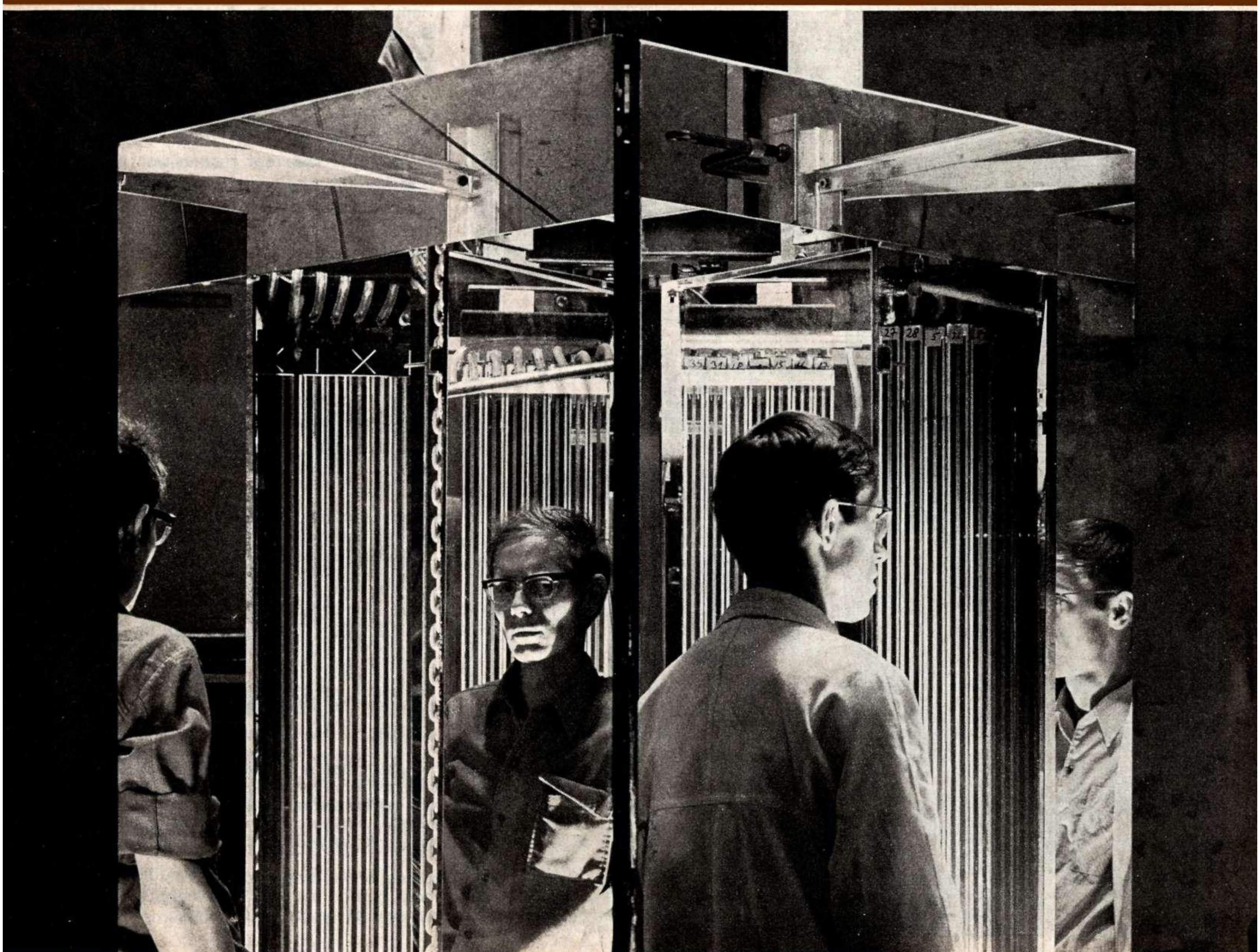
European Organization for Nuclear Research



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. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. 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 their research material from CERN.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2650 people and, in addition, there are over 400 Fellows and Visiting Scientists.

Thirteen European countries participate in the work of CERN, contributing to the cost of the basic programme, 235.2 million Swiss francs in 1969, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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CERN News

UK accepts Convention amendments

On 8 May it was announced that the UK has become the first Member State to accept the proposed amendments to the CERN Convention. Acceptance of these amendments is essential to enable the 300 GeV Laboratory to come into being and, now that the final decisions on the new Laboratory are very close, it is important to have them accepted by all the 13 Member States.

The existing Convention explicitly provides for the establishment of one research centre with two accelerators — a synchrocyclotron of 600 MeV and a proton synchrotron with an energy higher than 10 GeV. (The centre is, of course, the Laboratory at Meyrin near Geneva with its 600 MeV and 28 GeV machines.) It does not allow another centre to be established under the same Organization. To make this possible, a series of amendments were worked out and approved by the CERN Council at its meeting in December 1967. The revised version of the Convention was then passed to the governments of the Member States for their acceptance. (An explanation of the revised Convention appeared in CERN COURIER vol. 8, page 56.)

In being the first to accept the revised version, the UK follows the precedent of 1954 when it was the first Member State to ratify the original Convention. Ironically, the UK is the only State to announce its intention not to participate in the new Laboratory. But in accepting the revised Convention the UK has demonstrated that it does not wish to delay the efforts of the six countries (Austria, Belgium, Federal Republic of Germany, France, Italy, and Switzerland) who have declared themselves ready to support the 300 GeV project.

Booster progress

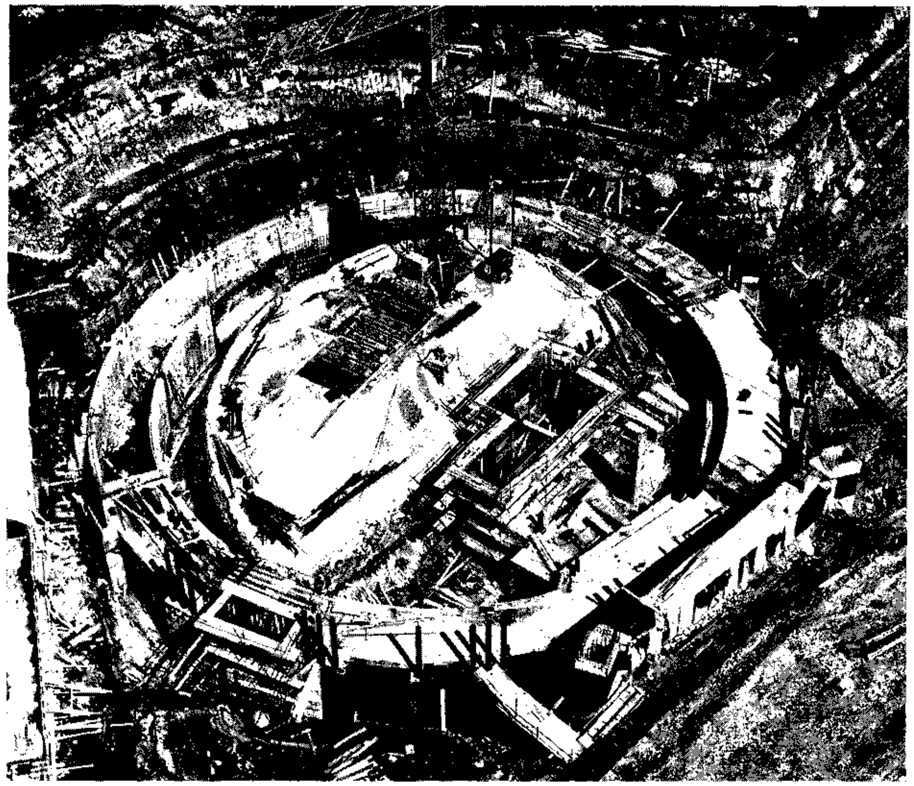
In May, the last roof section was put in place on the ring tunnel building to house the Booster. The Booster is one of the major items of the programme of improvements at the 28 GeV proton synchrotron, serving to increase the intensity

Contents

Cover photograph: It is all done by mirrors. The photograph is of the final mirror which brings together onto one film the information coming from four banks of optical spark chambers (the four separate banks, seen end-on, can be distinguished). The final mirror looks at two mirrors which seem to form two faces of a large cube in the photograph. In the two faces of the 'cube' are then seen further mirrors which receive the light from the spark chambers.
The chambers were used to measure the momentum of the proton coming from the beta decay of the lambda particle. The experiment, carried out by a Heidelberg/CERN team, has recently finished collecting data and is now at the stage of analysis. (CERN/PI 38.5.69)

An aerial view, taken at the end of April, of the construction work on the tunnel building to house the 800 MeV Booster at the proton synchrotron. At this time, the tunnel walls were almost complete and the roof sections were in place about half way round the ring.

Below: The octagonal vessel, containing target and detectors built at CERN, is loaded into its transport en route for Uppsala.



CERN/PI 320.4.69

CERN IPI 162 A.5.69

of the accelerated beam. It will do this by boosting the energy at which protons are injected into the synchrotron; protons from the existing 50 MeV linear injector will be accelerated in four small synchrotrons, stacked one on top of another, to an energy of 800 MeV before being fed to the main ring. The Booster was described in CERN COURIER vol. 8, page 3.

The basic design work is almost complete and all parameters will be fixed by July. The major contracts can then be placed. Full-scale models of a booster bending magnet and quadrupole (each with four apertures vertically to take the four beams) are scheduled to arrive at CERN in September for testing. It has been decided to power the magnets directly from the mains using static compensation rather than installing the usual alternators. This will be the first use of static compensators on an accelerator in Europe, apart from test assemblies which have proved the method at Rutherford and CERN. (The 200 GeV accelerator at Batavia will also use this method.)

The design and construction programme for the Booster is on schedule so far. An article on the developments over the past two years will appear in CERN COURIER in December.

Another-time reversal phenomenon

At the end of April, experimental equipment prepared at CERN was shipped to Uppsala for preliminary tests to be made on a beam from the 185 MeV synchro-cyclotron at the Gustaf-Werner Institute — thus travelling in the opposite direction to the traditional.

The main unit in the apparatus is an octagonal vessel containing a helium gas target surrounded by detectors. The helium, at 2 to 10 atmospheres pressure, is contained in a reinforced mylar tube. It is surrounded by two concentric cylindrical wire spark chambers working in an atmosphere of helium and 10% alcohol at 40 mm pressure. Surrounding these, in turn, are scintillation counters mounted on the faces of the vessel (one face being in use initially). All this is neatly packed into a volume of about 0.5 m^3.

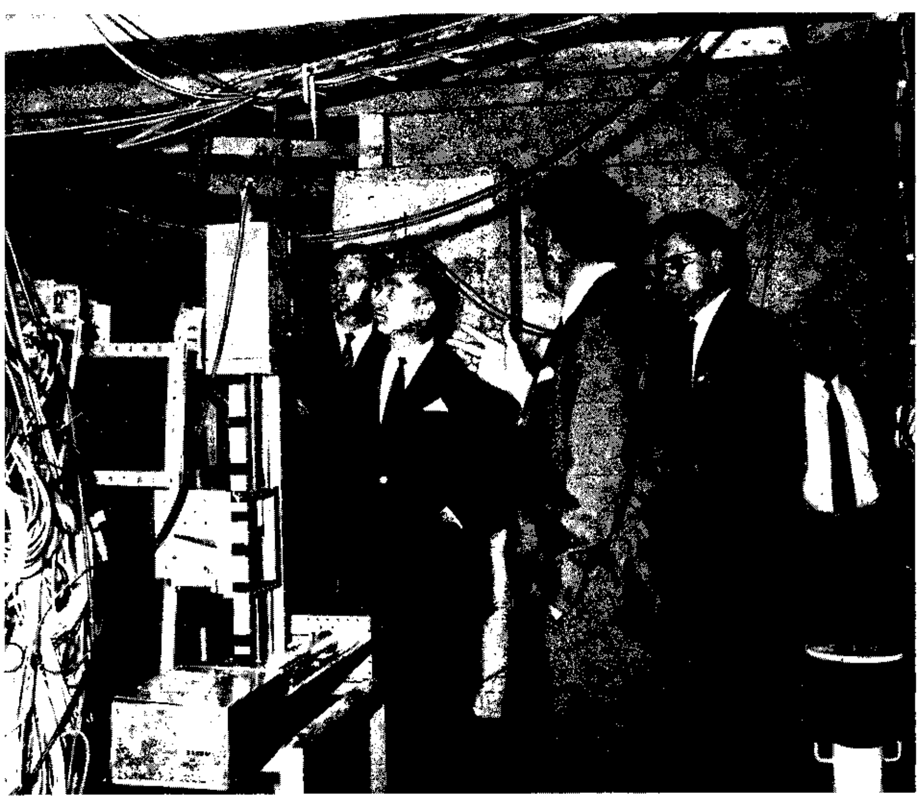
The experiment at Uppsala will be on

On 20 May, CERN welcomed the President of Austria, His Excellency Franz Jonas, on an official visit. The President saw the construction work on the intersecting storage rings and is seen here (centre of photograph) together with the Vice-President of the Swiss Federal Council, Hans-Peter Tschudi (right) listening to an explanation of the colliding beam principle.

Below: The same day, CERN also received the Geneva Conseil d'Etat, including the President, Gilbert Duboule. The photograph was taken during the visit to the experiment being carried out by the University of Geneva and Saclay at the proton synchrotron.

Interior view of one of 2m electrostatic separators. The cathode electrode in oxidized light alloy is at the top; the anode electrode in stainless steel at the bottom. The inter-electrode distance is 9 cm across which a voltage close to 1 MW can be applied.

Exterior view of one of the 2m electrostatic separators together with the cables supplying the voltage of 600 kV.



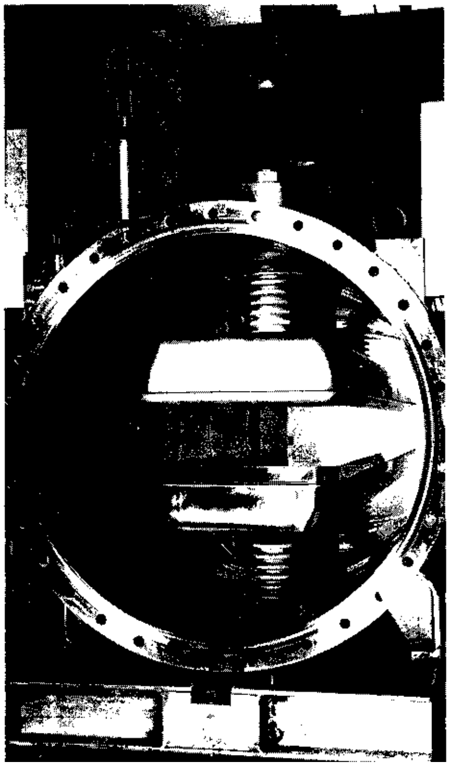
elastic scattering of protons on alpha particles (the nuclei of helium). It will make possible a detailed calibration of the equipment. The scintillation counters measure the energy of the recoil alpha particle by measuring the energy deposited in the scintillator and also the time of flight. In addition, they trigger the spark chambers. The resulting spark gives the direction of the recoil alpha. Other scintillation counters wilKbe installed at Uppsala behind the octagonal vessel to provide information on the scattered protons. The equipment is expected to return in about two months' time for experiments in a PS beam.

The apparatus has been developed at CERN by a group including S. Dahlgren, A. J. Herz, O. Kofoed-Hansen and S. Kullander in collaboration with the Gustaf-Werner Institute team under H. Tyrén.

Electrostatic separators

Electrostatic separators are units installed in secondary particle beam-lines to sift a particular type of particle at a desired momentum. The use of magnets alone, achieves a separation of momentum (the product of mass and velocity). Thus they will allow through the desired particles at the desired velocity but also, for example, heavier particles at lower velocity. Separators are then used to distinguish between velocities and thereby to complete the separation. Two types are in use — r.f. separators (see CERN COURIER vol. 7, page 125), which are used particularly for high momenta, and electrostatic separators. In both categories, there have been some outstanding achievements at CERN and this article covers some of the history and the present performance of electrostatic separators. It is based on information supplied by C. Germain who has led the work.

