Mr Michael ALBROW

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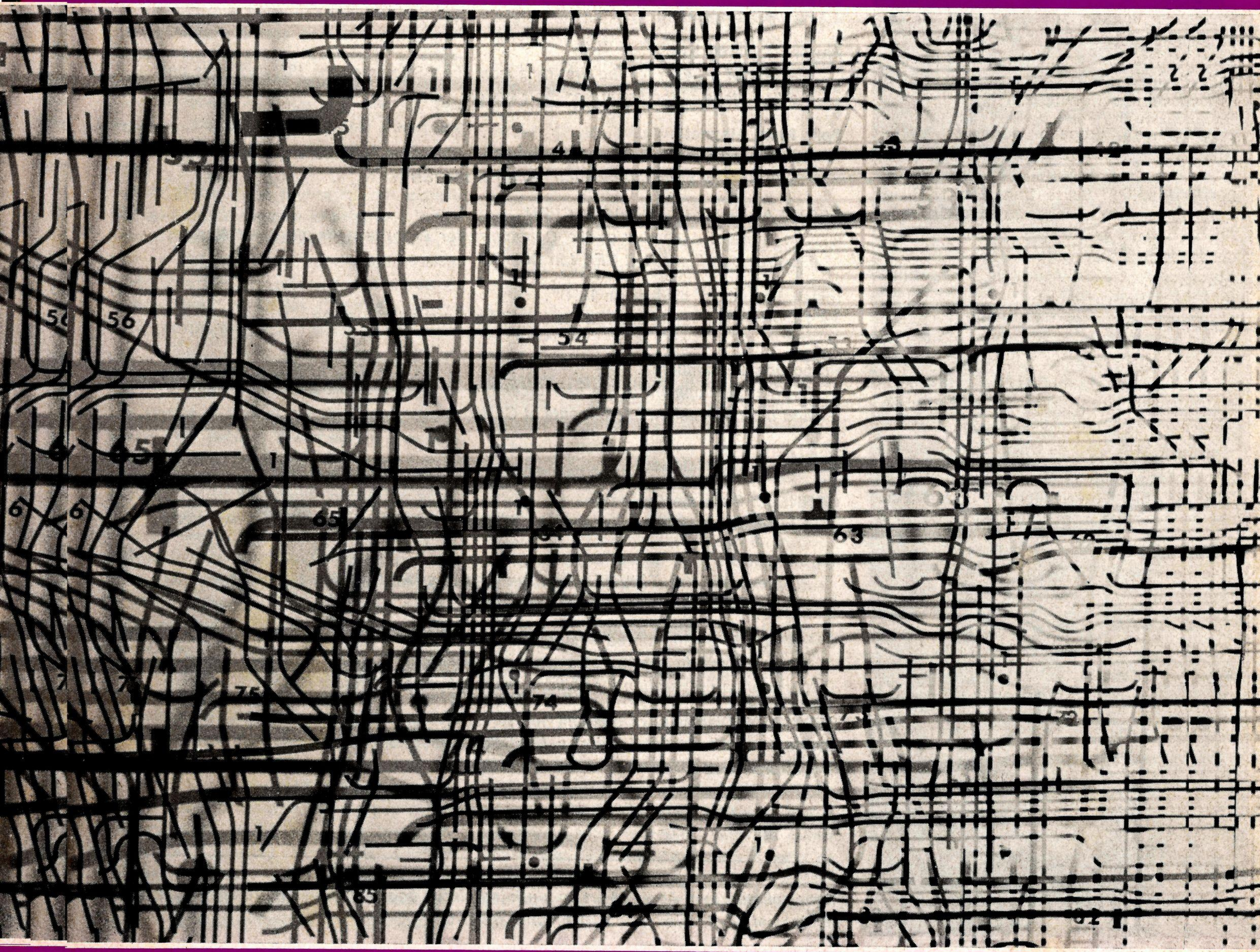

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 1200 physicists draw their research material from CERN.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2850 people and, in addition, there are over 450 Fellows and Visiting Scientists.

