# CERN COURIER

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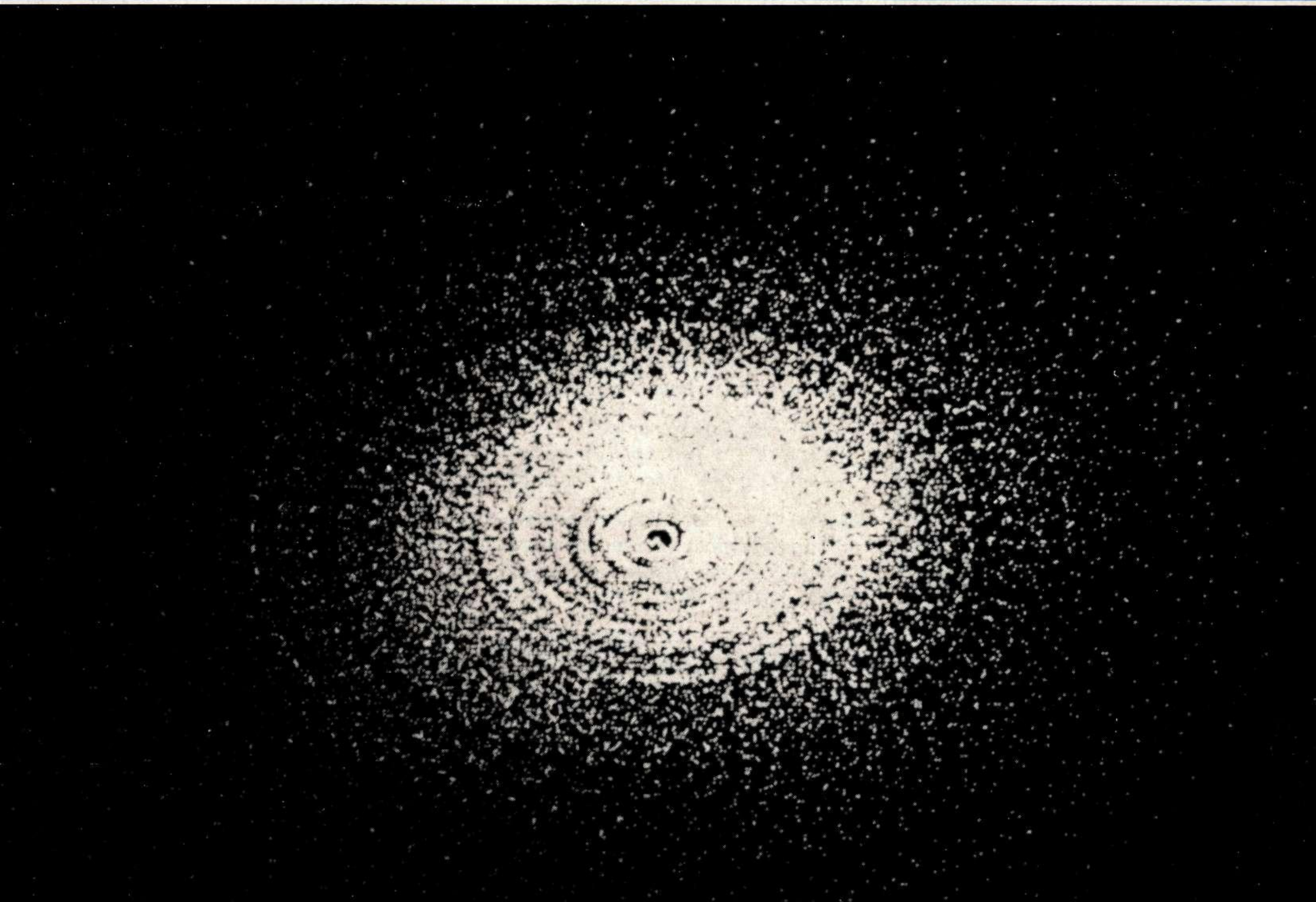
European Organization for Nuclear Research



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. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1200 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 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 Laboratory I budget, which totals 353.4 million Swiss francs in 1971.

The CERN Laboratory II was authorized by ten European countries in February 1971; it will house a proton synchrotron capable of a peak energy of hundreds of GeV. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1971 is 29.3 million Swiss francs.

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# Contents



*Cover photograph : Fireworks to celebrate Christmas — courtesy of the PS Booster. The photograph is a 'still' from a film illustrating multi-turn injection into a ring of the Booster by computer simulation. A thousand particles are fed in and the proton motions in the vertical phase plane during one eighth of a turn around the ring result in the distribution of particles as shown. The film was produced by C. Bovet, D. Lamotte and R. Le Bail with G. Bertin behind the camera.*

# CERN Laboratory II

*A review of developments at Laboratory II in the course of the year.*

On 19 February, ten of the Member States in the CERN Council approved the 'Programme for the Construction and Bringing into Operation of the CERN 300 GeV Laboratory'. Recruitment of the senior staff for 'CERN Laboratory II' began immediately afterwards and all the Group Leaders (listed in the July issue, page 189) were at CERN full-time by September.

By now the total number of staff who have arrived at Laboratory II has grown to about 100 and it will climb close to 300 by the end of next year. They are temporarily housed in four large huts close to the West Experimental Hall, part of which is being used for component testing. This arrangement will continue until early in 1973 when a laboratory and office building and a large assembly hall will become available on the Laboratory II site.

## Design of the accelerator

When the senior staff posts had been filled, the first item on the agenda was to re-examine the machine design. This review of the accelerator parameters and the assumptions from which they emerged was then being done by people directly responsible for carrying the project though to an operating machine.

Prior to the February decision a two-volume report (MC/60) entitled 'A Design of the European 300 GeV Research Facilities' was produced. It was summarized in the January issue of CERN COURIER. We will remind readers here of the main features which underlie the detailed design of the machine and then concentrate on the few design changes which have been introduced.

The accelerator is to be built under land (predominently in France) on the opposite side of the Geneva-St. Genis road from CERN Laboratory I. It will be installed in a tunnel several tens of metres below ground which, together with careful positioning of the major experimental area (the North Area), will avoid major disturbance to the present use of the land. In the total area of the Laboratory only a few regions (office and laboratory area, North Experimental Area, six machine tunnel access points) will require surface buildings.

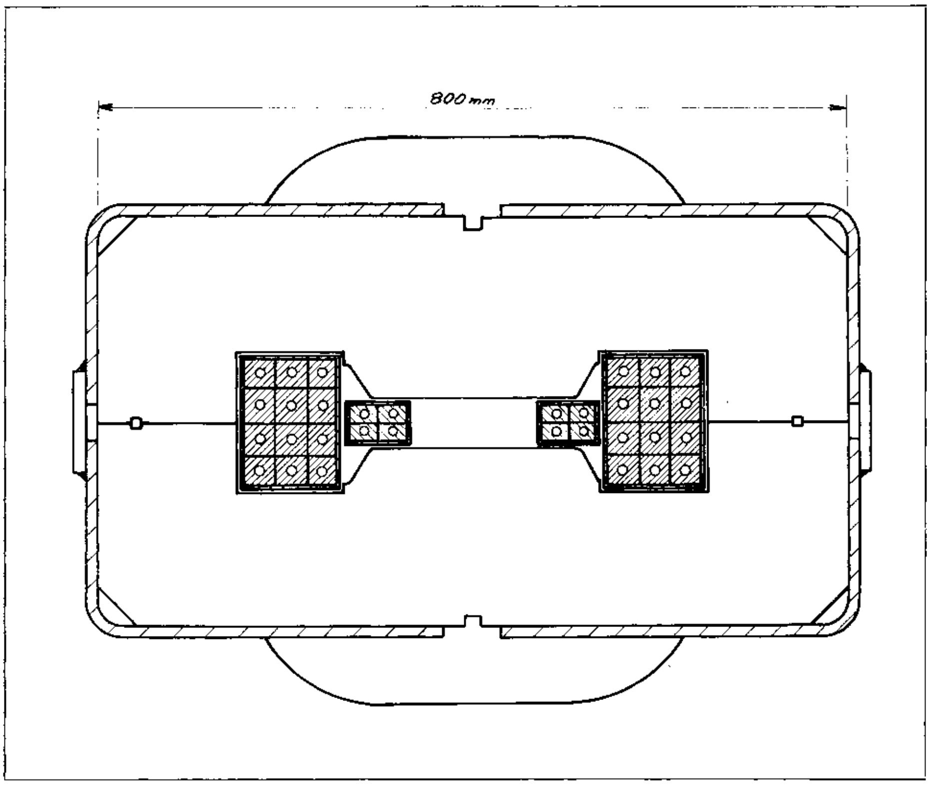
The machine diameter will be 2.2 km — the maximum ring diameter which can be accommodated in the molasse ridge which falls away into shallow valleys on either side. It will have six long straight sections. One will be used to receive the proton beam from the proton synchrotron which has been operating at CERN for eleven years and which will serve as injector. One will be used to eject beam to the existing West Hall so as to use the major experimental facilities which are already being built there (the 3.7 m bubble chamber, BEBC, and the spectrometer, Omega). One will be used for ejection to a completely new experimental area (North Area).