Some ten years ago, when the construction of the PS was just being completed, a programme of research into electrostatic separators began in the Nuclear Physics Aparatus Division. The programme was, at that time, rather modest in terms of resources but the intention was to surpass what was being done at the Bevatron in the pioneering Berkeley Laboratory, as had been the case



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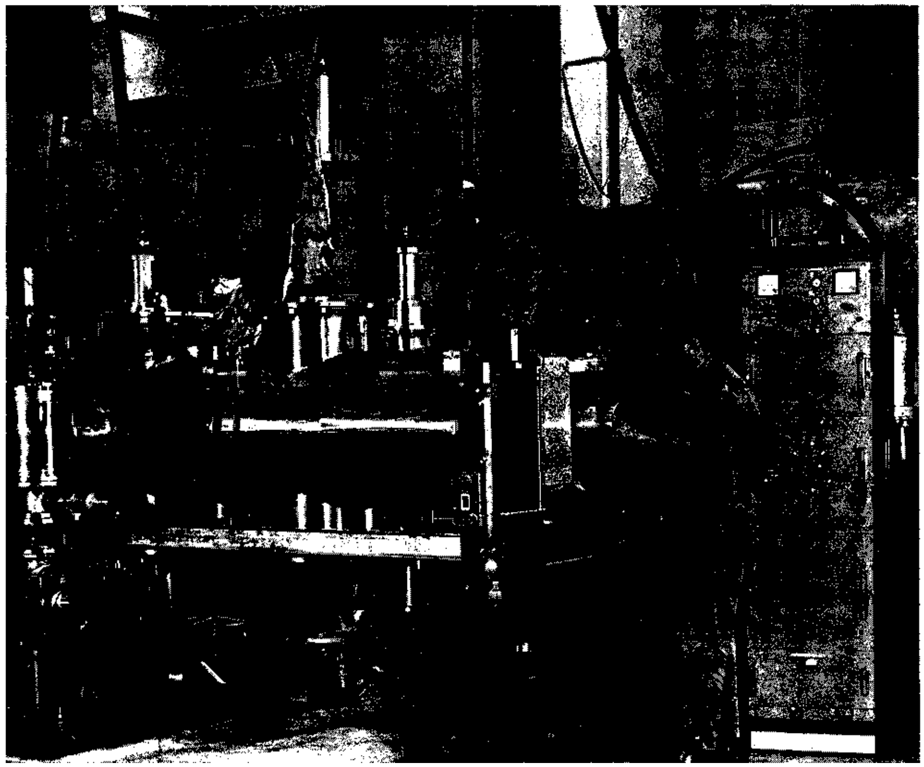


CERN/PI 192.5.69

with the accelerator. The original (at that time, highly optimistic) aim was to maintain, in vacuo, one megavolt between large electrodes 20 cm apart to achieve the separation of the first uncontaminated antiproton beams of momenta up to about 6GeV/c. While an electric field of 50 kV/cm was being reliably obtained at Berkeley, their separators sustained a voltage lower than 500 kV. CERN workers were soon to discover, as a result of abortive tests made on a model for several months, that extrapolations in the field of high voltage in vacuo were highly unreliable.

The first fruitful idea was to reduce the current passing in the vacuum (which limited the voltage which could be applied) by injecting gas into the separator instead of attempting to improve the vacuum. A series of systematic tests showed that, by increasing the pressure of the gas up to around 10^{-3} torr (the region of the Paschen discharge), it was possible to raise the voltage on the feed-through to 600 kV. The enthusiasm to which this result gave rise was temporarily damped by the discovery that the voltage could not be maintained in these conditions when attempts were made to apply the compensating magnetic field of the separator in the ordinary manner, i.e. in combination with the electric field in the same volume. This discovery, which seems rather obvious to-day in view of the geometry then used, led to a second innovation: the separation of the electric and magnetic fields. The advantages of this solution were such that it has been applied to all separators built at CERN since then.

The first generation of separators was produced over a period extending up to 1963. It includes five units 10 m long with stainless-steel electrodes. For separators working in beam-lines, the total voltage between electrodes can reach 800 kV and the field 50 to 60 kV/cm.

The design of a second generation, based on pushing the technology further, began in 1962. Studies showed that the performance limit was essentially due to the electrodes. At Berkeley, a great deal of progress had been made from 1960 onwards, using heated glass cathodes designed by J.J. Murray, enabling fields of 100 kV/cm over a distance of 5 cm to be sustained. Once again, therefore, the example of Berkeley was followed for the 3 and 6 m separators which were to be built.

In addition, another avenue opened up as a result of a visit by C. Germain to the High Voltage Research Laboratory at MIT in 1963. The work done by L. Jedynak from 1960 under J.G. Trump's direction showed that it was possible to increase the voltage between electrodes by using cathodes coated with an insulating layer, though unfortunately breakdowns usually caused the cathode to deteriorate rapidly.

A systematic investigation was launched at CERN in these two directions, and model tests revealed a way of avoiding the deterioration of the insulating layer by oxidation of the cathode (aluminium alloy) in certain well defined conditions. The cathodes made in this way had various advantages over those made of glass, and this solution was used for the second generation of separators (four units of 3 m) which was completed in 1964/5. Fields of 100 kV/cm were obtained in working conditions on the beam, and over greater electrode gap spacing than at Berkeley. Moreover, laboratory tests showed the possibility of even better performance with the use of a more compact geometry.

The third generation of separators, comprising four 1 or 2 m units developed in 1967/8, was the outcome of sustained technological effort. Many improvements in the geometry of the assembly, the choice of materials and the pumping system to obtain a clean vacuum, allowed the remarkable properties of aluminium coated cathodes to be exploited further. The excellent results obtained in the k11 separated beam (separating kaons at momenta from 0.8 to 1.2 GeV/c) are largely due to the trouble-free performance of the separators giving 800 kV over 7 cm. Even this is not their practical limit, which is about 800 kV over 5 cm, 900 kV over 7 cm or 1000 kV over 10 cm. The initial aim, therefore, of a total voltage of 1 MV (which is the practical maximum with the CERN high-voltage generators) has been attained, and with half the distance between electrodes that was initially considered. These results have not yet, as far as is known, been equalled elsewhere, though the techniques in use at CERN have been widely announced. Part of the accumulated experience cannot easily be communicated — as is shown by the pre-eminence of Berkeley in the use of glass cathodes.

The current stage of the separator programme is concerned with the improvement of the 10 m units which, in spite of a poor geometry which prevents them from equalling the performance of the 2 m units, can nevertheless be developed at little cost to sustain 800 kV over 10 cm and 950 kV over 14 cm. It is possible, too, that other equipment, e.g. electric septums will benefit by the experience gained

The photograph is of two Penning-type ion sources used at the synchro-cyclotron, and shows the improvement resulting from the new method of surface treatment. The one on the right was in operation for four weeks and has suffered badly from oxidation and deformation. The one on the left, which was surface treated, was in operation for eight weeks and is still in excellent condition. The ring visible in front of each source is the cathode.

on separators. After all, the potential properties of oxide-coated cathodes have not yet been fully exploited, for usable fields of 200 kV/cm could be produced.

Work on separators has been done by a group of people, especially R. Tinguely, A. Dind, L. Jeannerot, F. Rohrbach and D. Simon as well as J. Bleeker (HT generators), P. Coet and L. Danloy (separator operation). The Godet Workshop carried out the special treatment of the electrodes.

SC ejected beam intensity up

At the beginning of May, the intensity of the ejected beam from the 600 MeV synchro-cyclotron which is fed to the underground ISOLDE laboratory (the on-line isotope separator described in CERN COURIER vol. 7, page 22) reached 4.5×10^{11} protons per pulse. This intensity is just over twice that achieved when ISOLDE first came into operation towards the end of 1967.

The increase has resulted from two factors — a better adjustment of the beam transport system from the machine to the ISOLDE target, and an increase in the intensity of the beam in the SC itself.

In April, activation measurements were carried out along the beam-line using small pieces of aluminium whose induced radioactivity was subsequently measured. The way in which the radioactivity varied (and thus the way in which the particle losses were distributed) along the beam-line was thus found. It revealed that a high percentage of the loss came near the entry to the horizontal underground tunnel (the beam dips down through the foundations of the SC building). The eleven focusing lenses in the transport system were then adjusted to achieve the minimum beam cross-section in this region without causing too high a beam blow-up elsewhere.

Two beam current transformers (see CERN COURIER vol. 9, page 67), one at the input and one at the output end the beam-line, served to check the success of the adjustments. The beam loss was reduced to almost one third of what it had been; about 90 % of the proton beam can be successfully steered along the beam-line to the target compared with 70 % previously.

Since December 1968, the intensity of the internal beam of the SC has been steadily increasing (the present figure is near 1.4 μA compared with 0.95 uA). There have been three contributing factors — modifications to the control system of the tuning fork which sets the frequency of the accelerating fields in the machine; surface treatment of the ion source; adjustment of the ion source operating parameters.

The electronics which control the amplitude of vibration of the tuning fork have been rebuilt. The amplitude sets the frequency variation of the accelerating fields in the SC since the two arms of the tuning fork act as condensor plates in a resonant circuit. The movement of the arms is stimulated by a motor and is also reinforced by the electric fields in the SC,

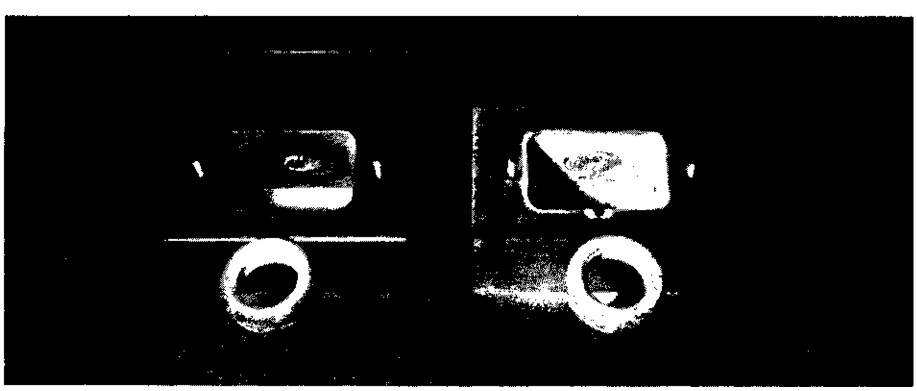
Until recently the electronic system which controls the motor in relation to variations in the SC electric fields was not precise enough to ensure that the amplitude of vibration was stable to the desired degree. This lack of stability appeared in the accelerating fields in the SC and made very precise setting of other machine parameters impossible. The new control system has improved the stability to about one part in a thousand and has indirectly contributed to the intensity increase by making it possible to achieve better settings of other parameters.

The new surface treatment of the ion source consisted of shot blasting the surface with tiny glass balls (0.5 mm diameter). The resulting improvement in the 'life' of the source during operation has been surprising. The old sources suffered rapid physical deterioration and their performance fell away very quickly; source changes were made at intervals between two to six weeks.

The first 'treated' source was installed on 12 February and it functioned for eight weeks without any sign of deteriorating performance. It was then removed and on examination appeared to be in excellent condition. Longer periods of satisfactory source operation are therefore expected. It had been intended to construct a Penning-type source from titanium but this is now considered unnecessary.

To have achieved a longer source lifetime is important because it reduces the frequency with which entry has to be made to a 'hot' region of the machine, where there is considerable induced radiation, followed by the necessity for precise realignment of a new source.

With the new frequency stability, the effect of various machine parameters on the intensity can be carefully studied. For example, parameters of the source such as its positioning, the length of the pulse applied to the cathode, the plasma pressure and the plasma composition are being examined and better settings have resulted in a higher SC beam intensity.



Around the Laboratories

An artist's impression of the National Accelerator Laboratory. Note the Central Laboratory which is planned to group virtually all office and laboratory accommodation (apart from those in close association with the experimental areas) in one building. The design is for a 'high-rise' building of near cylindrical shape with an open central area topped by a glass dome. The liberal representation of trees follows the intention to give the site a 'beautiful park-like atmosphere'. Many of the staff including the Director R.R. Wilson were out recently on Arbor Day planting over a hundred trees.

BATAVIA

Going ahead fast

With the arrival of good weather, construction of the buildings for the 200 GeV accelerator at Batavia is going ahead fast. Despite delays introduced by a particularly bad winter, the programme is ahead of the critical path schedule.

The floorof the building for the 200 MeV linear accelerator is complete and the walls are taking shape. Bulk excavation for the booster ring is almost finished and the booster prototype enclosure (where a section of the booster ring will be constructed, powered and under vacuum by September) is complete. The main ring prototype enclosure is also well advanced.

One minor crisis was averted in March when the actual cost of the booster building came out considerably higher than anticipated. A rapid re-think on the injection system, bringing the 200 MeV beam from the linear accelerator into the booster, retrieved the extra cost by a new arrangement, injecting at a different point.

750 keV beam

On 17 April, a 600 keV proton beam was achieved from the prototype pre-injector. The energy has now been raised to 750 keV, using a high voltage power supply on loan from Argonne, and the accelerated current has reached 70 mA. The eventual aim for pre-injector performance is a current of over 220 mA.

Rapid evaluation of the beam quality is made possible by an on-line emittance-measuring system giving phase plots from an SDS computer. It is possible to play wih the settings of quadrupoles immediately following the accelerating column and to watch the emittance change on the computer display scope. A systematic study of source parameters is under way.

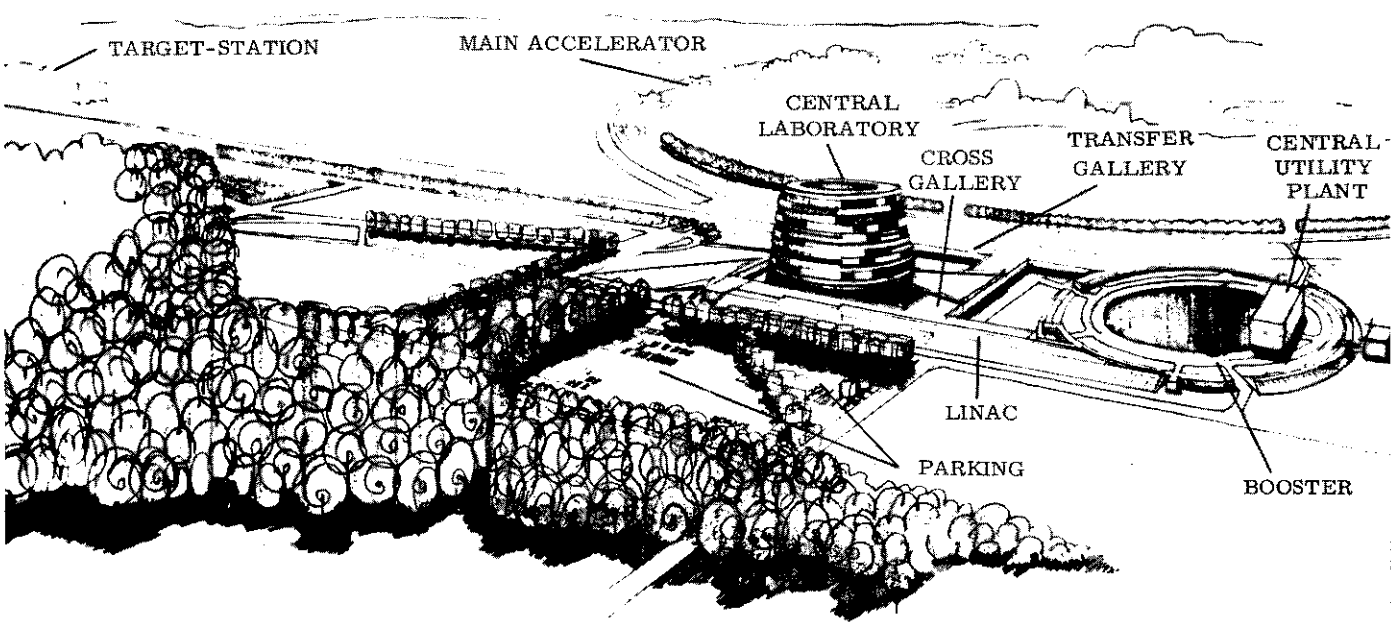
The first linac tank is ready and has been electrically tested (giving a Q factor of 90 000). 10 MeV beams are likely to emerge in the near future.

Experimental facilities

In preparation for the use of the accelerator, studies of a superconducting bending magnet and a superconducting solenoid have started. Coils for both have been wound and are being tested. The first co-ordination meeting on the proposed 25 foot hydrogen bubble chamber to be built in collaboration with Brookhaven was held in April. For the design, the field to be produced by a superconducting magnet has been fixed at 40 kG using coils separated by 1.5 m.

Name of the Laboratory

Dr. Glenn T. Seaborg, Chairman of the US Atomic Energy Commission, announced on 29 April that the Laboratory will be named the 'Enrico Fermi Laboratory' in honour of the Italian physicist who did much of his outstanding work in the United States. In particular, Enrico Fermi led the famous project which brought the first fission reactor into operation in 1942 in Chicago next door to the Laboratory site. The formal dedication and naming of the Laboratory will take place towards the end of 1972 after the 200 GeV accelerator has produced its first full energy beam.



DUBNA
Ultrasonic pictures in hydrogen

At the beginning of May, a Dubna group from the Laboratory of Nuclear Problems in the Division of G. Selivanov achieved the first ever photographs of particle tracks in a hydrogen bubble chamber in which the expansion was done by a combination of ultrasonic and conventional techniques.

This comes just six months after the first operation of an ultrasonic bubble chamber at CERN (CERN COURIER vol. 8, page 316). The CERN group used liquid helium which has the most favourable characteristics for ultrasonic operation; by working with hydrogen the Dubna group are carrying the technique a stage further. (The novel feature of the ultrasonic bubble chamber is that piezoelectric crystals emitting ultrasonic waves are used to produce the necessary pressure changes in the liquid, rather than the conventional mechanical expansion system.)

In the Dubna work, ultrasonic waves were applied on top of conventional expansion (the conventional expansion being set so that it was insufficient in itself to produce tracks). Attempts to achieve ultrasonic operation in hydrogen are under consideration at CERN and construction of some of the necessary equipment has begun.

BERKELEY
Pyramid project

A report on the search for hidden chambers in the pyramid of Chephren at Giza was issued by Berkeley and Ein Shams University, Cairo, on 30 April. The technique, using cosmic ray muons to 'x-ray' the seemingly solid mass of the pyramid, has been shown to be very sensitive to the pyramid structure, but no chambers have been found in the section of the pyramid investigated so far.

