CERN

COURIER

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September 1972

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 850 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 371.4 million Swiss francs in 1972.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of hundreds of GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1972 is 95 million Swiss francs and the staff will total about 300 people by the end of the year.

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Contents

Experimental programme at the PS and ISR 271
A brief description of all the experiments currently under way or being prepared at the 28 GeV proton synchrotron and the intersecting storage rings, together with a list of available beams and schematic diagrams of the layout in the experimental halls

Around the Laboratories

BROOKHAVEN : ISABELLE study and AGS performance 278
Three week study of the 200 GeV storage ring proposal and news of the performance of the improved 33 GeV alternating gradient synchrotron

RUTHERFORD : Equipment for high energies 280
Preparation of equipment for an experiment involving Oxford University at the newly available high energies of the Batavia machine

DESY : Electron-proton physics with DORIS 281
Planned addition of a proton injector at the double storage rings to make electron-proton colliding beam physics possible for the first time

TRIUMF : Cyclotron Conference 282
Review of the major topics from the 6th International Cyclotron Conference held at the TRIUMF Laboratory

BROOKHAVEN : Transition radiation detectors 284
Development of new detection technique which is particularly promising for distinguishing between charged particles at very high energies

CERN News

Synchrotron injector injects 285
Commissioning of the PS Booster brought to the stage where 800 MeV protons have been fed to the main ring

Omega testing 286
Three experimental groups begin testing their equipment at the Omega spectrometer where data-taking may begin soon

Superconducting quadrupole looking good 287
Good performance achieved from a superconducting magnet such as may be used in focusing very high energy beams at the SPS

Pop physics 288
A film on high energy physics prepared for showing to general audiences beginning with a TV screening in the UK

Perspective plan of CERN site 290

Cover photograph : One of the visitors who brought some colour into the CERN corridors during the summer. He is photographed here on the ISR site with the experimental hall, I1, and water tower in the background. (CERN 343.8.72)

Experimental programme at the PS and the ISR

A record number of experiments are now being carried out or prepared at CERN. The 28 GeV proton synchrotron is feeding electronics experiments in three halls — beams from internal targets supply the South hall, a slow ejected beam feeds many experiments in the East hall and a new slow ejected beam goes to the West hall where experiments with the Omega spectrometer are having their first tests. Since we last reviewed the experimental programme, two bubble chambers (the 81 cm hydrogen and the 1.1 m heavy liquid) have ceased operation but more modern chambers have taken, or are taking, their place. The 2 m hydrogen chamber continues at the end of the East hall, a small chamber specifically for hyperon experiments (HYBUC) sits in the North hall, the large heavy liquid chamber (Gargamelle) has its own South-East hall and the 3.7 m European chamber (BEBC) is coming into action at the end of the West hall.

In addition to the broad programme at the PS itself, there is of course a new list of experiments to be added since the Intersecting Storage Rings are in operation. Five of the eight intersection regions are being used for colliding beam experiments.

This article is a review of the experiments now in progress or being made ready. In the space available it cannot be very much more than a list of beams and experiments but it should give some idea of the extent and content of the CERN programme. On pages 272 and 275 there are sketches of the layout of beams and the experiments they serve.

Available beams

Beginning with the South hall : An internal target in straight section 1 provides particles for — t1, a beam of momentum up to 1 GeV/c which is used for testing equipment subsequently installed on other beam-lines; m11, a low energy electrostatically separated beam currently providing antiprotons with momenta up to 2.0 GeV/c ; m7, another electrostatically separated beam which has been substantiallly unchanged for many years and currently provides kaons with momenta up to 3.1 GeV/c ; d30, the highest energy beam in the South hall giving unseparated particles with momenta up to 15 GeV/c ; d30a, an extension of d30 ; b16, a neutral beam which is currently used for the calibration of neutron detectors after having been used for checking the set up for the collaborative experiment now under way at Serpukhov (see June issue page 199).

An internal target in straight section 8 provides particles for — k17, a low energy separated beam where kaons of momenta up to 1 GeV/c are available for atomic X-ray experiments and m9, an electrostatically enriched beam providing positive pions of momentum up to 4 GeV/c and kaons up to about 3 GeV/c. A new internal target station in straight section 11 is used solely to provide low energy negative kaons of momentum 0.5 GeV/c for the HYBUC bubble chamber in the North hall via beam-line k16.

Moving to the East hall — a fast ejection system gives an ejected proton beam e6 to feed the 2 m bubble chamber. When the chamber is in action, this ejection system usually operates twice per PS pulse. The protons can be used on three different target stations. The u5 beam is a three cavity r.f. separated beam which provides the highest energy particles to the chamber (kaons up to 16 GeV/c for example) whereas m6 and k8 are electrostatically separated beams for lower momenta (kaons up to 5 and 2 GeV/c respectively for example).

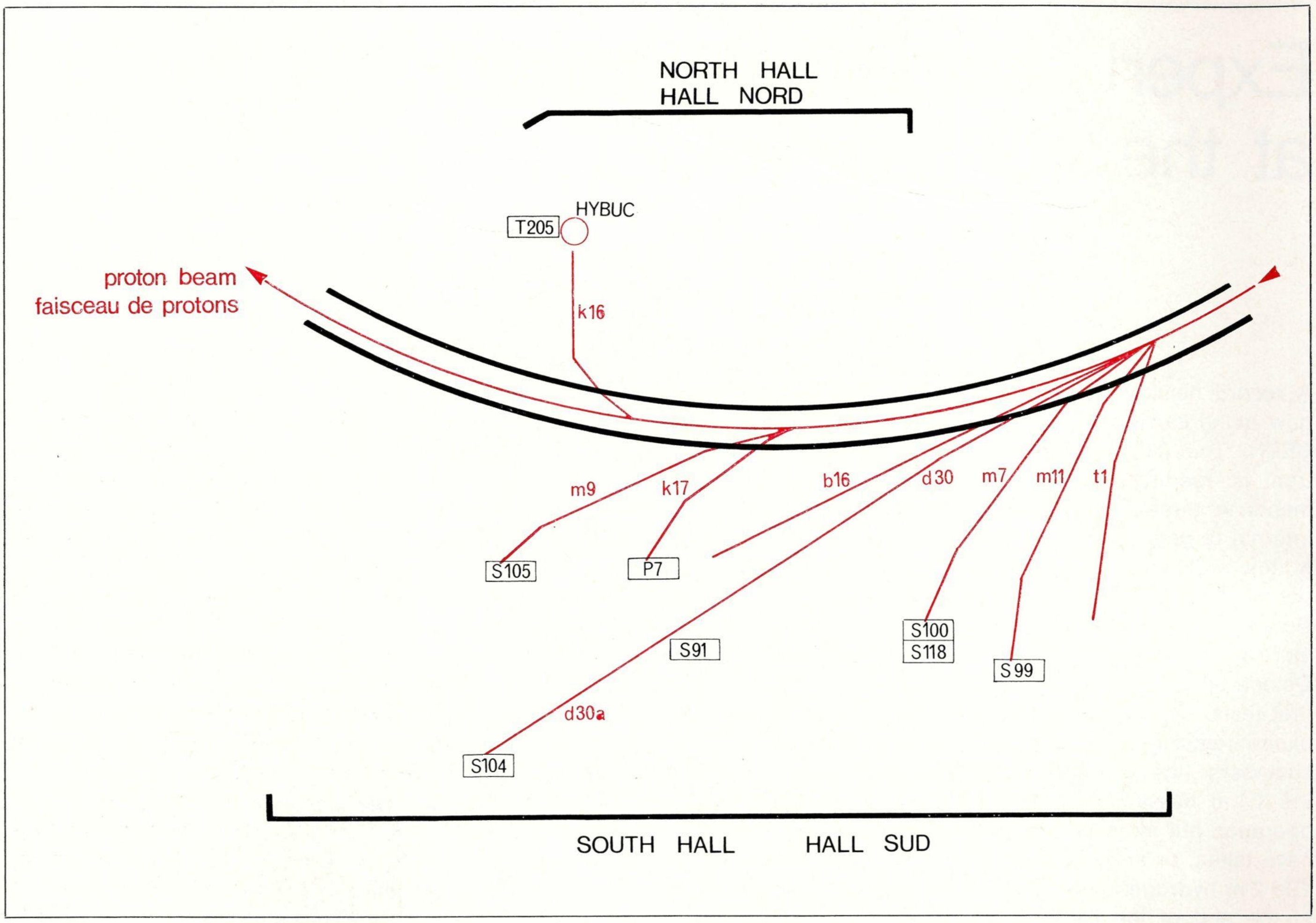
Electronics experiments in the East hall are fed by a slow ejected proton beam, e9, from straight section 62. A septum magnet can divide the beam on the same pulse between e9n (north) and e9s (south). On the north beam-line the ejected protons are used to give a hyperon beam. On the south beam-line a further septum magnet can divide the beam between two targets. One provides neutral particles along b19 where the neutral kaon is studied. The other provides two high energy beams — p8, where pions of momentum up to 18 GeV/c are available and p13, where pions up to 17 GeV/c are available.

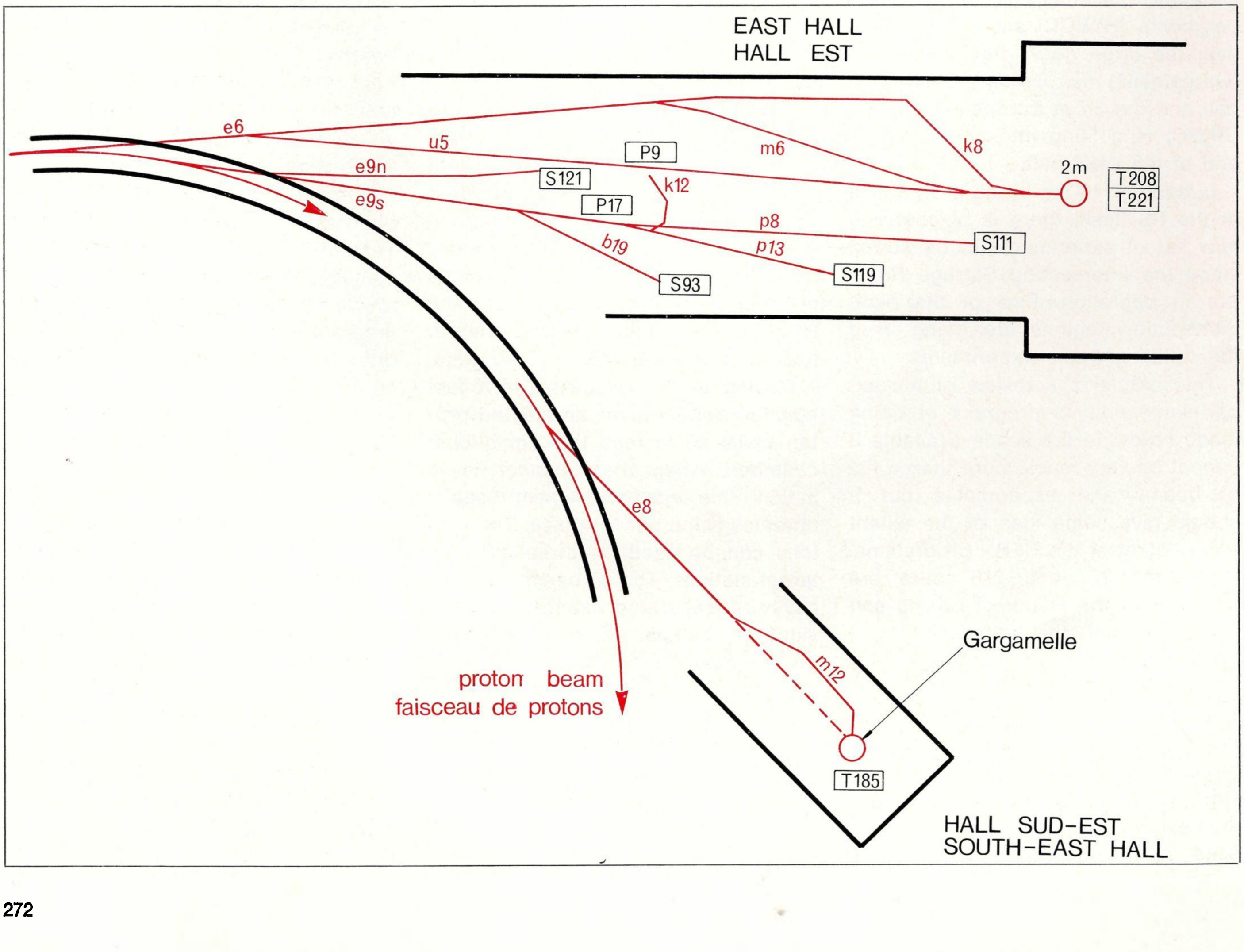
The Gargamelle bubble chamber in the South-East hall is fed by a fast ejected proton beam, e8, from straight section 74, which is used primarily onto a target to produce the pions and kaons which subsequently decay to give a neutrino or antineutrino beam. Other particles have however been fed to the chamber via beam-line, m12, which has recently provided antiprotons of momenta up to 2.6 GeV/c.

Completely new on the beam-line pictures are those in the West hall. They are drawn from the proton beam ejected down the transfer tunnel towards the ISR and then deviated to the hall. From targets, beams can be drawn for Omega (beam-line p9 currently providing 8 GeV positive and negative pions but capable of momenta up to 17 GeV/c) and for BEBC (beam-line u7 now under construction).

Using the proton synchrotron to spray this maze of beam-lines requires a variety of machine operating conditions ; the use of computer control to switch from one situation or another is therefore becoming increasingly helpful. To take the fortnight's run at the end of August — no less than five different machine cycles were called for. Some examples of these machine cycles are as follows :

During filling of the ISR on 21 August, one pulse in three (all twenty bunches) was fast ejected from straight


NORTH HALL
HALL NORD
HYBUC
T205
k16
proton beam
faisceau de protons
m9
k17
b16
d30
m7
m11
t1
S105
P7
S100
S118
S91
S99
d30a
S104
SOUTH HALL
HALL SUD


EAST HALL
HALL EST
e6
u5
P9
m6
k8
e9n
S121
k12
2m
T208
T221
e9s
P17
p8
S111
b19
p13
S119
S93
e8
Gargamelle
m12
proton beam
faisceau de protons
T185
HALL SUD-EST
SOUTH-EAST HALL

Schematic diagrams of four experimental halls fed by the 28 GeV proton synchrotron showing the layout of the particle beams and the location of the experiments they serve.

section 16 to one or other of the storage rings at a momentum of 26 GeV/c. The other two pulses followed a cycle also rising to a peak momentum of 26 GeV/c when five bunches were fast ejected from straight section 58 towards the 2 m bubble chamber. The remaining beam was then divided at lower energy between the internal targets in straight sections 1 and 8 thus providing particles to eight experimental teams. The pulse repetition rate was one every 2.5 s. Meanwhile the PS linac was also feeding the four-ring Booster which can be run for commissioning in parallel with the PS without interference (until, of course, the Booster is brought into action to feed the PS).

A week later the cycle had changed so as to send beam to the Omega spectrometer. One bunch was sent to the 2 m chamber twice in the cycle and the rest of the beam was split equally between internal target 1 and slow ejection from straight section 16. The new slow ejection system called SQUARE (see February issue, page 33) using the 6 ⅓ resonance makes efficient sharing between slow ejection and internal targets possible for the first time at the PS.

Electronics experiments

In listing the experiments using counter and spark chamber techniques we will follow the sequence of beams above beginning in the South hall with the experiments receiving particles from internal target 1. The code number used to refer to an experiment is that assigned to the experiment when it is first approved for the research programme.

S 99

A Daresbury, Queen Mary College, Liverpool, Rutherford team have been looking at differential cross-sections in the antiproton-proton interaction. Counters and wire chambers with core read-out plus a large spectrometer magnet have been used to identify

$$\bar{p} + p \to p + \bar{p}$$
$$\to \pi^+ + \pi^-$$
$$\to K^+ + K^-$$

Their incoming beam momentum ranged from 0.6 to 2.0 GeV/c and the detection angle could be changed enabling them to cover the region of the S, T and U resonances which showed up in the missing mass spectrometer experiments. These results are now being analysed and the experiment will continue (becoming designated as S 124) using a polarized proton target to provide additional information.

S 100

A Brussels, Caen, CERN team are using a target filled with deuterium so as to study the differential cross-section of elastic scattering of the negative kaon on the neutron. Their detection system includes multiwire proportional chambers and a neutron detector which is monitored by a Plumbicon camera (converting the light signals into electronic information immediately).

S 118

The above experiment will be followed by one to be carried by a Geneva, Saclay team which is currently testing its detection system. They will look at kaon decays giving four particles including an electron. Their system includes a magnetic spectrometer, wire spark chambers and large Cherenkov counters. They will be able to do low energy $\pi\pi$ phase shift analysis in a very clean way and will also look for any decays which violate the $\Delta S = \Delta Q$ rule. (In the decay by the weak interaction of a particle like the kaon the strangeness quantum number S can change by ± 1. When this happens the charge quantum number Q of the strongly interacting particle also changes in the same way. Thus $\Delta S = \Delta Q$.)

S 91

A CERN, Ecole Polytechnique, Orsay, Stockholm team have carried out an extensive survey of forward and backward scattering in the positive kaon-proton, negative kaon-proton, and antiproton-proton interactions using wire spark chambers and a gas Cherenkov counter. The interest in the measurements in the backward direction which have gone on recently is to pin down the exchange mechanism which is taking place in the interaction. For example

$$K^- + p \to p + K^-$$

there is no known particle which can be exchanged and the cross-section falls off steeply as the energy goes up. Theories call for some exchange mechanism possibly involving two particles.

S 104

A Rome, Rutherford team, with scintillation counters, optical spark chambers (the only optical chambers yielding data on film remaining in the experimental programme) and a water Cherenkov counter, are looking for resonances with strangeness $+1$. They detect the decay products of the lambda hyperon and from this knowledge of the lambda can study the missing mass spectrum in the interaction

$$\pi^- + p \to \Lambda^0 + \text{(missing mass)}$$

This experiment is just finishing.

S 105

A CERN, Trieste team are drawing beams from the target in straight section 8 to cover some gaps in scattering data. They use a polarized proton target, scintillation counters and wire spark chambers to look at the interactions

$$\pi^+ + p \to p + \pi^+$$
$$K^+ + p \to p + K^+$$
$$\pi^+ + p \to \Sigma^+ + K^+$$

The experiment has collected a large amount of data.

Moving to the East hall :

Experiment S100 studying the elastic scattering of negative kaons on neutrons using the m7 beam-line. The detection system involves multiwire proportional chambers and a neutron detector monitored by a Plumbicon camera.

Schematic diagram of the West hall, the latest experimental area to be fed by the PS. In the context of the budget restrictions in Laboratory I and in anticipation of the supply of beams of higher energy from the SPS, the experiments are to be restricted to the Omega spectrometer and the 3.7 m bubble chamber for the next few years.

Below is the layout of present experiments at the Intersecting Storage Rings.

S 121

A CERN, Ecole Polytechnique, Orsay team are studying the leptonic decay of negative hyperons. The special detection system involving a DISC, two large streamer chambers and a spectrometer was described in the May issue, page 163. They are looking at decays such as

$$\Sigma^- \rightarrow n + e + \bar{\nu}$$

$$\Sigma^- \rightarrow \Lambda + e + \bar{\nu}$$

The experiment should yield better values for the coupling constant of the axial and vector currents and possibly reach the limit of validity of the Cabibbo theory of the weak interactions.