The accelerator will be constructed in such a way as to leave open, for as long as possible, the option of incorporating pulsed superconducting magnets in the ring should they become technically and economically feasible. This will be done by having a 'missing magnet lattice'. Initially conventional bending magnets will be ordered in sufficient quantity to give a peak energy of 200 GeV (this is known as stage A). They will be distributed around the ring occupying half the circumference available to magnets so as to leave room for the insertion of superconducting magnets in the other half later on. The higher fields of the superconducting magnets could give a peak energy of 400 GeV or higher. Alternatively more conventional magnets could be added (finance is assured in the budget of the accelerator for sufficient magnets to take the energy to 300 GeV — stage B — but there is room for magnets to take the energy to 400 GeV — stage

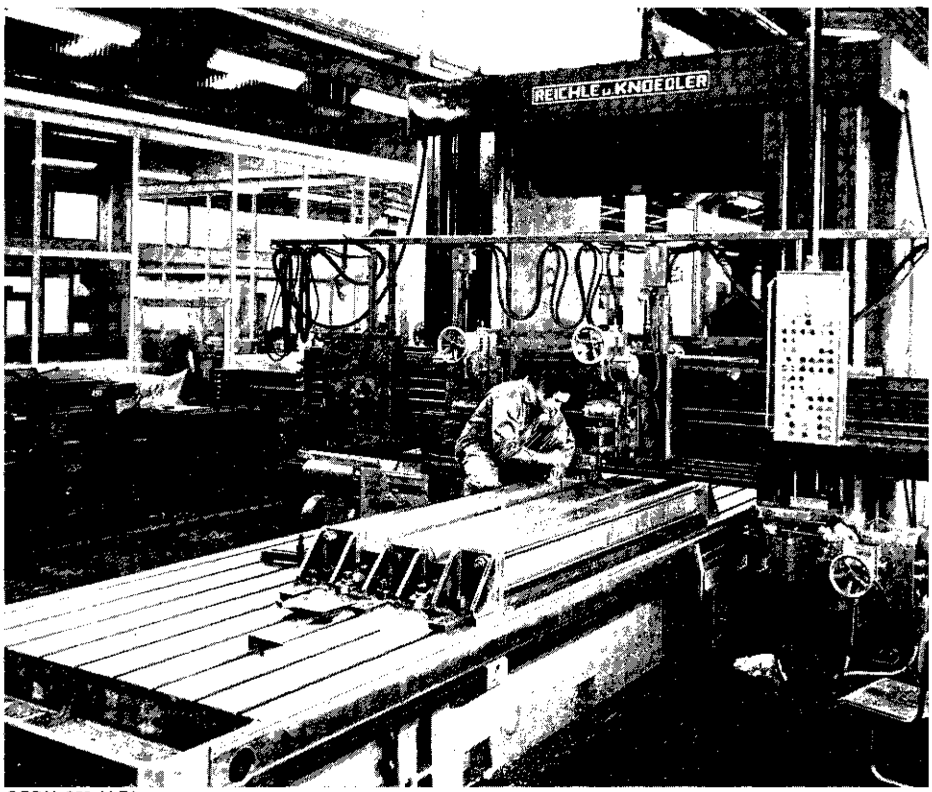
*A 'Management Board' meeting at CERN Laboratory II with the Director General J.B. Adams (left), and his Deputy H.O. Wüster at the head of the table. This is one of the two major internal committees which meet at fortnightly intervals. The Management Board concerns itself with general Laboratory matters and policy. A 'Design Committee' concerns itself with technical discussions on the machine design.*

*CERN 63.10.71*

*A cross-section of a B2 type bending magnet for the SPS. They will be of the 'window-frame' type 6.26 m long built from half-laminations giving a total core size of 800 × 450 mm² with a good field aperture of 52 × 92 mm². The two 'half-moons' above and below illustrate where the coils are bent up at the ends of the magnet.*




*Laminations for a model of a bending magnet for the SPS being machined in the CERN Main Workshop. It has been possible to begin building model magnets quickly once the design had been finalized thanks to the cooperation of the ISR Magnet Group who made available steel of the appropriate quality left over from ISR magnet production. Model magnets are being built to check both magnetic properties and construction techniques.*




*CERN 253.11.71*

C — and most components are being designed to cope with an energy of 400 GeV). Alternatively again, if superconducting magnets are a success a full ring of them could take the energy towards 1000 GeV. With all these energy options available we prefer to avoid the familiar title of '300 GeV' for the machine and to refer to it as the SPS (Super Proton Synchrotron).

When the construction team re-examined the MC/60 design which had emerged from these general features, it largely confirmed the parameters which had been selected. This was despite having considered some radically different lattices, r.f., injection and ejection schemes. The accelerator remains a separated function, missing magnet machine receiving its protons from the PS at a momentum of 10 GeV/c, accelerating them with travelling-wave type cavities and ejecting to West and North Experimental Areas.

Changes have come into the design of the bending magnets and of the ejection system. At the time of MC/60, two designs of bending magnet were studied — 'H' and 'window frame' — and both were left as possibilities though the emphasis was then quite strongly on H magnets. The decision has now swung to window frame magnets — a cross-section of a B2 type is shown in the diagram.

There are several technical reasons which prompted this change. An important one has come from a study of the effect of bending magnet field distortions on the required slow ejection conditions. This shows that the usually quoted 'good field' precision of 1 in $10^3$ is not adequate. Decapole and sextupole harmonics in the magnet fields (corresponding to field falling off at the extremities or at the centre of the aperture, respectively) could seriously affect the ejection efficiency. As a result of this study it has been decided to aim for a tighter tolerance in the magnets ($3 \times 10^{-4}$ across the good-field region). This is more easily achieved with window frame magnets.

These magnets will require more careful fabrication and positioning of the magnet coils but they reduce the magnet stored energy and the magnet steel cross-section. Another advantage is that the coils are necessarily turned up at the ends of the magnets which results in saving in the circumferential length taken up by the bending magnets. (Though comparatively small for a single magnet, this becomes significant when multiplied by the 750 magnets which would be needed for the 400 GeV stage). A gain in the circumferential length is particularly advantageous since it has been decided to increase the space allocated to ejection.

The ejection system is obviously crucial to the ultimate machine performance — so much so that modern machines tend to be designed around the ejection system. Since the report MC/60, a greater margin of safety has been fed into the design of the ejection system. Both fast and slow ejection will now take place in the horizontal plane rather than vertically. The distance between ejection components will be increased (the distance between the two septum magnets will be increased by a factor of three) to allow space for greater displacement of particles. Ejection components will include an electrostatic septum (probably 0.1 mm thick, 8.5 m long), a thin copper septum (4 mm thick, 1 m long), ejection magnet (two units of 1 m length with a 1 T peak field), special quadrupoles, sextupoles, bump magnets and a full aperture kicker (for beam shaving).

Other changes since the design described in the January COURIER include the selection of 200 MHz as the frequency of the r.f. acceleration system (corresponding to 4620 proton bunches in the ring). This sets the SPS r.f. frequency as a multiple of the PS r.f. frequency making beam trapping easier and also means that the r.f. equipment will be bought from an already developed market since several proton linear accelerators have used this frequency. Studies have also indicated that it might be possible to get away with two rather than three r.f. cavities but this decision is still open.

For injection of the beam from the PS more attention is being given to the possibility of 'continuous transfer' (which was also considered in MC/60) rather than the bunch-by-bunch method previously favoured. The PS beam would then be progressively nudged into an electrostatic septum installed in a 'high beta' section where the beam would be deliberately broadened. The septum would peal the beam off during eleven PS revolutions and send a ribbon of protons towards the SPS so as to fill the SPS circumference. This scheme has the advantage that it can be used with a debunched beam or with a beam which had already been bunched in the PS at the SPS frequency. It would also give a beam of lower horizontal emittance. (The scheme will be tested in the PS in the course of the coming year.)

There have also been refinements in the power supply, etc. and particularly in the plans for feeding particles to the West Hall (covered later in the article). All these topics will be described in much greater detail in a new design report, to be published in February 1972, which Laboratory II is required to produce within a year of the project approval by CERN Council.

It is worth repeating here how much the design of the SPS has benefitted from the work at the National Accel-

## SPS Main Parameters

| | | |
|---|---|---|
| Peak energy | stage A | 200 GeV |
| | stage B | 300 GeV |
| | stage C | 400 GeV |
| Ring diameter | | 2.2 km |
| Tunnel diameter | | 4 m |
| Tunnel depth | | 11 m rock |
| (at shallowest point) | and | 7 m earth |
| Number of long straight sections | | 6 |
| Number of ejection straights | | 2 |
| (fast and slow ejection to West Hall and North Area) | | |
| Injection momentum | | 10 GeV/c |
| Injection intensity | | $10^{13}$ protons per pulse |
| Pulse repetition frequency | | about 1 per 4 s |
| Number of r.f. cavities | | 3 (possibly 2) |
| Peak r.f. voltage | | 5.4 MV |
| R.f. frequency | | 200 MHz |
| Number of bunches in ring | | 4620 |
| Number of bending magnets | stage A | 180 (B1) 192 (B2) |
| | stage B | 360 (B1) 180 + 24 (B2) |
| | stage C | 360 (B1) 384 (B2) |
| Peak bending field | | 1.8 T |
| Bending magnet good field aperture | | $39 \times 129$ $mm^2$ (B1) |
| | | $52 \times 94$ $mm^2$ (B2) |
| Bending magnet length | | 6.26 m |
| Number of quadrupoles | | 216 |
| Peak quadrupole focusing gradient | | 21 T/m |
| Quadrupole good field aperture | | 125 mm |
| Mean power load on public supply | | 35.5 MW |
| Main ring pressure | | $10^{-7}$ torr |
| Number of ion pumps (each 50 l/s) | | 432 |
| Programme cost (stage B) | | 1150 MSF |

*A model of the buildings for CERN Laboratory II which will be built by the Société Aixoise de Construction. The large assembly hall and one of the office and laboratory blocks is scheduled to be ready early in 1973.*

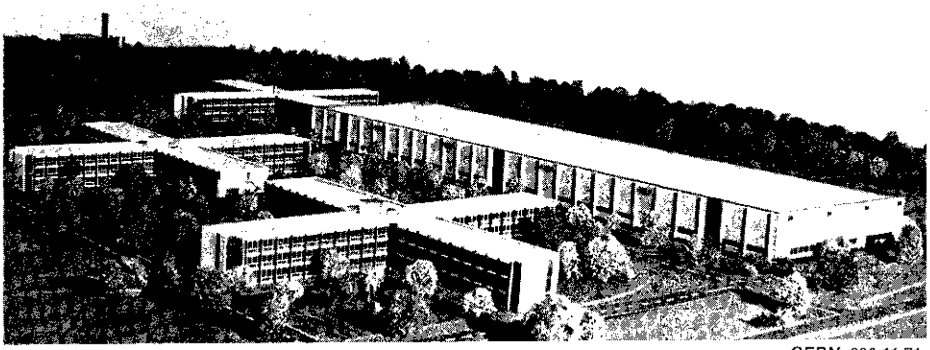
*To get a real feel for what the SPS tunnel will be like, a full-scale model of a short length of tunnel has been built in the West Hall. Wooden models of bending and focusing magnets are in place as are mock-ups of the provisions for the services — cooling water, power, monitoring and control. Seeing what this will look like in reality will help fix the final disposition of components in the tunnel. (Looking into this end of the tunnel model the centre of the ring would be on the right.)*

erator Laboratory, Batavia. A great deal of the imaginative thinking which went into the USA machine, transforming large accelerator design compared with the machines of the 1950s, has been absorbed into the SPS. We have also learned from the problems our American colleagues are now confronting in the final stages of commissioning. Thus greater safety factors are being fed into the design of the European machine on such things as magnet insulation, ejection system and so on.

## *Progress towards machine construction*

We pass now from what has been happening largely on paper to what has been happening in terms of practical moves towards the realization of the project.