It is believed that the Egyptian rulers deliberately designed the pyramids so as to conceal their actual burial chambers, leaving other chambers accessible to mislead grave robbers into believing that the tombs had already been sacked. This certainly appears to be true of the Great Pyramid of Cheops where several upper chambers remained concealed for 3500 years until they where accidentally discovered a thousand years ago. The neighbouring pyramid of Chephren has a similar lower chamber to Cheops with a suspiciously solid structure 160 m high above.

The investigation was proposed by L. Alvarez of Berkeley who realized that detection of cosmic ray muons in the lower chamber could reveal any sizeable void in the pyramid through which they had passed. Since muons lose energy and eventually stop as they pass through matter, a void, which could correspond to a burial chamber, would allow more muons through than an equivalent thickness of rock.

A spark chamber array designed to give the directions of incoming muons was built at Berkeley and installed in the lower chamber of Chephren in the spring of 1967. Some 1.2 million muons have been detected by the array, recorded on magnetic tape, and analysed by computer. The computer program takes into account 900 different muon directions, the pyramid's external dimensions and surface characteristics, the void of the lower chamber, and other factors. It then computes how many muons should arrive in each of the 900 directions and compares these values with the actual counts.

The detection method proved very sensitive. The resulting 'x-ray picture' clearly reveals the diagonal ridges and other features of the pyramid, agreeing to within 1 m with the measurements done by conventional survey techniques. Alvarez summed up the search so far by saying, 'When we can see, for example, an extra 6 feet of thickness formed by the smooth limestone cap, through a hundred yards of rock, we can be quite sure that everything was working as we had planned. If Chephren's Pyramid contained features like the Grand Gallery and the two chambers that are known in Cheop's Pyramid next door, and if they were similarly located we couldn't possibly have missed seeing them.'

So far, the experiment has scanned the central upper zone including all the rock within 35° of the vertical. They now hope to continue their search into the large lower zones on the four sides.

Element 104

It was announced on 16 April that the Berkeley nuclear physicists have discovered two isotopes of element 104, namely 104-257 and 104-259. The team was led by A. Ghiorso who has been involved in the discovery at Berkeley of nine heavy elements from 95 (americium) to 103 (lawrencium).

Observation of the 104 was first reported by Dubna scientists, led by G.N. Flerov, in 1964 (the particular isotope they reported, 104-260, was not seen in the Berkeley experiments). They christened the element Kurchatovium. It has particular significance, not only as the heaviest element identified with certainty to date, but also as the first 'transactinide' element. It is the first element beyond the actinidetransition series which ends with 103.

The recent experiments were carried out at the Berkeley Heavy Ion Linear Accelerator (HILAC) bombarding californium (98-249) with carbon-12 nuclei at 71 MeV and carbon-13 nuclei at 69 MeV. Both new isotopes decayed after a few seconds, by emission of an alpha-particle, into nobelium (102) isotopes whose properties have been thoroughly studied. There was also some evidence for the 104-258 isotope which decays by spontaneous fission in about 10 ms.

The identification of elements heavier than uranium began at Berkeley in 1940 with the discovery of neptunium (element 93). Within a surprisingly short time, many of them have proved to have practical applications as well as purely scientific interest — plutonium as reactor fuel and nuclear explosive, plutonium-238 as a heat source for auxiliary power supplies in space exploration, americum-241 as a gamma ray source for monitoring industrial processes, californium-252 as a neutron source with applications in medicine and in geological exploration on earth and in space.

BROOKHAVEN
Conversion project

A long shut down began at the Brookhaven 33 GeV Alternating Gradient Synchrotron on 24 May. It will be occupied mainly by civil engineering work around the main

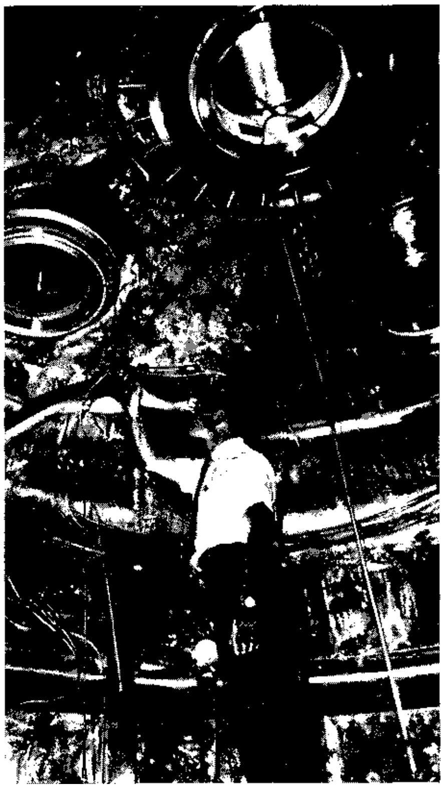
Three photographs from another important stage in the construction of the 12 foot hydrogen bubble chamber at Argonne (see CERN COURIER vol. 9, page 43). On 25 April the chamber vessel was moved from the workshops and installed in the superconducting magnet in the bubble chamber building.

1. Inside the vessel before it was moved; three camera ports can be clearly seen at the top. (If anyone had told D. Glaser, when he was proving, in the early 1950s, his invention of the bubble chamber with tiny glass vessels of a few cubic centimetres, that by 1969 people would be able to walk around inside a chamber, even a man of his vision would have shaken his head.)

2. The vessel is moved out to wrap it in its insulation shroud. The shroud is here being lowered into place.

3. A crane carefully lowers the vessel into the magnet. The familiar complex of surrounding equipment associated with operation of a bubble chamber can be seen.

Within the next few months the chamber will be cooled down for the first time and it is hoped to start taking pictures for the first physics experiment in autumn.



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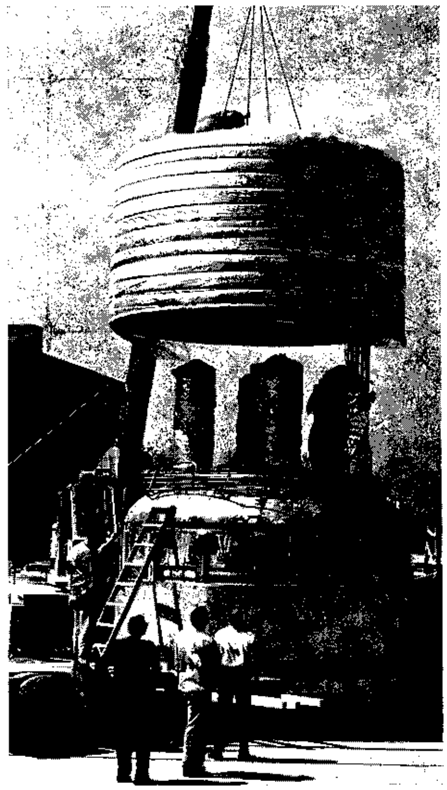

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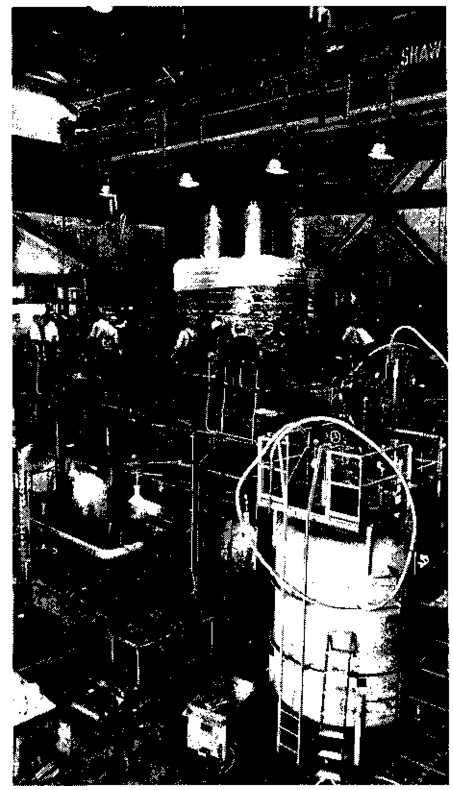

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magnet ring in connection with the improvements programme, or 'conversion project', at the AGS.

The project has similar aims to that at the CERN machine, namely to increase the intensity of the accelerated beam per pulse, to increase the pulse repetition rate, and to extend the experimental facilities. Major individual items are a new injector (200 MeV linear accelerator), a new power supply for the main ring magnet (doubling the voltage at the magnet to 12 kV),new r.f. system (doubling the energy gain per turn to about 200 keV), and new experimental areas. The increase in intensity also makes it necessary, because of radiation problems, to install extra shielding at various points around the ring and to replace the main ring vacuum system.

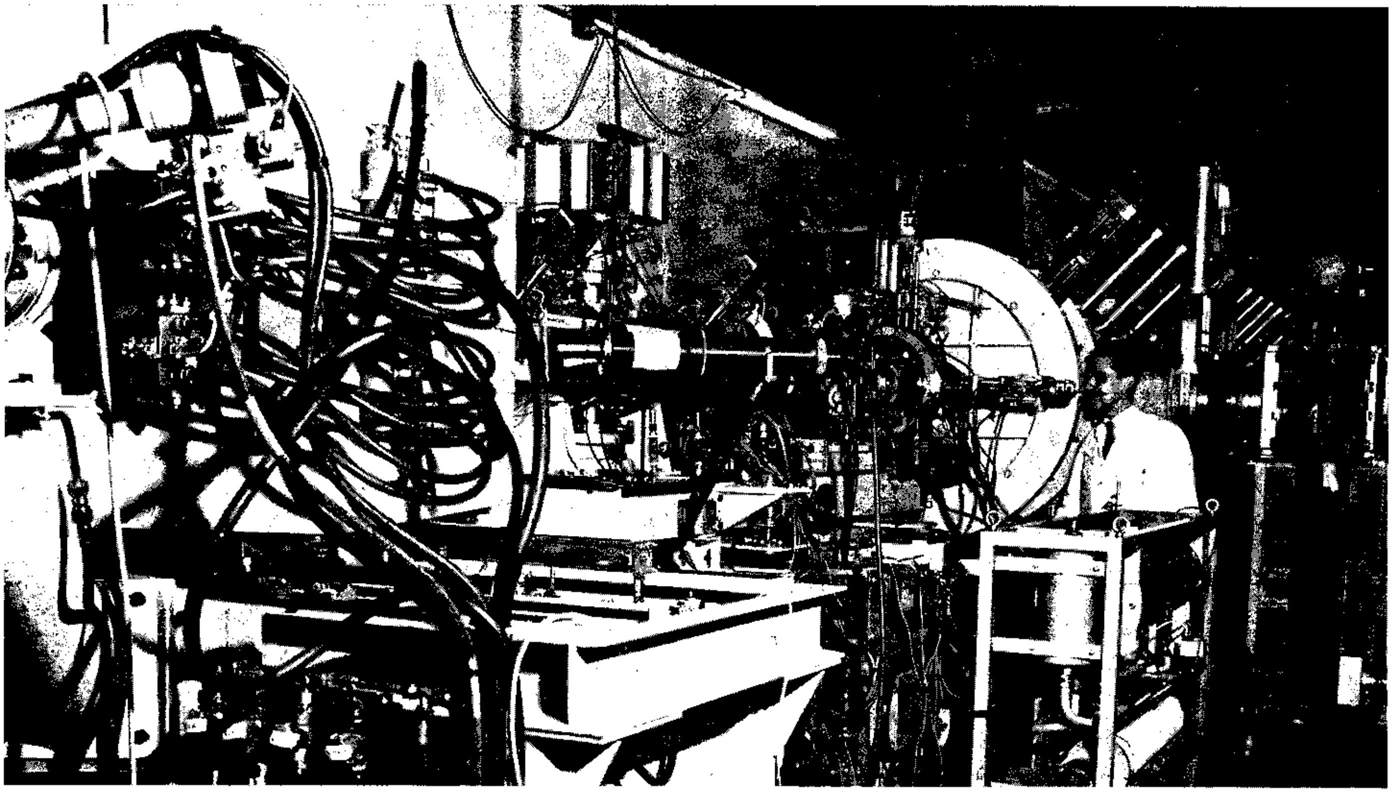
Construction of the building for the 200 MeV linear accelerator is well advanced and some installation of equipment began early in May. The building is scheduled for completion at the end of August. Many components for the injector have already been delivered. The high voltage set for the 750 keV pre-injector, a Cockcroft-Walton set manufactured by Haefely, is on site and will be erected soon. The copper-clad steel tanks of the first three accelerating cavities are ready and installation of the drift tubes in the first cavity has started. The 200 MHz r.f. system to power these tanks has been designed and components are on order — the first 5 MW system will be ready for tests in a few months time. By early 1970, it is expected to have a 10 MeV beam from the completed first section of the linear accelerator.

For the main ring, the new power supply has arrived from Siemens and installation is scheduled for June. (Two new buildings, located inside the main ring, for the power supply and the r.f. system are almost complete.) Some modifications on the r.f. cavities, to make the necessary impedance match with the new amplifiers, will be carried out during the shut down.

Five prototype sections for the new vacuum chamber have been installed and successfully tested on the synchrotron. These chambers use metallic C-ring vacuum gaskets which are compressed by a quick-release single-screw clamp. About 80 sections of the chamber will be installed during the shut down.

Construction of the addition to the East Experimental Area (which will give another 4 600 m^2 of floor space for experiments) is nearing completion. This building will be used to extend the beam-lines from the slow-ejected proton beam.

The civil engineering work, which makes it necessary to have a long shut down, concerns the extra shielding (to give a total depth of 6.5 m of sand) needed over the ring tunnel at the north and south ends of the target building. This involves major modifications to the tunnel structure and the foundations. Also, a new entrance point to the ring is needed where the 200 MeV beam will be injected; concrete arches have been placed over about 70 m of the ring tunnel in this region to support an extra 3 m of sand. (This type of construction, similar to that used over the internal target area at the CERN PS, is necessary because the original tunnel structure is not strong enough to support



the additional weight of sand.) A further break into the main ring will be made for a new fast ejected beam to feed the bubble chamber complex which will occupy the North Experimental Area.

The shut down is scheduled to end on 31 October.

SACLAY
New Saturne Injector

A new linear injector for the 3 GeV proton synchrotron 'Saturne' at the Saclay Laboratory is being moved to its permanent position at the synchrotron after successful operation in a test hall. The linear accelerator has an energy of 20 MeV and will replace the existing 3.6 MeV Van de Graaff.

Because of space charge effects with 3.6 MeV injection, the number of particles that can be accelerated in the synchrotron per pulse is limited to 3×10^{11}. It was therefore decided in 1966 to increase the intensity to 10^{12} by injection at 20 MeV. The new linac produced its first beam in May 1968 (see CERN COURIER vol. 8, page 134). It consists of a 750 keV pre-injector, an Alvarez-type accelerating structure and various auxiliary cavities.

The pre-injector gives a 50 mA beam with a pulse length of 600 JUS (or 100 mA for 250 fis) at an energy of 750 keV. Its high voltage generator is of the simple alternating-cascade type, with 16 stages ; the ceramic condensors were developed and manufactured by CGEC and on delivery were successfully tested at 100 kV for 100 hours. Slow adjustment of the voltage, and distribution of the * potential along the accelerating tube are effected by an organic liquid resistance designed and developed by SRTI in collaboration with Saclay. The pre-injector is equipped with a duoplasmatron source with expansion chamber, a Pierce-type extraction and a 15 kV/cm accelerator tube preceded by a 3 electrode lens.

The accelerating column and voltage generator are housed in a pressure chamber 2 m in diameter and 2.5 m long. The main advantage of this solution is the compactness of the pre-injector compared with conventional pre-injectors. Through the use of pressurized gas and the careful design of all components for operation at high voltage, it has been possible to build a pre-injector which requires no 'running-in' time and is free from insulation breakdown both in vacuum and in gas. These advantages largely outweigh the time required to open and close the chamber (which is in any case only 30 minutes).

The neatness of the design and its very successful operation may well make it the model for pre-injectors for some time to come. The injector group at CERN have been encouraged by the success of the Saclay approach in their considerations of a new high energy (over 1 MeV) pre-injector for the CERN proton synchrotron which would probably have much in common with the Saclay design.

The linear accelerator structure has 60 drift-tubes and 19 loops for controlling the field and adjusting the tuning frequency. A special feature is that it can operate with a synchronous phase varying from —45° at the input to —25° at the output; a large phase acceptance is thus obtained without a corresponding increase in the length of the accelerator.

The construction is based on the use of copper-plated steel, manufactured by Phœnix-Rheinrohr (Federal Republic of Germany), rolled and welded in 3 m lengths by the Chantiers Navals de La Ciotat (France). The firm CSF was responsible for producing the structure, including the quadrupole magnets installed inside the drift-tubes, working from the design provided by Saclay. The accelerator requires r.f. power of 2 MW, allowing for beam-loading, in 800 JUS pulses at a frequency of 200 MHz. The firm of CFTH produced the r.f. power source.

An additional cavity, referred to as the energy ramp, is situated at the output end of the accelerator; it is fed with constant power having a phase in relation to the beam varying from +45° to —45° during the beam pulse; a ferrite rapid-dephaser specially produced by LTT, which is capable of transmitting a power of 100 kW, is used for this purpose. Consequently, the output energy of the protons varies linearly from (20 MeV — 300 keV) to (20 MeV + 300 keV) during the beam pulse. This makes it possible to inject into the synchrotron, without introducing betatron oscillations, during a period of 600 [is, while the guide field of the main magnet ring is rising.