S 93

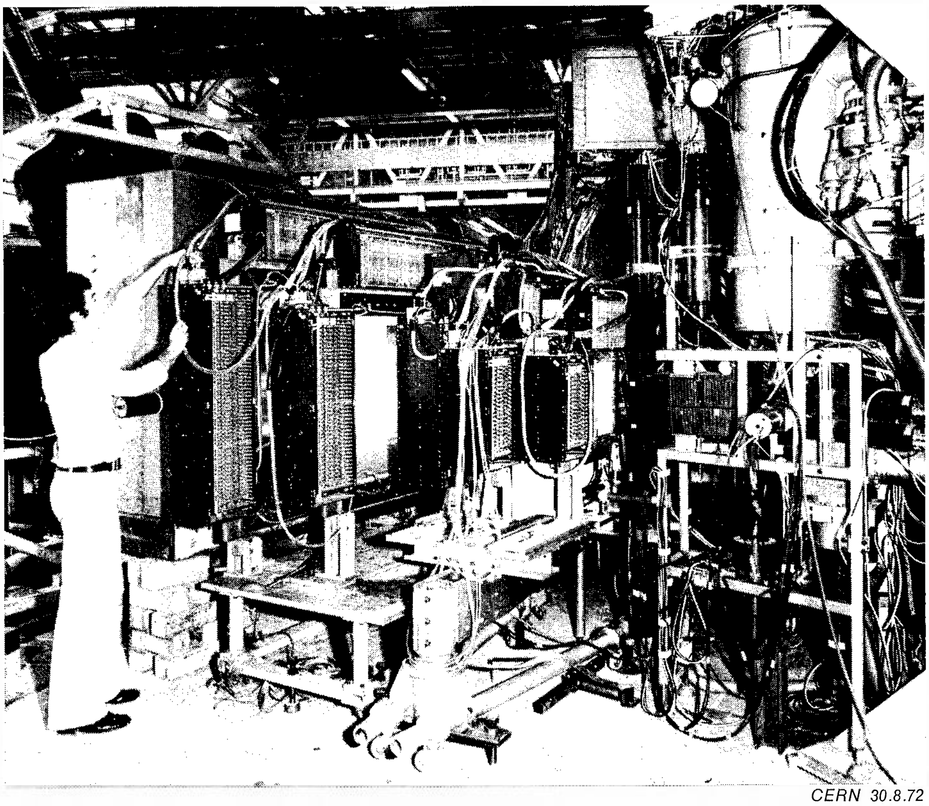
A CERN, Heidelberg team are carrying out a very thorough study of neutral kaon decays which violate CP conservation. This includes both the decays into two charged pions

$$K_L^0 \rightarrow \pi^+ \pi^-$$

and the leptonic decays

$$\begin{aligned} K_L^0 \rightarrow\ & \pi^+ + e^- + \bar{\nu} \\ & \pi^- + e^+ + \nu \\ & \pi^+ + \mu^- + \bar{\nu} \\ & \pi^- + \mu^+ + \nu \end{aligned}$$

where the negative pion decays occur slightly more often than the positive pion decays. They are also measuring the K_L^0, K_S^0 mass difference very accurately and looking at K_S^0 regeneration on carbon and hydrogen. A large array of multiwire proportional chambers makes it possible to amass data at the rate of 2000 events per pulse — a rate which cannot be achieved with any other detection technique. The high statistics will make it possible to pin down the parameters of the kaon decay very accurately, for example — the phase measurement to better than one degree. The number of lambdas in the neutral beam also makes it possible to measure the lambda-proton and lambda-neutron cross-sections.



CERN 30.8.72

S 119

A CERN, Munich team are continuing an extensive programme of boson studies looking at the interactions

$$\begin{aligned} \pi^+ + p & \rightarrow \pi^+ + \pi^+ + n \\ & \rightarrow K^+ + K^0 + p \end{aligned}$$

These are 'quasi two-body' interactions the pions or kaons coming from a parent boson. This team covered the region of the A2 meson at an earlier stage of their study and returned it to the fold as an unsplit particle (see vol. 11, page 63). They are using wire chambers, Cherenkov counters and a magnetic spectrometer and will assemble high statistics using pions at 15 GeV/c and at 7 GeV/c.

S 111

An IPN, Orsay team are to look for 'exotic exchange' interactions of the type

$$\begin{aligned} \pi^- + p & \rightarrow K^+ + \Sigma^- \\ & \rightarrow d + \bar{p} \end{aligned}$$

These interactions should not occur since they involve the exchange of particles with forbidden quantum numbers. They will use a hydrogen target surrounded by two cylindrical hodoscopes — the inner one will catch the charged particles, the outer one will catch gamma rays.

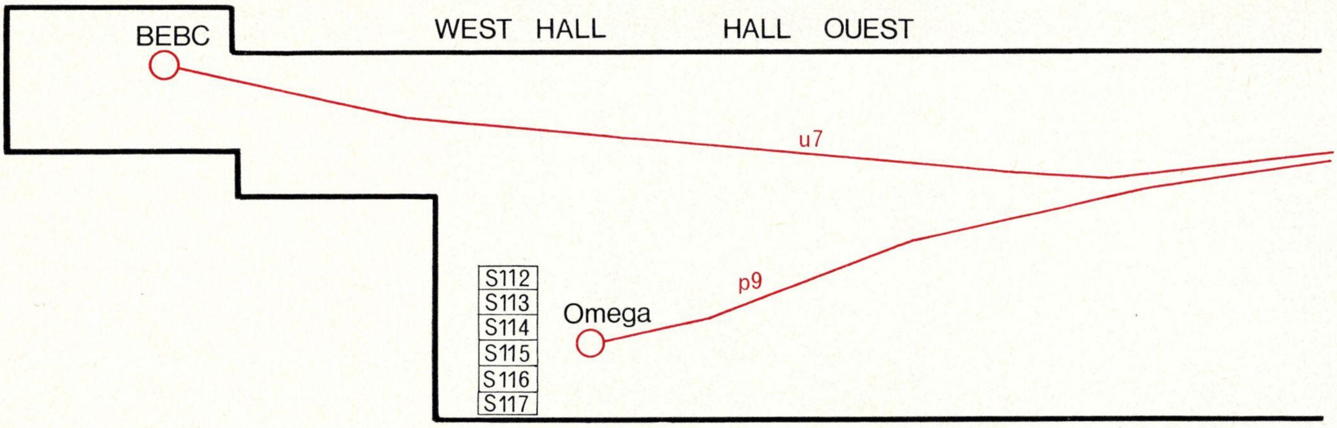
Three nuclear physics experiments which we have not mentioned in this list are :

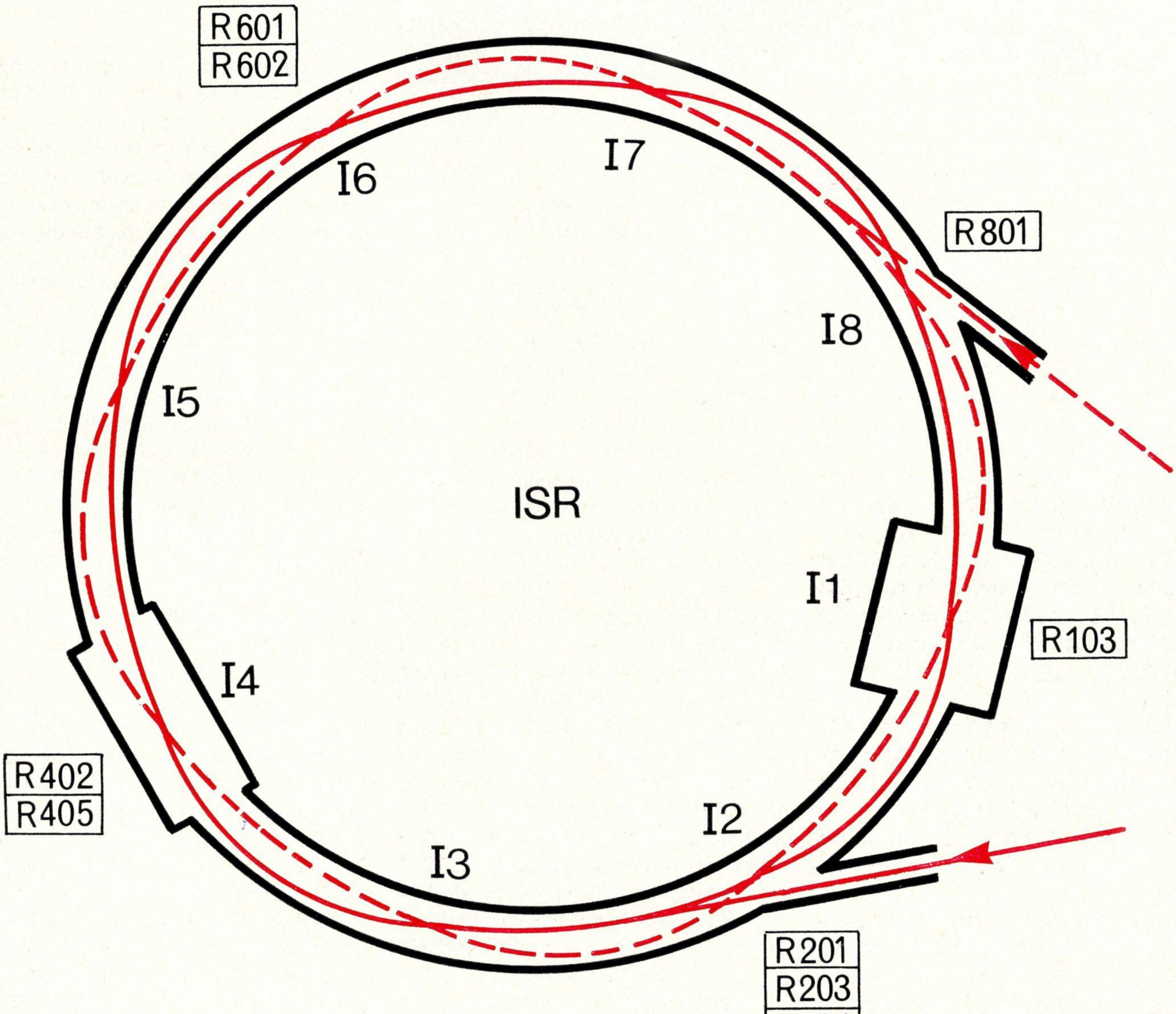
P 7

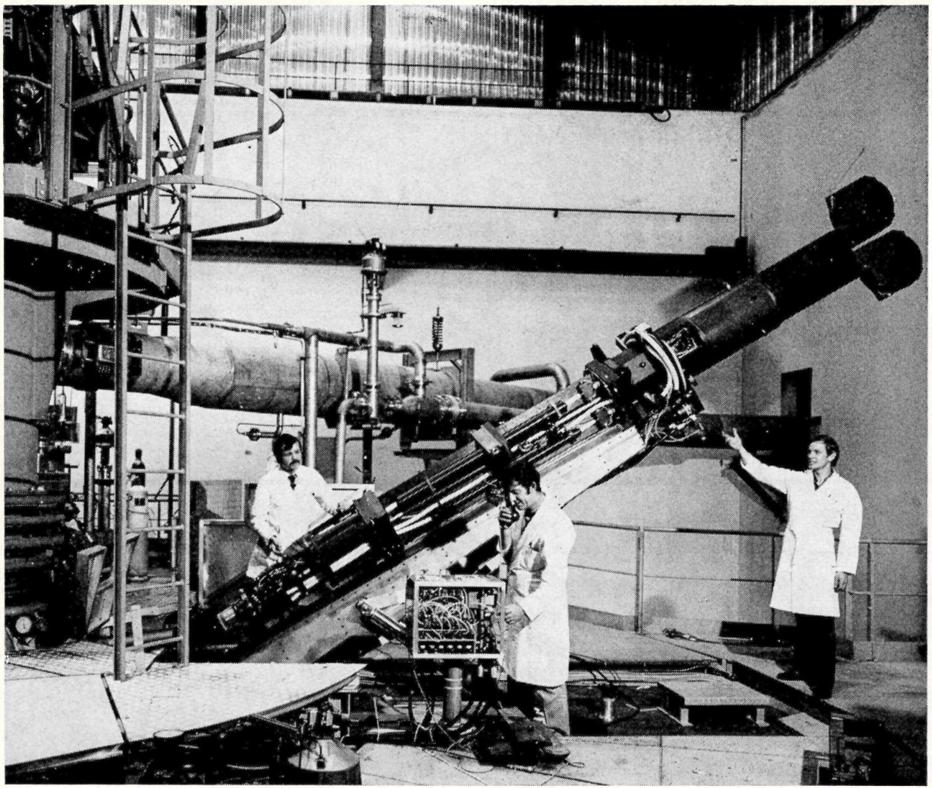
A Karlsruhe, Stockholm team are looking at exotic atoms in the South hall. Using a stopped beam from target 8 they produce and study antiprotonic, kaonic and sigmic atoms. The negative antiprotons, kaons or sigmas are captured 'in orbit' by nuclei and the X-rays they emit can be measured by lithium-doped germanium counters of high resolving power. This has been a very successful line of research at CERN (see vol. 10, page 251).

P 9

A CERN, Torino team are looking at the production of hypernuclei by


BEBC
WEST HALL
HALL OUEST
u7
p9
Omega
S112
S113
S114
S115
S116
S117


R601
R602
I6
I7
R801
I8
I5
ISR
I1
R103
I4
R402
R405
I3
I2
R201
R203
R204



Mounting of a camera at the 3.7 m bubble chamber, BEBC. First tests with the chamber took place in the summer and it is hoped to begin physics in the near future.

CERN 1.6.72

negative kaon interactions in flight using the k12 beam in the East hall.

P 17

A Clermont-Ferrand, Strasbourg team have a gaseous helium target in the e9 ejected beam (where it is almost completely 'transparent' so that the experiment can run parasitically) to study coherent scattering of the proton and helium nucleus. The detection system uses a spectrometer which fastens onto the recoil helium nuclei with solid state detectors.

In the West hall the Omega spectrometer will be used by several experimental teams. Progress in commissioning the spectrometer is reported later in this issue. Six experiments have been accepted for the first year's running.

S 112

A Birmingham, Rutherford, Westfield College team will study zero strangeness bosons the main objective being to obtain precise information on the $I = 0$ and $I = 1$ bosons in the mass region 1.5 to 2 GeV/c.

S 113

A Bari, Bonn, CERN, Daresbury, Liverpool, Milan team will carry out a related experiment studying the zero strangeness, charged boson spectra over the same mass region.

S 114

A CERN, ETH, Freiburg, Karlsruhe team will study baryon exchange in a variety of interactions involving the production of a fast lambda in the forward direction.

S 115

A Glasgow, Saclay team will study the production of baryon — anti-baryon pairs fastening onto a fast antiproton emerging in the forward direction.

S 116

A CERN, ETH team will study K^* resonances which are produced non-diffractively.

S 117

A CERN, Collège de France, Ecole Polytechnique, Orsay team will study quasi two-body interactions which take place via the baryon exchange mechanism.

Bubble chamber experiments

A long list of experiments has been carried out at the 2 m bubble chamber since it came back into action, filled with hydrogen, in May. During this time the chamber took its twenty millionth picture. Beginning in September, the two experiments listed below are scheduled to take 300 000 pictures each with beam from the low momentum k8 beam-line. Then, probably in November, the chamber will be out of action for a week while the hydrogen filling is replaced by deuterium and will come back for higher momenta runs with the u5 r.f. separated beam-line.

T 208

A Glasgow, Pisa, Rutherford team are measuring the parameters of the τ and the semi-leptonic decays of the long-lived neutral kaon.

T 221

An Imperial College London, Rutherford team are extending their study of the negative kaon-proton interactions in a lower momentum range (0.88 to 1.04 GeV/c) available from the k8 beam.

In the North hall the small hydrogen bubble chamber known as HYBUC is continuing its hyperon experiment. The chamber is specifically designed for this experiment and involves a very high magnetic field (11 Tesla) produced by a superconducting magnet.

T 205

A Copenhagen, Munich, Vanderbilt team are measuring in HYBUC the magnetic moment of the sigma hyperon to a precision of 5 %. The sigmas are produced in the interation

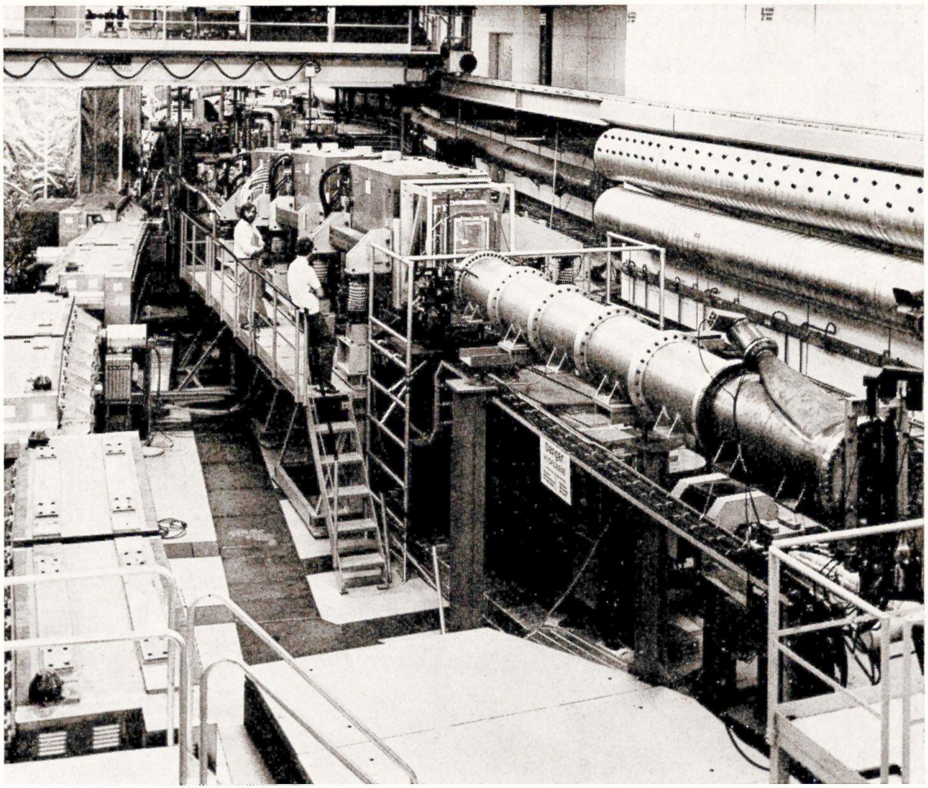
$$K^- + p \rightarrow \Sigma^+ + \pi^-$$

and the magnetic moment can be calculated by seeing how the sigma polarization direction precesses measuring the angular asymmetry of the proton emerging from the sigma decay. The experiment is likely to involve about a million pictures.

In the South-East hall the heavy liquid bubble chamber, Gargamelle, is being made ready to continue the neutrino experiments which are one of its particular fortes.

T 185

An Aachen, Brussels, CERN, Ecole Polytechnique, Milan, Orsay and University College London team will analyze the data collected in the experiment. About a quarter of a million pictures with both neutrino and antineutrino beams were taken in the previous runs which were completed in 1971. An equivalent number (i.e. about 500 000 pictures), again probably evenly divided between neutrinos and



The intersection region I-2 where spectrometers are set up to look at small and large angles and a muon detector is used in an intermediate boson search. The small angle spectrometer can be seen on the right in the photograph where it climbs up above the magnets of Ring I of the storage rings.

CERN 27.8.72

antineutrinos, will be taken in the coming run with the chamber filled with freon. The main aim of the experiment is to study the behaviour of deep inelastic neutrino scattering, measuring neutrino and antineutrino cross-sections as a function of energy. Information will also be gathered on such things as the existence of neutral currents, heavy leptons and intermediate bosons and on coupling constants and lepton number conservation laws.

Bubble chamber physics at CERN awaits a new lease of life when the 3.7 m chamber, BEBC, comes into action at the end of the West hall. The first tests took place this summer and it is hoped to start physics soon. Proposals for experiments have already been discussed and the Track Chambers Committee has the hard job of selecting and trimming experiments so that the best possible programme will be mounted in the months that BEBC can run before the West hall is closed to prepare it to receive beams from the SPS. Probably between 1.5 and 2 million pictures will be possible whereas well over this figure has been requested by experimental teams.

Experiments at ISR

Experiments are set up at five of the eight intersection regions of the ISR and another (I-7) will fall to the high energy physicists soon with the installation of a streamer chamber. I-7 will later be the scene of attempts to increase the luminosity by having a low beta section. The first number in the code number referring to an experiment indicates the intersection region where it is located (e.g. R 201 is at intersection I-2).

R 103
A CERN, Columbia, Rockefeller team are carrying out one of the particle searches at the ISR. They are looking for dileptons of high mass. The intermediate boson, the postulated carrier of the weak interaction, is one particle which could be seen by this experiment if it exists within the mass range which can be examined. A wide aperture photon and electron detector catches particles coming off at large angles to the proton beam directions and the intermediate boson would be detected through its electron decay mode.