Two of the major construction contracts have already been placed. Both were necessary at this time in order to fit in with the schedule which dictates that beams shall be available for physics in the sixth year of the programme (1976). The first concerns the laboratory and office buildings and a large assembly hall whose design was completed early in 1971. A photograph of the model of this complex can be seen on page 350.



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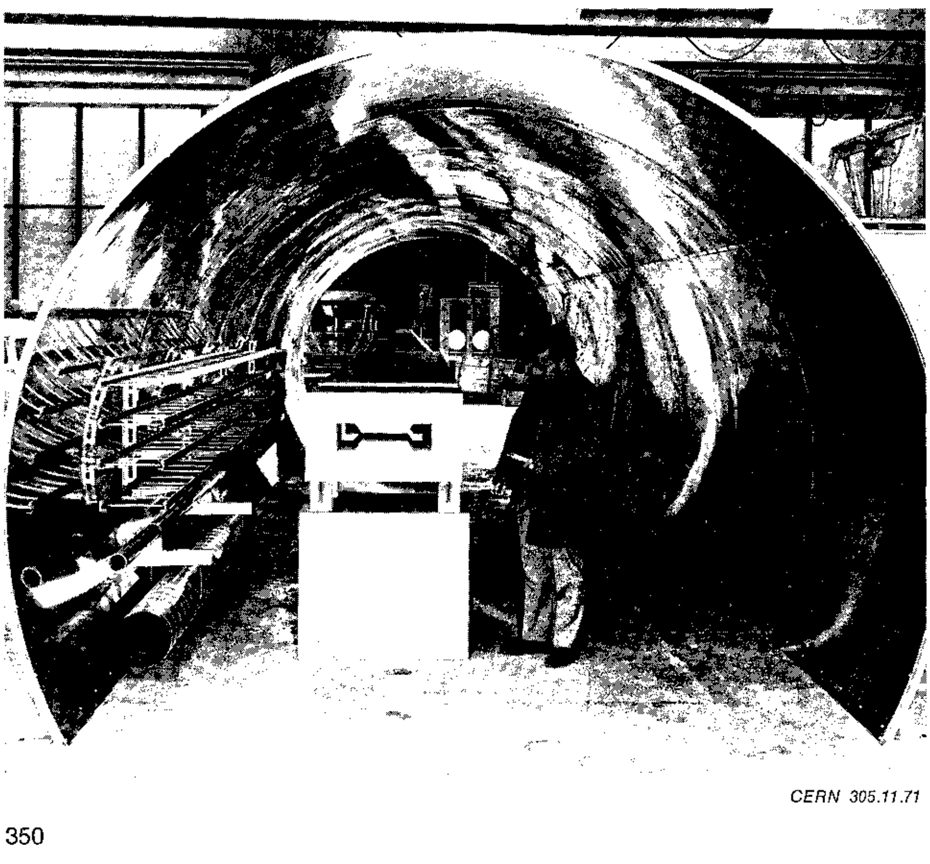


CERN 305.11.71

The contract has been placed with Société Aixoise de Construction. Some work has already begun on the site and one office and laboratory building and the large assembly hall are scheduled to be available early in 1973. This date has to be met to provide accommodation for the growing number of Laboratory II staff and to have space available for the assembly and testing, particularly of the magnets which are scheduled for production from early in 1973.

The second major contract is for the machine tunnel and it has been placed with the construction group of Losinger, Prader, Grands Travaux de Marseille, Società d'Esecuzione Lavori Idraulici and Cuenod. The final details of the contract are now being negotiated. Before this contract could be placed, very detailed work was necessary to fix the precise position and configuration of the tunnel by the beginning of November. This involved final decisions on the machine lattice and ejection requirements and took in the civil engineering limitations and the relation of the machine to its injector and experimental areas.

Early next year digging to tunnel level will start (appropriately at the position of the long straight section meant for injection). The large boring machine will then be assembled down the hole and will begin its mole-like journey around the 7 km of machine circumference. The tunnel is scheduled to be finished by the end of 1974. We will be returning in more detail to both these civil engineering contracts at appropriate times in the near future.

Before the building and tunnelling can be implemented, the necessary agreements have to be reached with the owners of the land on the Laboratory II site (there are about 600 of them). These agreements vary according to the location (and hence the purpose for which the land is to be used) but all those necessary for the start of construction have been settled. This has required the cooperation of the French and Swiss governments both of whom have passed the necessary legal measures.

Another site question which has been settled concerns the telephone network (to avoid going via two international telephone exchanges in contacts between Laboratory I and Laboratory II). Negotiations are also well advanced concerning the customs arrangements in passing from one Laboratory to the other and on the supply of electricity, by Electricité de France, and of cooling water from the Geneva lake, by the Swiss authorities.

On machine components, preliminary enquiries have been sent to manufacturers concerning r.f. equipment, magnets, and vacuum chambers. Experimental work has started on power supply units and on the bending magnets. Magnet models are being built — a 1 m model of each type (B1 and B2), on which magnetic measurements will be carried out to ensure that the required precision can be achieved, and full-scale 6.26 m long models of each type which will check particularly the construction techniques. A fast start on the 1 m models has been possible thanks to the ready availability of some steel of appropriate quality left over from the production of the ISR magnets. The 6.26 m models will be built using steel samples supplied by manufacturers. Tenders for the magnet contracts will go out in January 1972 and the contracts should be placed the following July.

## *ECFA Working Group*

It is essential that the entire high energy physics community in Europe be well informed of progress at CERN Laboratory II and that it participates in the development of the project in as many ways as possible. This is particularly true for the experimental physicists who will eventually use the machine. Their interests and priorities need to be fed into the project from an early stage.

For many years now a major forum, where the interests of the entire community are represented, has been the European Committee for Future Accelerators, ECFA, and it was natural that the mechanism to ensure the participation of high energy physicists should emerge from ECFA. In October 1970, ECFA asked P. Falk-Vairant to act as convenor of a Working Group which would discuss scientific and technical problems in the exploitation of the new accelerator. These problems include such things as the optimum lay-out of experimental halls, desirable beams and detectors, development of new detection techniques, etc...

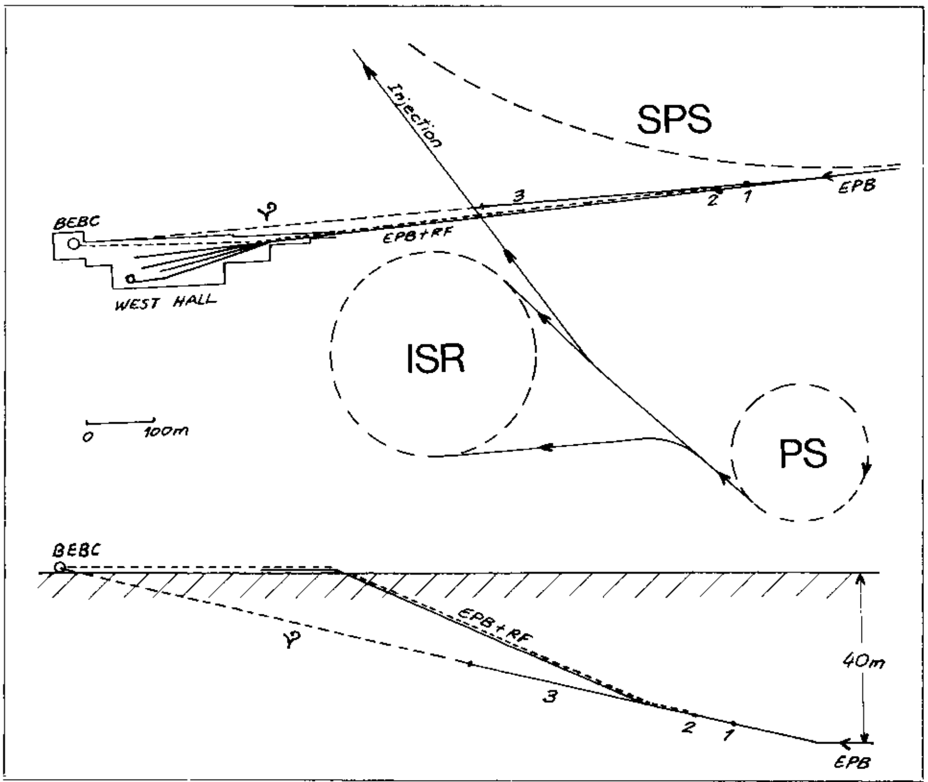
An Executive Committee has been set up consisting mainly of active experimental physicists who will devote a good proportion of their time in the next few years to thinking and working on the SPS experimental programme. The membership of the Committee is divided amongst the experimental disciplines and is distributed geographically around the Member States: J. Drees, D. E. C. Fries, P. Soding (Federal Republic of Germany); I. Butterworth, P. G. Murphy, J. J. Thresher (U. K.); G. Barbiellini, G. Giacomelli, I. Manelli (Italy); F. Jaquet, D. Treille, R. Turlay (France); M. Steuer (Austria); J. P. Stroot (Belgium); E. Lillethun (Norway); R. T. Van de Walle (Netherlands); J. Allaby, W. Beusch, G. Brianti, C. Michael, C. Rubbia, H. W. Wachsmuth, E. J. N. Wilson (CERN).

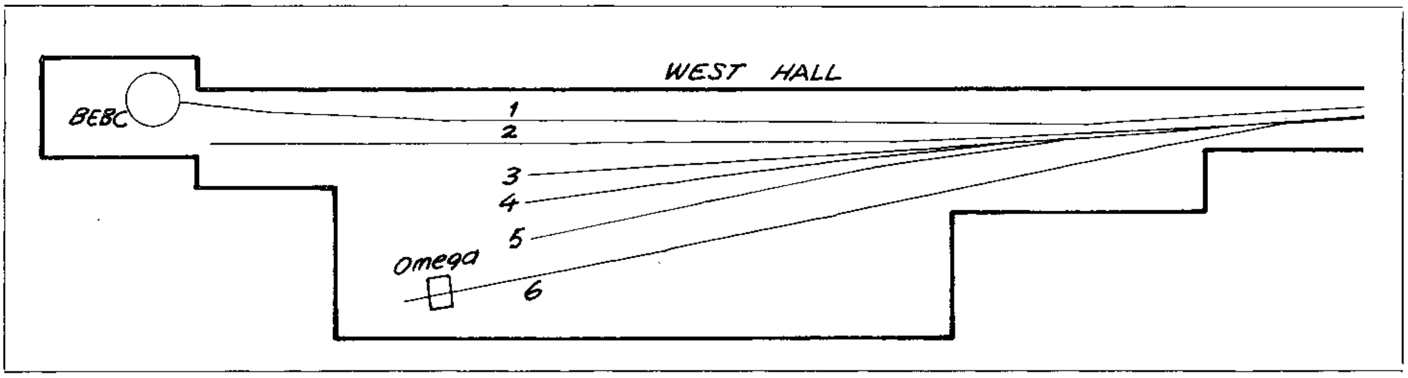
On the initiative of the ECFA Working Group a Study Week was held at Tirrenia, Italy, from 13-18 September bringing together about 140 physicists. The purposes of this meeting were — to study the characteristics of the accelerator and its experimental facilities (particularly with reference to the West Experimental Hall which is likely to be the main scene of activity for the first few years of exploitation of the accelerator); to look at how Batavia had tackled similar problems; to discuss how experiments are likely to be carried out at the new range of high energies and to initiate work on specific topics.