Twelve European countries participate in the work of CERN, contributing to the cost of the basic programme, 244.1 million Swiss francs in 1970, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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Cover photograph: Abstract art on a printed circuit board such as proliferate at CERN in millions of electronic circuits. (CERN/PI 378.3.70)

Experimental programme at the CERN proton synchrotron

A record number of experiments, distributed in four Experimental Halls, is set up to use the 28 GeV CERN proton synchrotron. Three bubble chambers (2 metre and 81 centimetre hydrogen chambers and 1.2 metre heavy liquid chamber) are in operation and ten electronics experiments are running (not counting those on test) as well as two nuclear structure experiments.

Eighteen beams are available to feed them — eight secondary beams come from internal targets in the synchrotron ring itself; two fast ejected beams give four secondary beams for bubble chambers; one slow ejected beam gives six secondary beams for electronics and nuclear structure experiments. In addition there is a newcomer which is just being commissioned, as reported later in this issue — the fast ejected beam which will feed protons to the intersecting storage rings.

This article is a review of the experimental programme now in progress. In the space available it cannot be much more than a list of beams and experiments. When appropriate, reference is made to other issues of CERN COURIER where fuller stories have been given.

Available beams

The layout of beams and the experiments which they feed is sketched on the next page.

Beginning with the South Hall: An internal target in straight section 1 provides particles for — t1, a beam of particles of momentum up to 1 GeV/c which is used for testing equipment before it is mounted in its definitive position; q9, a low energy negative pion beam of momentum up to 3.5 GeV/c; m7, an electrostatically separated beam of momentum up to 3.5 GeV/c; d29, the highest energy beam in the South Hall currently giving unseparated negative pions of momentum up to 12 GeV/c (the beam-line could be tuned higher to 16 GeV/c) for two experiments in series; b16, a beam of neutral or charged particles currently being used for test purposes. An internal target in straight section 8 provides particles for — q7, a low energy beam which can be used for pions, kaons or antiprotons with momentum up to 3.5 GeV/c; m8, a separated beam of kaons with momentum up to 5 GeV/c (though it is currently in use without separator).

For the North Hall, an internal target in straight section 6 provides an electrostatically separated beam, k13, of positive or negative kaons and antiprotons from 0.6 to 1.2 GeV/c for the 81 cm hydrogen bubble chamber.

In the East Hall two ejected proton beams emerge — fast ejection, e6, from straight section 58 and slow ejection, e7, from straight section 62. The fast ejected beam can be fired on to different targets to produce any one of three beams of secondary particles to feed the 2 m hydrogen chamber — k8, currently in operation for low momentum positive or negative kaons (1 to 2 GeV/c); m6, which has electrostatic separators for kaons of momentum up to 4.5 GeV/c; u5, a versatile beam which can give the highest energy separated beam at present available in the world (see CERN COURIER vol. 9, page 7). u5 has three radio-frequency separators. When they are in operation it can give kaons in the range 5 to 16 GeV/c or pions of lower momenta and up to 16 GeV/c; used for unseparated beams it can give negative pions up to about 21 GeV/c or protons up to about 25 GeV/c. The slow ejected beam, which can spill protons for as long as 350 ms, is fired onto a target giving five secondary beams — k12, a partially separated (using an absorber) low energy kaon beam which climbs vertically at 15° to clear other beams and is used for nuclear structure experiments; b17, a neutral beam used for the study of long-lived kaons; p4 a high momentum pion beam giving positive or negative pions up to 17.5 GeV/c (radiation problems introduce restraints when the positive pion beam is run); p5, a similar high momentum pion beam; b18, currently in use as a neutral beam for test purposes. The target area which supplies these secondary beams has become very 'hot' and CERN is encountering here radiation problems which are likely to occur more frequently as beam intensities climb still higher. Some fifty metres upstream of the target for secondary beams, a hydrogen target is installed in the slow ejected beam-line and particles emerging from interactions can be studied down s5. s5 is not a beam-line properly so-called but rather an extended double focusing spectrometer.