R 105
A Saclay team will join the ISR experiments at the beginning of next year looking at high transverse momentum charged particles using spectrometers with large acceptance positioned on either side of intersection region I-1. This will follow completion of experiment R 103.

R 201
A CERN, Holland, Lancaster, Manchester team are looking at stable particle production at small angles. They have a spectrometer arm which climbs above an ISR ring to study particle distributions between 20 and 150 mrad. Spectra for pions, kaons and protons at different energies have been obtained and, in general, support scaling.

R 203
A British and Scandinavian Universities team are doing a similar study at large angles. They aim to assemble production spectra of positive and negative pions, positive and negative kaons, protons, deuterons, etc. In addition they are able to detect quarks and are carrying out a quark search in parallel.

R 204
The British Universities involved in the above experiment have also installed a large muon detector. They are searching for the intermediate vector boson by looking for high transverse momentum muons but, as with the other experiments, no sign of its existence has emerged yet.

R 402
A CERN, Munich team have carried out the most intensive of the searches for fractionally charged particles. Their detection system was able to detect quarks emerging from the high energy collisions up to masses of about 22 GeV. There was no sign of the quarks in about 5×10^9 particles through their telescope with the normal unit charge.

R 405
A CERN, Karlsruhe team are looking at neutron production at small angles. Their results will complement the series of measurements on charged particles mentioned above.

Intersection region I-4 will soon be cleared ready for installation of the large Split Field Magnet (see last issue page 235). The first experiments for the SFM have been approved and are listed briefly here. The multiwire proportional chamber detection system in the SFM (and also the streamer chamber at I-7) will make it possible to study multiparticle events.

R 401
A CERN, Hamburg, Orsay, Vienna team will measure the energy dependence of isobar excitation in proton-proton collisions.

R 406
A Bologna, CERN team will search for quarks or other massive particles.

R 407
A CERN, Karlsruhe team will measure two-particle correlations in multiparticle events in the fragmentation region.

R 408
A CERN team will study inelastic proton-proton scattering.

R 409
Another CERN team will study typical beam-beam events using a minimum bias trigger.

R 410
A MIT, Orsay, Scandinavian team will study particle correlations at large angles.

In intersection region I-6 two experiments have collected a lot of data on elastic scattering.

R 601
A CERN, Rome team have been measuring elastic scattering down to very small angles (2 mrad). At these small angles the nucleon scattering (scattering under the influence of the strong force) interferes with Coulomb scattering (scattering under the influence of the electromagnetic force). The effect of Coulomb scattering is well known and therefore can be used to normalize the nucleon scattering result to give an absolute total cross-section independent of the ISR luminosity.

R 602
An Aachen, CERN, Genoa, Harvard, Turin team have studied elastic scattering at larger angles and have published many results. The measurements have overlapped those of R 601 and they link up with those of the CERN, Rome team. They have also looked at isobar production and, like the other experiments, they see no sign of quarks.

R 701
An Aachen, CERN, Munich team will look at inelastic proton-proton collisions using streamer chambers as mentioned above.

R 801
A Pisa, Stony Brook team have large detectors set up around intersection region I-8 trying to get an accurate measurement of the total cross-section for the high energy proton-proton interactions. They already have results on charged particle multiplicities. One of their concerns is to obtain a measurement of the luminosity as reliable as possible and to do this intend to sputter titanium at the interaction point so that beam collisions with the titanium will make it possible to measure the beam profiles and hence calculate the luminosity.

R 802
A CERN, Rome team will study particle production in the forward direction (around zero degree) installing a spectrometer between the two rings to detect negative particles swept out of the beam by the first ring magnet downstream of the intersection. A neutron detector will also measure neutron production at very small angles. The experiment will start next year.

And that concludes the list of experiments at the PS and ISR. Those who have struggled through the full list will appreciate that the machines are sustaining a high energy physics programme far greater in extent than could ever have been foreseen.

Around the Laboratories

BROOKHAVEN ISABELLE study and AGS performance

A three week study was organized at Brookhaven in June to take an intensive look at the ISABELLE storage ring proposal. The name ISABELLE emerges from Intersecting Storage Accelerators and it is obviously BELLE in the eyes of its originators. The initial outline scheme was described in CERN COURIER in August of last year (page 228).

Major features of the initial proposal are as follows. The existing AGS would feed protons at 30 GeV to two rings of superconducting magnets. Each 'ring' would consist of two magnet semi-circles of 220 m radius joined by two long straights of 300 m (giving 2 km total circumference). In these rings the proton energy would be taken to 200 GeV. The corresponding peak magnetic field would be 4 T over a useful aperture of 5 cm (the total internal diameter of the magnet coil being 8 cm). The two rings would sit one above the other as closely as possible so that adjacent magnets could be contained in a single dewar.

In the long straight sections the beams, travelling in opposite directions in the two rings, could be brought into collision at a very small angle or head-on. To achieve the necessary high density in the circulating beams, and hence an interesting interaction rate in the long straights, it is proposed to concentrate the normal twelve bunches in the AGS into a single bunch (debunching and rebunching) before transfer to ISABELLE. About 30 such bunches would give a stored beam of 15 A (6×10^{14} protons) in each ring (assuming that by then the AGS is providing 2×10^{13} protons per pulse). The optimum luminosity could be as

An aerial view taken in February of the 33 GeV proton synchrotron, AGS, at Brookhaven. The proposed location of the 200 GeV storage rings, ISABELLE, is drawn in with their injection lines coming off from the ejected beam which feeds the new North Experimental Area. The geometry of the storage rings has changed since the study held in June — the straight sections have been increased in number.

(Photo Brookhaven)

high as 10^{33} per cm^2 per s along each metre of the interaction region using low beta sections and a very small angle of collision between the beams.

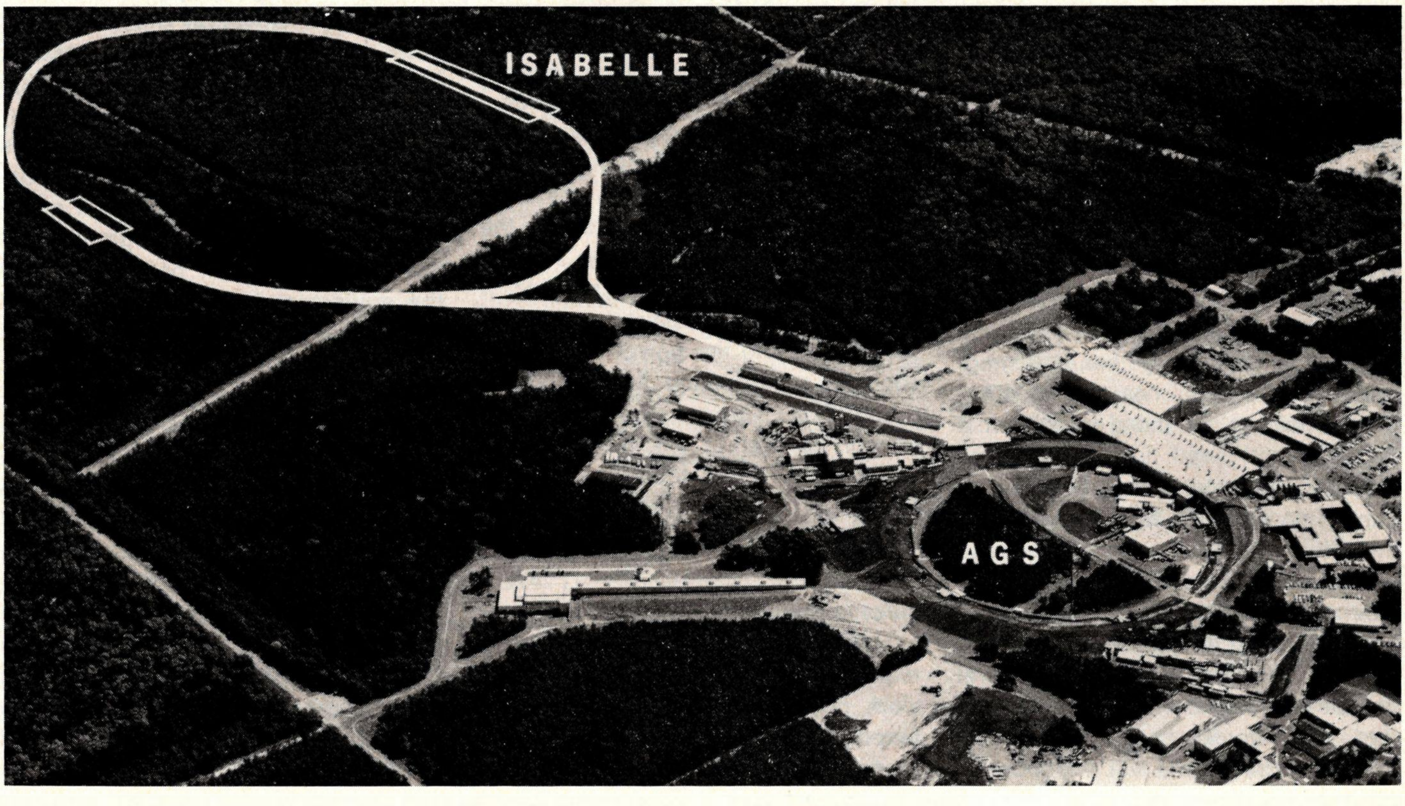
Further developments of such a system have also been considered. They include the possibility of 200 GeV physics by drawing protons from one of the rings, higher collision energies if superconducting magnets can be built to top 4 T, antiproton beams in one of the rings, or the addition of an electron ring as promoted on the West coast of America. The Preliminary Design Study (BNL 16716) was issued in May.

112 visitors went to Brookhaven for the June study. Most of them (75) were high energy physicists; the others were accelerator specialists including some from the CERN Intersecting Storage Rings team and from the Berkeley-Stanford collaboration which has put forward a proton-electron-positron colliding beam scheme known as PEP (see CERN COURIER vol. 11, page 279). The storage ring groups on each side of America will maintain regular contact probably holding joint meetings every few months.

The high energy physicists were enthusiastic about the range of physics which such an advanced facility would open up. There was fairly general agreement that, to follow the 100 s of GeV energy with the 'conventional' accelerator at Batavia, high energy colliding beams giving very high centre of mass energies would be the most important next step. The possibility of studying electron-proton collisions in order to gain more knowledge of the weak interaction was recognized as an important further option and the machine designers took the point that they should do nothing in their initial scheme which would shut the door on this option for the future.

On the design itself a number of important changes emerged from the discussions. For example, experience at the ISR suggests that holding a beam bunched under d.c. conditions is not easy. A transfer scheme more like that used for the ISR may therefore be adopted. The number of straight sections needs to be increased and more detailed work done on their layout. Further studies on the AGS and more experience with the ISR will be useful to have a better understanding of the behaviour of the beams. The ISR experience to date has certainly not indicated any fundamental limitations but there are some phenomena which cause proton loss and which are not understood (a tiny proportion of the beam seems to diffuse out and get lost for some obscure reason and is the main source of background for the experiments).

The need for extremely good



vacuum has also been underlined by the ISR. To achieve figures in the 10^{10} torr region over a large system requires a lot of care. ISABELLE has the complication of having to bake out the vacuum chamber at several hundred degrees as required for good vacuum while the same chamber is within a liquid helium temperature magnet system. The chamber will be isolated from the magnet by superinsulation and further vacuum space.

Finally, of course, the performance and costs of superconducting magnets have not yet emerged, though the present work at Brookhaven and elsewhere should give the necessary figures in the near future.

Studies on ISABELLE are continuing and it is hoped to submit a proposal to the AEC next year requesting construction money as from fiscal year 1975. If authorization came through at such a fast rate, Brookhaven could have 200 GeV colliding beams before this decade is out.

AGS Performance

The 33 GeV alternating gradient synchrotron has been struggling for almost a year to reap the full benefit of its improvement programme (known at Brookhaven as the 'conversion project'). An extensive revamping of the machine has been carried out involving a new injector (200 MeV linac), new vacuum system, new magnet power supply, new r.f. cavities, extra shielding and more experimental facilities.

Since the refurbished accelerator came into action it has pushed peak intensity to 6×10^{12} protons per pulse (a figure which has not been reached elsewhere) and operates happily at 4×10^{12}. Up to now the experimenters around the machine have in general not been able to make use of this increased intensity but the next generation of experiments will undoubtedly be designed to take advantage of the new figures. Pushing to higher intensities has not therefore up to now had high priority. There has been more concern with the reliability of the machine.

The percentage of scheduled physics time lost due to machine failures has been uncomfortably higher than before the modifications were carried out. The linac, the vacuum and ejection systems have been major sources of trouble and have needed more nursing than was expected. The conversion project in its final phases suffered considerably from the financial cut-backs at Brookhaven and the number of qualified people available to see the programme through was well below the 'design figure'. This seems to have had its effect on the ease with which the accelerator could be brought in again.

However, recently, the reliability had been picking up until a major failure on 19 August. Carbon brush dust collecting on the motor rotor resulted in a current path across incomplete insulation. During braking, when the rotor voltage is high, an arc was struck and the conductor melted through. The damaged area has been carefully stripped to pin down the source of trouble precisely so that steps can be taken to prevent it happening again. Repairs are nearing completion and the power supply will soon be reassembled and realigned. (The CERN PS power supply is similar enough to that of the AGS to send CERN experts to their machine in fear and trepidation to look at the same area. There is no sign of trouble.)

Fortunately the enforced accelerator shutdown is not damaging the experimental programme very much. Further work needed on the machine, combined with a shortage of operating money, had led to a 14 week shutdown being planned to begin in December. It is estimated that about four weeks will be absorbed by the rotor repairs (during which time work on the ring, such as installation of the new r.f. cavities, can go on) and a corresponding amount of time can be trimmed from the long shutdown.

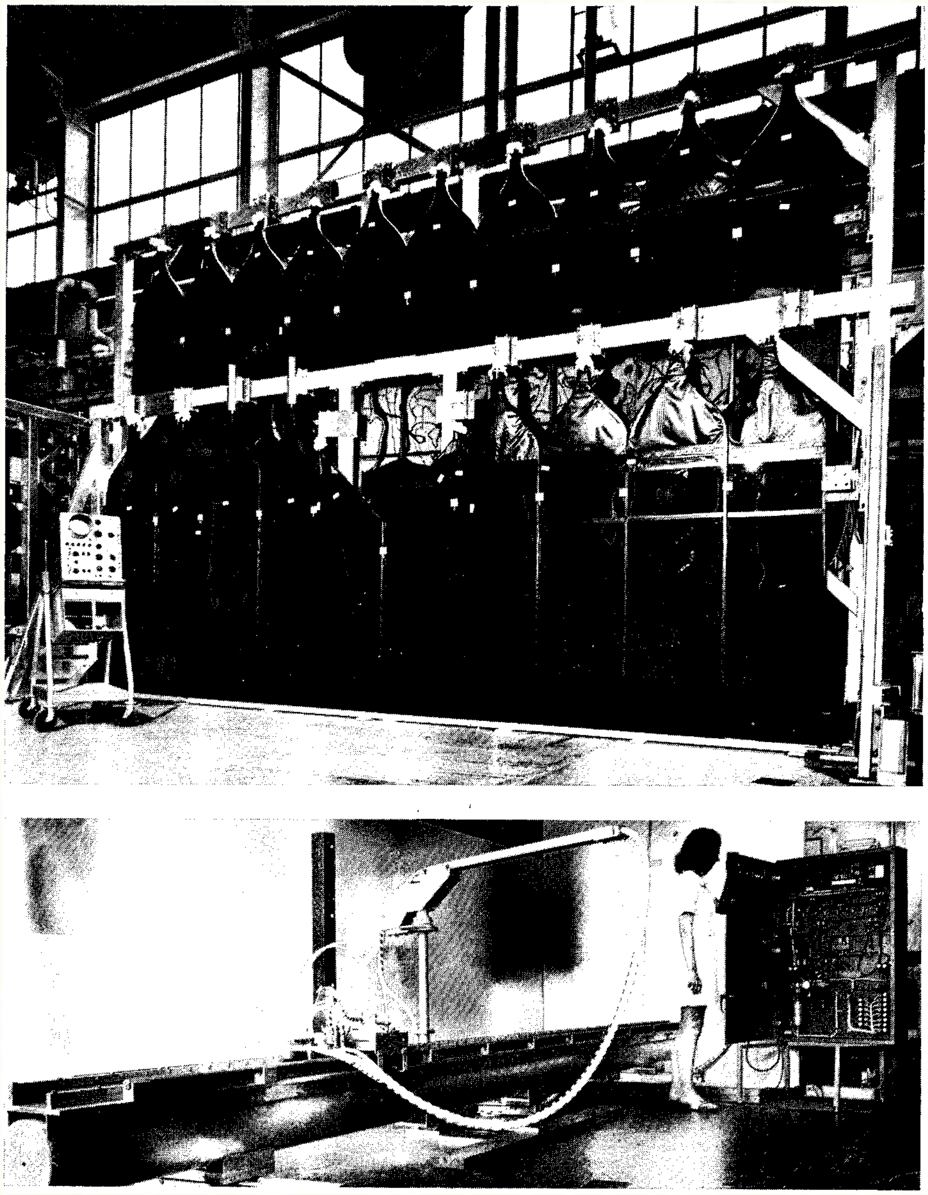
RUTHERFORD

Equipment for high energies

A group from the University of Oxford, UK, is participating (together with Chicago and Harvard University groups) in an experiment at the Batavia accelerator. They will study inelastic muon-proton scattering at high energies (experiment number 98 on the NAL list of approved experiments).

Experimental equipment to cope with high energy particles is generally very large, complex and expensive and can soon get beyond the scope of individual University groups. Oxford have had the help of the nearby Rutherford Laboratory in the design and construction of units which they are providing for the experiment. This includes four large scintillator hodoscopes — the 'halo scintillation counter' is shown in the photograph.

Another indication of the scale of the equipment is that the magnet of the dismantled Chicago cyclotron is being used in the spectrometer. For this Rutherford has supplied a machine for mapping the field in the large magnet aperture. The field survey apparatus will take readings in three planes over an aperture of about 9 m diameter and about 1.25 m high. An automatically operated electro-pneumatic indexing system will position a Hall probe to within 0.013 cm. Some 60 000 positions will be measured in the magnet volume and fed to a computer to be stored on magnetic tape.



Equipment developed at the Rutherford Laboratory for use in an experiment at Batavia in which the University of Oxford is participating. Above is a 'halo scintillation counter'. Below is a field measuring unit which will do automatic field plotting in the large aperture of the experiment's spectrometer magnet which was previously in action on the Chicago cyclotron.

(Photo Rutherford)

At Batavia installation of the cyclotron magnet is being completed. In July muons were sent to the Muon Laboratory and detected. The muon beam-line was tuned for 100 GeV.

In the absence of further large-scale investment in the national high energy physics programme in the UK, the Rutherford Laboratory has been very concerned to keep its physicists and engineers on their toes by joining in front-line projects which are probably destined to find their major applications elsewhere. Thus the Laboratory has a strong team in the GESSS collaboration working on superconducting magnets. It has a leading position in the bubble chamber track sensitive target technique, which may result in collaboration with Batavia for application in the 15 foot chamber (now ready for first cool-down) and with CERN for application in the 3.7 m chamber, BEBC. The Laboratory may also work on a 2 m polarized target for use at Batavia or on the new CERN accelerator. In addition there is extensive support of UK teams which come to CERN to participate in experiments.