An analysing magnet and equipment to measure the energy spectrum of the beam are installed near the output of the linac to help optimize the performance. A debuncher, similarly fed from a rapid-dephaser, can be used to bring the energy spectrum to within ±50 keV of that desired.

The injector has been operating in a test hall. After adjustments had been made, a 15 mA beam was accelerated with

The output end of the new injector for Saturne. From right to left : linac, energy ramp, beam transport system, analysing magnet. On the right (near ground-level) is the coaxial feed to the linac tank.

(Photo Saclay)

a pulse length of 600 μs, without optimizing the quadrupole focusing. Since this performance is considered satisfactory, the Saturn accelerator has been temporarily shut down while the linac is moved to its permanent site. It is due to come into operation in September with optimized focusing which should feed higher intensity beams into the synchrotron.

Conferences

An International Conference on Cyclotron Design and Operation will be held at St. Catherine's College, Oxford, UK on 17-19 September 1969. It will cover the design and operation of isochronous cyclotrons and synchro-cyclotron improvement programmes.

This will be followed on 22-23 September by an International Conference on the Use of Cyclotrons covering use in chemistry, metallurgy and biology. (In addition, a short symposium on the use of cyclotrons in medicine will be held at Hammersmith Hospital, London, on 20 September.)

An eight day tour of European cyclotrons is arranged to start from Oxford on 23 September finishing in Paris on 1 October. Registration literature for the conferences and tour are available from F.K. Pyne, AERE, Harwell, Didcot, Berks, UK.

A conference on Nuclear and Elementary Particle Physics is being arranged at the University of Sussex from 24-26 September 1969. Topics included in the programme are :

The few body problem

Developments in hypernuclear physics — R.H. Dalitz (Oxford)

Few nucléon problem — H.P. Noyes (Stanford)

Weak interactions

Astrophysical aspects — J.N.Bahcall(Cal.Tech.)

Neutrino physics — N. Dombey (Sussex)

CP situation — N.H. Lipman (RHEL)

Nuclear structure

Superheavy nuclei — S.G. Nilsson (Lund)

Theory of analog resonances — A.K. Kerman (MIT)

Conference summary — D.H.Wilkinson (Oxford)

Short contributions are welcome — abstracts (not more than 300 words) should be submitted in duplicate before 15 July to the Nuclear Physics Conference Secretary, School of Mathematical and Physical Sciences, University of Sussex, Falmer, Brighton, BN1 9QH. Further details and application forms are available from the Meetings Officer, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, S.W.1.

VILLIGEN

Original SIN

A 'meson factory' of novel design is being built by SIN (Schweizerisches Institut fur Nuklearforschung — Swiss Institute for Nuclear Research) at Villigen near Zurich. It involves a two stage cyclotron machine capable of accelerating intense beams of protons to energies in excess of 500 MeV which is well above the threshold (450 MeV) for the production of pi mesons. The machine will be used particularly for intermediate energy physics with pion and muon beams; the first acceleration stage will however be capable of accelerating many types of particle to different low energies for nuclear physics research. The project is led by J.P. Blaser with H.A. Willax as chief design engineer and H.J. Gerber as head of the research division.

The design is based on the isochronous (or sector-focused) cyclotron — the first stage is a 70 MeV isochronous cyclotron (being manufactured by Philips) injecting into an isochronous ring cyclotron (being developed by SIN and manufactured in cooperation with Oerlikon Engineering Co.) which completes acceleration to over 500 MeV. To help in understanding the design we divert here to give a little of the history of the cyclotron and a little on the different properties (without covering the related focusing problems) of the three major stages of its evolution.

Evolution of the cyclotron

The cyclotron was invented in 1930 by E.O. Lawrence who, together with M.S. Livingston, built the first cyclotron in 1931 at Berkeley. It had a 10 cm magnet and accelerated protons to an energy of 80 keV. The principle of operation depends upon the fact that, in a uniform magnet field, charged particles will take the same time to travel round their orbit regardless of their velocity. Thus, setting up a gap across which protons are accelerated each time they come round the cyclotron, the protons spiral outwards increasing in energy but continuing to cross the accelerating gap after equal intervals of time. The voltage applied to the accelerating gap is of fixed frequency.

Operation in this way remains efficient up to energies around 20 MeV when the speed of the protons becomes a significant fraction of that of light and their mass begins to increase noticeably in accordance with the theory of relativity. Because of this mass increase, particles with different velocities no longer take the same time to circle round their different orbits in the constant magnetic field. A 20 MeV proton weighs 2% heavier and takes 2 % longer to go round its orbit than a proton at the centre of the cyclotron.

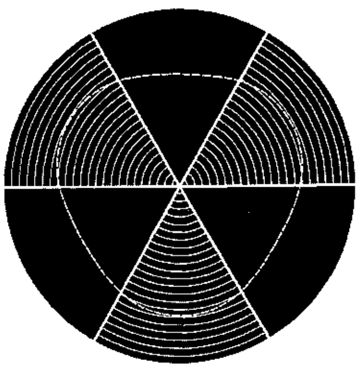
Following the work on accelerator theory by V.I. Veksler and E.M. McMillan in 1944, it was realized that it is possible to accelerate to much higher energies, still holding the magnetic field constant but continuously adjusting the frequency of the field in the accelerating gap to keep time with the frequency of rotation of the particles. This second generation is known as the synchro-cyclotron or frequency modulated cyclotron and the first machine of this type came into operation at Berkeley in 1947. The generation includes the 600 MeV machine at CERN and the highest energy machine is the 1 GeV at Gatchina near Leningrad.

A disadvantage of the synchro-cyclotron is that it is a pulsed machine. Since the accelerating gap voltage has to be varied, it cannot deal with particles at the centre of the machine and at the outer orbits at the same time. Particles are injected and accelerated in pulses many times per second. To regain the continuous beam of the fixed frequency cyclotron, designers returned to a theoretical paper written by L.H. Thomas in 1938. He proposed putting sectors on the poles of fixed frequency cyclotrons in such a way that the circular orbits become scalloped. The magnetic field seen by the particle can then increase with

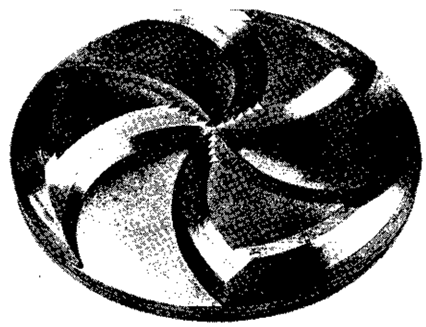
1. A schematic diagram of an isochronous cyclotron which has three sectors (the shaded areas). In the sectors, the magnetic field is stronger causing the orbits of the particles (represented by the dashed line) to be more curved. A field configuration like this makes it possible to compensate for increasing mass without varying the frequency of the accelerating voltage.

2. The sectors in an actual cyclotron are usually shaped as indicated in this photograph of a three sector pole. The profile of the sector is a spiral and gives rise to the name 'spiral ridge' cyclotron.

(Photo Philips)



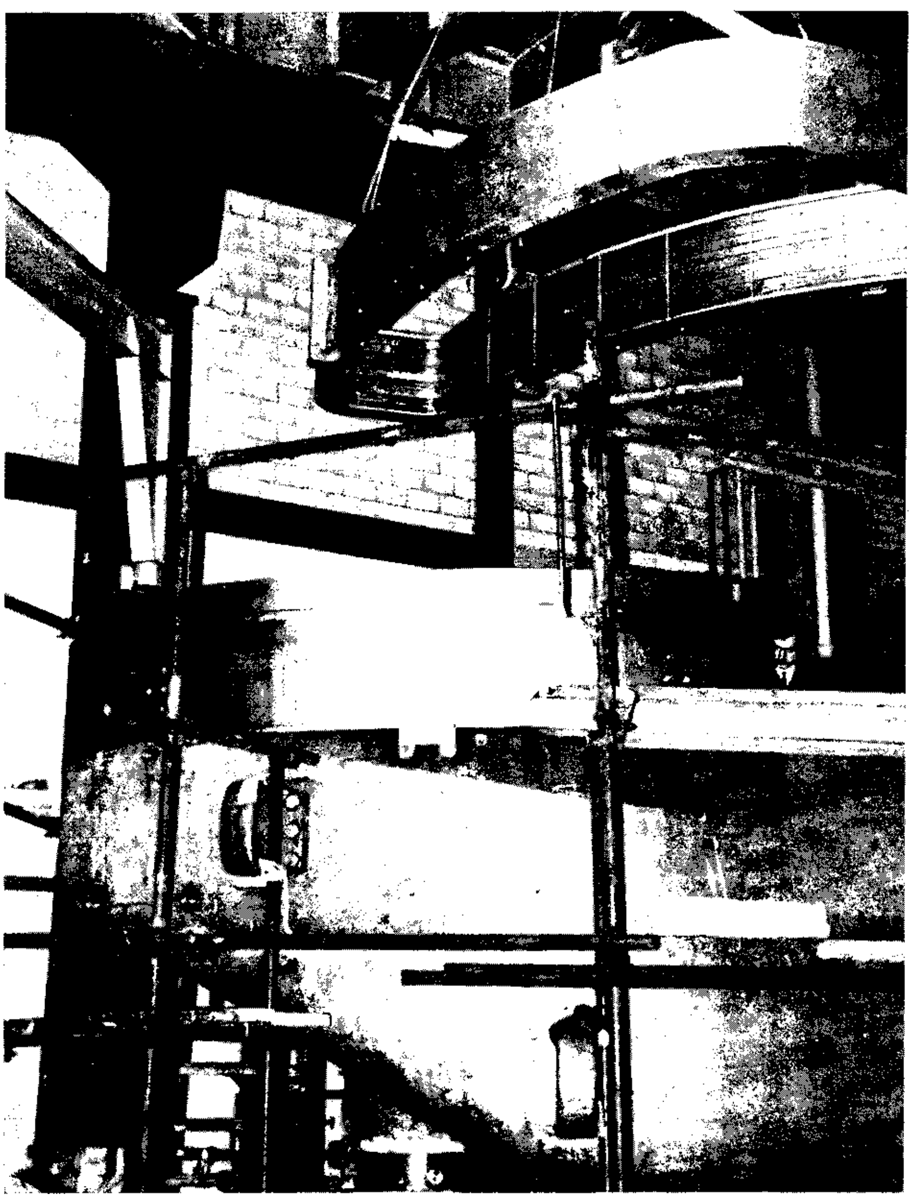
1.



2.

Mounting of a main coil on the prototype sector magnet of the 500 MeV ring cyclotron to be built at the Swiss Institute for Nuclear Research, Villigen.

(Photo SIN)



A simplified layout drawing of the 500 MeV accelerator for Villigen :

1. injector cyclotron
2. r.f. system for the injector cyclotron
3. beam-transport system to the ring cyclotron
4. beam-switch for simultaneous use of the 70 MeV beam for low energy experiments
5. low energy beam analyzing system
6. sector magnets of the ring cyclotron
7. r.f. cavities of the ring cyclotron
8. 'free' section of the vacuum chamber
9. vacuum pumping system and r.f. power stages
10. beam-transport system for the ejected protons.

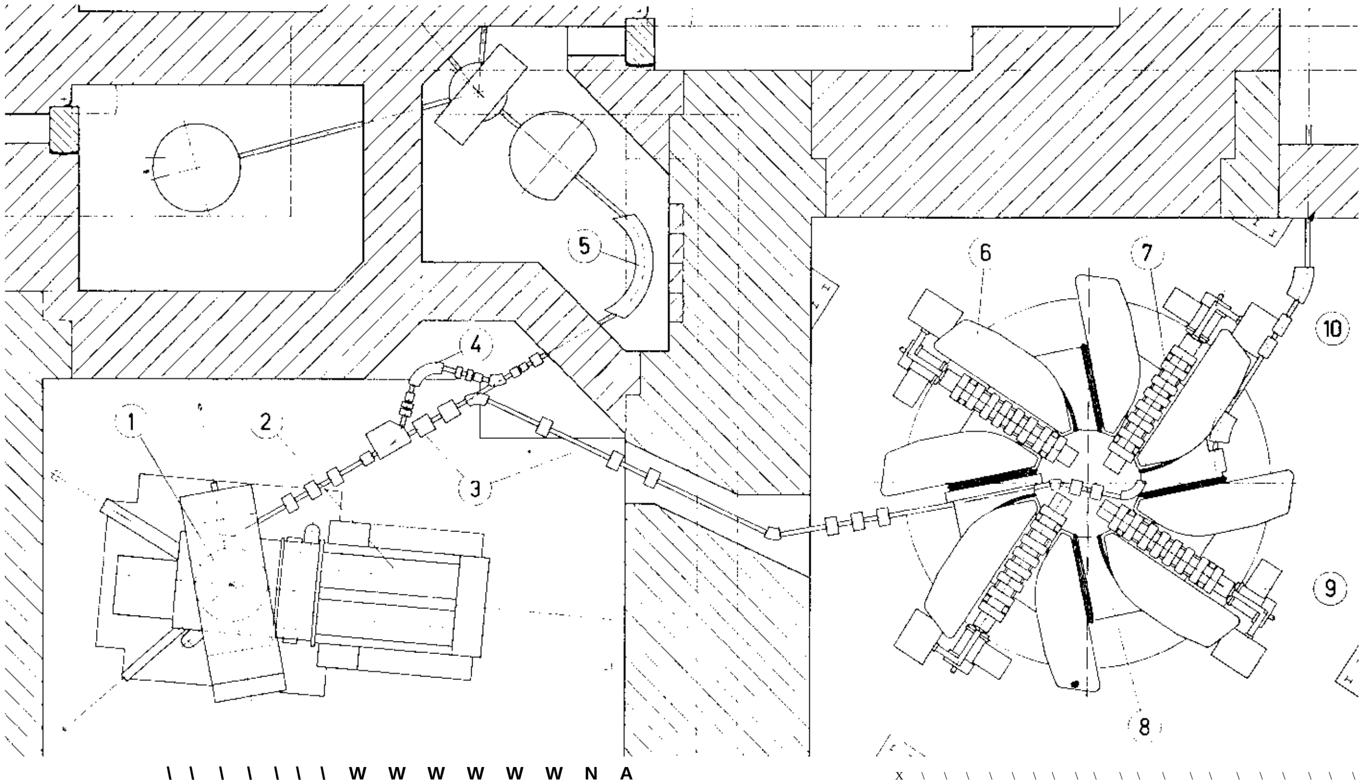
radius, i.e. with increasing particle velocity, and the distances travelled by the particles can be arranged to compensate for their increase in mass. The frequency of the accelerating gap voltage is constant and continuous beams can be accelerated. The principle was successfully tested for the first time in 1950-52, again at Berkeley, using electron models. This third generation of cyclotrons goes under a variety of names — isochronous c/clotron, sector-focused cyclotron, azimuthally varying field (AVF) cyclotron, spiral ridge cyclotron. These machines can accelerate different particles to a continuously variable energy and can provide high beam intensities.

Achieving high ejection efficiency

In the preliminary thinking about the Swiss project the goals were set as — an energy of over 500 MeV with a proton beam intensity of the order of 100 |iA. To achieve this intensity a continuous beam is needed, eliminating the synchro-cyclotron. The superconducting linac was considered but rejected in view of the many new technological problems which needed solving. An isochronous cyclotron was then chosen.

The novel features of the design emerge from the need to ensure very high beam extraction efficiency (at least 90 %) when accelerating such an intense beam. Quite apart from the desire to extract as many particles as possible for use in the experiments, the loss of a high percentage of a 100 JJLA beam in the machine would introduce formidable problems from radiation and induced radioactivity.

To have high extraction efficiency it is necessary to ensure that the outermost particle orbits are well separated radially. Fields can then be applied to the full energy orbit to bend particles out of the machine without affecting the neighbouring orbits. Good radial separation can be achieved by having a large accelerator (since the separation depends upon the radius) or by having a high energy-gain per turn (applying high voltages to the accelerating gaps). The first solution is expensive and the second is difficult to achieve in a conventional design. SIN selected a solution where both radius and energy-gain can be made reasonably large.



It would be difficult to install high voltage cavities within the magnet aperture of an isochronous cyclotron. They can however be positioned between the magnet sectors at the outer part of the machine but there is no room between sectors at the centre. This led to the decision to effectively lift out the centre portion of the machine, leaving an outer ring of an isochronous cyclotron. This ring can be enlarged by separating the magnet sections giving enough space between the sections to install high-voltage cavities. The removed centre portion then sits alongside as a fairly conventional isochronous cyclotron serving as an injector into the ring. It is important to keep the rotation frequencies of the particles in both stages of the machine at a certain constant ratio.

Machine parameters

The injector cyclotron will be used also for low energy physics. It is designed to accelerate many types of particle to variable energy. Used as an injector its specification is to accelerate protons to 70 MeV giving 100 JIA of extracted beam with 0.3% energy spread. Used for low energy physics its specification is to accelerate protons from 10 to 75 MeV (25 (JLA), deuterons from 10 to 65 MeV (25 pA), alpha particles from 20 to 135 MeV (15 jiA), helium 3 ions from 15 to 160 MeV (15 jiA) and heavy ions from 0.6 to 10 MeV per nucléon (2 jiA). Axial injection of polarized protons and deuterons will be possible.

The magnet diameter of the injector cyclotron is 2.45 m with a field varying from about 13 kG at the centre to about 20 kG at the extraction orbit over an aperture of 20 cm. Philips received the contract to build the injector on 31 October 1968 and it is scheduled to produce its first beam before the end of 1973.