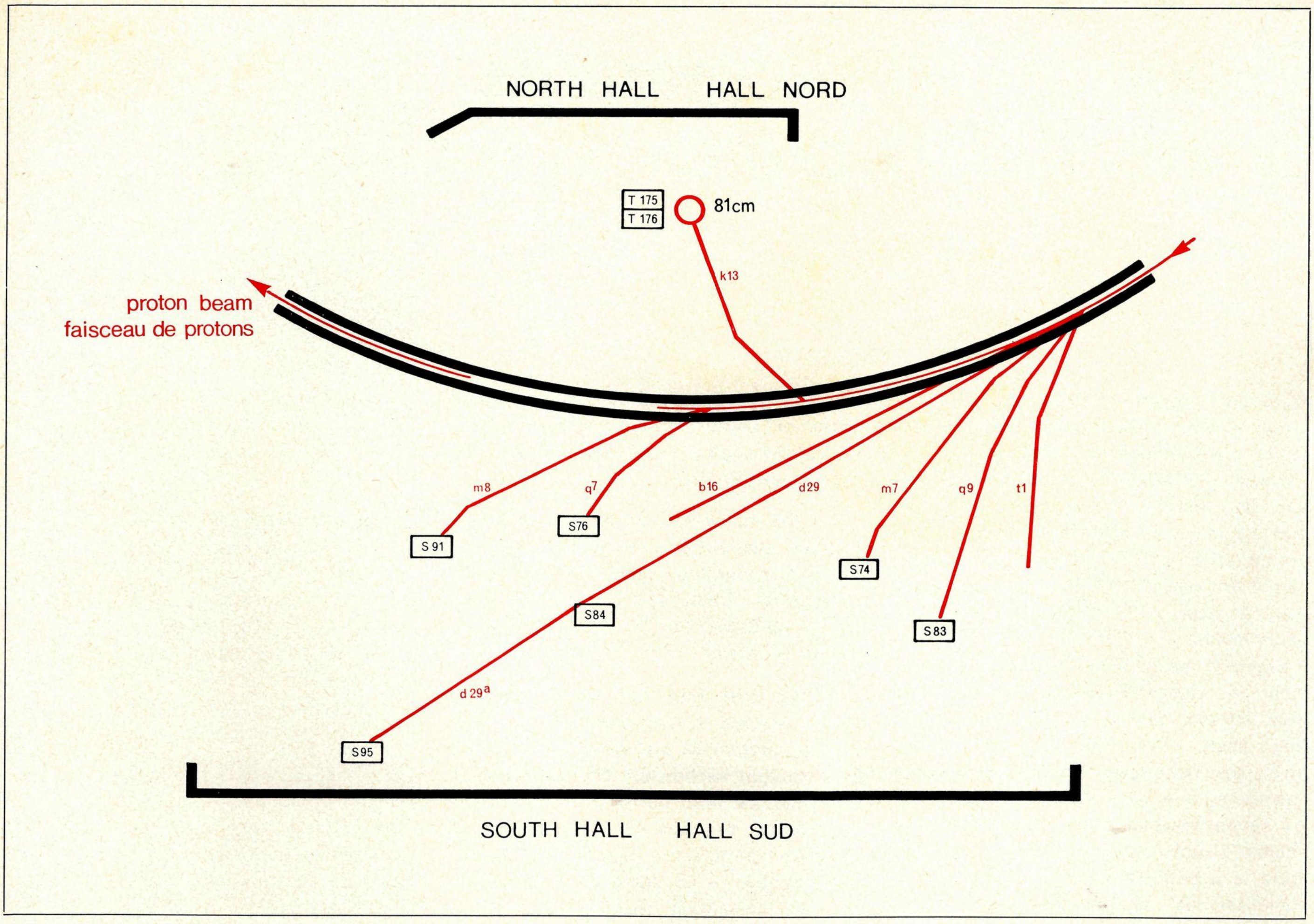
Finally, the South-East Hall is fed by the fast ejected beam, e8, from straight section 74. It is currently being used to produce a separated secondary beam of positive pions of momentum 3.5 GeV/c for the 1.2 m heavy liquid chamber. It will eventually be reconverted to provide a high energy neutrino beam for the new heavy liquid chamber, Gargamelle.

The accelerator schedule is usually organized so that a large number of experiments can receive particles during the same machine cycle, though, obviously, with a smaller number of 'main users'. At the beginning of May, for example, fifteen experiments were receiving particles including two bubble chambers — 1 % of the accelerated beam went onto internal target 1 at 15 GeV and particles could be received by seven 'parasite' experimental teams; 10 % went onto internal target 6 at 18 GeV for the 81 cm chamber; two bunches were ejected twice at 21 GeV during a 150 ms 'flat-top' to the 2 m chamber which was 'double-pulsing' (two expansions of the chamber per accelerator cycle); and the rest of the beam was slow ejected at 24 GeV during a 430 ms flat-top and could feed five experiments as main users and one on test.