There was a fruitful dialogue between the machine builders and the future machine users. This conveyed, for example, the timescales within which experiments will need to be prepared — research probably beginning in the West Hall during 1976 and in the North Hall two years later — and, at exactly the right time, conveyed back to the machine designers some vital thinking on beam provision for the West Hall which modified the previous plans in a major way (see the diagrams).

Discussions on the experimental areas concentrated almost entirely on exploitation of the West Hall where the 3.7 m hydrogen bubble chamber, BEBC, and the spectrometer, Omega, will be in action. There are also thoughts about moving the heavy liquid bubble chamber, Gargamelle, to join this battery of detectors. Some of the proposals concerning neutrino and lepton beams were mentioned in the last issue (page 285). To handle the much higher energies, it would help to improve some of the present detection techniques, or to apply them

*Following the Tirrenia meeting, provision for use of the West Hall with the SPS beams at present foresees a scheme as illustrated :*
*1. The top diagram is a bird's eye view of the scheme. The ejected proton beam EPB can be used either on a target to produce neutrino parents (1), or on a target to produce an r.f. separated beam (2), or brought to the surface to targets at the run-in to the West Hall. The lower diagram illustrates this on the vertical scale. The ejected proton beam emerges horizontally from the machine and then climbs to the targets. If it is decided to produce a neutrino beam in this way the neutrino target will be followed by a decay tunnel (3) and the neutrino parents will be pointed at the 3.7 m bubble chamber, BEBC. After the decay tunnel the neutrinos will pass through about 600 m of earth which will serve to filter out all other particles. The proton beam-line and the r.f. beam-line will climb in the same tunnel.*
*2. Preliminary thoughts on the beam layout in the West Hall foresee a scheme in which BEBC would be fed by an r.f. separated beam (1), with momenta up to 150 GeV/c, as would be the spectrometer Omega (6) with momenta up to 50 GeV/c. Other beams could be — a high resolution beam with momenta up to 200 GeV/c (2) ; two conventional beams with momenta up to 100 GeV/c (3) and 50 GeV/c (4) ; a neutral beam (5). There is sufficient length available in the hall for one of the beams to be converted for electron and photon experiments.*




in different ways, or to develop new techniques.

Particularly to attack this last range of problems the Executive Committee of the ECFA Working Group is setting up working parties. The present list of topics to be tackled is — superconducting devices, special beams (particularly lepton beams), particle identification, spectrometers (including the use of Omega), experimental areas and shielding, hybrid bubble chamber systems and the use of BEBC and Gargamelle, and neutrino physics.

*Advisory Machine Committee*

Accelerator specialists from the National Laboratories in Europe had participated extensively in the preparation of the new project prior to its approval. The '300 GeV Machine Committee' consisted predominently of people from these Laboratories and the Committee was a major mechanism whereby expertise from all the big European Laboratories was fed into the new project. It was this Committee which issued the two volume design report (MC/60) at the end of last year.

To sustain these contacts, an Advisory Machine Committee has been set up under the Chairmanship of F. Ammann (Frascati). Its members are F. Arendt, W. Heinz (Karlsruhe) ; G. Bronca, M. Gouttefangeas (Saclay) ; P. Brunet, G. Danon (Orsay) ; D. Degèle, M. Teucher (DESY) ; A. J. Egginton (Daresbury) ; D. A. Gray, N. M. King (Rutherford) ; D. Husmann, G. Nöldeke or K. H. Althoff (Bonn) ; C. Pellegrini, N. Sacchetti (Frascati). The Secretary of the Committee is E. J. N. Wilson who is Head of the 'Parameters Section' in Laboratory II.

The Committee, which met for the first time on 2 December, is advisory to the Director General of Laboratory II and will serve, on the one hand, as a channel of communication to the national Laboratories concerning the progress of the project and, on the other hand, will continue to make available, when needed, the special expertise to be found in the national Laboratories.

Progress on the project so far is on schedule to yield beams for physics in 1976. The emphasis will now move more and more to construction on the site and to the production, testing and installation of machine components. We expect to be reporting Laboratory II news regularly from now on.

# CERN News

*A photograph of the dilution refrigerator built at the Technical University of Helsinki to achieve very low temperatures (0.05 K range) for use with polarized targets. A) mixer chamber, B) heat exchangers, C) counterflow heat exchanger, D) vacuum jacket flange, E) still, F) vacuum jacket pumping tube, G) condenser, H) gas heat exchanger, I) pumping head flange, J) $^3He$ inlet tube.*

*The graph shows the cooling power available in the mixer chamber as a function of the temperature.*

## Getting colder

In August (page 225) we reported the bringing into operation of a polarized proton target of volume 45 cm³ working at 0.55 K which was an important advance in the development of these targets. It now looks as if the development can be carried further with the testing of a new refrigerator using a 10 cm³ sample which can be maintained at a temperature of less than 0.05 K. This is a step not only towards obtaining higher rates of polarization but also towards realizing 'frozen spin' targets which could allow particles emerging from collisions to be detected over almost $4\pi$ solid angle.

The refrigerator, built by T. O. Niinikoski of the Technical University of Helsinki in collaboration with the CERN Polarized Targets Group, is based on the principle of $He^3/He^4$ dilution. It was designed for integration in a Roubeau-type precooler producing a temperature of 1.04 K. In other words, it had to be housed in a cylindrical space of 3.9 cm diameter. This very compact structure was made possible by using sintered copper heat exchangers, which are only slightly sensitive to the Foucault currents caused by rapid variations in the magnetic field.

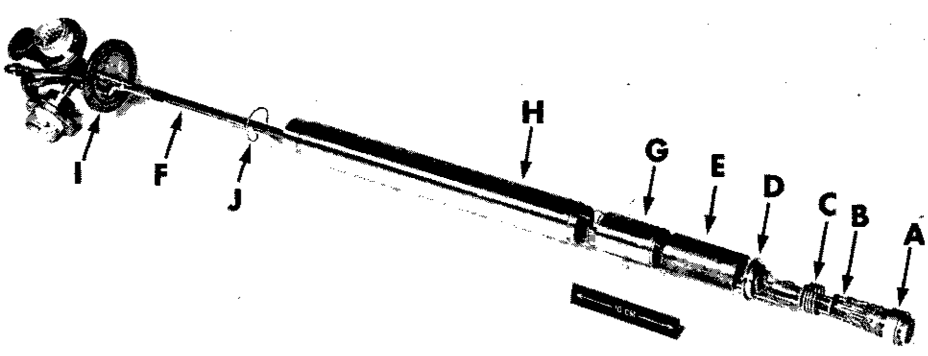
Furthermore, the use of high speed pumps (250 m³/h) gives a cooling power which is without doubt the greatest ever reached for such low temperatures — it was possible to maintain the 10 cm³ sample at 0.03 K under normal operating conditions and to sustain temperatures as low as 0.022 K.

The next stage involves polarization measurements of various substances at these temperatures. The final aim, however, is to perfect 15 cm long targets intended for the large aperture magnet in the East Hall or for use with the Omega spectrometer.

In order to derive the maximum amount of information from these spectrometers, it is desirable to be able to analyze the particles leaving the target at any angle. However, with the targets built so far, working on the principle of dynamic polarization, it was necessary to have a very homogeneous and intense magnetic field, which meant poles coming very close to the target and reducing the solid angle over which observations could be made.

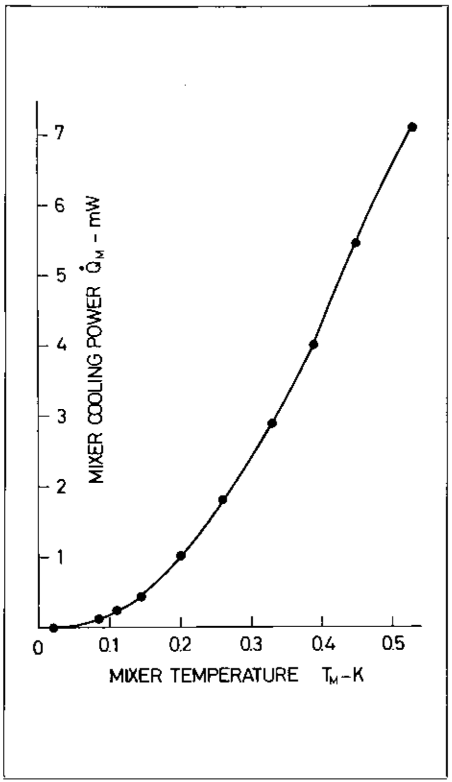
The lower the temperature, the longer the relaxation time, i.e. the longer it takes for the polarized protons to revert to a completely disorientated state. But the inertia of the spins at very low temperatures is such that their orientation is maintained even if the necessary conditions for dynamic polarization are no longer ensured. Thus it is possible to maintain prolonged polarization even if the magnetic field ceases to have the intensity and the homogeneity necessary for creating the effect. This is a 'frozen spin' target. It is hoped that, once placed in Omega's 1.5 T field, the target will be able to maintain its polarization for several days at a temperature of 0.06 K.