Particles are injected into the ring cyclotron at a radius of 2.1 m and are accelerated from 70 to over 500 MeV spiralling to the extraction radius of about 4.5 m. (The outer diameter of the magnet poles is 9.2 m and the largest diameter of the machine is 14 m.) The magnet is in eight sectors with a total weight of 2000 tons, each sector being itself a C-shaped magnet with its contours shaped to give the spiral ridge configuration. The profiles of the pole gaps are shaped to give the field of the isochronous cyclotron. Within the pole, field varies from 14 kG at the injection radius to 20 kG at the extraction radius over an aperture decreasing from 9 to 5 cm. A prototype of a sector has been built and successfully tested.

In four of the eight gaps between the magnets, r.f. cavities are stationed each giving up to 500 keV to the protons so that the total energy gain per turn can be as large as 2 MeV. This will give an orbit separation at 500 MeV of 8 mm. (For comparison, the orbit separation on the CERN synchro-cyclotron is currently 0.04 mm.) With such a separation it is calculated that a septum extraction system can yield efficiencies of 95%.

Site preparation has begun and it is hoped to have the main accelerator hall (50X85 m^2) ready to receive the first components at the beginning of 1971. First full energy beams are planned for 1974. The total cost of the project is estimated at 93 million Swiss francs.

Experimental Programme

The experimental programme of the accelerator will be determined by the high beam intensity (which in turn leads to large fluxes of secondary and tertiary particles) and by the macroscopic duty-cycle of 100%. This opens up new fields of research which until now have barely been touched or have been without prospects. Some of these fields connect different branches of science — for example, muonium chemistry will apply the methods of elementary particle physics to the study of chemical processes ; radiation biology, using stopped pions, will aim to achieve efficient radiation therapy.

Nuclear physics research using pions and muons can be extended to 'rare processes'. There are a number of fundamental problems in classical elementary particle physics which have not been solved with present accelerators but which can finally be attacked with the beams of a 'meson-factory', e.g. the study of rare decay modes, the question of additive versus multiplicative muon number, and many more. The abundance of particles will make it possible to use instruments with unprecedented resolution, such as crystal spectrometers.

The Swiss Institute for Nuclear Research has been established in order to give Swiss scientists a modern research centre where they can investigate a wide and challenging field, touching fundamental as well as applied sciences. The centre will be open also to a number of groups from other countries and will provide in Europe a unique facility operating fully from the middle of the 1970s.

DESY

Deutsches Elektronen-Synchrotron

Right: The electron synchrotron ring tunnel. Note the ceramic vacuum chamber, installed in the magnet apertures replacing the original epoxy chamber which had been giving trouble.

Below: An aerial view of the DESY Laboratory at the end of 1967. The ring shape of the accelerator and its two experimental halls can be clearly seen. By now construction of the lecture hall and office building (bottom right) is complete, as is the building housing the new linear injector for which excavation work (top left) had just started when the photograph was taken. ,

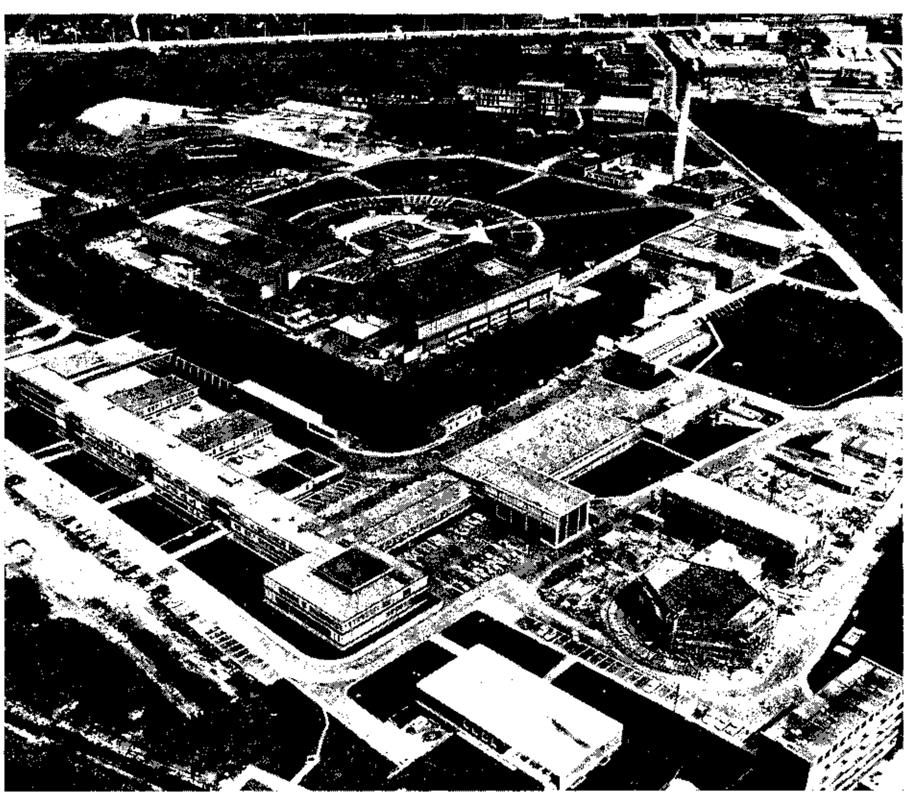
The DESY Laboratory at Hamburg is the major Laboratory for sub-nuclear physics in the Federal Republic of Germany. It has a staff of 900 people of whom 120 are research scientists involved in the experimental programme. In addition there are 50 to 60 visiting research scientists mainly from 12 Universities and Institutes in Germany but with visitors from other countries also. (Teams from Collège de France and Pisa have been prominent in the programme in recent years and there is a sprinkling of scientists from other countries distributed among many experimental groups.)

The Director of the Laboratory is Professor W. Jentschke heading a five-member Directorate. A Scientific Committee consisting of 30 University Professors from throughout the country meets twice a year and helps the Directorate in evolving lines of general policy. The detailed research programme at the synchrotron is in the hands of an 'Investigations Committee' which selects from proposals for experiments.

The operating budget for 1969 is 50.7 MDM and is provided half by the Federal Ministry for Scientific Research and half by the eleven States of the Federal Republic. Investment programmes involve additional funds which are provided in different ways. Original investment for construction of the synchrotron and the Laboratory amounted to 110 MDM and came from the Federal Government (83 M) from Hamburg (17 M) and from the Volkswagen Foundation (10 M). Current investment programmes involve the construction of a new linear accelerator for injection into the synchrotron (for which 20 MDM is being spent in the UK as part of an agreement to offset UK expenditure in Germany) and the start of a project for 3 GeV electron-positron storage rings at a total cost of 84 MDM of which 8 M has been allocated this year.

The synchrotron

The electron synchrotron came into operation in 1964 at an energy of 6 GeV. Since 1966, extensive modifications have improved the performance of most components. It now operates at 7.5 GeV, the peak energy being limited not by available r.f. power or magnetic field but by horizontal beam spread, due to synchrotron radiation at high energy, filling the vacuum vessel aperture.

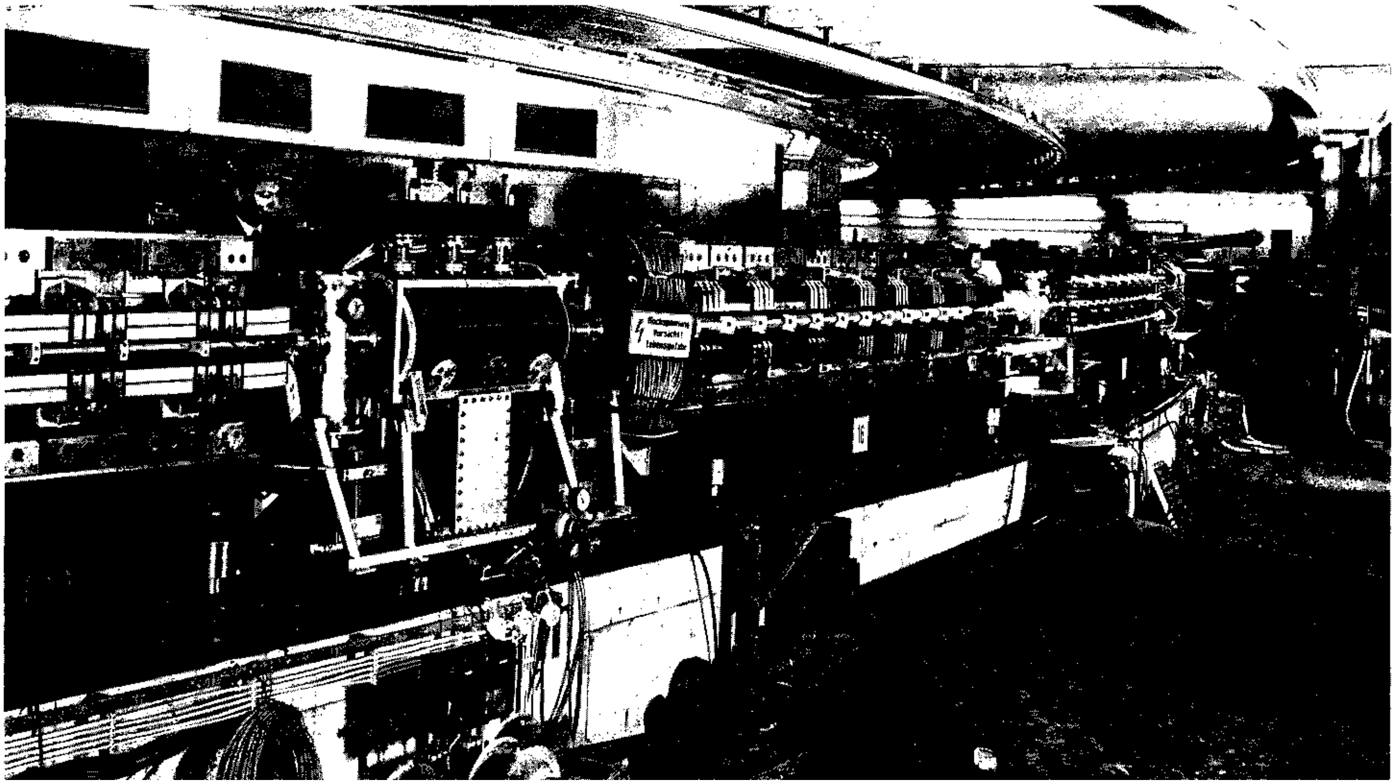


The design intensity was 10^{11} electrons per pulse at 50 pulses per second, the average current within a pulse being 16 mA. 18 mA has been achieved but the usual operating condition is 12 to 14 mA irrespective of energy. The limitation on intensity comes at injection from the 40 MeV linac, when beam loading of the r.f. cavities in the ring is proportionally high. (The influence of remanent field effects in the magnets is not significant by comparison even though the injection field is only 42 G.) A new linac (described below) for 300 to 500 MeV injection is now in an advanced state of construction and will result in higher intensity.

The machine operates very reliably. It is scheduled in 14 day periods with five shifts for maintenance. In 1968, the percentage of scheduled hours for which particles were provided to experiments was just over 90%, which is a fairly standard figure for synchrotron operation, but in March of this year, out of 616 scheduled hours, the experiments received 612.5 hours of beam — an efficiency of 99.4%. There are usually one or two 'main users' and one or two 'parasitic users' taking beam at the same time.

Two external electron beams are installed, one in each of the two experimental halls. The ejection efficiency is low (about 35 %) but the reasons for this are now understood and it is hoped to push the figure up to near 80% when new equipment is available. The ejection system uses the 6 V_z resonance and the losses come mainly from crossing other resonances en route to the 6 V_z resonance from the working point of the machine. Tests have been carried out at low energy shifting the working point of the machine to avoid crossing resonances and the efficiency improved to 60%. Some new components (quadrupoles, sextupoles, septum magnets etc.) will be installed to enable this to be done at full energy.

Among the many modifications to the machine in the past few years the most important has been the replacement of the



entire vacuum chamber in the synchrotron ring. The original chamber was made from epoxy and stainless steel. When electron beams were injected, residual gas (mainly water vapour) came off from the epoxy raising the pressure and causing ionization and breakdown in the r.f. cavities. Eddy current heating at high energies had the same effect. The new vacuum system, which is all ceramic and metal, has proved entirely satisfactory giving vacuum of 5X1CT° to 5X1CT° torr which is not influenced much by the presence of a beam, or by running the synchrotron magnets to high energy.

Of the original 40 MeV linac, there is little more than the waveguide structure and main modulator left. A new electron source (with cathode lifetimes of about 5000 hours compared to about 100 hours in the previous type), a new 500 MHz pre-buncher, new oil-free vacuum system and new electronics have been installed. Operation is now more stable and a higher beam intensity is achieved (about 180 mA within an energy spread of 1 % and an emittance of 1 mm mr).

The magnets of the main ring have new pole-face windings and back-leg windings, the r.f. has higher power klystrons, and new controls are installed in the power supply system and in the Main Control Room.

Both operation and development work on the synchrotron is carried out by the same team of people. This has advantages both ways — development of machine components brings variety into the life of operators, and operating the machine ensures that interest in development does not finish with the first working prototype but only when the unit is functioning reliably on the machine.

New linac

The new linear accelerator, which will inject electrons into the synchrotron at an energy of 300 MeV, has been manufactured by Varian (UK) and is almost completely installed. It is scheduled to be taken over by DESY at the end of 1969. There will then follow about a year of development work, during which the linac will be used progressively more and more in the operation of the synchrotron, before it is handed over completely to synchrotron operation towards the end of 1970.

The linac has twelve waveguide sections each 5 m long powered by 24 MW klystrons at 3000 MHz. It is designed to inject 125 mA of electrons within an energy spread of 1 % at 300 MeV.

Besides its contribution to higher intensity, the linac is also built for the production of positrons. This will make positron experiments possible at the synchrotron and will be the source of positrons for the storage rings (see below). The positron converter supplied by Varian is similar to the one in use for ADONE at Frascati. It consists of a water cooled tungsten ring onto which electrons are fired after acceleration through five of the linac sections. The two sections immediately after the converter have a superimposed solenoid field of 4 kG along the axis (probably the strongest field ever to be superimposed over an accelerator waveguide — it has been successfully tested) and there are, at appropriately spaced positions downstream, 25 quadrupoles also over the waveguides. The focusing units help to catch more of the positrons coming off from the converter. The positron beam intensity injected into the synchrotron at 300 MeV should be about 1 mA.

Work has begun on a more efficient positron converter which will have a focusing cone of wire strips (taking a pulsed current of 15 kA) to focus positrons emitted within a cone of about45° opening compared with about 15° opening of the initial solenoid arrangement. This should gain a factor of around three in positron beam intensity.

The beam from the new linac has to be transported over about 150 m to the synchrotron. The beam transport line will be computer controlled — the computer monitoring the beams and setting the magnets. It is intended to extend computer control later to operation of the linac itself. This will provide valuable experience (since computer control has not yet been incorporated into operation of the synchrotron) in preparation for the start up of the storage rings for which computer control will be vital.

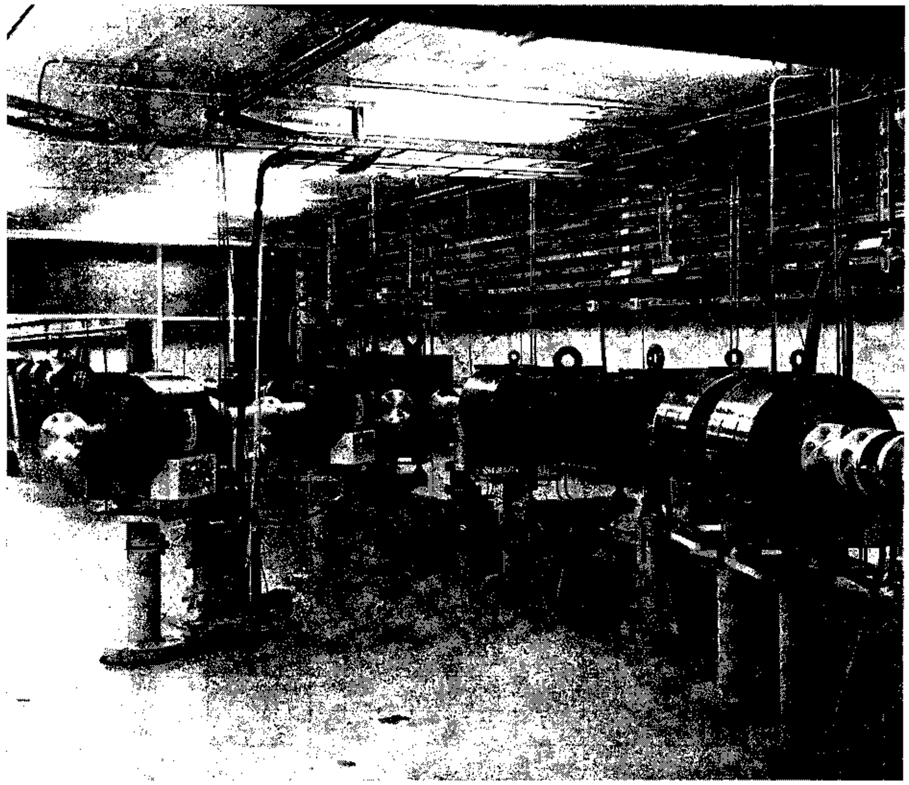
Experimental programme

There are two experimental halls each with an area of about 3000 m². Hall I has an ejected electron beam and two photon beams; at the end of this hall the streamer chamber (see below) is installed. Hall II also has an ejected electron beam and two photon beams; an additional experiment is set up in a small annexe at the end of the hall.