The limitations on operation are that slow ejection into the East Hall and internal targeting into the South Hall cannot, at present, be used simultaneously. Also either the 81 cm hydrogen or the 1.2 m heavy liquid are operated in the same cycle with the 2 m hydrogen chamber. There are also some limitations imposed by the d.c. power available for the experiments in South and East Halls.

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 experiments receiving particles from the internal target in straight section 1. The code of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81cm
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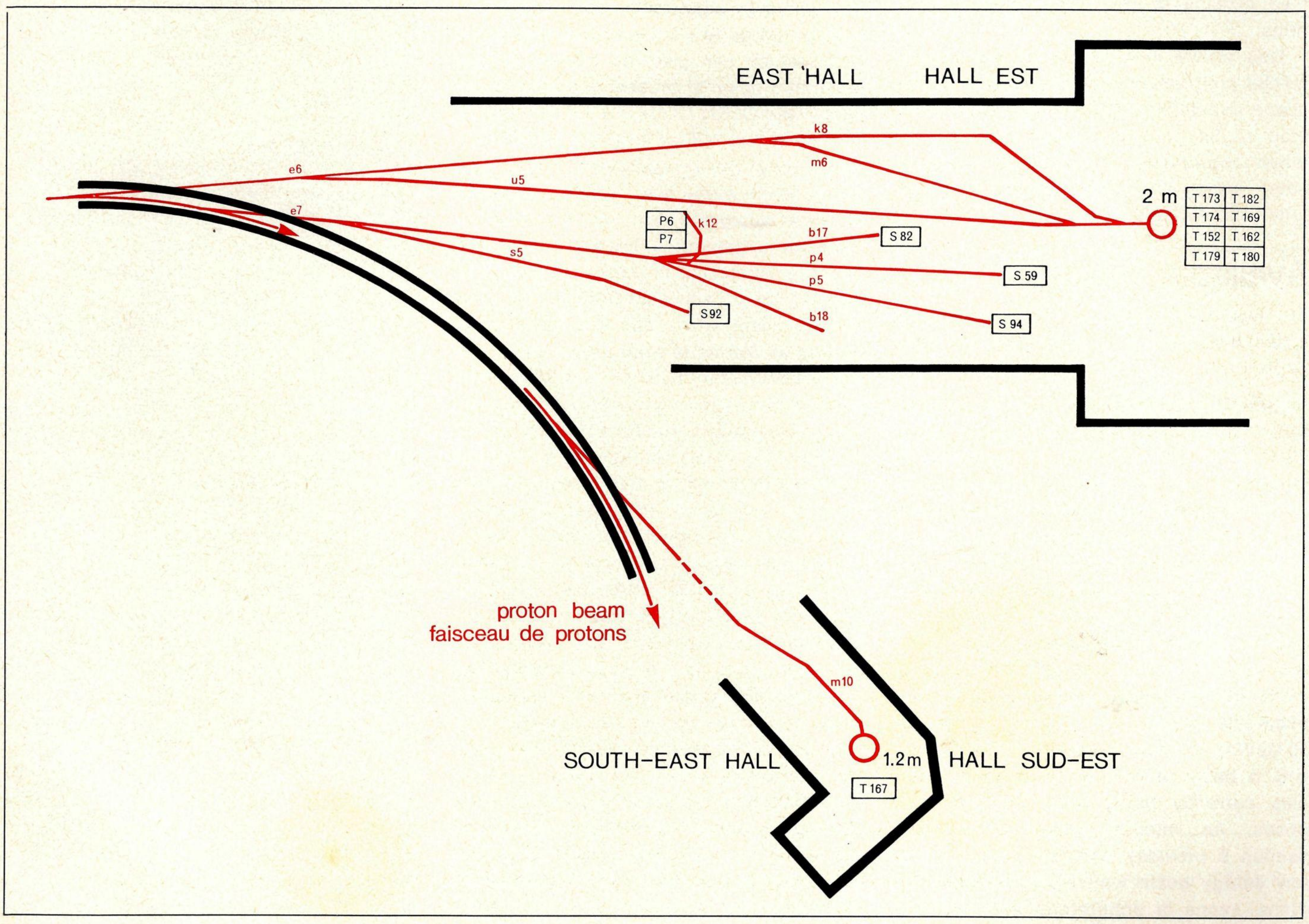
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S 82
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p5
S 59
S92
b18
S 94
proton beam
faisceau de protons
m10
SOUTH-EAST HALL
1.2m
HALL SUD-EST
T 167

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

numbers used to refer to experiments is that assigned when the experiments are first approved for the experimental programme.