DESY
Electron-proton physics with DORIS

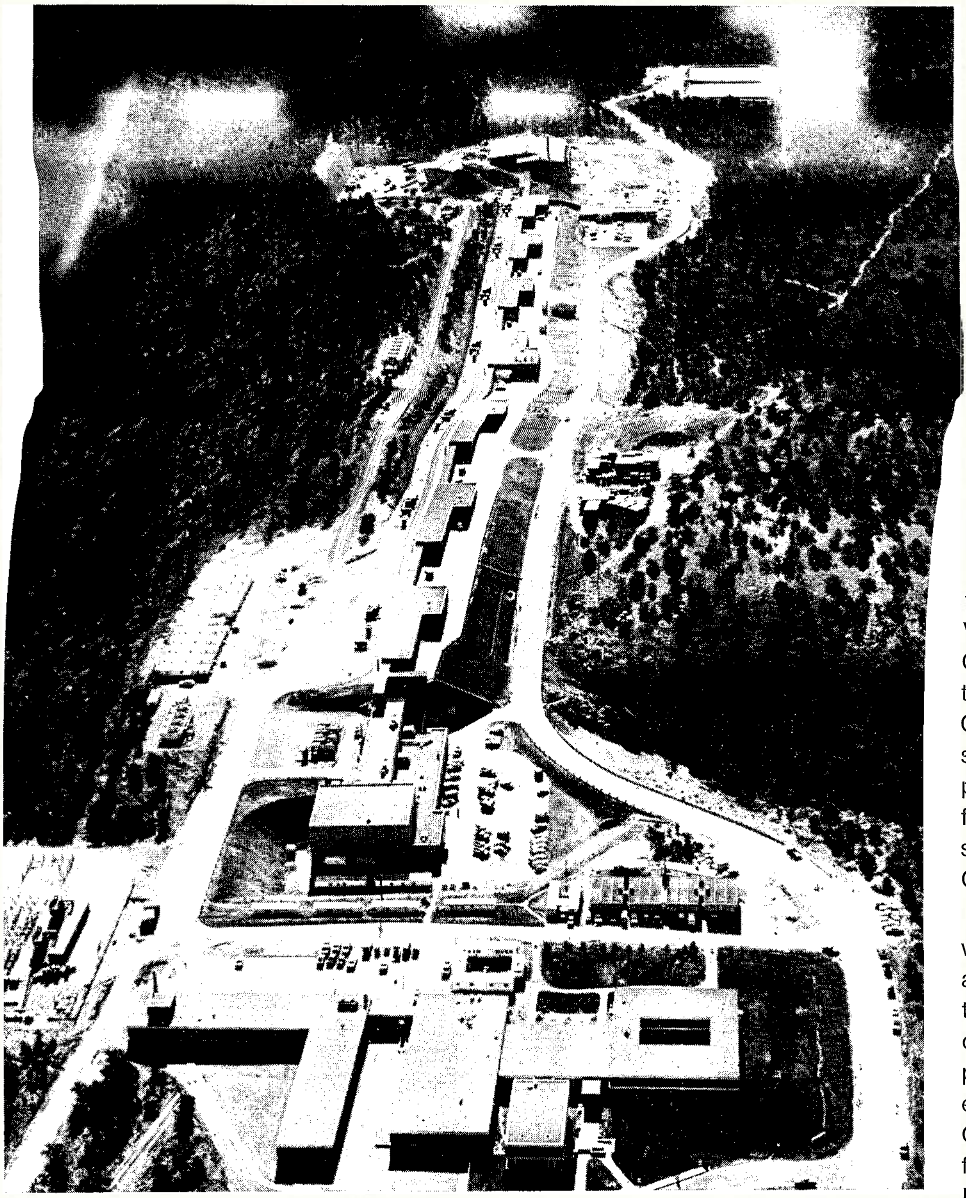
The double storage ring project at DESY, known as DORIS, has shown its underlying versatility already two years before its completion. There has recently been a study of the possibility of using DORIS not only as an electron-positron device, the purpose for which it was originally intended, but also as an electron-proton colliding beam facility.

Interest in the possibilities of doing electron-proton physics has grown suddenly in the past year with two adventurous colliding beam schemes being discussed in the USA. For several years inelastic electron scattering has been a key topic because experiments have shown much higher cross-sections than expected ; this could be a consequence of the existence of an internal structure in the nucleons. It is important to extend the investigation of deep inelastic interactions between electrons and nucleons to higher regions of energy and momentum transfer, a task which is obviously within the province of electron-proton storage rings.

The studies at DESY have shown that a rather simple extension of the Laboratory's hardware is sufficient to make DORIS suitable for electron-proton physics. The extension could provide valuable information for the construction and operation of larger electron-proton storage rings. Also, interesting experiments would become possible since the range of kinematical variables would increase considerably in comparison with those obtainable at present.

Since high energy protons are not available at DESY, which is of course an electron Laboratory, the first requirement is to build an injector to feed DORIS with protons. For both economical and physical reasons the idea of using a proton linac was discarded. Instead, it is planned to build a small 1 GeV synchrotron to be fed by a 3 MeV Van de Graaff. The synchrotron will be located close to already existing injection beam-lines ; in this way only 5 m of new beam transportation system will be necessary.

Space charge effects will limit the intensity of the proton beam to 5×10^{10} particles per pulse. Several hundred pulses will thus need to be injected into the storage ring from the synchrotron in order to obtain an adequate stored proton intensity (4×10^{13} protons). Since the cycling period of the



An aerial view of the completed proton linear accelerator LAMPF at Los Alamos which gave its first 800 MeV beams in June. We are looking from the injector end along the machine to the experimental areas. LAMPF is mentioned in the review of the Cyclotron Conference held in Vancouver.

(Photo Los Alamos)

synchrotron will be 0.5 s the filling can be accomplished in 5 to 10 minutes.

The mean radius of the synchrotron is to be 3.82 m with a bending radius of 2.23 m. During the acceleration, the frequency of the r.f. will rise from 1 to 9.1 MHz. As soon as the maximum energy has been reached the synchrotron will switch to a second cavity, running on the third harmonic at 27.3 MHz in order to obtain bunches about 6 m long.

Following ejection from the synchrotron, the protons will be stacked in one ring of DORIS. For this purpose the storage ring will be equipped with a cavity running at 27.3 MHz linked to the synchrotron cavity by a common fixed frequency generator. When all the 'r.f. buckets' are filled, the protons will be accelerated further to a maximum energy of 4.2 GeV. The cavity will then be turned off and the beam will debunch to give a continuous ribbon of protons.

Because of synchrotron radiation the intensity of the electron beam which it is possible to store in DORIS depends strongly on the peak energy. The design currents for electron beams correspond to luminosities between 2×10^{30} per cm^2 per s at 4.2 GeV/c and 5.5×10^{31} per cm^2 per s at 2 GeV/c. By operating DORIS at 4.2 GeV in each ring, a centre of mass energy of 8.4 GeV, corresponding to a laboratory energy of 36.5 GeV, will be available. The highest value of momentum transfer will be 70 $(GeV/c)^2$.

Design studies will be completed this year so that construction could start in 1973. The first experiments could then be carried out in 1976. By careful economizing, it will be possible to meet the total cost from within the research budgets allocated to the Laboratory.

TRIUMF Cyclotron Conference

The Sixth International Cyclotron Conference was held on 18-21 July at the University of British Columbia in Vancouver where a collaboration of Canadian Universities is engaged in the TRIUMF cyclotron project. The Conference took place under sunny skies, just escaping a three-day downpour which broke the rainfall record for the full month of July. This is a selection of some topics from the Conference.

On the 'new machine' front there were several proposals for heavy ion accelerators. The Hahn-Meitner Institute in Berlin propose a heavy ion cyclotron with a tandem injector. This project may well go ahead at an estimated cost of about $5 million. Oak Ridge Laboratory are putting forward a modified 'National Heavy Ion Accelerator' proposal which would be a multi-stage machine integrated with the existing isochronous cyclotron ORIC facilities. A four sector isochronous cyclotron would use ORIC or a 20 MV tandem Van de Graaff as injector.

(Incidentally, the on-line isotope separator at ORIC has come into action since the Conference at the beginning of September. Known as UNISOR, for University Isotope Separator at Oak Ridge, it is the second major facility of its kind to operate on a heavy ion cyclotron, the other being at Dubna. From 2 to 12 September, test experiments were performed using nitrogen ions accelerated to 100 MeV onto niobium foils. Cadmium isotopes of number 100 to 103 were identified.)

Other proposals for new machines were put forward by Scandinavian groups from Uppsala at the Gustav Werner Institut, Akademiska Sjukhuset and Instrument AB Scanditronic (a

200 MeV proton cyclotron exclusively for medical applications) and from Tokyo University (where it is believed they are interested in a copy of the Louvain cyclotron, again for medical applications). More way-out was a paper by H.G. Blosser which discussed the feasibility of a 'kaon factory' based on a proton machine of energy 2 GeV or above with a beam intensity of 50 μA. This was not a proposal as such but an illustration of how far the cyclotron technique could be pushed. The feasibility study was based on a separated sector (twelve in all) machine which absorbed the recent technical advances in isochronous cyclotron construction.

There were many reports from machines under construction. First operation of the injector stage cyclotron of the Indiana machine was achieved on 18 May of this year and it is now in routine operation with internal beams. The magnets for the main stage are complete and field measurements have begun. At SIN, Zurich, the injector cyclotron magnet has been assembled and trim coils are in place. Many of the main ring components have been commissioned and the present scheduled date for beam tests in the main ring is near the end of 1973. Close on their heels comes the TRIUMF project where assembly of the magnet is now complete. The huge vacuum tank is also complete and has been successfully leak-tested. R.f. power tests are progressing well and first beam date is now given as early 1974.

The 800 MeV linear accelerator LAMPF at Los Alamos was discussed at the Cyclotron Conference since it feeds the same sort of research programme as the high energy cyclotrons (qualifying, like SIN and TRIUMF, as a 'meson factory'). First operation at peak energy of 800 MeV took place on 9 June. Work is now concentrated on mastering the machine behaviour. Accelerated beam intensities are being kept very low compared with the design value of 1 mA average (with a 6 % duty cycle). A few minutes of operation at design intensity would give uncomfortably high induced radioactivity levels if the beam was going astray. The start of the experimental programme at the machine is not scheduled for some months yet during which time LAMPF will be tamed.

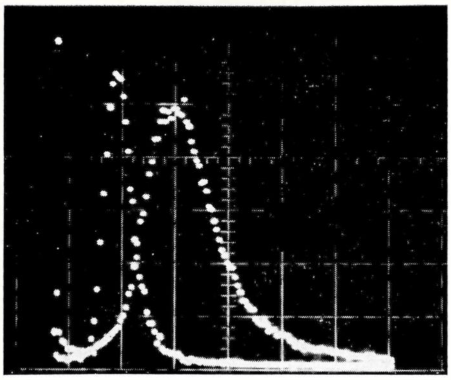
Another machine recently completed is the cyclotron at the Catholic University of Louvain where design and construction were completed within forty months. The machine is now yielding an extracted proton beam of 20 μA. It will provide protons from 10 to 80 MeV and also deuterons, helium 3 and alphas. The Kiev 240 cm isochronous cyclotron is also designed for protons up to 80 MeV and there are plans to accelerate xenon ions injected from a tandem. The Calcutta University cyclotron is about 50 % complete ; it is based on the Berkeley 88 inch machine with some modifications similar to the Texas A and M University cyclotron.

Three synchro-cyclotron conversion programmes were reported. At Dubna, construction of a pion hall and data processing room are under way. A new beam for medical applications has been added to the planned beam systems. At CERN, most units for the conversion are ready for installation — the go-ahead still awaits successful testing of the rotary condenser. At Columbia, a feature of the conversion is the construction of a sectored magnet. The peak energy will be raised from 385 to about 570 MeV by additional field coils. The magnet is complete and the new sector-focused synchro-cyclotron will probably come into operation at the new energy early next year. To make use of the high intensities which the conversion projects will make available, the extraction efficiency of the machines will have to improve greatly to the 70-90 % level so that induced radioactivity problems will not make it impossible to service the machines.

Some new achievements on cyclotrons already in operation: The machine at Michigan State University has given beam energy resolution reaching Van de Graaff levels — 6×10^{-4} in the extracted beam which could be further refined to 5×10^{-5} after a spectrograph (this is equivalent to 1.5 keV energy spread in a 30 MeV proton beam). At Dubna, heavy ion injection from one cyclotron (310 cm) to another (200 cm) with intermediate stripping has been achieved. Fluxes of 4×10^{10} of Xe^{27} ions per second having 7 MeV kinetic energy per nucleon have been obtained. The TRIUMF test cyclotron has pushed axial injection energy higher than achieved before (up to 300 keV). At Birmingham, the novel axially injected polarized beam system is being improved. At Michigan, W.C. Parkinson has used r.f. electrostatic plates to correct for Dee misalignments ; a similar system is proposed at TRIUMF.

The use of computer control in the operation of cyclotrons is still an area of controversy. At a panel discussion during the Conference there was disagreement as to the use of many small or one large computer and as to the feasibility of optimization of beam quality. Developments in this field have included the incorporation of CAMAC systems at Eindhoven, Julich and TRIUMF and automatic control using beam monitors which is being implemented at Eindhoven.

One theme which came up time and time again in the course of the Conference was that of applications of cyclotrons (other than for nuclear research itself). There were many papers on this theme, for example — proton beams being used as a diagnostic tool and in radiation therapy (Har-



A pulse height distribution demonstrating the use of the transition radiation phenomenon in the identification of charged particles. This particular experiment showed that particle identification is possible even at very low energies (1.4 GeV). Styrofoam was used to provide the many boundaries for the particles to cross and these 'radiators' were used in conjunction with multiwire proportional chambers. The peak on the right is for electrons and the peak on the left for pions.

vard), deuteron beams in cancer treatment (Argonne Cancer Research Hospital), therapy with fast neutrons (Royal Marsden Hospital, London), cyclotrons in materials science (Harwell), etc. Industrial firms such as the Cyclotron Corporation are now manufacturing compact cyclotrons for a variety of uses, mainly in hospitals. It seems certain that the number of cyclotrons dedicated to 'applications' is going to expand considerably.

BROOKHAVEN Transition radiation detectors

A different method of identifying very high energy particles has been under investigation in recent years. It uses the phenomenon known as transition radiation whose existence emerged from the work of V.L. Ginzburg and I.M. Frank in 1946. Transition radiation is the radiation emitted by a charged particle as it crosses the boundary from one medium to another of different refractive index. The phenomenon had remained hidden for so long because the quantity of radiation emitted is very small and special measures have to be taken before the radiated energy is enough to be measured.

The possibility of using the phenomenon became apparent after the work of another Soviet theoretician, G.M. Garibian, who treated the problem more completely and simplified the theory bringing it into usable form by showing what could be expected from relativistic particles — particles travelling with velocities close to that of light. Research in Germany, Japan and UK using high intensity particle beams of comparatively low energy verified the existence of the transition radiation and confirmed also that the emerging radiation is 100 % polarized in the optical region.

At the Yerevan Physics Institute in Armenia, A.I. Alikhanian pursued the possibility of application in identifying particles and did research with cosmic rays and electron beams (see the report of the Dubna Instrumentation Conference in vol. 10, page 275). Alikhanian has now turned to looking for enhancement effects which might come from resonances in crystal structures — thin slices of diamond and mica are being tried.

The reason for trying to master transition radiation so that it can be used in detectors is that a measurement of the radiated intensity is an excellent handle to identify a particle and would have particular advantages at high energies. A favourite identification technique is the Cherenkov counter which, in its DISC form, is proving capable of extension to hundreds of GeV energies (see last issue page 234). The Cherenkov counter is sensitive to the 'beta' of a charged particle (the ratio of the particle velocity to the velocity of light) and hence the technique really has to be pushed hard to differentiate between particles when they are all flying around at very high energies — all close to the velocity of light. Transition radiation intensity is proportional to the 'gamma' of a charged particle and less precise measurements are needed to differentiate between particles of different velocity in the relativistic region. Knowing the energy of a particle, the pinning down of gamma completely identifies the particle.

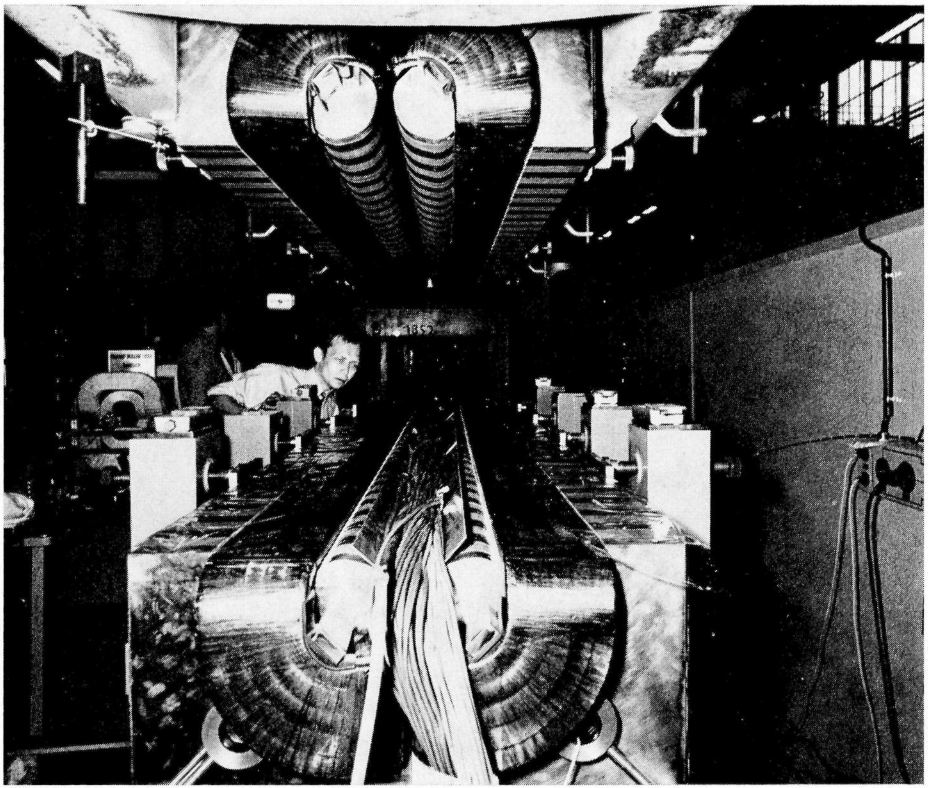
A few years ago research on transition radiation detectors began at Brookhaven under L.C.L. Yuan with the aim of identifying individual particles as is necessary in high energy physics research. The initial experiments were to confirm the predictions of the Garibian theory. This was done with pions and protons from the 33 GeV alternating gradient synchrotron fired through an array of 230 thin metal foils (silver and aluminium were used) stacked together with a small separation between each foil to provide many surfaces at which transition radiation would be produced. The radiation emitted in the optical spectrum was observed by photomultipliers with the foils tilted at an angle of 30° so that the light could emerge. (To measure background effects due to scattering or other sources the foils were temporarily replaced by a solid block of the same material.)

The intensity of the transition radiation in the X-ray region was shown to be directly proportional to the gamma of the particles. This was further confirmed when measurements were extended to much higher gamma values by transporting the detector to the 12 GeV electron synchrotron at Cornell.

A look at the transition radiation in the X-ray region moved to yet another Laboratory for experiments on the 6 GeV electron synchrotron at Cambridge, Massachusetts. Here the foils were set vertically, the charged particles passing through were bent off by a magnetic field and the radiation was observed in the forward direction. Again the gamma dependence was clear and measurements were also made of the way in which the radiation becomes progressively more concentrated in the forward direction as the particle energy goes up.

Back at Brookhaven, further tests showed that even at low energies (around 2 GeV) the transition radiation phenomenon could be used to distinguish pions and protons from electrons. A thirty stage detector is now being built. As the technique comes more and more under control the potential applications become clearer. A proposal to use such a detector in experiments at the CERN SPS is being put forward.

CERN News



CERN 327.8.72

Assembly of the prototype quadrupole for the SPS in August. Field measurements are now under way. The contract for the manufacture of the 216 quadrupoles for the machine will be discussed at the October meeting of the Finance Committee. Manufacture of the bending magnets has already been discussed by the Finance Committee and the final details of contracts are being negotiated with three European firms.

Synchrotron injector injects

Commissioning of the 800 MeV synchrotron injector, or Booster, for the 28 GeV proton synchrotron, which started in May of this year, has continued throughout the summer months (in parallel with the normal programme of the PS). On 24 August it fed protons at 800 MeV to the PS for the first time. We will record the major advances chronologically since our last report (June issue page 197).