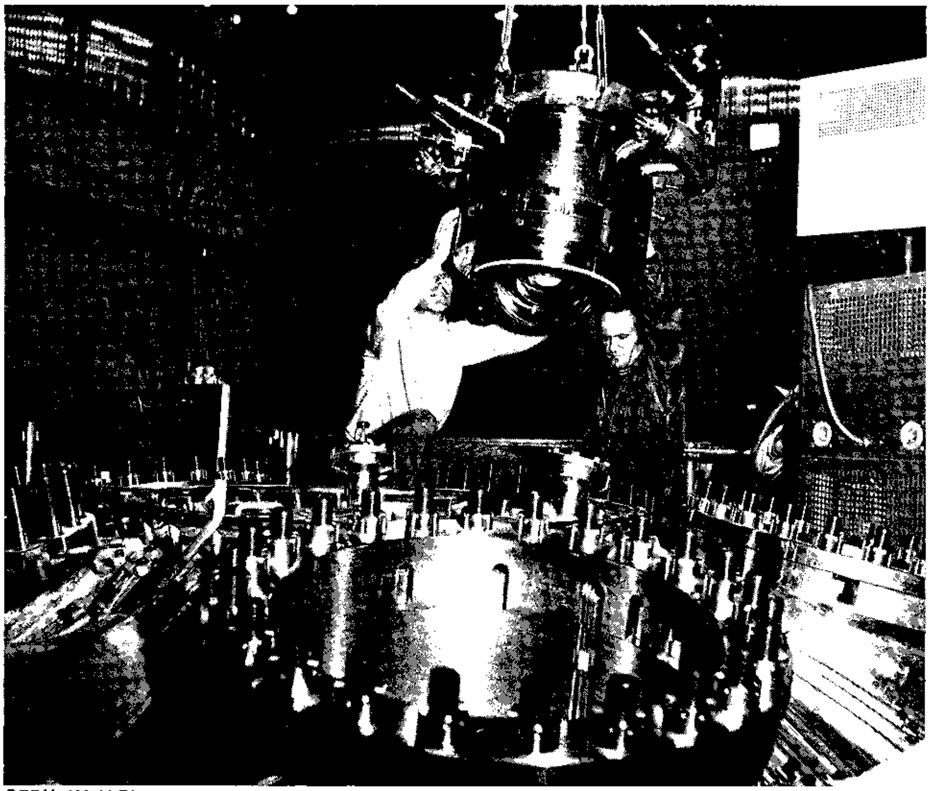
Work on frozen spin targets being carried out at the Rutherford Laboratory (where different conditions make it possible to use a 3 T holding field) was briefly mentioned in the last issue (page 330).




## HYBUC Rapid cycling

The small hydrogen bubble chamber, HYBUC, has just added another remarkable feature to its list of properties in becoming the first rapid cycling chamber to operate at CERN. The chamber is designed particularly for experiments on hyperons and it was at the beginning of December, in the course of the third test run





*Installation at the end of November of one of the five 'fish-eyes' of the 3.7 m bubble chamber, BEBC, at the top of the chamber body. The first operating tests are scheduled for mid-1972.*

*CERN 193.11.71*

prior to an experiment to measure the magnetic moment of the positive sigma hyperon, that rapid cycling was successfully attempted.

We will not return here either to a description of the chamber (for which see vol. 10, page 353) or to an explanation of the interest in rapid cycling chambers (vol. 11, page 91) but will limit ourselves to relating what was achieved and how.

The tests were carried out in the k 13 beam in the North Hall drawn from target 6 in the PS. They were aimed at optimizing chamber operating conditions, flash units, film, etc., which determine the optical quality of the photographs. These aspects of the tests were satisfactorily cleared and the team (from the Max Planck Institute for Physics, Munich, with help from the Niels Bohr Institute, Copenhagen, and Vanderbilt University, USA) are now confident that they can obtain the quality they require when they begin collecting data for their experiment. This is scheduled for the spring of next year when the chamber will be installed in the k 16 beam, still in the North Hall, fed by a target in straight section 11 of the PS.

When the required performance had been assured it was decided to test the capability for rapid cycling which had been built into the hydraulically operated expansion system, even though it is not needed for the sigma hyperon experiment. The system gave up to ten consecutive expansions at a 25 ms repetition time and it was demonstrated that four successive cycles could certainly be used to give pictures of the required quality. The chamber was operated at 4 expansions in 75 ms on each PS pulse for several hours. The system was by no means pushed to its optimum performance and it is expected that with an improved oil pump and accumulators a rate of 20 expansions in 500 ms should be well within the chamber's capability.

Although this is not needed for the first experiment, it would be vital if, for example, it were agreed to continue with a measurement of the magnetic moment of the Xi hyperon, where the production cross-section is much lower. Such a measurement would become feasible using HYBUC in a hybrid arrangement with a selection of the events of interest (see vol. 11, page 248). We leave aside here the difficult question of how beam could be provided for rapid cycling operation.

The crucial features, which made rapid cycling possible at the first attempt, even though other chamber conditions were not yet ideal, were concerned with the expansion cycle that was applied. It was possible to have a decompression time of only 4 ms which limited the time for the growth of parasitic bubbles. The hydrogen temperature was 26.5 K. The optical system was in sufficiently good shape to record 'wanted' bubbles which had grown to diameters of only 100 to 200 μm.

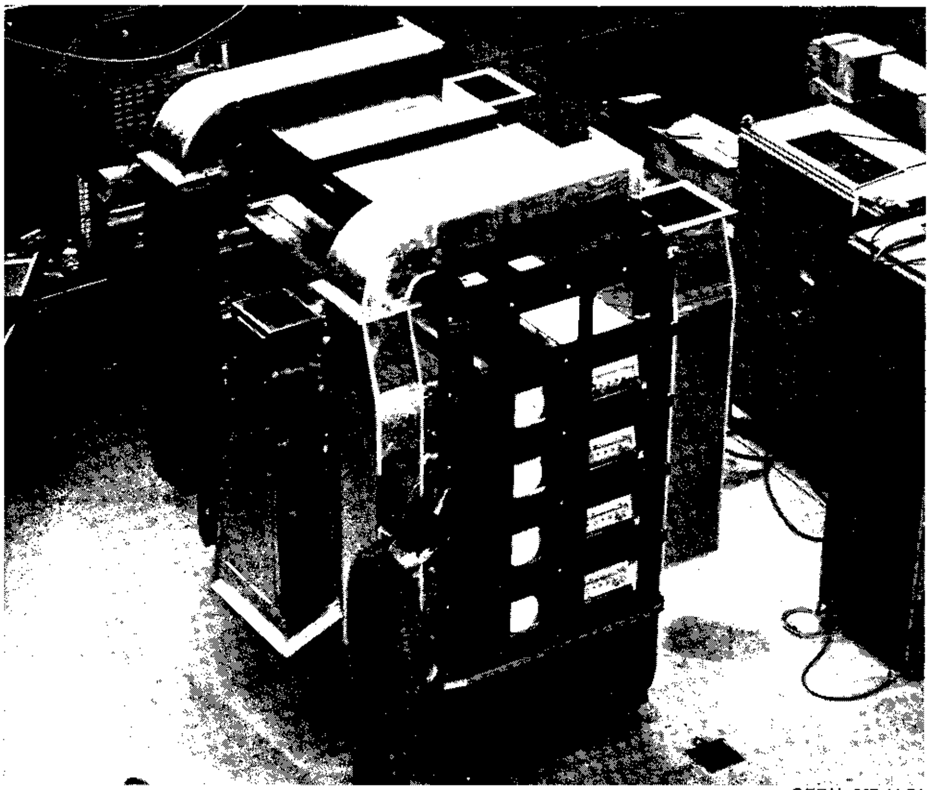
The next trick was to over-swing when forcing in the piston when applying the recompression to the hydrogen. This small over-compression helped snuff out all the bubbles produced in the previous cycle so that the subsequent cycle did not have the remnants of bubbles which would begin to grow immediately the next decompression started. The pressure cycle parameters can be varied over a wide range and the results already obtained in these first tests could probably be improved.

While on the topic of HYBUC it is worth mentioning that the two-stage superconducting magnet to provide a very high field in the chamber volume is working well. It is operated at field levels up to 10 T which is a little below the design figure of 11 T but, when some power supply problems are cleared, reliable operation is expected at the design figures or above.

## ISR, over 10 A stacked in Ring I

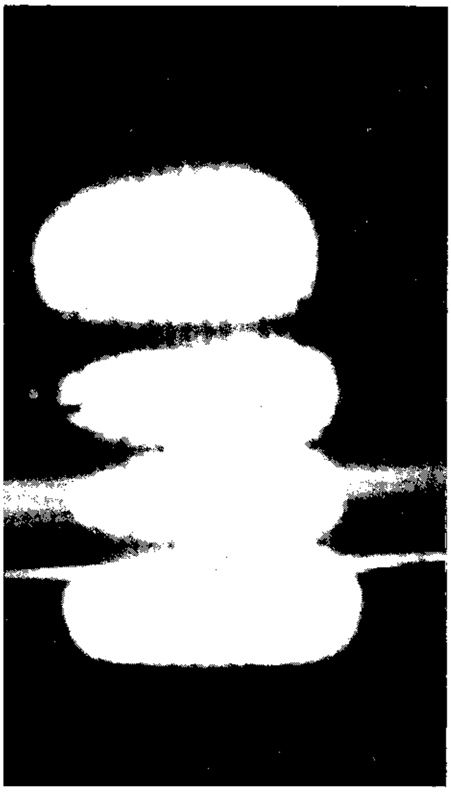
With methodical thoroughness the performance of the Intersecting Storage Rings continues to be improved towards the design goals. We last covered the operating figures in the September issue, page 243, when stacked currents were touching a peak of around 6 A. Since then currents of over 10 A have been stacked in Ring I. As before, decay rates at the peak currents tend to be too high for comfortable operation in the physics experiments but it is now usual to run for physics with 6 A in Ring I (decay rates are between $10^{-5}$ and $10^{-4}$ per minute).

Most of the improvement seems to have come with better vacuum conditions following the full bake-out of



*The four superposed r.f. accelerating cavities for the PS Booster. The unit was ready for installation in the machine tunnel at the end of November. The outer pipes are used to convey the large volume of cooling air.*

CERN 267.11.71



*Below: On 10 December a beam from the PS linac was brought along 82 m of injection beam-line towards the Booster. A fast magnetic deflector was used to produce beams going towards the four superposed rings for the first time. The photograph, taken via closed circuit television, records the beams going off at four levels. After the magnetic deflector, magnets guide the beams to the correct position and angle.*

Ring I during shutdowns which were scheduled on the occasions of the CERN Accelerator Conference and of the ISR Inauguration. It was the first time the entire ring had been baked with the temperature pushed to 300° C rather than the usual 200° C. This has greatly eased the problems associated with the vacuum pressure pumps (see page 245) though they still appear at the 10 A levels. Because of the obvious importance of the vacuum conditions it has been decided to try baking out the rings at still higher temperatures and to increase the available pumping speed by installing more sublimation pumps in critical places. There are also some laboratory tests under way to judge the usefulness of gas discharge cleaning of surfaces.

Another help towards better performance has been the installation of more clearing electrodes particularly in places where the form of the vacuum chamber could lead to electrons being trapped in potential wells. Switching on and off the clearing electrodes has demonstrated their beneficial effect on the decay rates.