S83

A Bologna, CERN team is studying neutral resonances using a neutral missing mass technique. A negative pion beam, q9, is directed onto a hydrogen target and neutral meson resonances can be identified by the missing mass technique observing the emerging neutron

$$\pi + p \rightarrow n + \text{(missing mass)}$$

In some of the measurements, the neutral meson electromagnetic and neutral pion decays are detected using a sandwich of lead (to convert the gammas into electron-positron pairs), of thin spark chambers and of scintillators. The large detectors can be swung around on a turn-table to select optimum positions.

In recent years, the team has studied the properties of neutral mesons such as eta, omega and phi and has achieved some notable results (see vol. 6, page 69; vol. 8, page 245). They are now looking at decays into neutral particles in the low mass region and in particular will attempt to spot the 'splitting' of the A2°. The splitting of the A2⁻ (vol. 10, page 79) has so far been a unique and intriguing observation which is expected to be repeated for the neutral A2.

S74

A CERN, Orsay, Vienna team are carrying out a high precision study of the $\Delta S = \Delta Q$ rule. They use the m7 beam to fire positive kaons at a hydrogen target in order to produce neutral kaons in the interaction

$$K^+ + p \rightarrow K^\circ + N^{*++}$$

The K° production position is measured by observing the proton and positive pion emerging from the N* decay by means of cylindrical wire spark chambers surrounding the target

$$N^{*++} \rightarrow \pi^+ + p$$

The K° decay into three particles including leptons is then measured in a detection system of spark chambers, magnet and Cherenkov counter. An on-line computer (Varian 620) is used.

The $\Delta S = \Delta Q$ rule applies to the weak interaction such as the decay of the neutral kaon. Strongly interacting particles have a property given the name 'strangeness' (and a corresponding strangeness quantum number S) which is normally conserved in particle interactions. In the decay of such a particle, where the weak interaction prevails, the strangeness quantum number can change by ± 1. When this happens the charge quantum number Q of the strongly interacting particle changes in the same way. Thus $\Delta S = \Delta Q$.

For the neutral kaon this has the consequence that these decays are allowed:

$$K^\circ \rightarrow \pi^- + e^+ \text{ (or } \mu^+) + \nu$$
$$\overline{K}^\circ \rightarrow \pi^+ + e^- \text{ (or } \mu^-) + \overline{\nu}$$

and these decays are forbidden:

$$K^\circ \rightarrow \pi^+ + e^- \text{ (or } \mu^-) + \overline{\nu}$$
$$\overline{K}^\circ \rightarrow \pi^- + e^+ \text{ (or } \mu^+) + \nu$$

The experiment checks this to high accuracy and is also going on to study the neutral kaon decay into three pions.

S84

The Pisa, Karlsruhe experiment studying neutral meson resonances at high energies by the missing mass technique was described recently (vol. 10, page 41) and will therefore not be returned to in much detail here. The d29 beam provides pions onto a hydrogen target (in which a technique, developed by Pisa, observing Cherenkov light to identify the interaction point is used) to produce the neutral mesons.

$$\pi^- + p \rightarrow n + \text{(missing mass)}$$

The emerging neutron and the decay products of the meson are observed in counter and optical spark chamber arrays and there is an on-line computer (Telefunken TR86). The experiment will investigate a high mass range continuing the work of a previous CERN, Karlsruhe experiment.

S95

The d29 beam continues through S84 to feed another experiment which, apart from its immediate physics interest, is pioneering a technique which may prove of great importance when much higher energy accelerators come into operation. The experiment is a collaboration of Caen, CERN, ETH, Imperial College and Uppsala, though up to now only a small team has been involved.