In June the Booster had just one of its four superposed rings (Ring 3) in action while waiting for the septum magnets, which send beam from the 50 MeV linac to other levels, to be replaced by the definitive versions. On 16 June, adiabatic trapping was tried and worked beautifully. This is a comparatively new technique (see vol. 10, page 355) in which the r.f. fields creep up on the injected beam (magnetic fields increasing slowly also). Theoretically it is possible for the accelerating fields to get hold of all the injected particles in this way. At this first attempt the remarkably high figure of 94 % trapping efficiency was achieved (and has only rarely been matched since !). A beam of 3×10^{11} protons was accelerated to 800 MeV.

Three days later, tuning of the r.f. feed-back system progressively nudged the accelerated intensity higher until the 10^{12} protons per pulse level was reached. On 21 June, multi-turn injection was tried again and it proved possible to feed 3×10^{12} protons into Ring 3 with no sign that this high intensity (at the low energy of 50 MeV) was causing any space charge effects. This confirmed the multi-turn injection results of earlier in the month when 5×10^{12} was injected into one of the four rings. With an adiabatic trapping efficiency of around 75 %, beams in excess of 10^{12} protons per pulse were being accelerated to 800 MeV.

Then came a month of frustration caused by a series of equipment faults combined with poor performance of the linac. Instability of the linac beam often made it very difficult to make any progress in the commissioning programme (the Booster requiring an injected beam of higher stability than the PS itself). The only important advance in July was the bringing in of Ring 1 when one septum was ready for action. On its first run, 12 July, 90 % trapping efficiency was achieved with only 7 % lost in subsequent acceleration. Two days later ejection was successfully tried from Ring 3. The five ejected bunches were detected at a pick-up station and by a beam transformer in the transfer line to the PS where the protons were halted in a beam dump.

Early in August all the septum magnets were back in action and, on 11 August, beams were injected into all four rings. 17 August saw one of the best runs to date with very stable beams from the linac. This made it possible to do a very careful check on the magnet system in all the rings. The magnet performance proved to be in excellent agreement with the design predictions. Closed orbit distortions were 3 mm peak in the horizontal plane and 4 mm peak in the vertical plane. The Q values in the four transverse planes were equal to within ± 0.004.

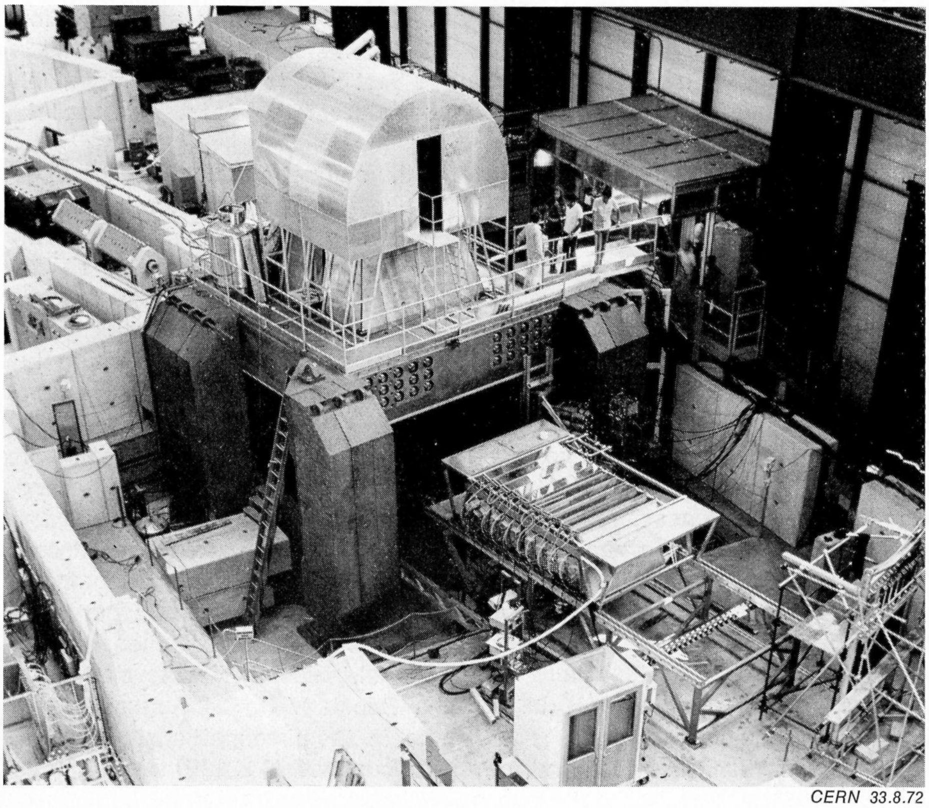
On 21 August, all four rings were accelerating beam to top energy together for the first time. Two days later the highest accelerated intensity at 800 MeV to date was recorded in Ring 3 (1.4×10^{12} protons per pulse which is a little more than half the nominal intensity to achieve 10^{13} from the Booster). On 24 August, Ring 3 was in the limelight again when its five bunches (3×10^{11}) were ejected and transferred to the PS. These protons from the Booster at 800 MeV were observed in the PS for three turns. At the second attempt, 3×10^{11} protons coasted in the PS until (after 7 ms) the rising magnetic field drove them into the vacuum chamber. The injection efficiency was about 97 %.

Omega testing

Since the beginning of June there have been five short runs (three days each) during which beams have been fed to the Omega spectrometer. Three experimental groups were setting up and testing their detectors and the performance of the spectrometer is looking healthy.

To recall briefly the major features of Omega: A superconducting magnet provides a 1.8 T field in a very large aperture (3 m diameter, 2 m between poles and 1.5 m between coils). The aperture contains a detection system which is initially a series of optical spark chambers observed by Plumbicon cameras. A large 'dedicated' computer system, involving PDPs, an EMR 6130 and a CII 10070, receives the data on-line. The spectrometer is a 'universal' detector intended to serve many experiments with essentially the same components. Several experiments can be set up at the same time, the data collection being dictated by different trigger systems.

On 8 June the first run began with beam from the PS taken all the way to the Omega installation in the West Hall. Three of the spark chamber modules were powered and were watched by two Plumbicon cameras. The second run saw all ten spark chamber modules and six Plumbicons in action. The third run brought on the magnet also for part of the time providing a 1.1 T field in the aperture (only one superconducting coil is installed at present — the second coil will be put in place probably in November to achieve the design field). For the last two runs it was all systems go.



Recent view of the Omega spectrometer. The beam-line providing the high energy particles can be seen coming in top left. The large spectrometer magnet itself is now topped by an 'igloo' in which the Plumbicon cameras are operating. Above the igloo, helium transfer lines can just be seen heading for the helium refrigerator which cools the superconducting coils. The ten optical spark chamber modules (100 gaps in all) have been rolled out of the magnet aperture to the right. Notice that they are inclined to the vertical so that the cameras can see into the gaps without involving many mirrors.

CERN 33.8.72

The performance of the various components can be summarized as follows: The long beam-line from the PS is performing well. Positive and negative beams of momentum 8 GeV/c were available at will throughout the runs. The magnet gave no trouble and it looks as if the new force-cooled type of superconducting coil will be a very successful feature of the spectrometer. At present the helium refrigerator is holding one coil down well enough and work is progressing to meet the technical specifications required for operation with two coils.

The optical spark chambers were operated during the runs both to optimize their performance and for data acquisition. The Plumbicons have operated well and the on-line computer system looks in reasonable shape already. Obviously there is a lot of work to be done to improve the computer programs and to get more accurate information on track positions (it is hoped to achieve 0.5 mm in space or better). But overall the quality of the data is looking reasonably good.

Three teams were testing their experimental set-ups during the runs and an example of event reconstruction by the computer for each of the three trigger systems is shown in the photographs.

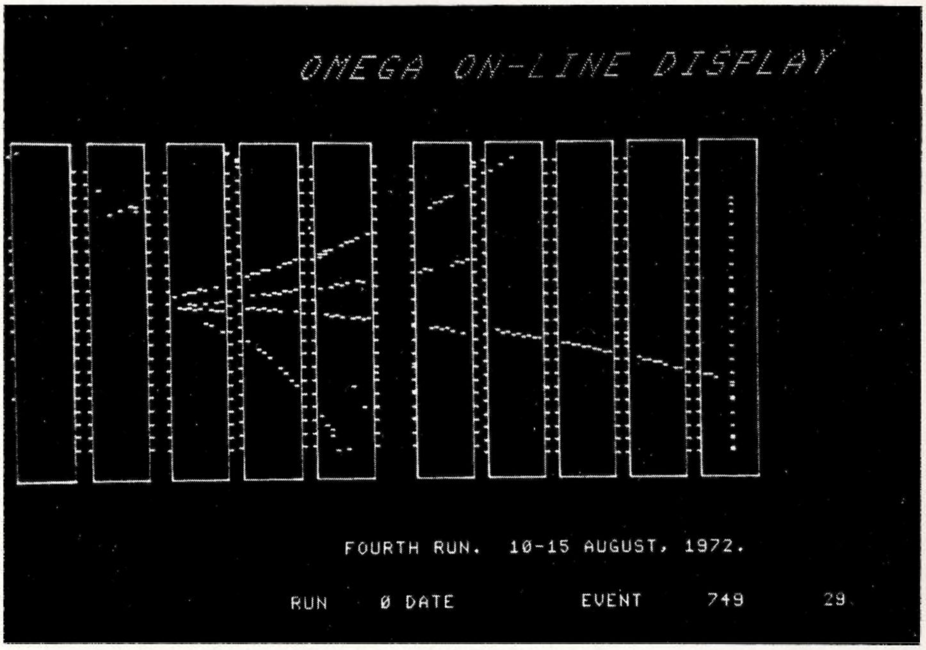
One experiment, to be carried out by a Birmingham, Rutherford, Westfield College collaboration, will study neutral bosons having zero strangeness. The interaction is $\pi^- + p \rightarrow n +$ boson and the detection system is triggered when a neutron is detected. This experiment has almost all its components ready and may be the first to take data in the Autumn. Another experiment will be carried

Computer displays of events recorded by the three experiments which are now setting up in the Omega spectrometer. The experiments have different triggers — the spark chambers are fired to record the events when different interactions occur. The Plumbicon cameras detect the sparks in the chambers, convert the light signals to electronic form and feed them to the on-line computer system. There events can be displayed on a TV screen.

1. Detection of a neutron caused this event to be recorded. Note fiducial marks on the edges of the spark chamber modules.

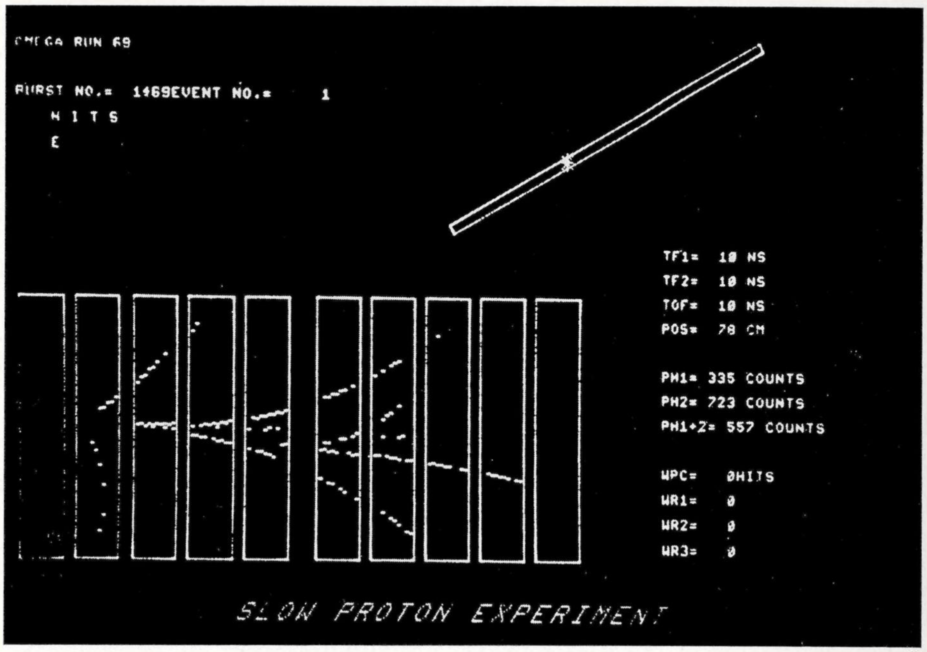
2. A slow proton is the trigger for this experiment. In the photograph a star indicates where it was detected outside the Omega magnet. Thin walled spark chambers help low momentum particles to escape on one side without scattering.

3. A fast forward proton coming from the decay of a lambda is the trigger. Its path outside the magnet is traced between two scintillator arrays.



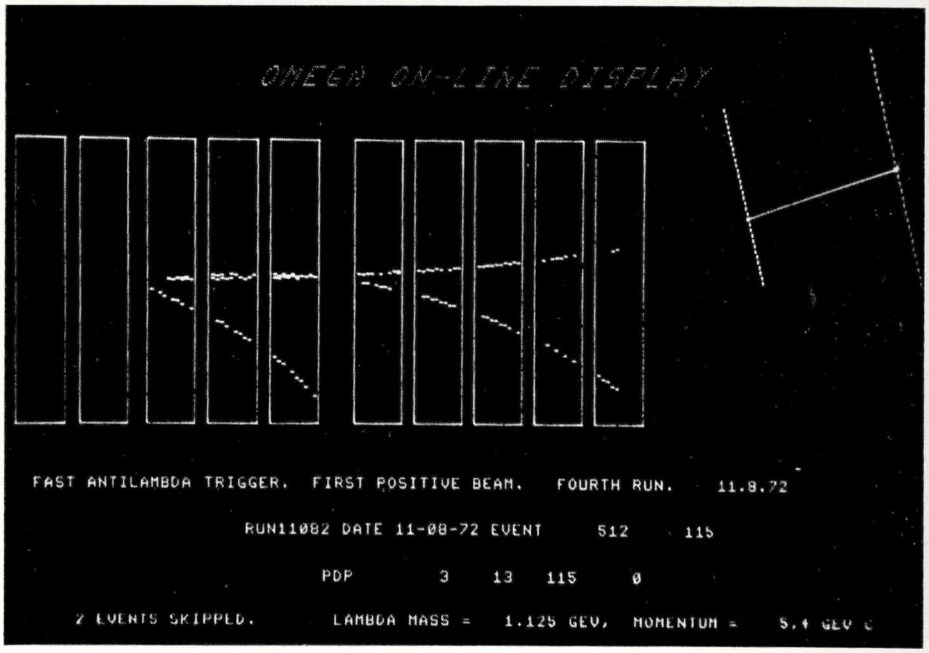
```
OMEGA ON-LINE DISPLAY

FOURTH RUN.  10-15 AUGUST, 1972.

RUN     0 DATE              EVENT      749      29
```

1.



```
CMEGA RUN 69

RURST NO.=  1469EVENT NO.=     1
   H I T S
   E

                                          TF1=  10 NS
                                          TF2=  10 NS
                                          TOF=  10 NS
                                          POS=  78 CM

                                          PH1= 335 COUNTS
                                          PH2= 723 COUNTS
                                          PH1+2= 557 COUNTS

                                          WPC=   0HITS
                                          WR1=   0
                                          WR2=   0
                                          WR3=   0

SLOW PROTON EXPERIMENT
```

2.



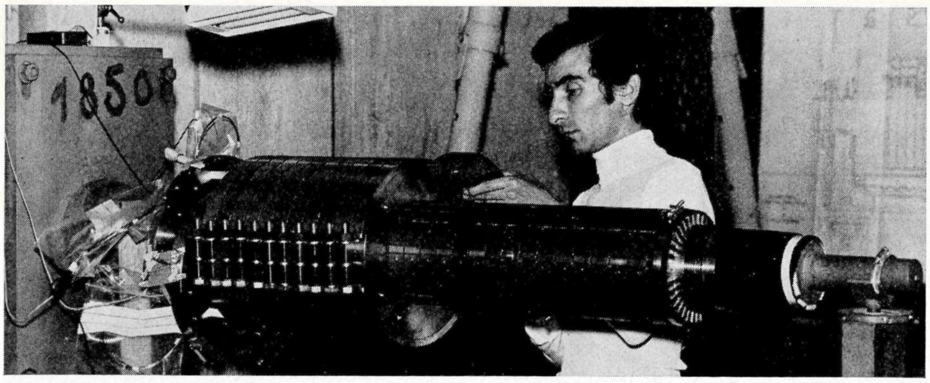
```
OMEGA ON-LINE DISPLAY

FAST ANTILAMBDA TRIGGER.  FIRST POSITIVE BEAM.   FOURTH RUN.   11.8.72

            RUN11082 DATE 11-08-72 EVENT     512     115

                  PDP        3    13   115     0

   2 EVENTS SKIPPED.      LAMBDA MASS =  1.125 GEV,  MOMENTUM =   5.4 GEV C
```

3.

out by a Bari, Bonn, CERN, Daresbury, Liverpool, Milan collaboration. It will study charged bosons from the interaction $\pi^- + p \rightarrow p + X^-$. A slow proton is the trigger for the detection system. All components are not yet in place. A third experiment, to be carried out by a CERN, ETH, Freiburg, Karlsruhe collaboration, will study baryon exchange involving the production of a lambda. The interactions are then of the form $\pi^- + p \rightarrow \Lambda^0 + (K^0$ or $K^+\pi^-$, etc.). The trigger for the detection system is a fast proton in the forward direction coming from the decay of the lambda. A large Cherenkov counter has just been mounted for this experiment and almost all components are now in place. By early next year the Omega spectrometer is likely to be pouring out data.

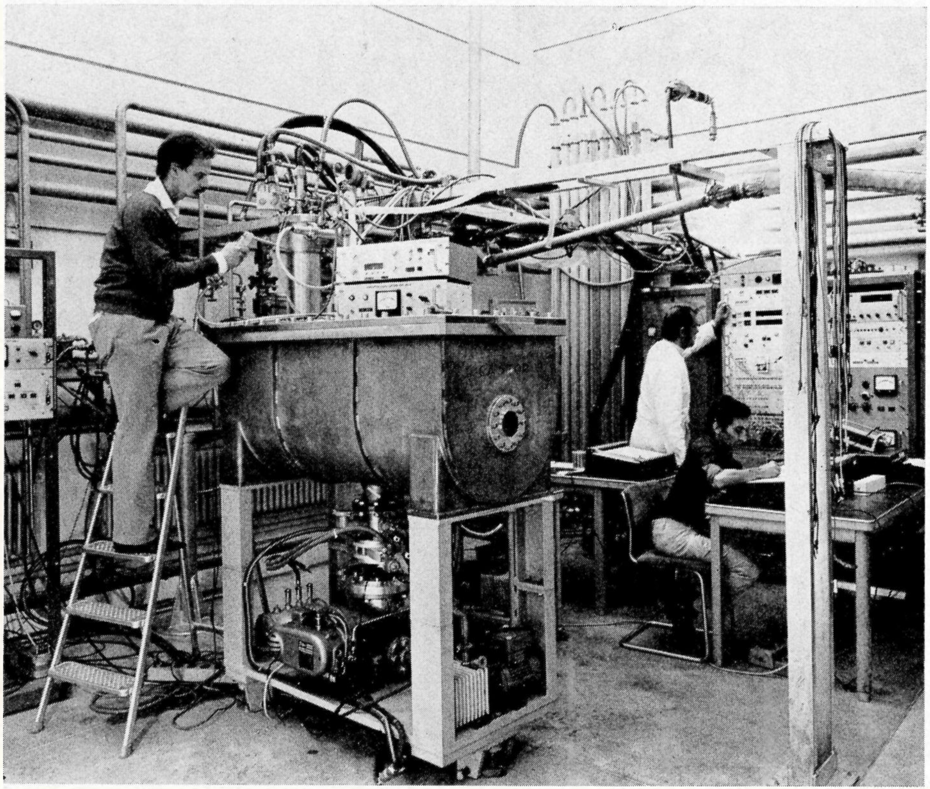
Superconducting quadrupole looking good

Another item in the list of preparations for the day when beams of hundreds of GeV energy become available at CERN was given its first trial run in August. A superconducting quadrupole was constructed in the Synchrotron Injector Division and on 21 August, only a few days after it was first cooled down, it climbed to 90 % of its critical current. This is a very high figure compared with what has been usually achieved in sizable superconducting beam-handling magnets in other Laboratories. The total losses of the



Construction of the prototype superconducting quadrupole nearing completion. At this stage the central stainless steel bore has been surrounded by insulation, the superconductor has been wound on in quadrupole form, the structure to allow helium cooling channels is in place and the surrounding iron is being clamped around.