Ring II is, as usual, behind Ring I in terms of the attention it has received. It is generally providing currents of around 3 A during the physics runs. However it is intended to use the long shutdown at the beginning of next year to bring Ring II into the present Ring I state. This will include a full bake-out and installation of more clearing electrodes.

The most encouraging feature of the latest news on ISR performance is that there is still no sign that any fundamental limit has been reached. Climbing to higher levels is likely to become progressively more difficult but there is still nothing to indicate that it cannot be done. There are some mysteries of course — for example, the odd phenomenon noted in the article on the sodium jet beam detector in the last issue (page 324) where the beam appears less intense at its centre — but none of them are noticeably inhibiting performance.

It goes almost without saying that all the excellent work with the ISR has depended on an excellent feed from the proton synchrotron. In the past few months the feed has been improved also. Several times, pulses of about $2 \times 10^{12}$ protons have been available for entire runs. In addition to this increase in intensity there has been, via some tricks played in the PS itself, an increase in the density of the proton bunches which helps the stacking efficiency in the ISR.

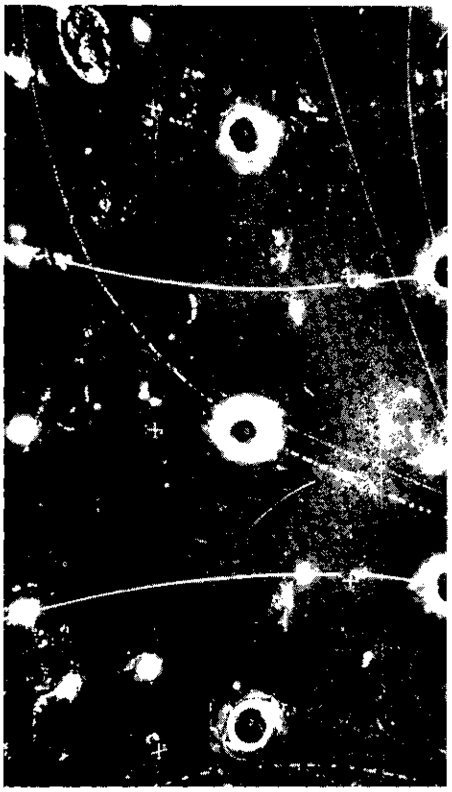
## Ready to accelerate

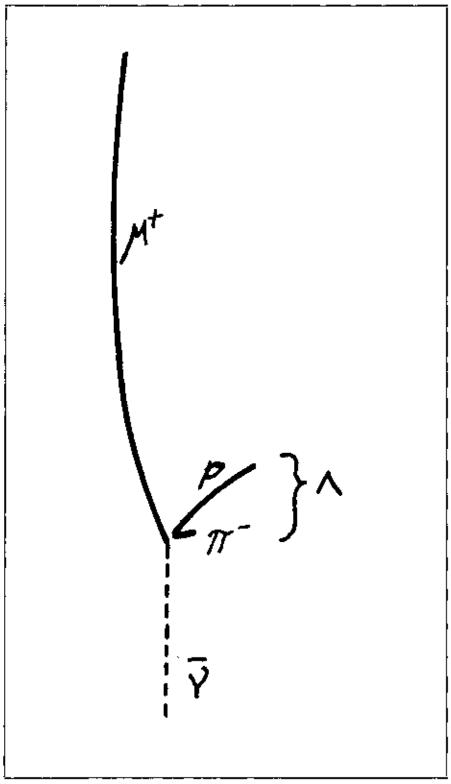
The Booster is nearing the day when it will be ready to accelerate beam from the 50 MeV linac up to 800 MeV to give higher energy injection into the proton synchrotron. The magnets are in position in the machine tunnel and their power supply has been installed in its building (see the July issue page 192), the controls have been tested and now the accelerating cavities have successfully undergone voltage tests.

The cavities were tested at 125 % of normal voltage and were then installed in the machine. The unit, shown in the photograph, contains four cavities superposed in the same way as the four rings of the machine. The limited height between the rings (36 cm) is one reason for the compactness of the unit.

For various reasons, including economy, it was decided to have only one cavity for each ring, but this meant working at the limits of known technology, particularly for the tuning ferrites of the cavities. Ferrite is notoriously difficult to use, as its quality, and even more its reproducibility, depend on minute details of the manu-

*A candiate for a hyperon production event observed in Gargamelle. An incoming anti-neutrino interacts with a proton to give a positive muon and a lambda. The lambda is identified via its decay into a proton and a negative pion.*






facturing process. However, as a result of close consultation between the supplier (Philips) and the engineers of the Synchrotron Injector Division, it has been possible to produce ferrite giving a performance better than originally offered by industry.

The design, engineering and assembly of the final cavity-amplifier was entirely done at CERN. This solution proved very advantageous, since it made possible close contact between all the machine specialists connected with accelerating cavity techniques. This contributed to the success of the operation, which was completed on schedule and within the prescribed cost-limits.

## Gargamelle's 500 000

The 500 000 picture mark for the heavy liquid bubble chamber Gargamelle was passed in November during an experiment to study neutrino interactions in the deep inelastic region. Equal numbers of neutrino and antineutrino pictures were taken. Less than a year has elapsed between the first expansion of Gargamelle and the completion of this first batch of photographs.

The Six European laboratories sharing the photographs with CERN (Aachen, Brussels, Milan, Orsay, Ecole Polytechnique, University College London) are busy scanning all the events discovered (not just those featuring special topographies). The photograph above illustrates an outstanding one. It is interpretated as showing the production of a lambda hyperon and is interesting as it concerns the inverse reaction to the beta decay of the lambda — a weak interaction with change of strangeness, in a hitherto totally unexplored four momentum transfer region.

# Around the Laboratories

## RUTHERFORD
### On target

At the end of November a track sensitive target was successfully operated in the 1.5 m bubble chamber at the Rutherford Laboratory. In the following few days over 60 000 pictures were taken with the chamber fed by a pion beam from the 7 GeV proton synchrotron, NIMROD. Their quality and their content show that a series of physics experiments, previously impossible or very difficult, can now be carried out.

Work on this type of composite bubble chamber system began in 1967 following an idea of H. Leutz at CERN. It aimed to fasten onto the advantages of both the hydrogen chamber (which provides the simplest target — the single proton at the hydrogen nucleus — and greatly eases the analysis of an interaction) and of the heavy liquid chamber (which has a much shorter ' radiation length ' — giving a greater probability that neutral particles will convert to charged particles within the volume of the chamber and thus be more fully identified).

The system has a liquid hydrogen volume in the path of the incoming beam (this is the ' track sensitive target') surrounded by a heavier liquid (hydrogen-neon mixture). The hydrogen is contained within transparent walls, so that tracks can be seen as they emerge from the vertex of the interaction. The walls can move and transmit to the hydrogen the pressure changes applied to the mixture. Thus the complications of having two separate bubble chambers each with its own expansion system etc. are avoided.

The idea was first tested at DESY in the 85 cm chamber (see vol. 7 page 112) and the results were promising enough for the Rutherford Laboratory to begin a major development programme, in collaboration with a group from CERN, to produce a track sensitive target for the 1.5 m chamber.

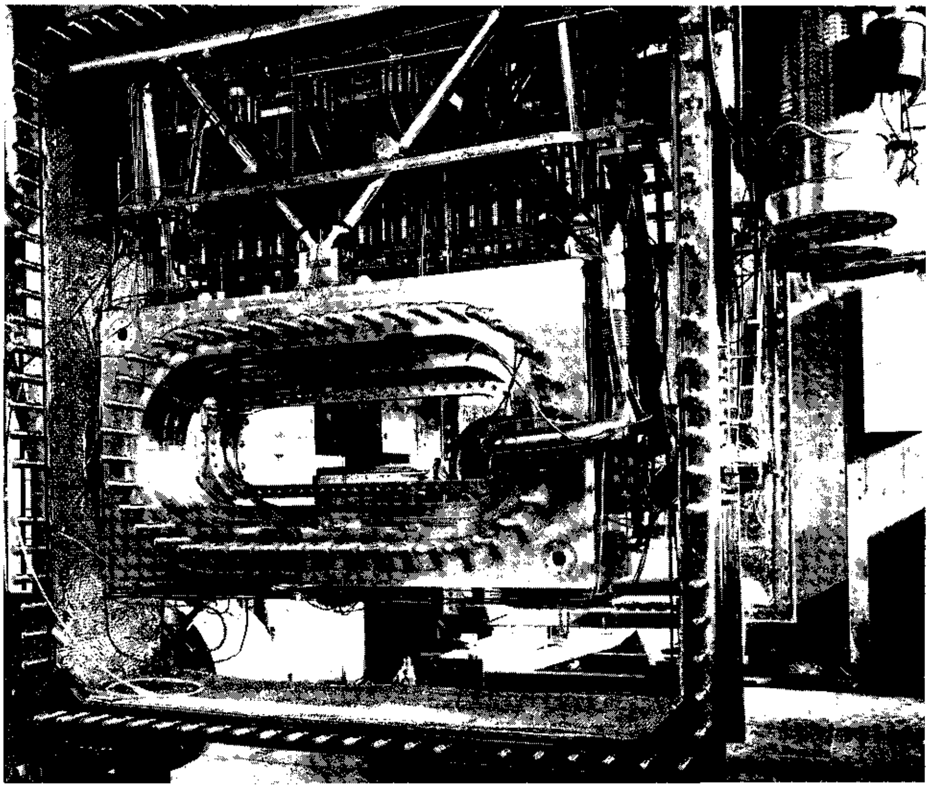
The engineering of the target chamber met several difficulties. For example, an attempt to produce an entirely plexiglass target chamber ran into trouble with cracking of the plexiglass where it had been curved. The present target is made of two flat windows of plexiglass 6 mm thick held by a stainless steel frame. The problem of the big difference in the coefficient of thermal expansion of the two materials is solved by only making the seal between the two when the operating temperature of the chamber is reached. This is done by inflating flexible tubes with liquid hydrogen under pressure to push the plexiglass against indium seals in the stainless steel frame.