The programme covers three major areas of research — studies on quantum electrodynamics, photoproduction, and elastic and inelastic electron-nucleon scattering experiments.

In the first category there is the well

The beam transport system at the output end of the new linear injector. The linac itself is just visible coming in from the left. Going off to the right is the long transport line to the synchrotron ring, and the short blanked-off arm to the left can be extended later to feed the storage rings.



known experiment on wide-angle electron-positron pair production. Earlier results on this topic had indicated a breakdown of quantum electro-dynamics but the DESY experiment restored faith in quantum electro-dynamics, effectively measuring down to distances of the order of 10^{-14} cm. Taking advantage of the higher energy of 7.5 GeV now available from the synchrotron, the team who had carried out the first experiment, extended their measurement, improving greatly the sensitivity of this test of QED. The team has also carried out measurements on leptonic decays of the rho and phi vector mesons contributing to the results on this topic reported at the Vienna Conference. Measurements are now being taken on the photoproduction of K'K" and *K'K*~ pairs at invariant mass above 1 GeV/c^2.

Other photoproduction experiments are a measurement of the total cross-section for photoproduction at energies from 1 to 7 GeV; photoproduction of rho mesons using coherent, linearly-polarized photons produced from diamond crystals positioned in the synchrotron; photoproduction of charged pions in hydrogen and deuterium also using linearly polarized photons. Another experiment, which is being prepared by a team from the University of Bonn, is the photoproduction of eta mesons at small angles in the energy range 4 to 7 GeV.

Three experiments look at electron scattering. One (by a DESY/Collège de France team) looks at electroproduction of the neutral pion in the region of the 3/2, 3/2 resonance in inelastic scattering of electrons on protons. A second one looks at quasi-elastic electron-deuteron scattering. This is a coincidence experiment which will measure neutron form factors. A third also looks at quasi-elastic electron-deuteron scattering (team from the University of Karlsruhe). It will measure form factors extending previous measurements to higher momentum transfers.

The streamer chamber, described below, will be initially used for photoproduction experiments with tagged photons in the energy range 4.5 to 7 GeV. This is an Aachen, Bonn, Hamburg, Heidelberg, Munich collaboration.

Finally there is a team doing research with synchrotron radiation, where also visitors from Universities from different parts of the world participate. Topics of the experimental programme are for instance to measure absorptive power of metals and plasma oscillation identification.

Streamer Chamber

In the field of experimental techniques, DESY is doing some leading work in the development of streamer chambers. These new particle detectors were described in CERN COURIER vol. 7, page 219 and the DESY chamber was covered in vol. 8, page 190. They involve the application of a very short high voltage pulse (about 10 ns) across a gap in which the passage of a charged particle has produced ionization along its track in, for example, a helium-neon gas mixture. Under the influence of the electrical field of the pulse, the primary electrons build up electron avalanches giving visible streamers. The streamer length is defined by the pulse length ; streamers about 5 mm long are necessary to become directly photographable with present techniques.

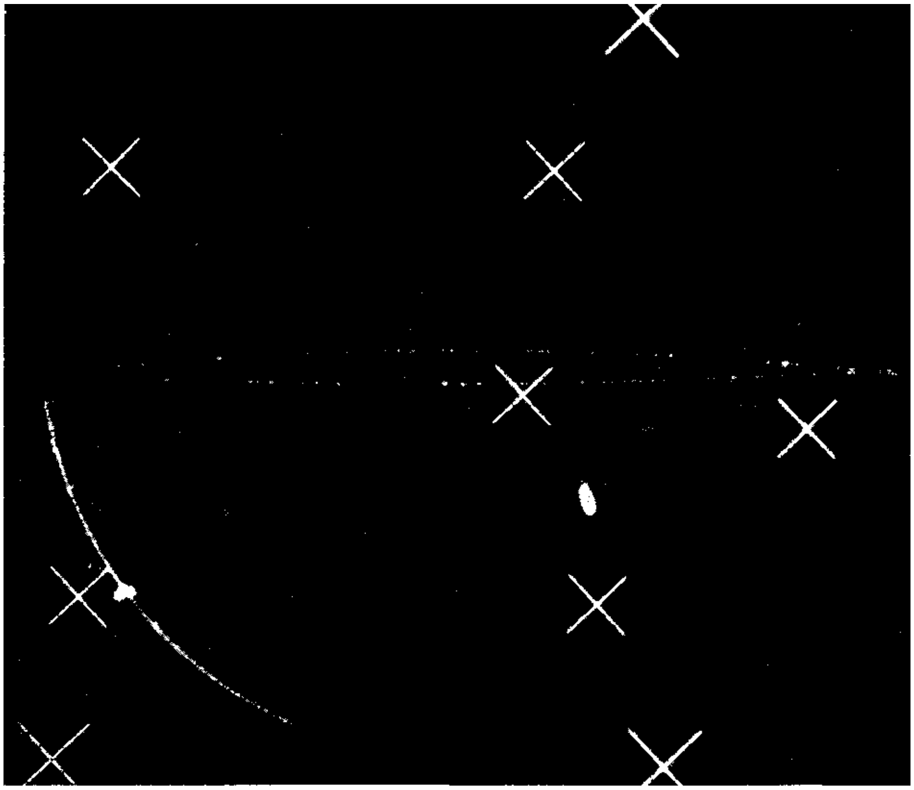
At DESY, a double-gap streamer chamber 100X60X32 cm^3 is installed in a 22 kG magnet previously used to enclose an 84 cm hydrogen bubble chamber. About 20 000 pictures have been taken and are now being analysed. A long run is scheduled at the beginning of June to continue the studies of the photoproduction of hadrons in the energy range 3 to 7 GeV, gathering much higher statistics than a previous bubble chamber experiment on the same topic.

In the past six months several technical problems have been ironed out. One problem concerned the cooling system of the liquid hydrogen target. Since the refrigeration system is rather unusual due to its narrow geometry inside the magnet yoke, several technical difficulties arose which are now solved.

A second, more tricky, problem was spark breakdown in the region of the target. The target cell (a tiny cylinder 40 mm long, 25 mm diameter) is surrounded by a cylinder of thin scintillator material which is one of the counters which trigger the chamber (ensuring that the observed particles originate from an interaction in the target). This cylinder is evacuated to heat-insulate the target cell. The sparking occurred along the gas surface of the scintillator cylinder, and its origin was traced to weak discharges along the vacuum surface of this cylinder. It has been cured by coating the surface with a thin layer of a special oil. The effect of the oil is to suppress the discharge by electron attachment.

A third problem is connected with the 'memory time' of the streamer chamber. Ideally, only the desired tracks of the interaction, on which the chamber was triggered, should be found on the photograph. This would greatly simplify the analysis of the pictures. However, if the chamber gas 'remembers' all the charged particles that have gone through it, say in the 50 [is before the high voltage pulse is applied, the picture will be more confused. The memory time can be reduced by adding electro-negative gases to the chamber gas. At DESY, this was done simply by adding air, but the light output of the streamers decreased considerably when attempting to achieve memory times of as low as 2 fis.

Now SF6 (sulphur hexafluoride) is used for this purpose resulting in no loss of



A photograph taken in the streamer chamber at DESY. It shows the photoproduction of a rho meson from a tagged photon coming into the chamber from the left. The visible tracks are of the recoil proton (the strong track bending towards the bottom of the picture) and of the two charged pions from the rho decay.

light down to 1 [is. The use of SF6 was mentioned by B. I. Dolgoshein at the Dubna International Seminar on Filmless Spark and Streamer Chambers, held in April.

A memory time of 2 jis is now used for the DESY chamber, compared to 10 [is previously. This is about as short a time as is practicable because, from the time the desired event has taken place in the target and signalled by the counters, it takes about 0.7 [is for the electronic logic and pulse amplifiers to apply the high voltage pulse to the chamber.

The work with the DESY streamer chamber so far is very encouraging. Using a liquid hydrogen target located at the input end of the chamber the interaction rate and average measurable track length is similar to the larger 2 m streamer chamber at Stanford which uses gaseous hydrogen running through a tube along the beam axis. With new optics giving a demagnification of 40 instead of 65, track positioning in the plane parallel to the film is accurate to within ±0.28 mm. Momentum resolution of the tracks is comparable to that achieved in bubble chambers of similar size ; for example, a 2 GeV/c pion giving a track 70 cm long can be momentum analysed to within ± 1.2%.

Storage rings

At the beginning of 1969, DESY received authorization for the construction of 3 GeV storage rings for electron-positron colliding beam experiments. A group has been set up to finalize the design and to construct the storage rings.

The initial proposal was described in CERN COURIER vol. 8, page 289. It consists of two separate rings stacked one on top of the other with two interaction regions in the centre of long straight sections where the electron and positron beams, orbiting in opposite directions, can be brought into collision crossing one another in the vertical plane.

Since authorization, the group has had a good look at two new ideas for electron-positron colliding beams. One comes from P.C. Marin's group working with the 550 MeV 'ACO' at Orsay. They have developed a scheme for head-on collisions in a two-ring system using one bunch of particles in each ring (ratherthan a virtually continuous ribbon of particles). This would avoid the limitation on luminosity due to space charge effects of one beam on the other. The ultimate luminosity in the scheme would be above 10^{33} at 3 GeV. The second idea comes from the group of M. Sands and B. Richter at Stanford, and is the result of efforts to cut costs and construction time in view of the failure to get money for the 3 to 4.5 GeV single ring project proposed some years ago. They have developed a new scheme having two rings (slightly pear-shaped overlapping at two points) which gives horizontal beam-crossing at 11°.

The DESY group investigated the different beam-crossing geometries and corresponding luminosities and have decided to stay with their two rings vertically stacked. They are now thinking of approaching the design luminosity in three steps so as not to confront too many problems immediately when switching-on the machine.

Step 1 would give a vertical beam-crossing angle of 2° to 3° in an interaction region 5 m long where the detectors can be installed. There would be no magnets common to the two beams — the last magnets on either side of the beam-crossing points would be special lozenge-shaped quadrupoles (with coils of triangular cross-section), one quadrupole for each beam. Though this results in comparatively low luminosity it should give very stable operation and could help greatly to bring the rings into action smoothly and quickly.

Step 2 would be to remove the lozenge quadrupoles and to kink both beams using bending magnets, a current-sheet septum and large-aperture quadrupoles common to both beams so that the beam-crossing angle is reduced to 3 to 30 milli-radians depending upon the energy. Independent control of each beam is then lost, because of the common quadrupoles, but the luminosity should climb to 2 X 10^{33} at 1.5 GeV falling off towards 3 GeV.

The final step would replace the septum by an electrostatic separator making the beam-crossing angle . even smaller and achieving the design luminosity of 10^{33} at 3 GeV. The electrostatic separator for this use is a difficult piece of equipment to build. A spark breakdown results in the stored beams being lost and the rings have to be filled with particles again (as opposed to conditions with a conventional separator in a secondary beam-line where a breakdown just looses one pulse).

It has been decided to produce the bending magnets for the rings 'out of solid' rather than with the usual laminated construction. The magnets will be curved (3 m long, 12 m radius), which makes laminated construction difficult and expensive, and the DESY group also want to keep the fringe fields of the magnets as seen by the beam as linear as possible. This can be done by tapering-off the poles hyperboiically which is also difficult with laminated magnets. Studies have been carried out on solid magnets and the required accuracy of field configuration and of reproducibility was achieved.

Within the next few months, contracts will be placed for components of the r.f. system and for the bending magnets. The design of the building is ready and building work will probably start in the autumn. Construction of the actual rings could then start in 1971 with the aim to begin operation in 1973.

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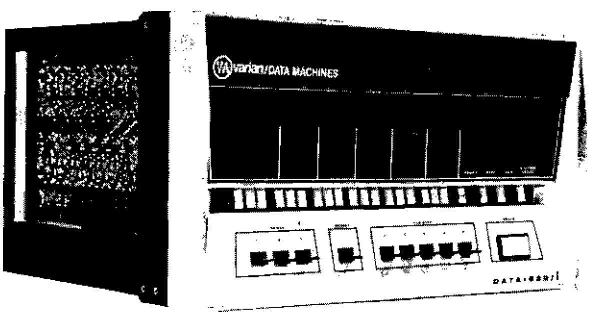

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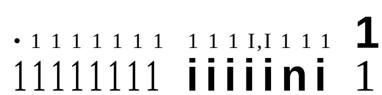

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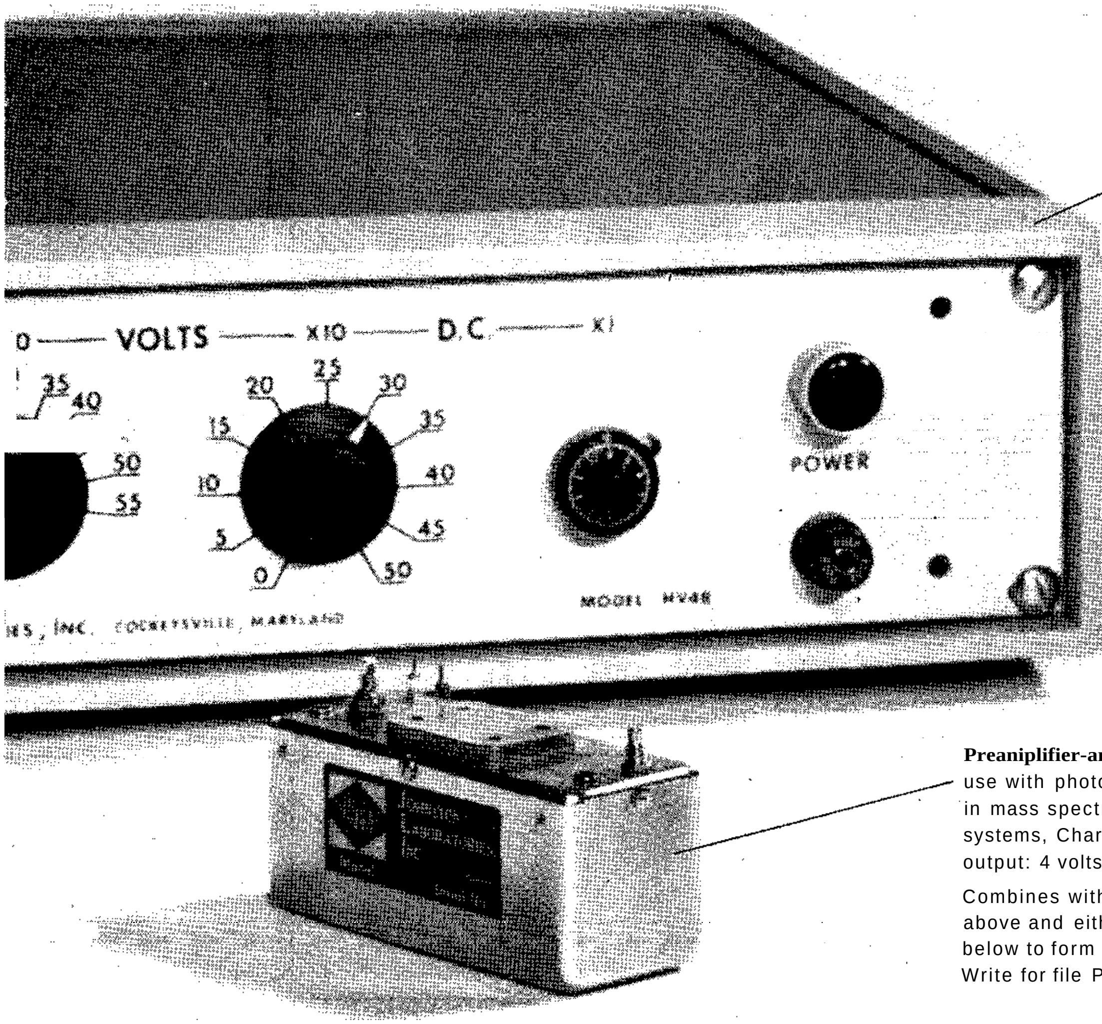

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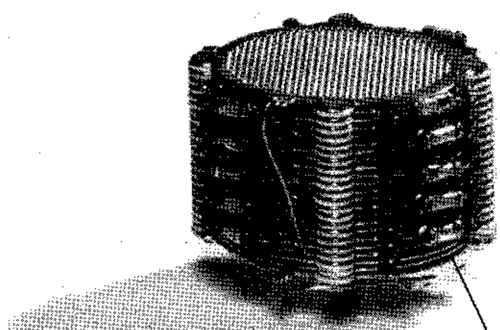

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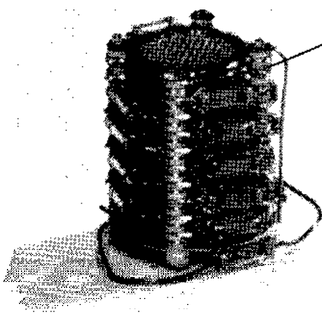