CERN 350.6.72



Below: The completed superconducting quadrupole in its cryostat during tests. The control system can be seen in the background.

CERN 227.8.72

cryostat together with the helium transfer line, when the magnet is powered, do not exceed 5 W.

The quadrupole is 1 m long with a 10 cm bore (the bore is at room temperature rather than cooled to helium temperature like the magnet itself). It is designed to provide a field gradient of 50 T/m which is several times higher than is available from conventional quadrupoles. The high focusing power will be a great help in handling higher energy beams.

The nominal current of 810 A, corresponding to an overall current density in the winding of about 300 A per mm², was reached on 21 August in the first test. 'Training' has been observed — the current rose progressively after each quench as the magnet was powered — suggesting that the magnet was settling down mechanically. It is hoped to learn more about the origin of the training effect during subsequent tests. Field measurements in the magnet aperture are in excellent agreement with the values expected from computation.

The intrinsically stable superconductor has niobium-titanium filaments of 53 μm diameter, 361 filaments being twisted with a 25 mm pitch in a copper conductor of 1.3×1.8 mm² cross-section. The conductor was provided by IMI, UK. Some idea of the construction techniques can be obtained from the photographs. The construction has been under the direction of A. Asner and D.F. Leroy.

Pop physics

How to give insight into the concepts of particle physics ? How to show to the general public something of the inherent fascination and fundamental importance of a subject which seems so far removed from ordinary affairs and so dependent on advanced mathematics ? This was the problem confronting Dennis Postle, of Tattooist International, the producer of a film which CERN has made as a co-production with the British Broadcasting Corporation, London.

The project started nearly three years ago after Postle had come to Geneva to make a film on CERN for the regular BBC science programme 'Horizon'. This film, like others before it, talked about CERN, about the machines and about the physicists, but the physics remained for the most part in the background, intangible and inaccessible.

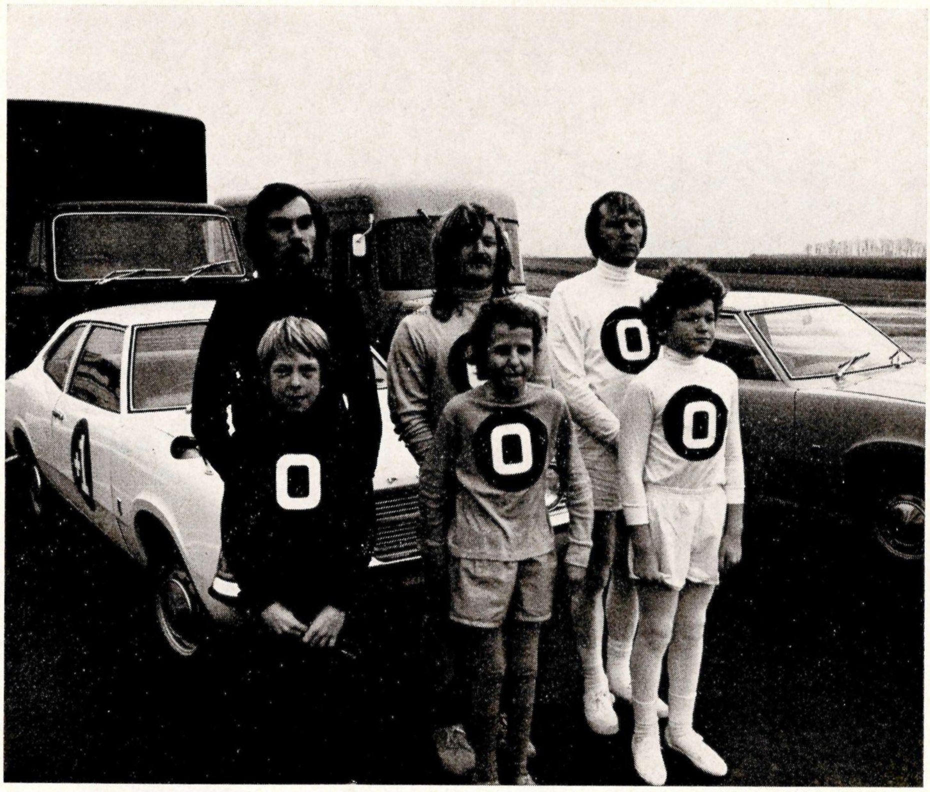
We needed a new style, a new approach and we had to be selective in the phenomena we described. It was pointless to try to cram into forty minutes of film a course in physics which most students find difficult enough when spread over as many months. In any case, few members of the public wish to turn themselves into physicists over-night. But the public is interested in knowing what particle physics has to do with them and how it relates to their day to day affairs. It wants to know what this research reveals.

In the production of the film, CERN has provided the physics know-how and many people have spent a lot of time and effort in trying to explain in simple terms the principal themes of present-day research — none more so than R. Hagedorn. The BBC, in the person of Peter Goodchild, editor of Horizon, has provided expertise on presentation and has been the final arbiter on audience acceptance. Postle as producer has turned the talk into a theme, pictures and text. In the process, compounds have become bubble rafts, atoms concert halls, protons motor cars, pions small boys, interactions dances and quarks a series of moves in a special game of chess. The accelerators, the ISR and the big detectors remain in the back-

Physics on film — shots from the film to be released in November :

Hadrons (vehicles), pions (boys) and kaons (adults) prepare for interactions. The last two carry zero hadronic charge. They are black, grey, white for negative, zero, positive electric charge. Unfortunately from a photograph it is not possible to hear the hypercharge !

Below, Jeremy confronts the quark model on a special chess board.



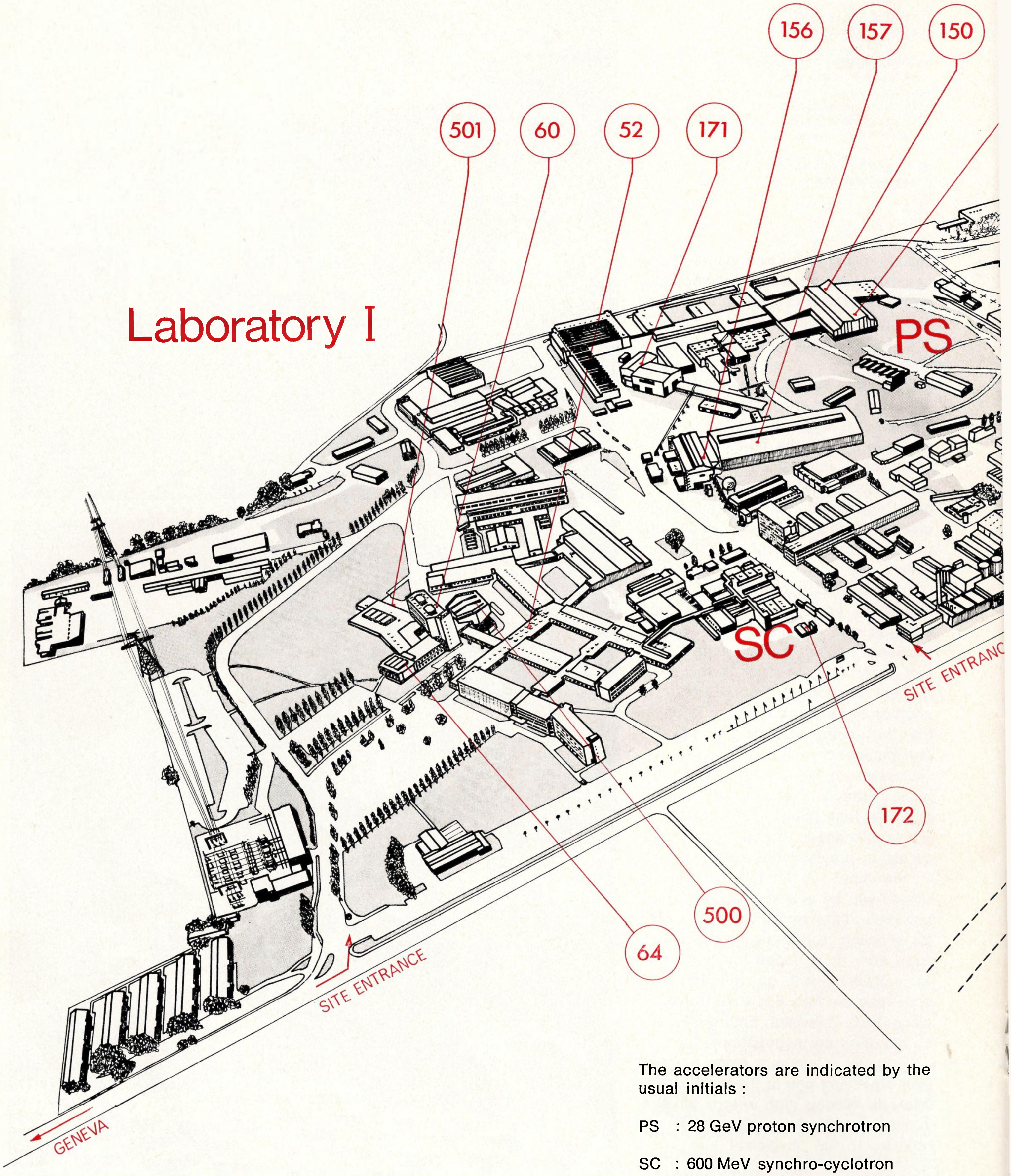
ground giving place to a machine gun and paper target which provided the participants at least, with a lot of fun. The music has been composed and is played by Pete Townshend of 'The Who'.

The film is meant to be entertaining, but it is, nevertheless, a serious attempt to show something of the methods behind the research and to give some impression of the surprising order and harmony which the physics reveals as underlying the disorders and divisions which are usually more apparent in our daily lives.

For the BBC it represented a new approach both in technique and organization. For Tattooist it was a challenge to get to grips with a subject that must be one of the most difficult to portray. For CERN it is another experiment — if not in physics this time, at least in physics communication.

Copies are being produced in English, French, German and Italian and the first public transmission to U.K. audiences in the new TV Horizon series is provisionally scheduled for 2 November. A limited number of copies will be available on loan from the Public Information Office at CERN for showing to non-paying audiences soon after. It is hoped too that other TV networks will be interested in screening the film. For such transmissions, BBC Television Enterprises will be handling the negotiations.

Footnote : Comment from a physicist on seeing one of the many drafts 'We risk making high energy physics crystal clear to the public and totally obscure to the physicist !'



The accelerators are indicated by the usual initials :

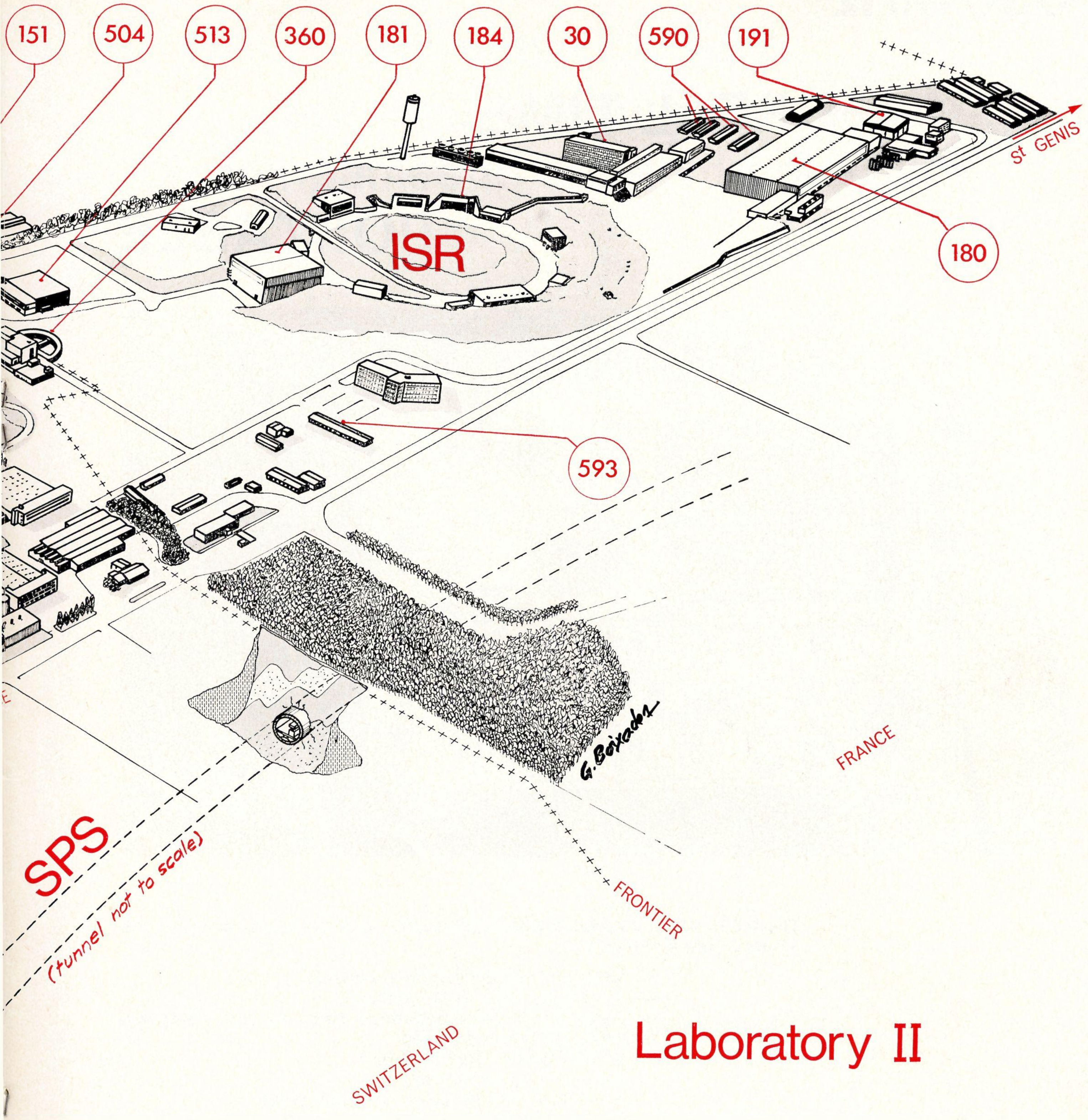
PS : 28 GeV proton synchrotron

SC : 600 MeV synchro-cyclotron

SPS : accelerator being constructed underground to provide energies of several hundred GeV

ISR : intersecting storage rings

Perspective plan of CERN site



Laboratory II

The location of major detectors, etc. is indicated by means of the bulding numbers which are listed here in numerical order :

30	Office block of Intersecting Storage Rings Division
52	Main Library
60	Administration building
64	Council Chamber ; Public Information Office
150	PS South experimental hall
151	PS North experimental hall
156	2 m bubble chamber
157	PS East experimental hall
171	Heavy liquid bubble chamber (Gargamelle)
172	On-line isotope separator (ISOLDE)
180	West experimental hall ; Omega spectrometer
181	Hall I1 experimental area at ISR
184	Hall I4 experimental area at ISR ; Split Field Magnet
191	3.7 m bubble chamber (BEBC)
360	PS synchrotron injector (Booster)
500	Main auditorium ; post office / bank / travel agency
501	Restaurant No. 1
504	Restaurant No. 2
513	Central computer building
590	Barracks providing temporary accommodation for Laboratory II
593	European Southern Observatory offices

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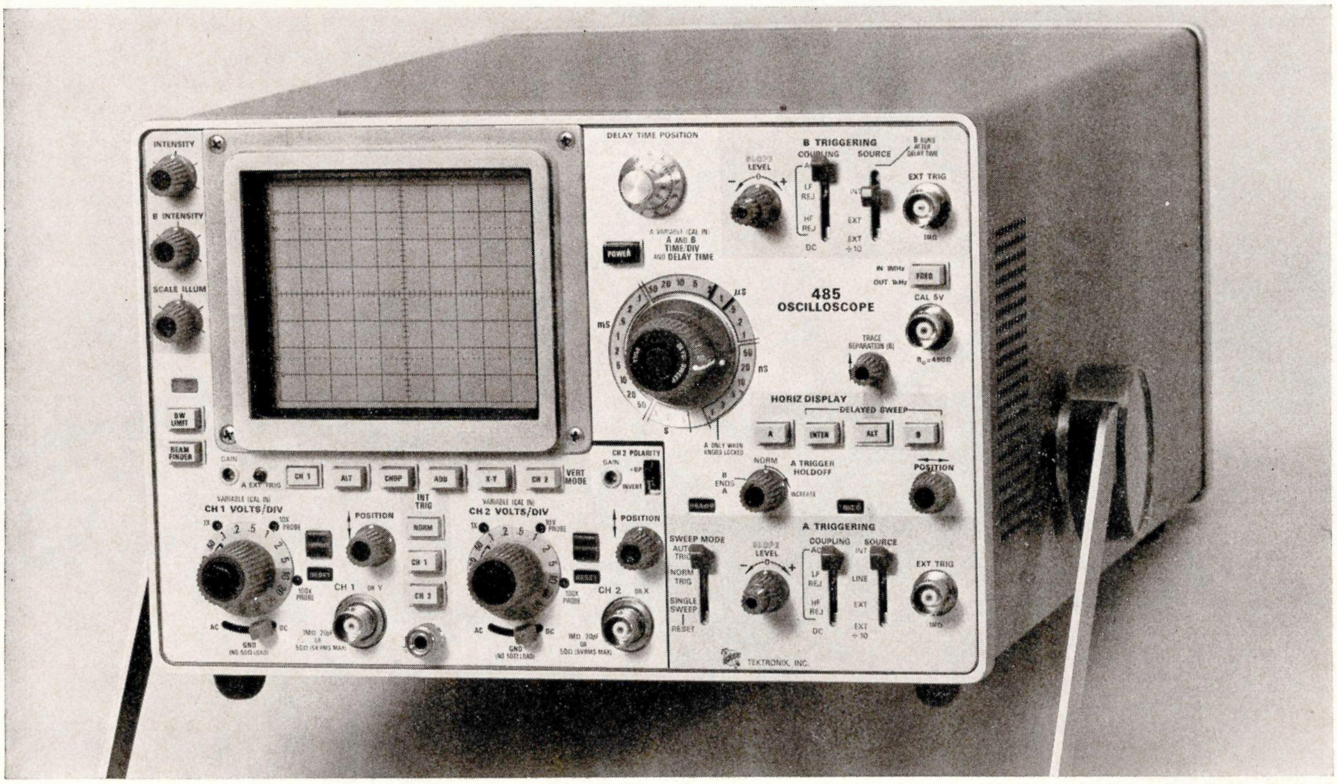