The essence of the technique is to observe the recoil target nucleus as well as the ongoing particle. This trick has been done before at the CERN PS using a deuterium target; the present experiment uses a high pressure helium target. The recoil helium nucleus (alpha particle) is measured in surrounding low pressure helium spark chambers and scintillators. (The ETH large aperture magnet may be used for momentum measurement of the outgoing pion if this proves useful at a later stage).

For elastic scattering, knowing the input (beam particle and target nucleus) conditions, it does not matter which outgoing particle is measured to obtain the required information. For inelastic scattering of the 'coherent' type (where the target nucleus remains intact though the beam particle is transformed), again, precise information can be obtained from observing the recoil nucleus. Also, given a nucleus with properties like that of helium, various 'selection rules' prevail which limit the number of possible interactions and simplify the interpretation.

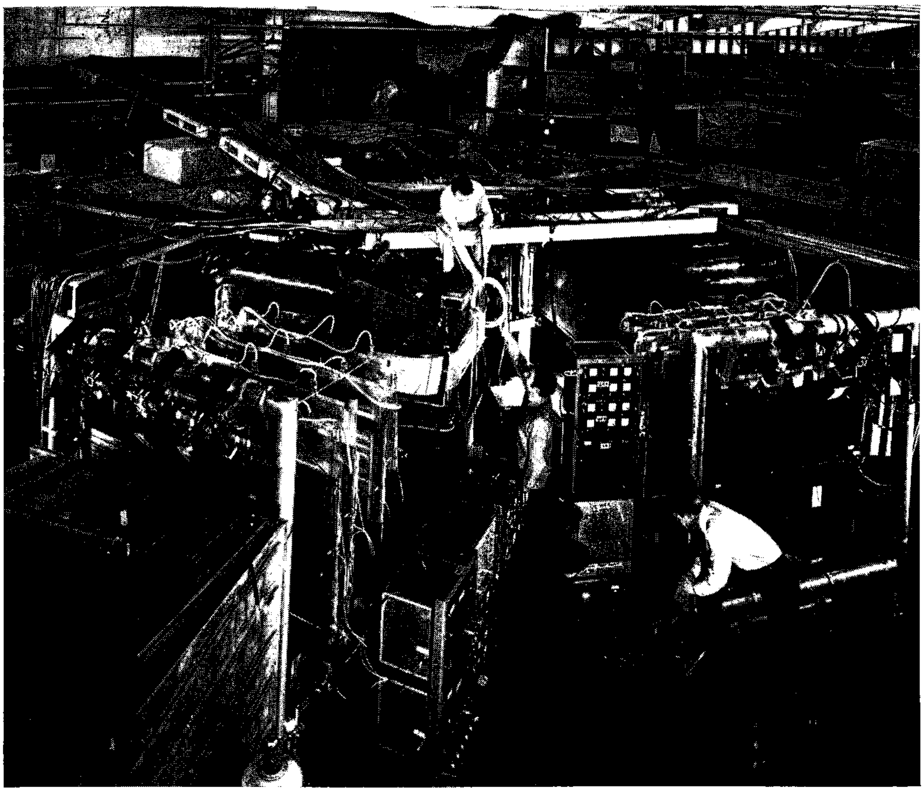
When beams in the hundreds of GeV range become available, measurements on the particles emerging from an interaction could involve large and expensive spectrometer systems. For many experiments however, measurements could concentrate on the recoil nucleus which will be of very much lower momentum and for which 'conventional' detection techniques will be adequate. Hence the extra interest in the scattering experiment on helium which is now under way.

S76

A CERN, FOM (Netherlands) team is carrying out one of the two scattering experiments using a polarized target at present in the programme. It uses the q7 beam to provide positive and negative kaons and antiprotons onto a polarized butanol target where polarizations of over 60 % are now achieved (see vol. 10, page 112).

For positive kaons, the aim is to investigate the K^+p amplitudes for a possible resonance. From the results, it appears that the K^+p system indeed shows either a resonance or a 'threshold' effect in the suspected region of energies; a resonance

Adjustments being made to the detection system of experiment S91 which is to study the scattering of kaons and antiprotons on protons. The experiment is currently taking data at energies up to 5 GeV and will later extend the investigation to higher energies. In the picture can be seen the two arms of the detector, coming out from the target position, each with a large C magnet, wire spark chambers and counters on-line to a computer.