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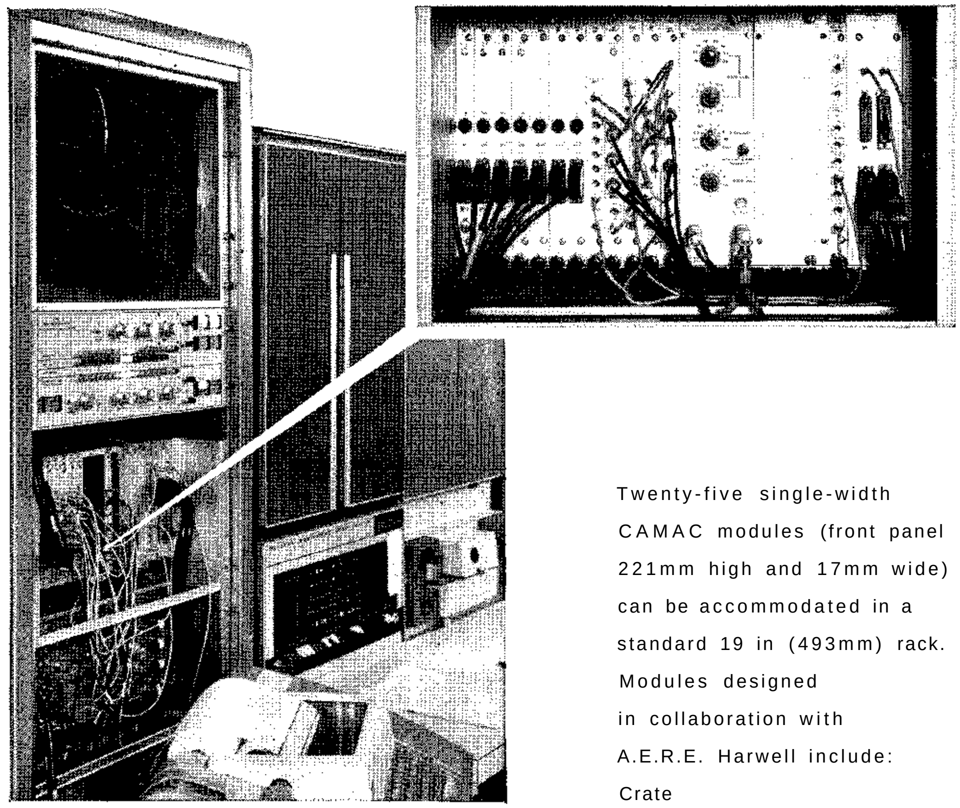

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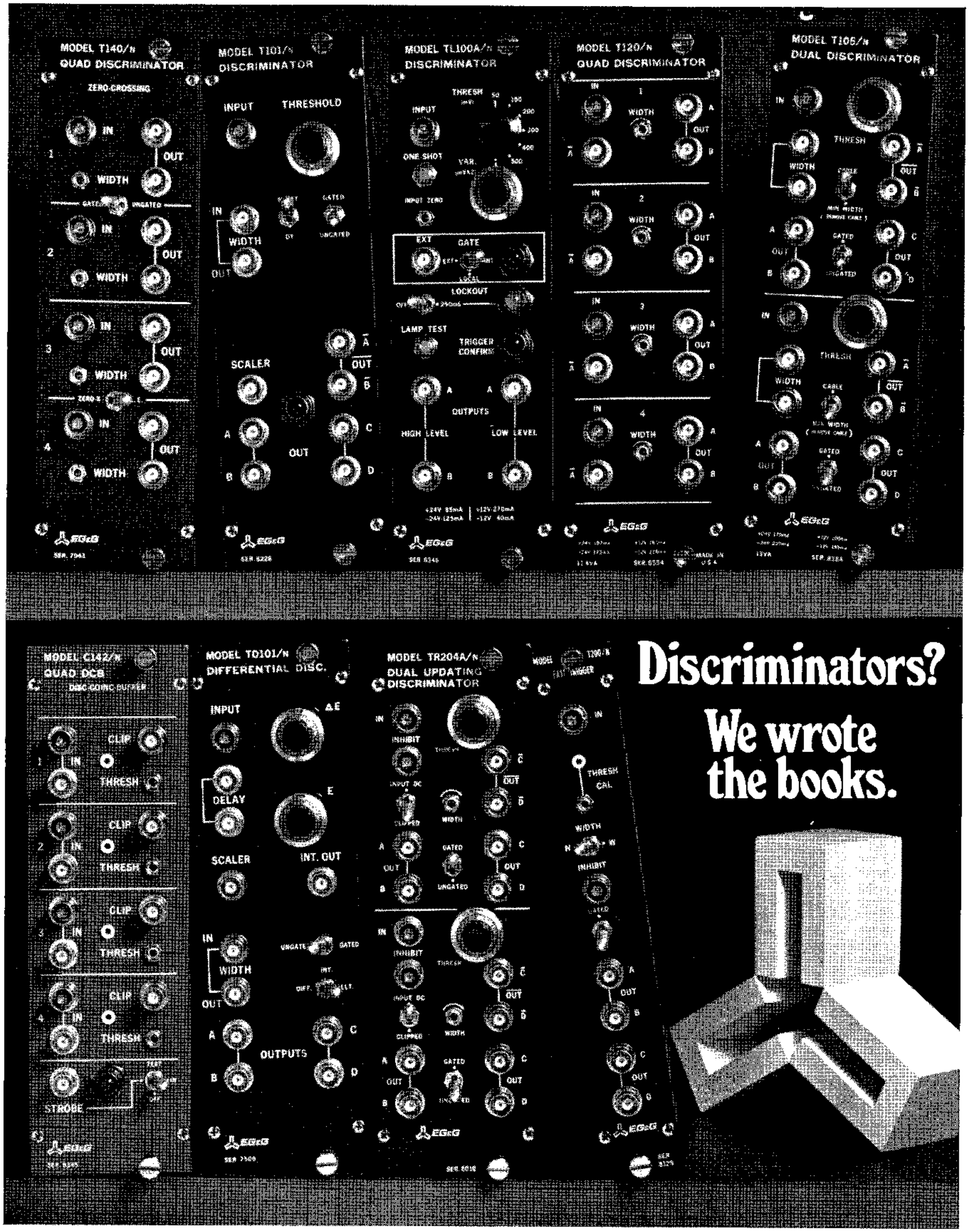

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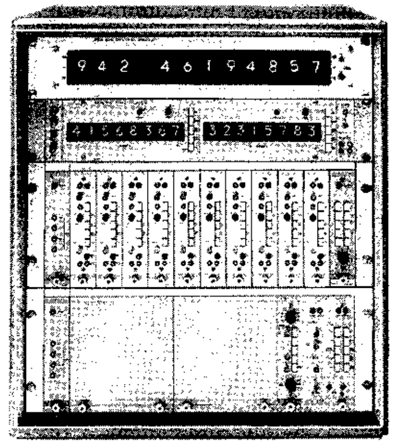

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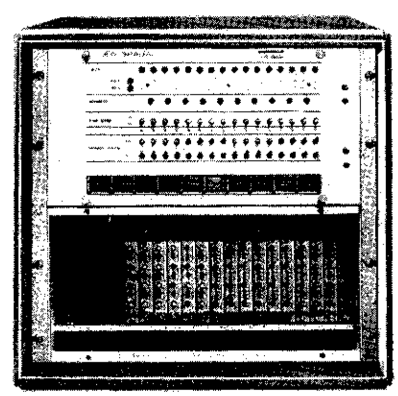

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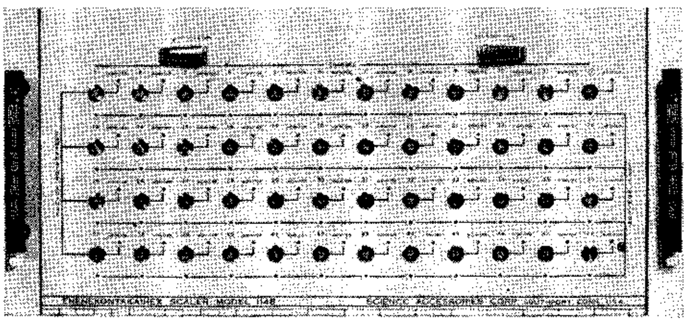

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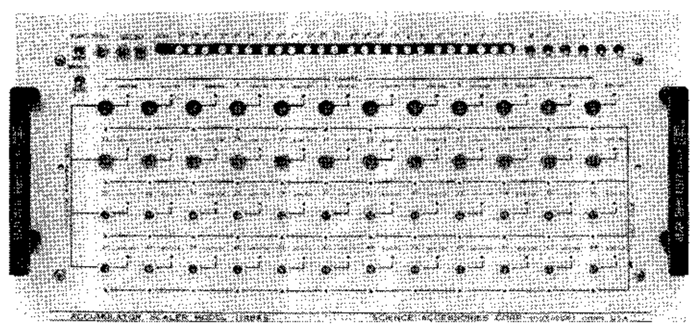

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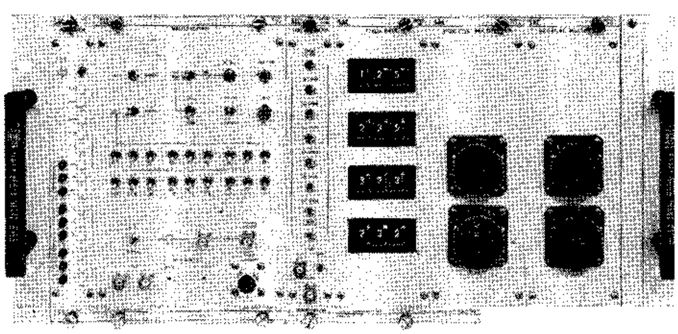

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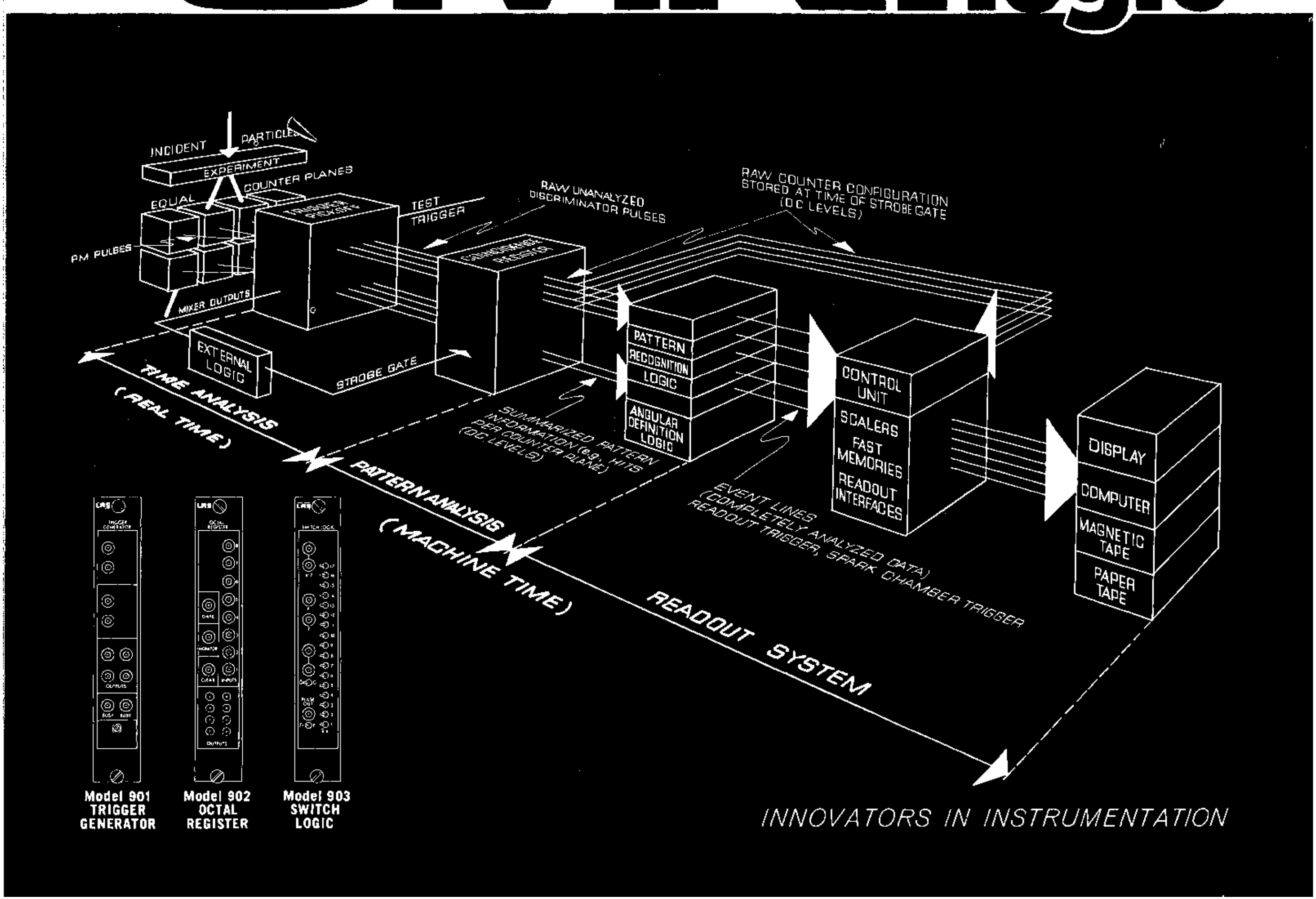

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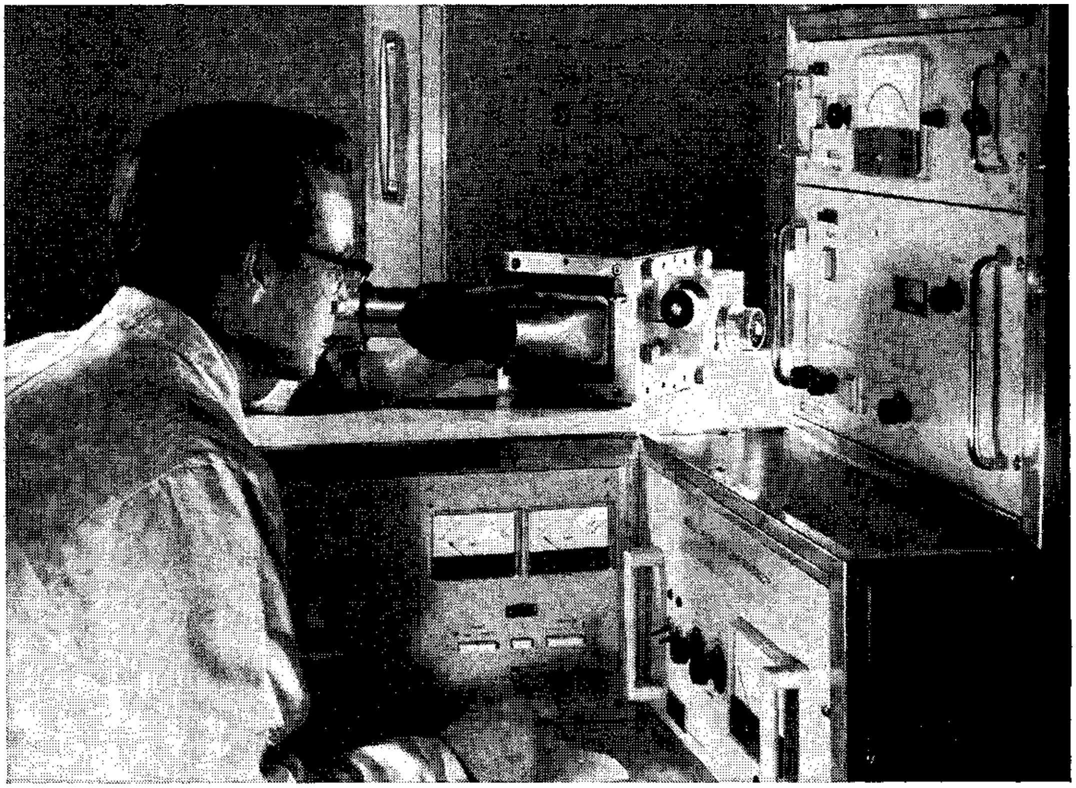

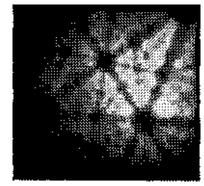

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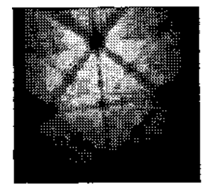

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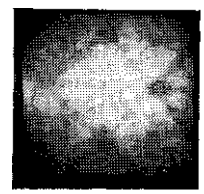

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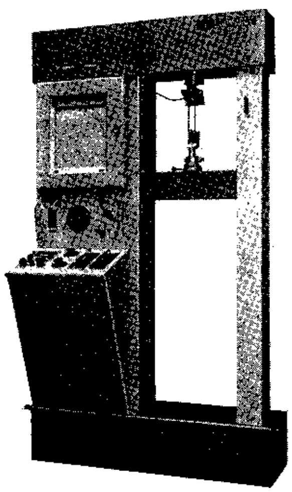

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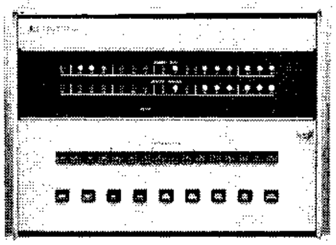