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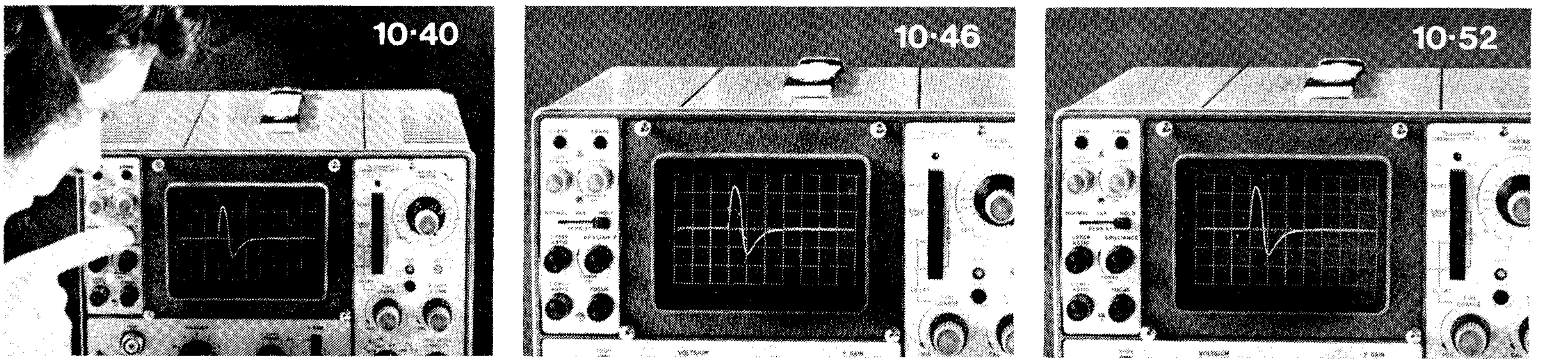
10·40
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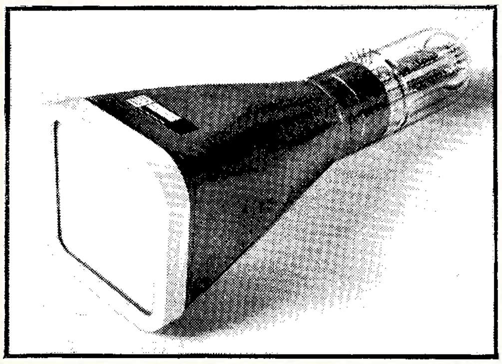
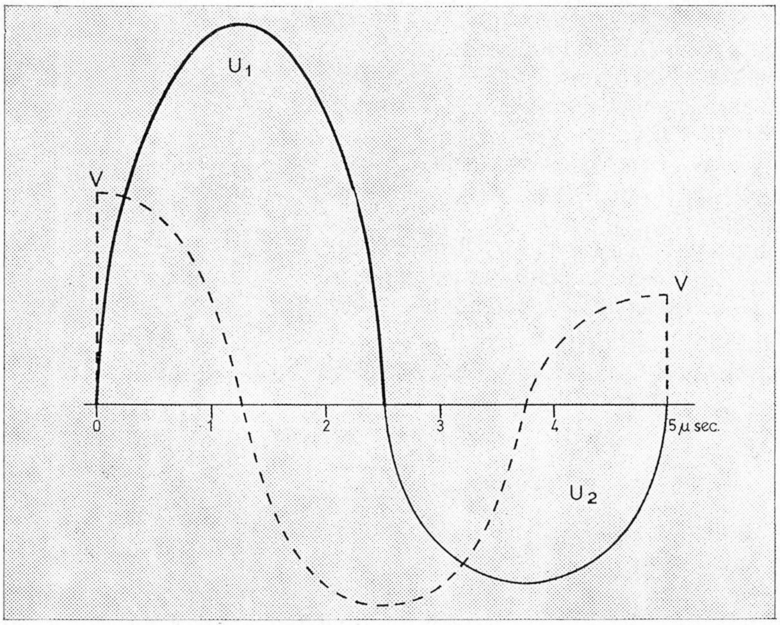
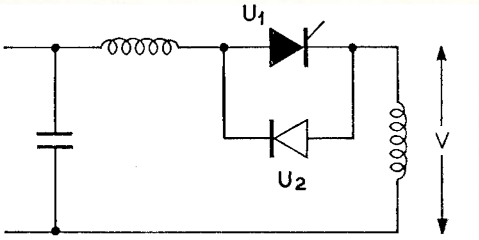
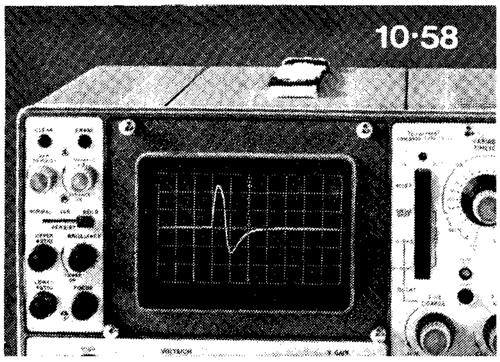
10·52

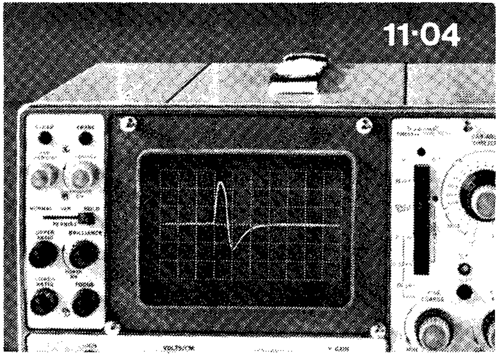


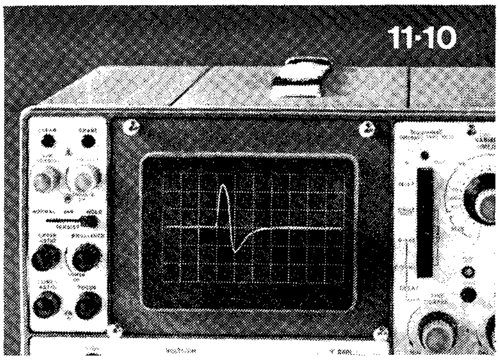

U₁
V
V
0
1
2
3
4
5 μ sec.
U₂


U₁
U₂
V

minutes with their storage tubes.







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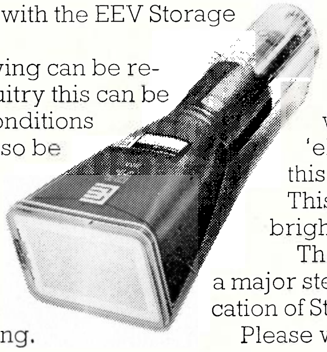

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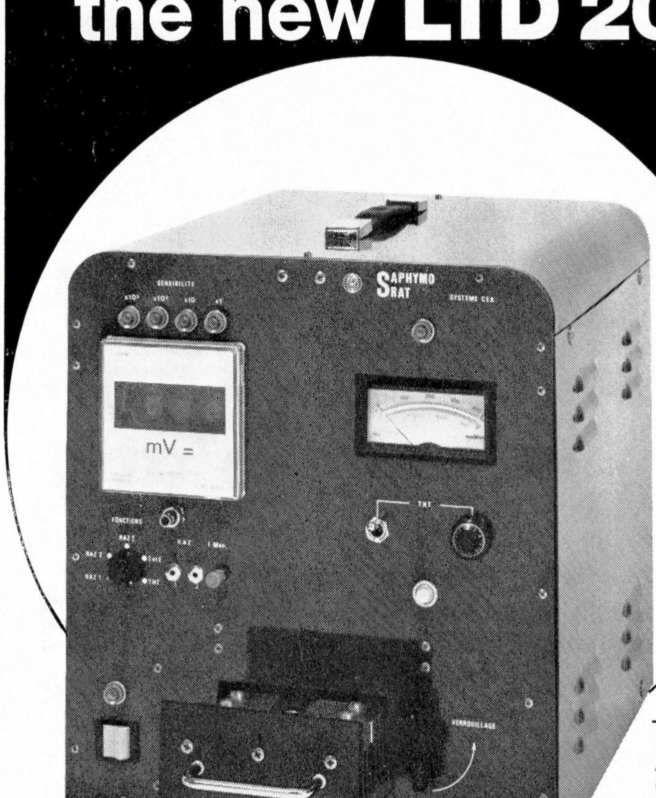

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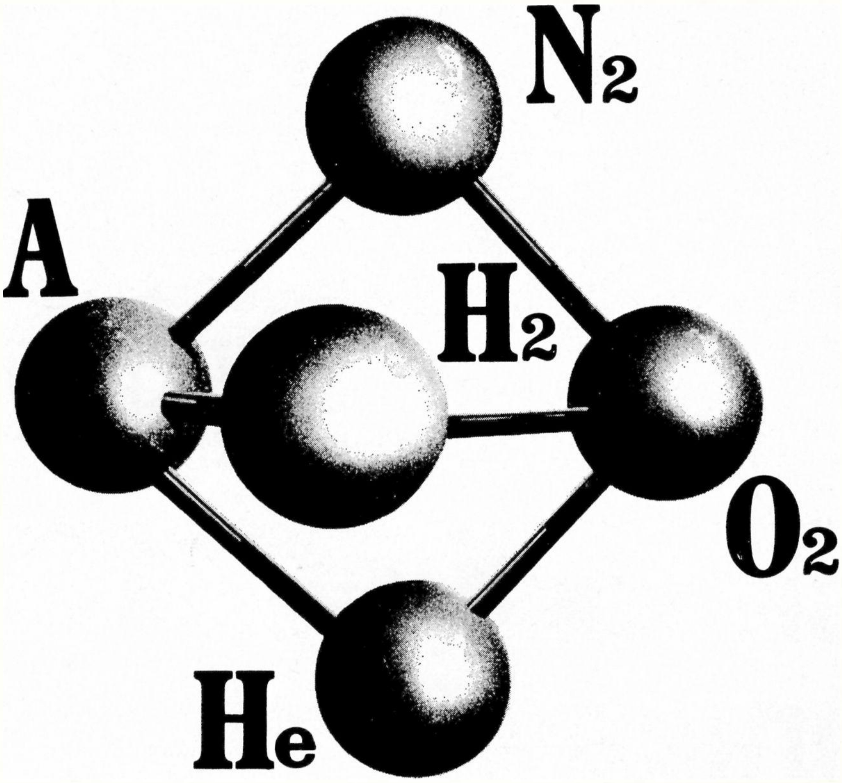
N_2
A
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He

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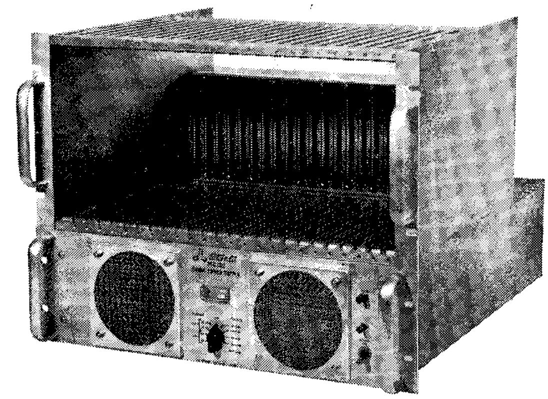

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When equipped with TC024 Terminator Module and CC101 Type A Crate Controller (not shown), crate forms cornerstone of any new CAMAC system. MC102 power supply is forced-air cooled.

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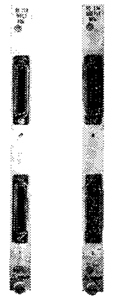

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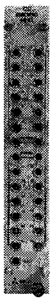

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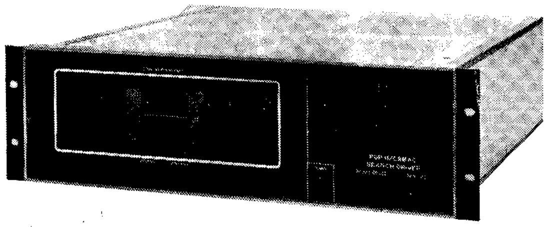

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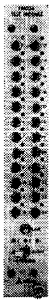

TM024 Branch Driver Test Module

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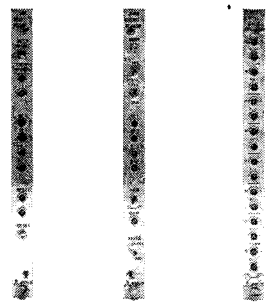

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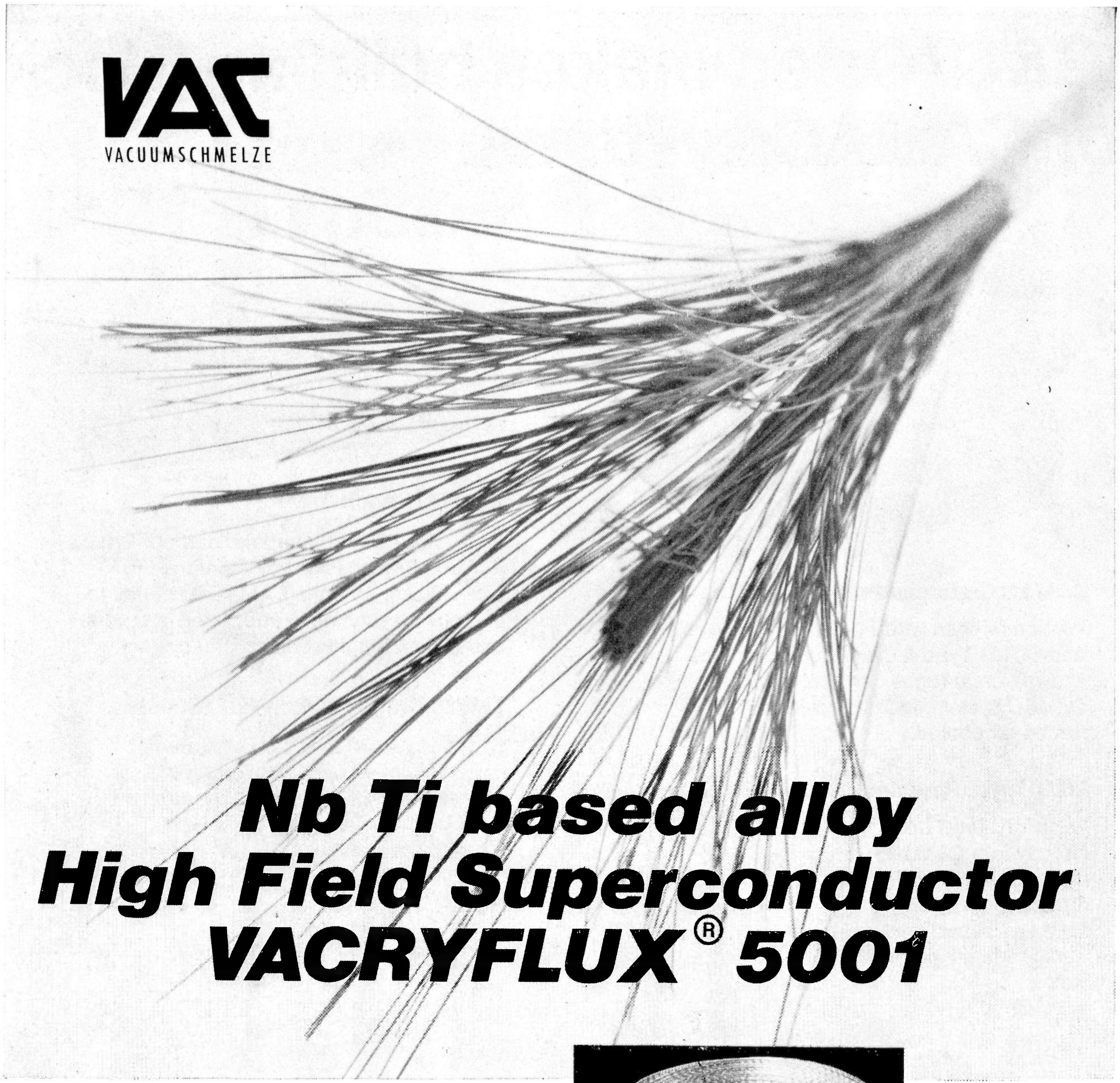

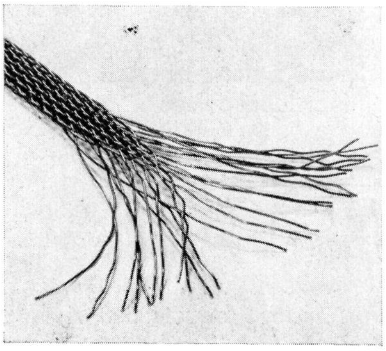

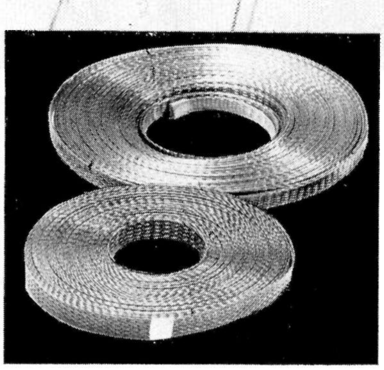

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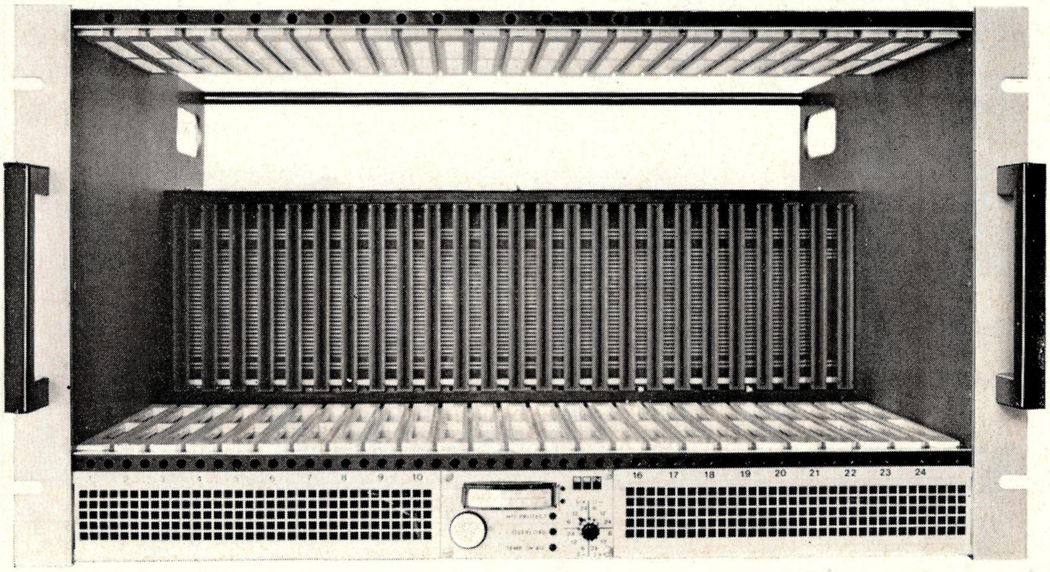

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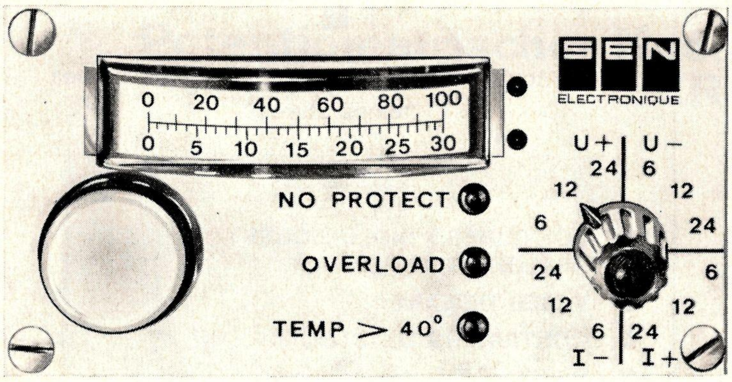

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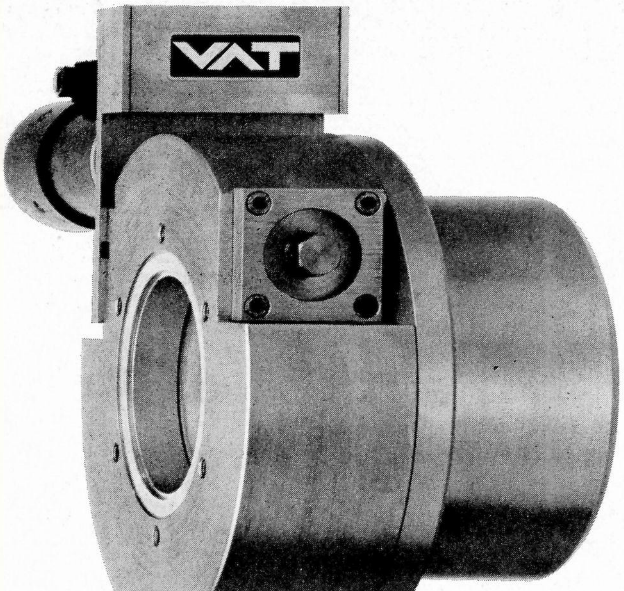
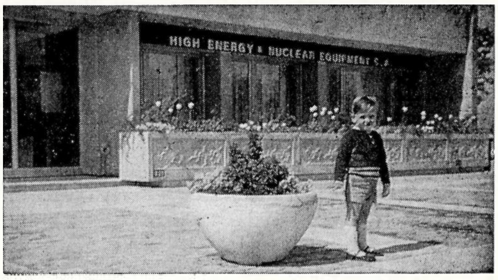