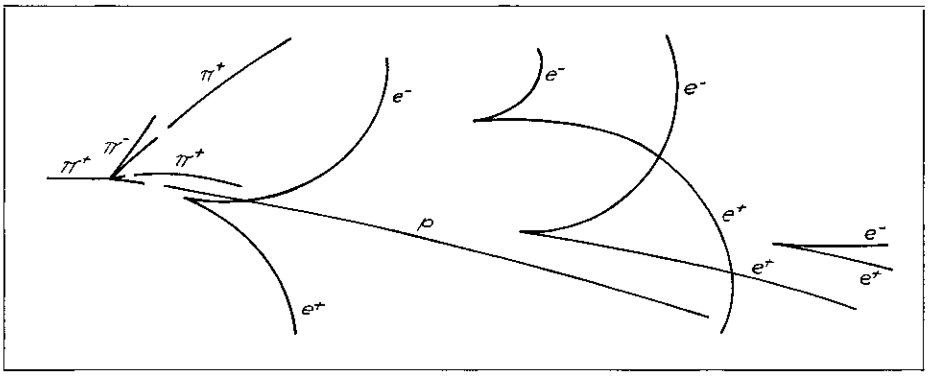
The hydrogen-neon mixture can be varied in composition over a wide range which is an advantage since the optimum composition can be selected for each experiment. The range in radiation lengths extends from between pure neon at 25 cm to pure hydrogen at 820 cm (not exactly true since obviously there would be no point in installing the target in pure hydrogen and to achieve track sensitivity both inside and outside of the target with pure neon would be extremely difficult). For comparison, the usual liquids in heavy liquid bubble chambers are propane with a radiation length of 109 cm and freon with 11 cm.

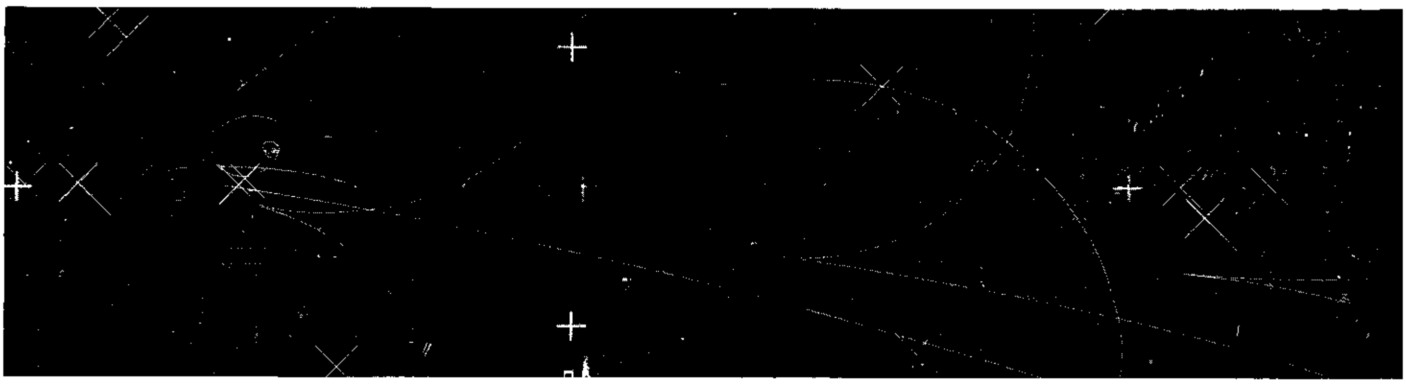
Selecting operating conditions is a delicate matter because the hydrogen and neon in the mixture have a well developed tendency to separate one from the other. The combination of temperature and pressure to which the mixture is subjected has to be outside the region of phase instability,

*A view of the 1.5 m chamber at the Rutherford Laboratory when it was partially dismantled for the installation of the track sensitive target. The target is shown in position — the inner metal ellipse holds the perspex windows within which is the hydrogen volume.*

*Below is an example of a ' four gamma event ' initiated in the hydrogen by an incoming 4 GeV/c positive pion. Such an event is rarely captured in bubble chamber photographs.*





which does not give much room for manœuvre.

The recent Rutherford tests were carried out with 45 molecular % neon in the 480 litres of mixture, held at 29 K, surrounding a hydrogen target volume of 25 litres. This mixture has a radiation length of 73 cm. A 4 GeV/c positive pion beam was fed to the chamber and the photograph on the previous page is an indication of the quality of the pictures and of the potential of this new facility. In the interaction shown, two neutral pions were produced and both could be fully documented via the 'materialization' of the four gamma rays into which they decayed.

The track sensitive target at Rutherford is unique in the world and likely to remain so for some time. Although a track sensitive target may be developed at CERN for the 3.7 m chamber, BEBC, it is not intended at present to bring such a target into service before the SPS begins to provide beams. The Rutherford Laboratory is however very ready to consider the participation of bubble chamber physicists from other Laboratories in the research programme with the new facility.

## STANFORD Bomb incident

On the morning of 7 December it was discovered that two small bombs had exploded in the klystron gallery of the SLAC 20 GeV electron linac. A long shutdown of the machine had begun five days earlier.

The incident occurred in 'sector zero' which is above the injector. No damage was done to the structure of the building, the machine tunnel or the accelerator itself. The components affected were electronics units — the master oscillator, the master trigger generator and portions of the r.f. drive system. Repairs are estimated at $ 45 000.

Fortunately there will be no delay introduced in the physics programme. The accelerator was already scheduled to be shut down for the whole of December and all units were ready for operation again (with the exception of a special purpose beam knock-out system) on 10 December. There is no clue yet as to what provoked the incident.

## BATAVIA 15 foot chamber

The major bubble chamber facility at the National Accelerator Laboratory is to be a 15 foot chamber which is now at an advanced stage of construction in the experimental area known as the 'Neutrino Laboratory' at the 200/500 GeV accelerator. Alongside it stands the 30 inch hydrogen chamber previously operated at Argonne.

Initially, it had been hoped to build a 25 foot chamber in collaboration with Brookhaven and a design report for such a chamber was prepared in the group of R. Shutt. Unfortunately there was no sign of money to construct a chamber of this size and it was decided to trim down the scale to a 15 foot version. Design and construction work has proceeded at a very rapid pace.

An important factor in this has been the readiness of the NAL group under W. Fowler to absorb other people's ideas and to bring in the extensive help of other groups with particular specialities. Thus the chamber design incorporates ideas from Argonne on the magnet, from Stanford on the expansion system, from Brookhaven on the vessels, and from CERN on the optics, piston and seal. The construction of the superconducting magnet was subcontracted to the group of J. Purcell at Argonne (which has built the very successful magnet of the Argonne 12 foot chamber) and of the hydraulic expansion system to the group of J. Ballam and R. Watt at Stanford (which has a lot of experience in the construction of such systems and has been among the leaders in multipulsing work).

The chamber design is shown in the diagram. The volume of liquid is 30 000 litres contained in an almost spherical vessel with a length along the beam direction of 15 foot. It is designed to operate with hydrogen, deuterium or neon (or mixtures). The super-conducting magnet will provide a field of 3 T at the centre of the chamber.

The expansion system is located at the bottom of the chamber and will operate at a repetition rate of about one expansion per second (giving the possibility of four expansions in one accelerator cycle). Six cameras are located at the top of the chamber arranged in two triangular arrays. The reason for this profligate use of cameras is to enable hadron pictures to be taken (using the film in one set of three cameras) while neutrino experiments are running. Thus the neutrino beam to the chamber might absorb 70 % of the beam early in the flat top, while still leaving the opportunity for a burst of charged particles to the chamber at the end of the flat top. This will avoid the use of the chamber being completely submerged by neutrino experiments.

There is provision for the installation of track sensitive targets, (see the article above) and for internal metal plates to help make gamma rays 'materialize'. The integration of the chamber in hybrid set-ups, with, for example, arrays of multiwire proportional chambers, is also under study.

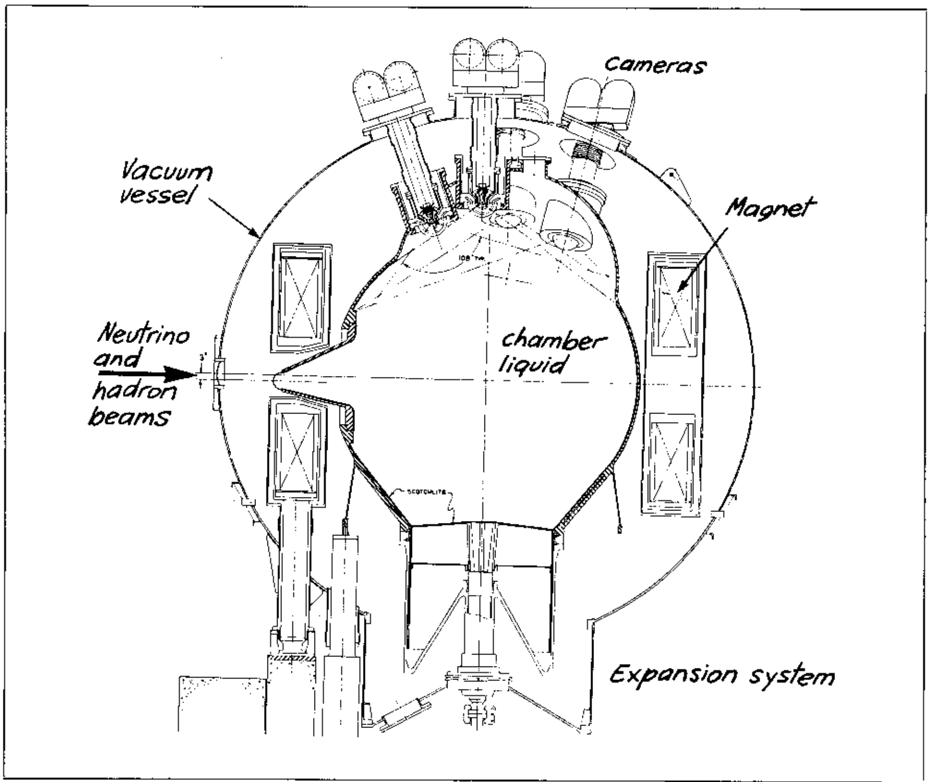
The bubble chamber project began in the summer of 1970. Its capital

1. Diagram of the 15 foot bubble chamber under construction at Batavia showing the disposition of the major components.

2. Aerial view of the Neutrino Laboratory on the NAL site taken during the summer. The globe shape of the bubble chamber vacuum vessel can be seen on the right and on the left the bubble chamber control room, which will be topped by a geodesic dome, is being built.

3. Arrival of the chamber body on the site at the end of October. The photograph is taken looking at the top of the chamber where the six camera ports are located. It was installed inside the vacuum tank on 30 November.

cost is estimated at $ 4.5 million plus $ 0.5 million for installation and $ 2.0 million for manpower. Since early this year, the globe of the 7 m diameter vacuum chamber has been a prominent feature of the NAL site and on 25 October the chamber body itself arrived at the Laboratory and was installed in its final position in the vacuum tank on 30 November. It is hoped that if everything continues on schedule the first cooldown of the chamber will take place in July 1972 and that it will be ready for experiments by the beginning of 1973.