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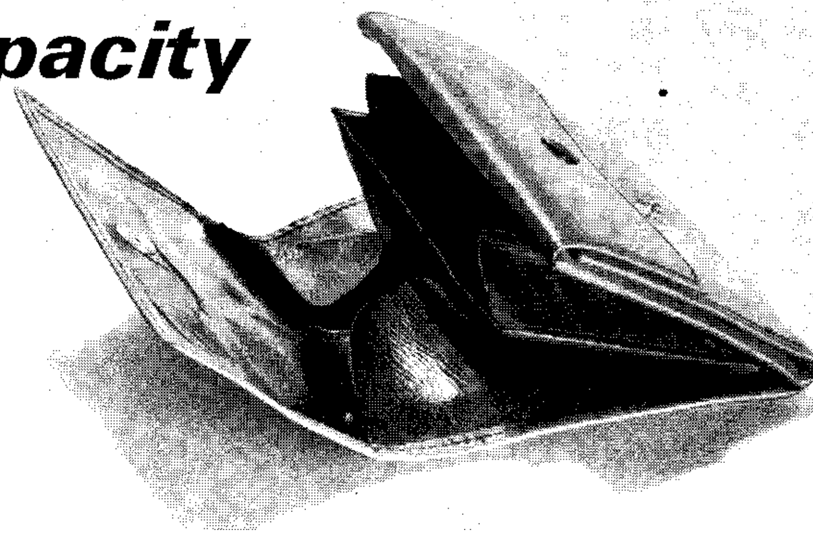

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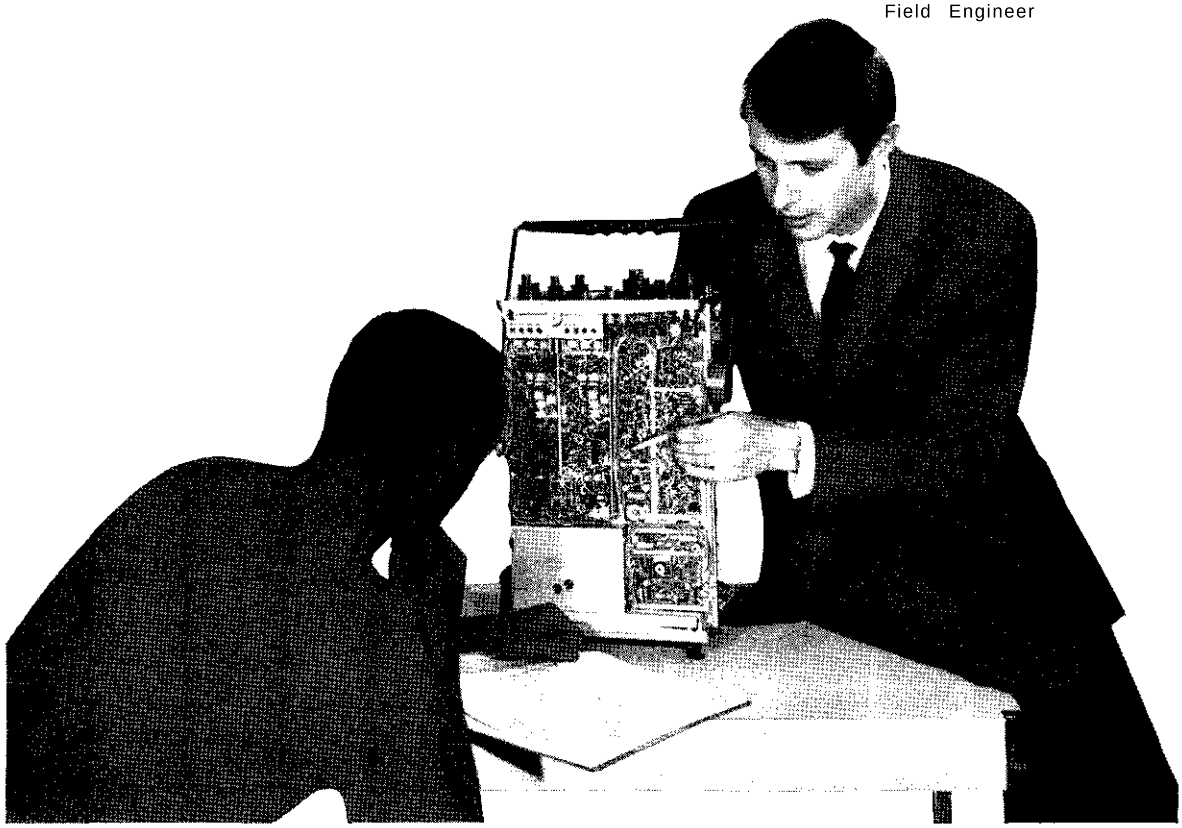

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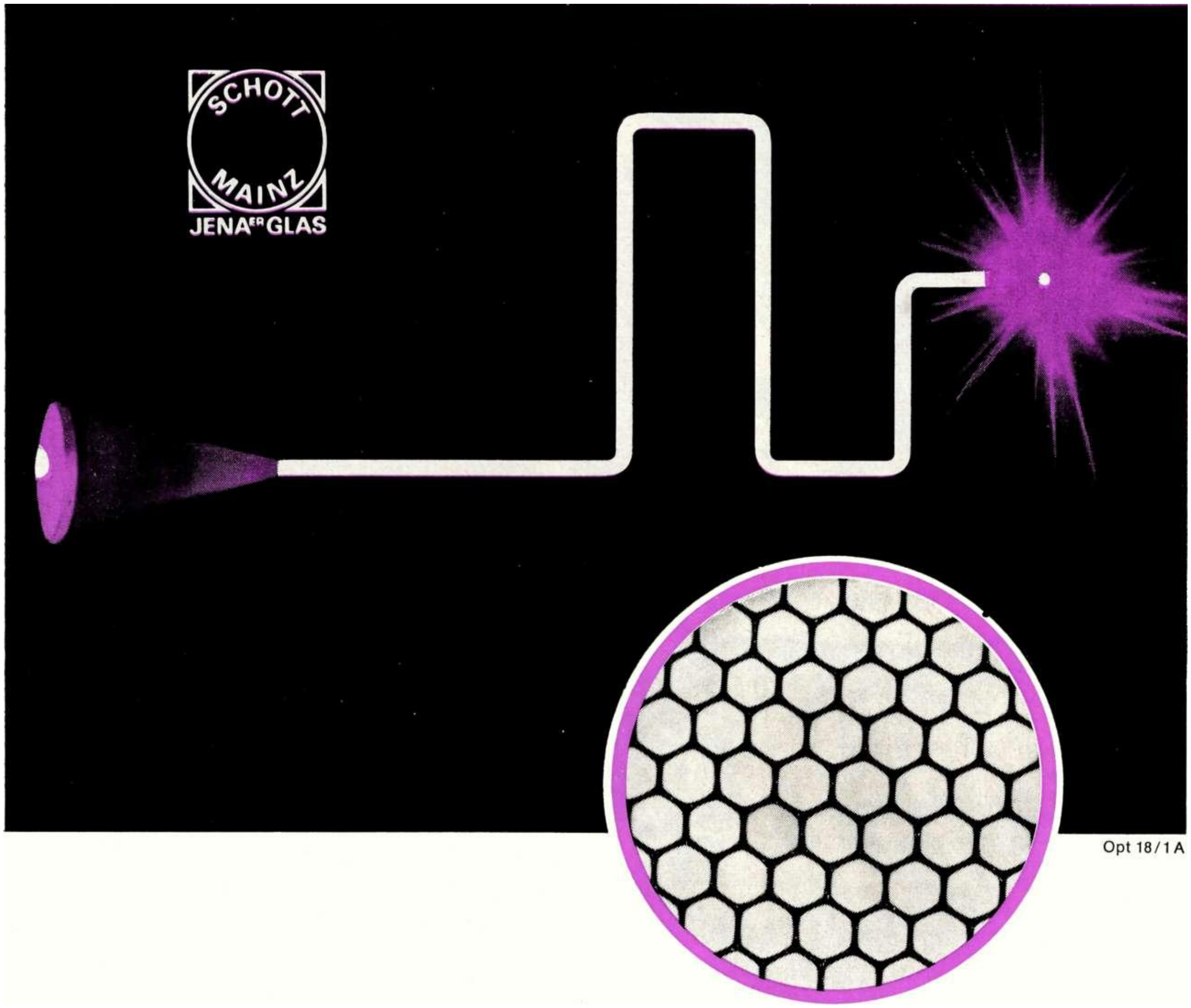

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Light-guiding fibres transmit light along any bent path. They consist of a core of optical glass having high refraction with the minimum of colour and a cladding of another glass with a low refractive index. Light rays penetrating a fibre are totally reflected on the interface of the two glasses and follow a zig-zag path to the end of the fibre. (The encircled micro-photo shows the cross-section of fused parallel and optically insulated fibres. Light-guiding fibres usually have diameters in the range from 0,01 to 0,10 mm. Actually they are available for the ultra-violet, visible and near infra-red spectral regions. - We supply fibre optical components such as flexible light guides, cross-section transformers, fibre rods (see illustration) and cladded light transmitting rods. Further components are under development. — We are always prepared to undertake the design and development of new systems of fibre optics.

Applications: Control, measuring and regulation techniques, refrigeration, photo-electrotechnique, medical optics, physics, chemistry, physiology, photography etc.

JENAER GLASWERK SCHOTT & GEN., MAINZ

(West Germany)

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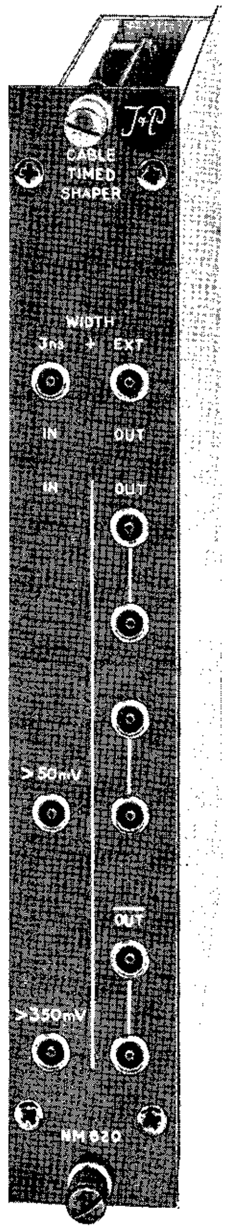
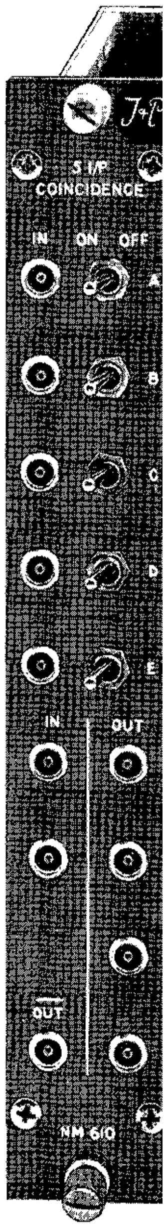
NANOSECOND LOGIC by ^

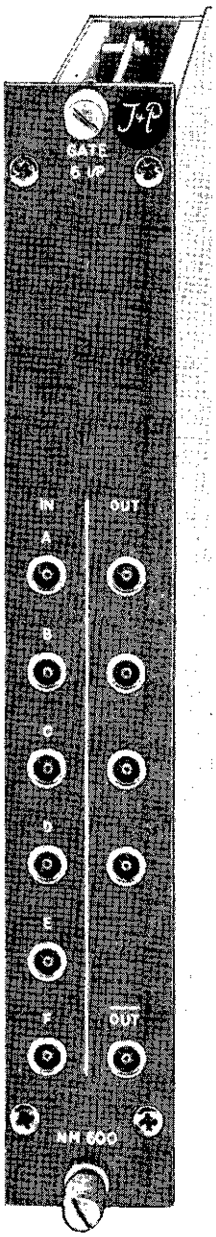
NM 620



NM 610



NM 600



* **NM 600**
6 input OR

NM 601
6 input gate

NM 605
Dual 4 input gate

* **NM 610**
5 input coincidence
with dead - time - less
output

* **NM 611**
5 input coincidence

* **NM 620**
Trigger with cable timing

NM 630
Dual attenuator with
push button control

NM 640
Delay unit with
push button controls

NM 641
Delay unit

NM 642
Delay unit

* The family of instruments now available includes modules based on the current range of CERN designs.

Write for details of these and other instruments to :
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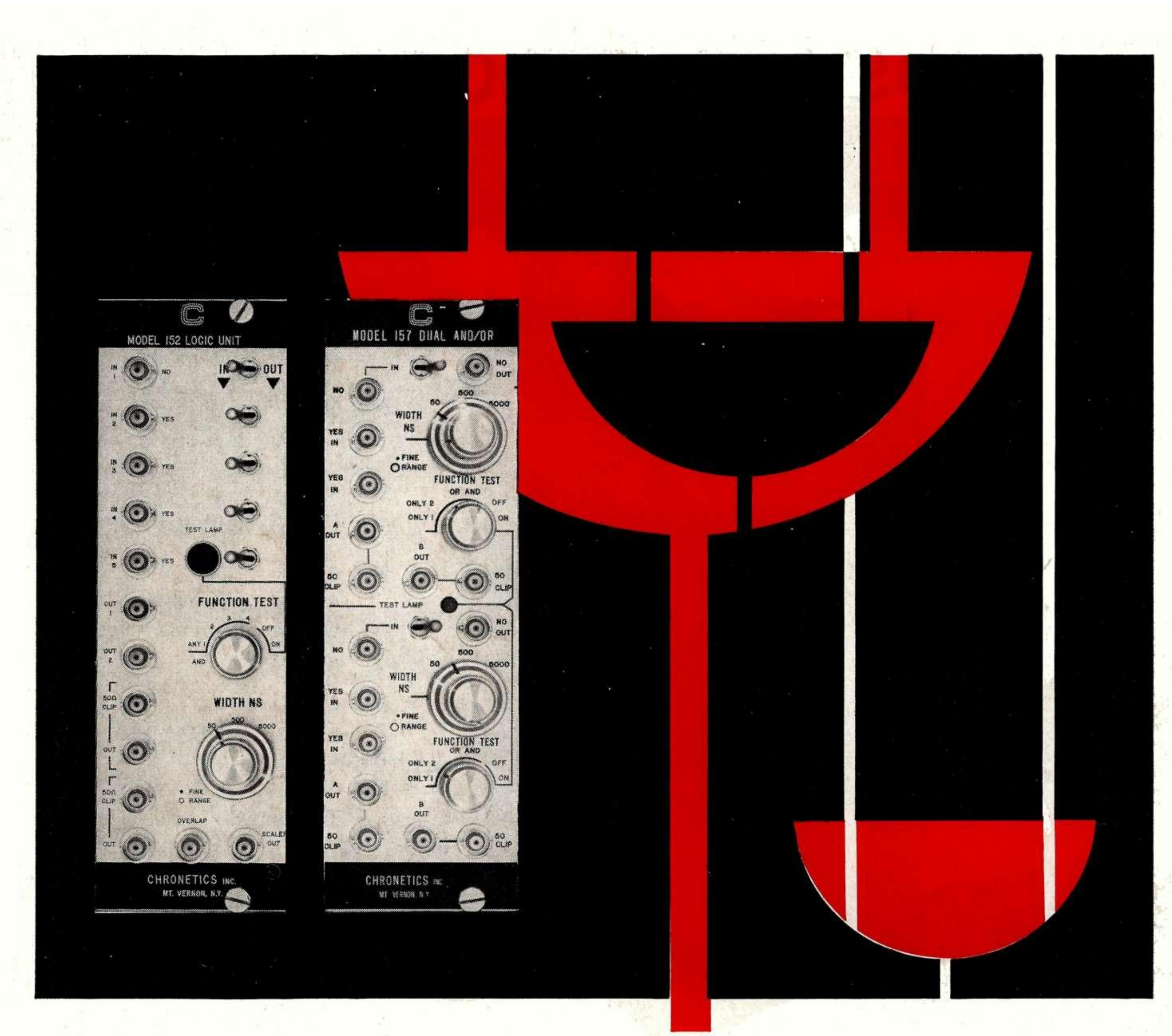
J&P Engineering (Reading) Limited



LOGICAL CHOICE

These are the Nanologicians.

Logic Units to make your discriminator outputs as meaningful as the inputs. With Nanologic discriminators these logic units will give your experiment a front-end that's the fastest, most flexible and most reliable anywhere commercially available.

Consider Model 152.

Performance: random access to better than 200 MHz; less than 5 ns pulse pair resolution; coincidence resolution better than 50 picoseconds; minimum resolving time curve, 1.5 ns FWHM.

Flexibility: km, OR, Majority Logic, ANTI-, Selective AND (2-, 3-, 4-fold AND). Completely DC-coupled. Any combination of YES and NO using complementary inputs. Two of the five inputs bridged out to front panel BNC's. Normal or complementary outputs switch-selectable. Variable output width. Overlap output for exact coincidence detection. *Reliability, Stability, Quality:* Nanologic.

Another choice: Consider Model 157.

Model 157 is a dual logic unit. Just as fast; same 50 psec coincidence resolution; 1.5 ns FWHM minimum resolving time curve; 5 ns pulse pair resolution at 200 MHz, gated burst or CW. Functions are AND, 0R, ANTI- and Singles Selection (ONLY 1, ONLY 2). Bridged NO input; normal-complementary outputs. Variable output width.

If you're thinking about numbers for the logic blocks of your experiment's block diagram, may we suggest 152 and/or 157? Can't imagine a better choice.

Available from stock. Literature or a demonstration at once at your request.

CHRONETICS

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