VAT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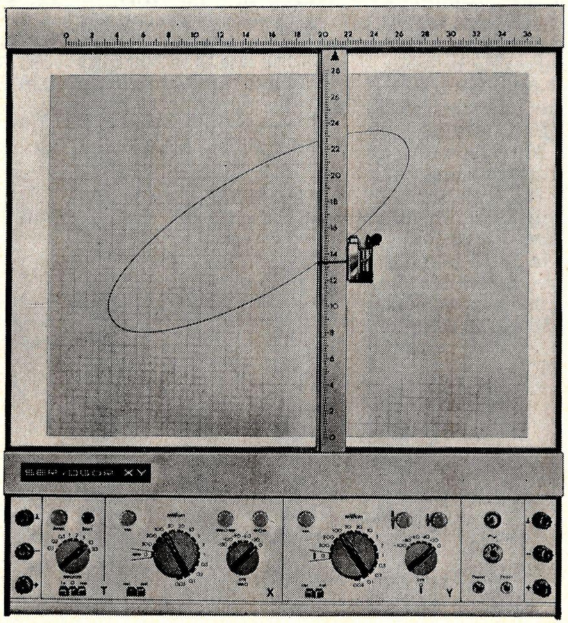
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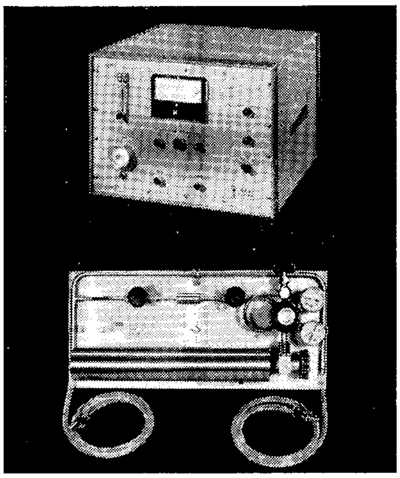

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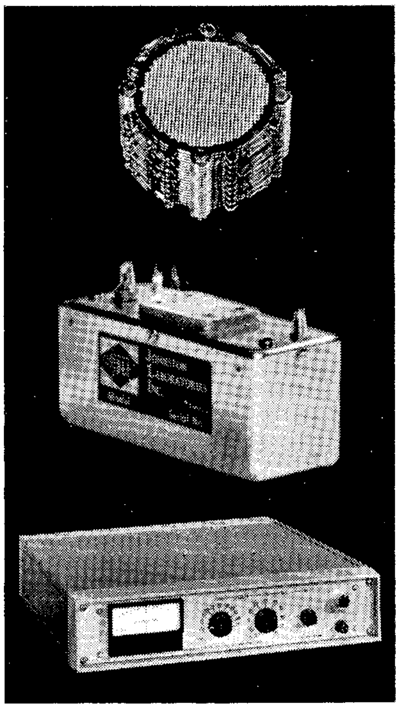

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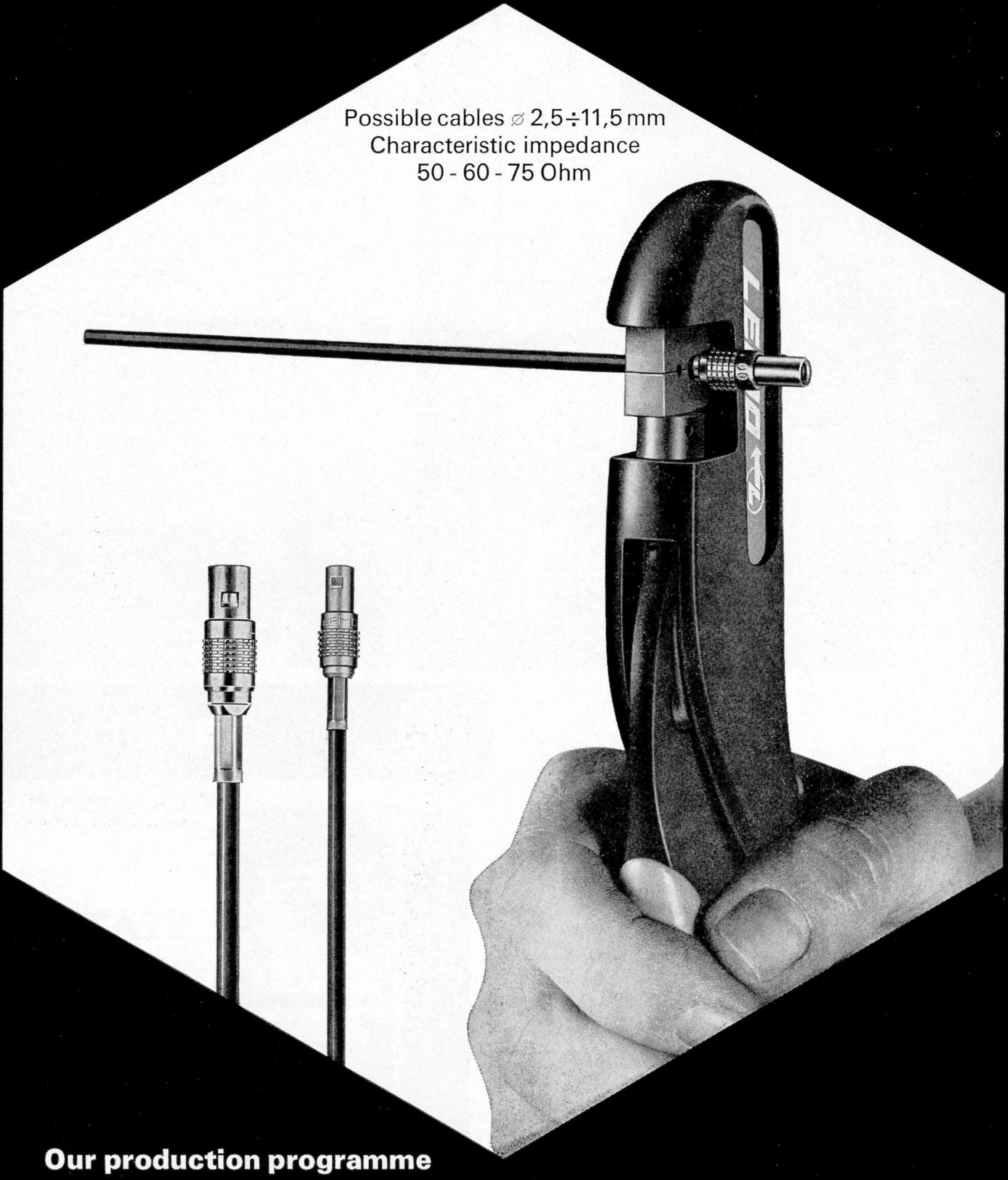

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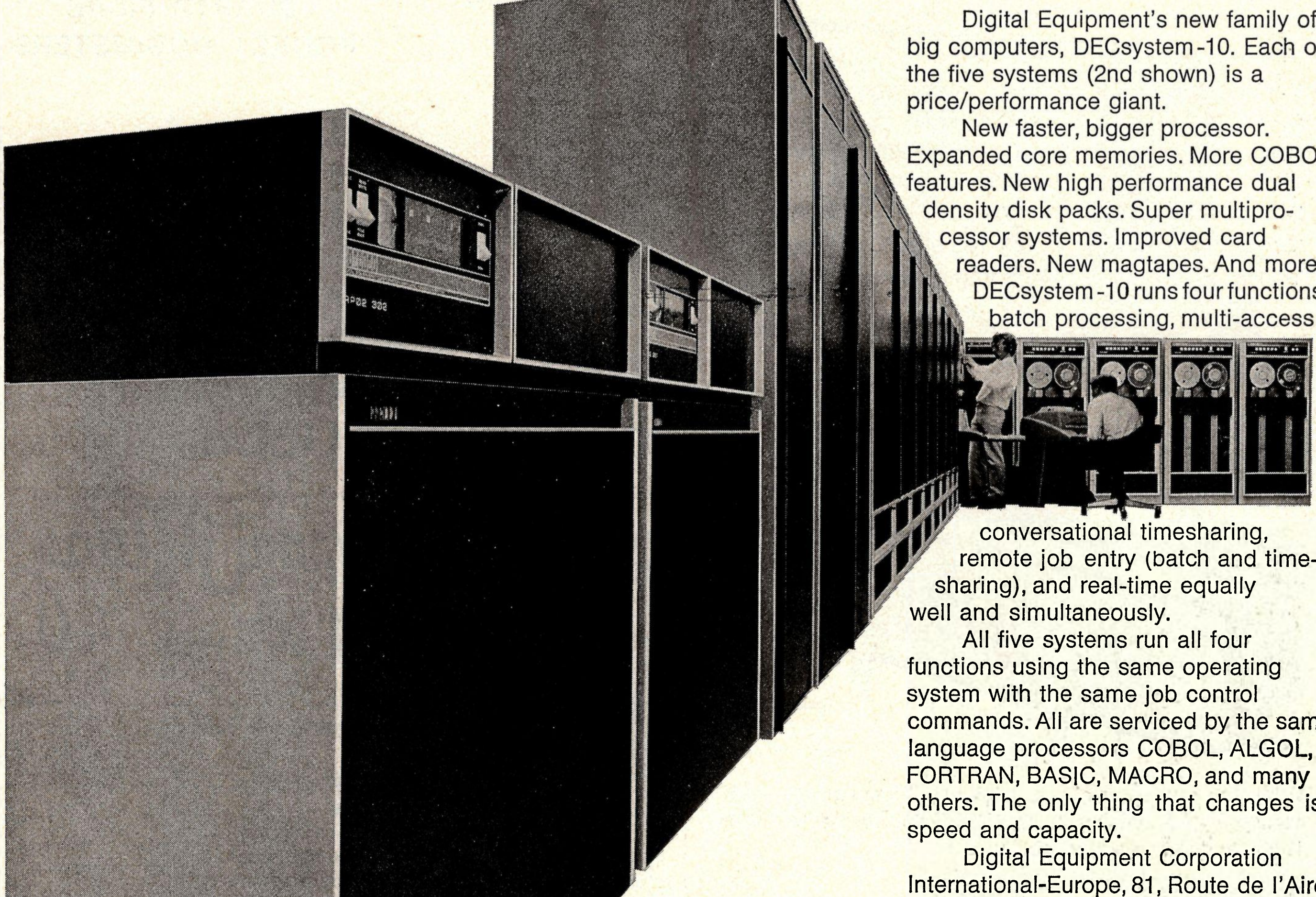

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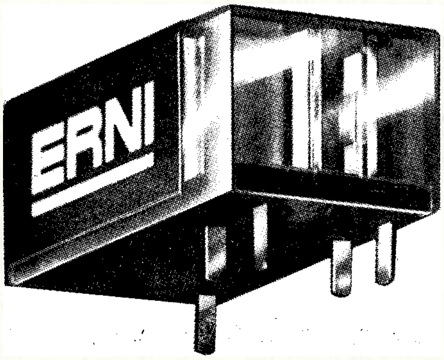
Series REL 14



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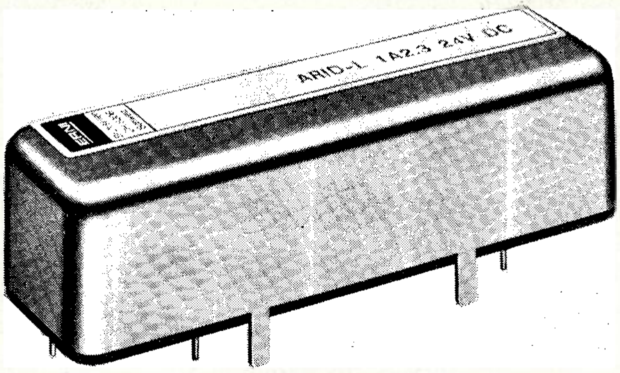
Dimensions :	26 × 12.5 × 10.5 mm
Terminals :	to 1/10" standard grid spacing

Series REL 35



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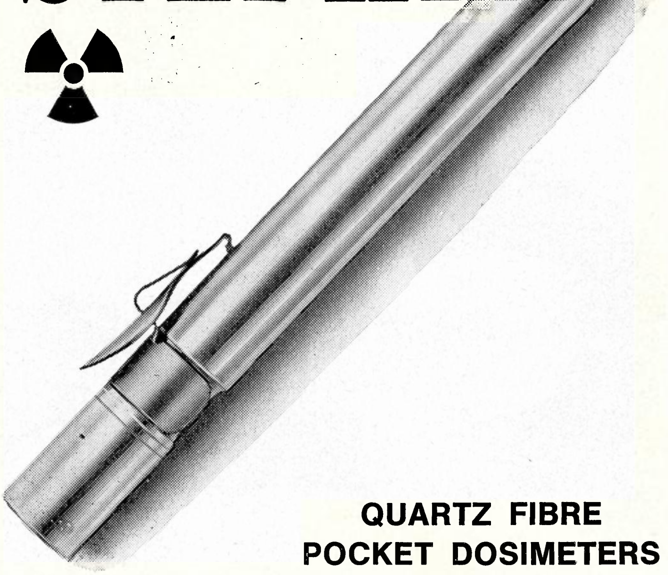

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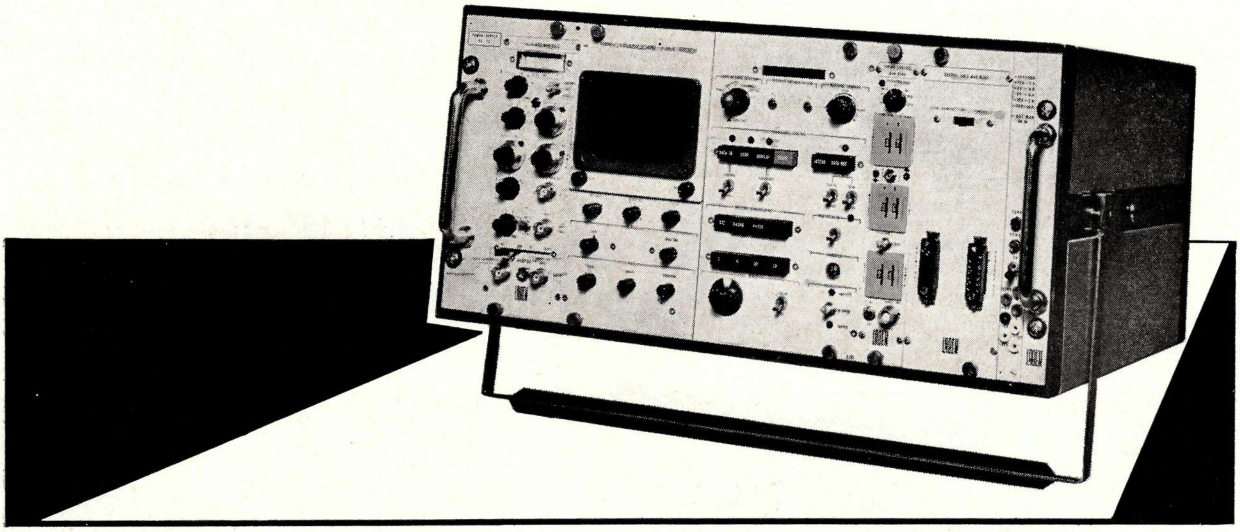

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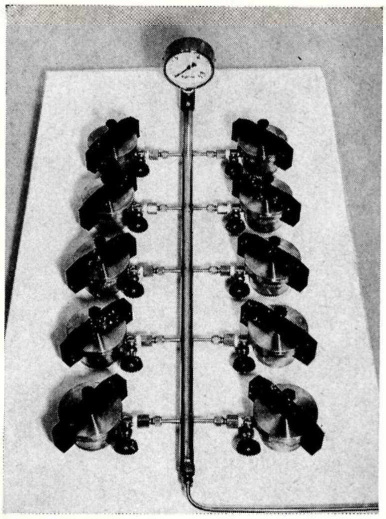

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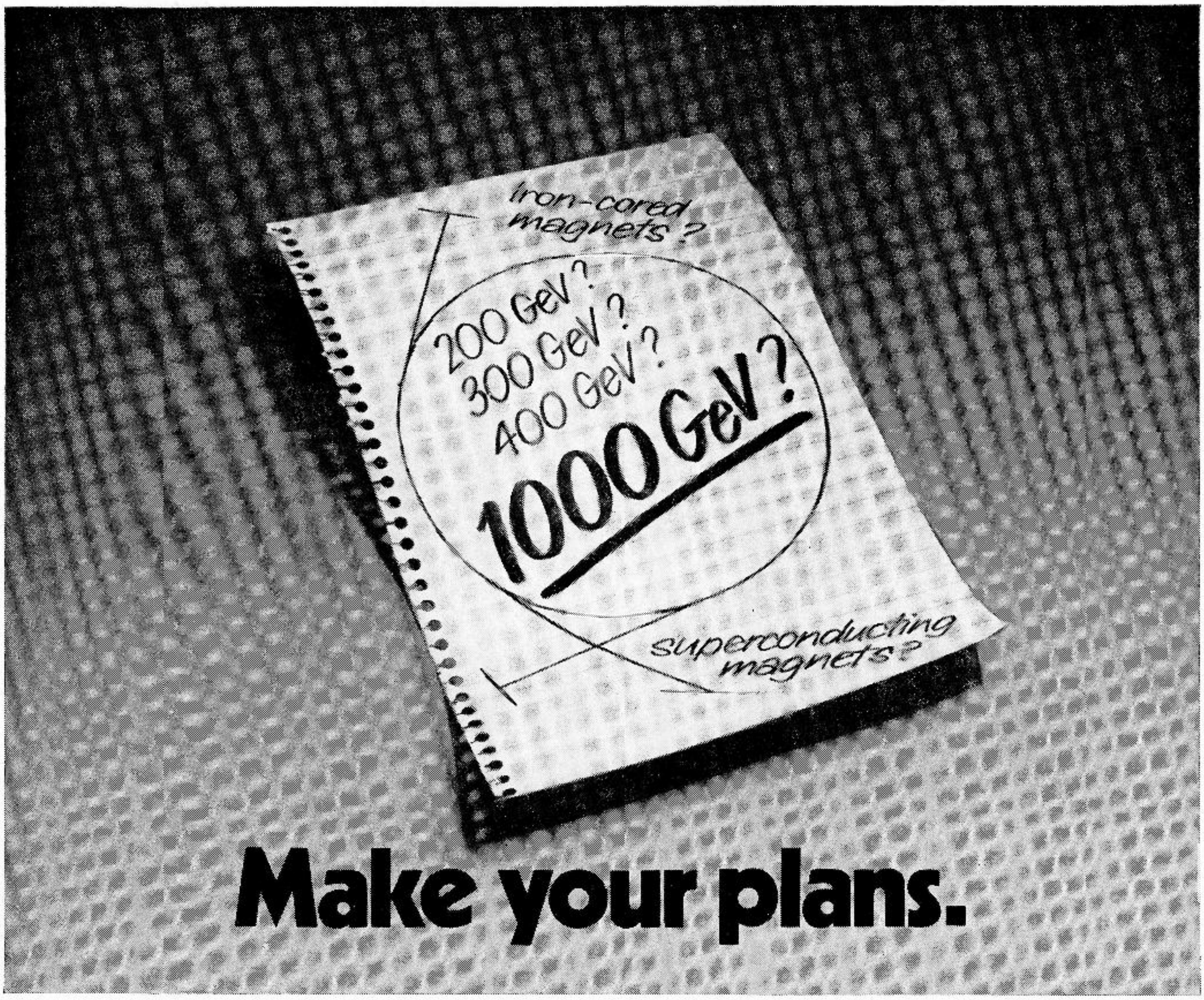
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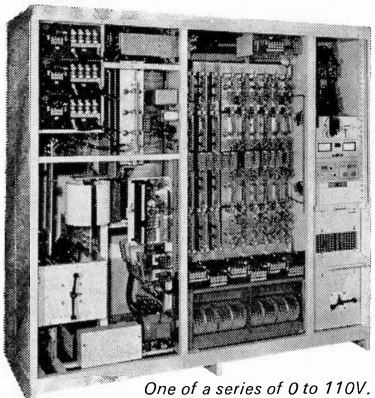

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