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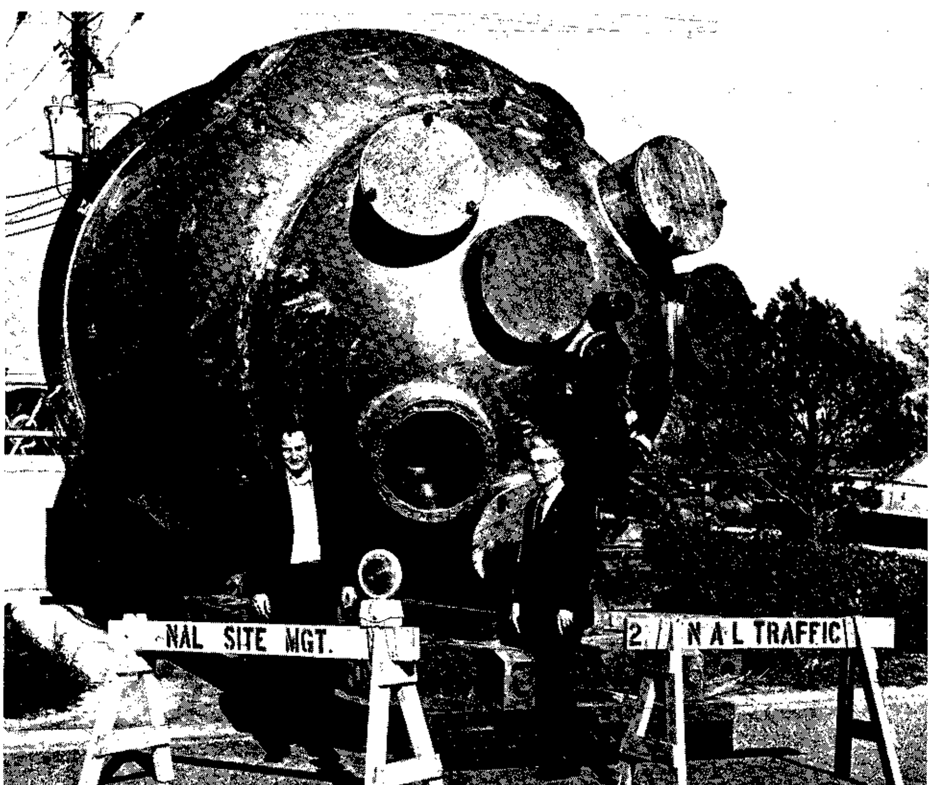

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## CC correspondents

Our concluding words in the 1971 edition of CERN COURIER are words of thanks to all those who have helped in the supply of news throughout the year. In particular, we should like to express our appreciation of the efforts of our correspondents in other Laboratories whose ready response to requests for information adds greatly to the value of the journal :

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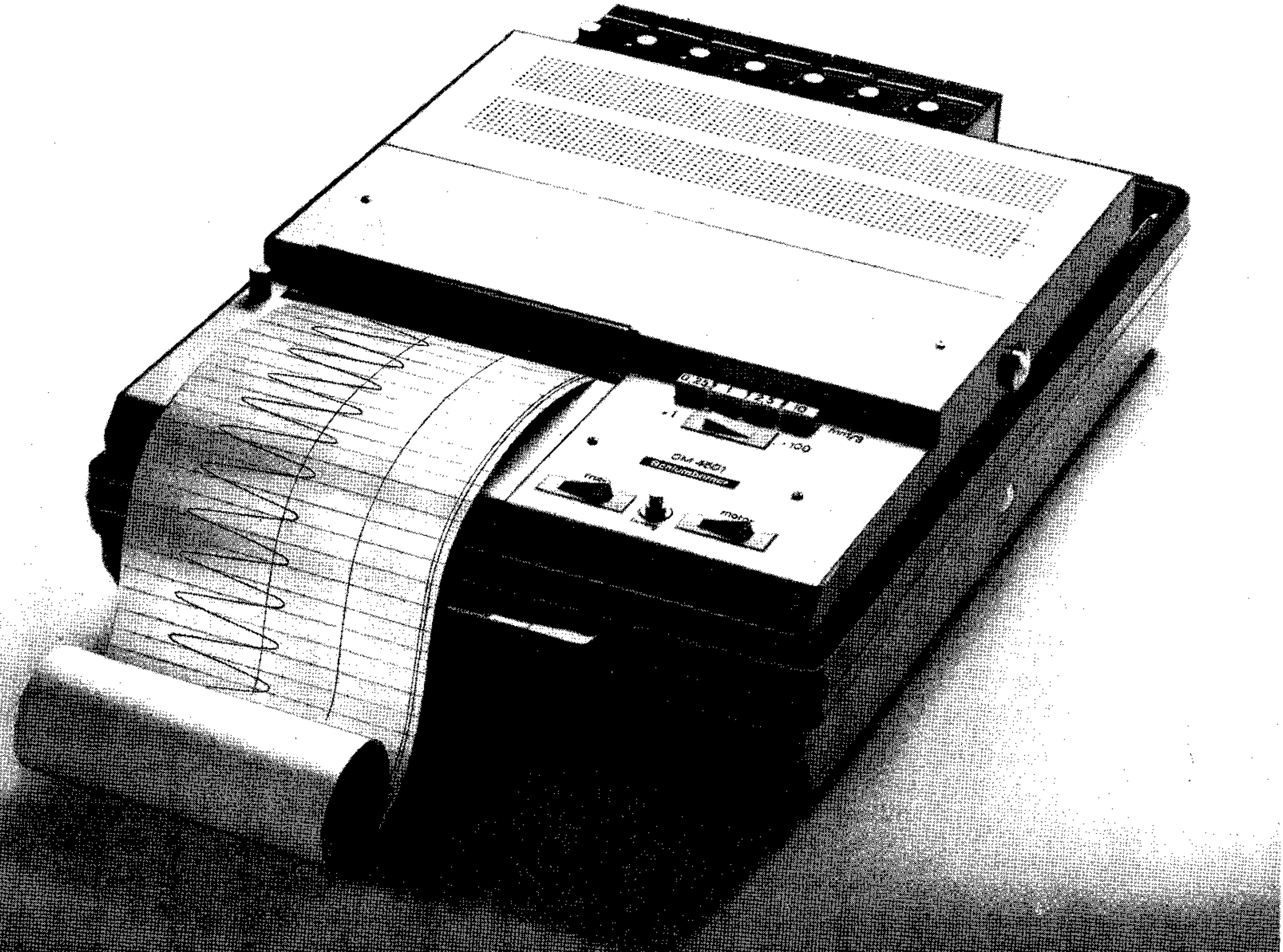

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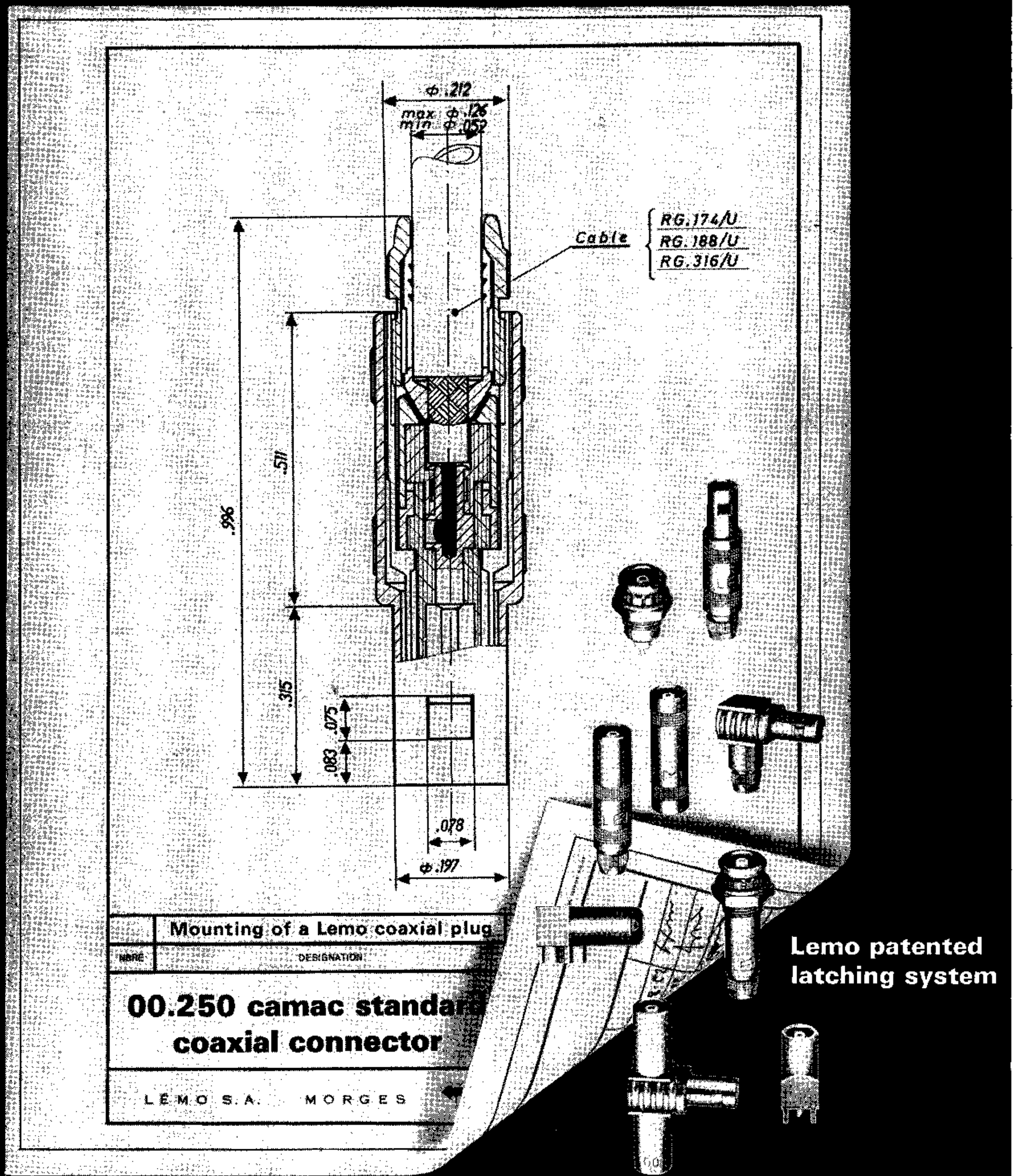

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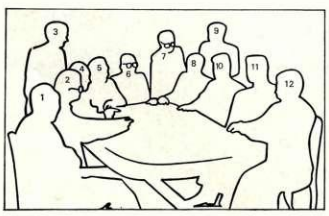


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