CERN/PI 213.3.70

would lead to difficulties with the well-known three quark model for nucleons. Inelastic scattering is possibly the best way to pin down this question completely. For negative kaons the aim is a systematic study of the K^-p amplitudes in the region of resonances of low mass, with a view to determining their spins and parities.

At the higher energies the pion data seems to be in good agreement with Regge-type models, for kaon data the agreement is only qualitative. The team has measured over 60 angular distributions and polarizations using counters with on-line computer control. The data taking is continuing.

S91

A CERN, Ecole Polytechnique, Orsay, Stockholm team are carrying out the first phase of an experiment on forward and backward scattering of kaons and antiprotons on protons using the m8 beam at energies up to 5 GeV. They will later move onto the d29 beam to extend the measurements to 10 GeV.

The observations of the kaons in the near forward directions are made to look for structures as in proton-proton scattering, where they have been interpreted as being due to the finite size of the particles involved.

The backward measurements, where a great deal of energy is exchanged between the scattering particles, are twofold. For the positive kaon case

$$K^+ + p \rightarrow p + K^+$$

the interpretation of the scattering mechanism as being the exchange of a hyperon from one particle to the other fits the observations. For the negative kaon case

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

there is no single known particle which can be exchanged and the cross-section falls very steeply as the energy goes up. Here one is looking for another exchange mechanism, possibly involving two particles. Such a mechanism is highly desirable in current theories of strong interactions, but no clear evidence for its presence has so far been obtained.

For the antiproton scattering, very little data exists at present. The data from the experiment also contains events due to a number of inelastic processes.

The experiment uses counters, wire spark chambers, two large magnets and an on-line computer (IBM 1800).

We turn now to the East Hall and the experiments drawing their particles from the slow ejected beam.

S82

An Aachen, CERN, Torino team has carried out a series of experiments to study the neutral kaon and have contributed to some important results concerning CP violation in the decay of the long-lived neutral kaon (K°_L). They are now moving on to make a very accurate measurement of the ratio η_{00}/η_{+-} using the b17 beam.

The significance of this ratio has been discussed before (vol. 8, page 242). It relates the decay of long-lived neutral kaons into two neutral pions to that into two charged pions. A possible interpretation of the K° decays into two pions which violate CP is that the K°_L converts first into the short-lived neutral kaon K°_S which then decays into two pions. This is known as the super-weak theory involving a force, about a thousand times weaker than the known weak force, which converts K°_L to K°_S. It results in $\eta_{00}/\eta_{+-} = 1$.

The experimental measurements so far have fallen into two camps about half of them supporting the super-weak theory. The present experiment hopes to resolve the conflict by measuring the ratio to an accuracy of 3 %.

The decays into charged pions will be compared with those into neutral pions under conditions as identical as possible. Doing it as a comparison eliminates many possible systematic errors. A magnetic spectrometer and wire chambers observe the charged pions and are replaced by a total absorption gamma spectrometer (lead glass counters) to observe the neutral pions. The experimental set up should be capable of much higher accuracy than that used in previous investigations which have involved separate measurements of η_{00} and η_{+-}.

S59

This is the second experiment (a collaboration between CERN, Orsay and Pisa) using a polarized proton target. The aim is to measure the polarization parameter P_0 using positive and negative pions, positive and negative kaons, protons and antiprotons. With particles from the p4 beam they can carry out these measurements at higher energies and over a higher momentum transfer range than has ever been investigated before.

The team has been collecting data on polarization for several years and has compiled a great deal of information. They can study the role of the spin of the target proton in high momentum elastic scattering in a systematic way.

The experiment uses a transversely polarized target of the butanol type where polarizations of over 60 % are achieved. There are counter hodoscopes and an on-line computer (IBM 360-44).

S94

A CERN, Munich experiment has just begun in the p5 beam carrying out a very detailed study of bosons. With a negative pion beam onto a hydrogen target the detection system will record the interactions:

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

The pion beam is set at high momentum and measuring the emerging pions or kaons (distinguished by a Cherenkov counter) surveys the boson spectrum up to 2.5 GeV.

Bosons such as ϱ°, f°, g°, ... will be identified through their decays such as

$$\varrho^\circ \rightarrow \pi^+ + \pi^-$$
$$f^\circ \rightarrow K^+ + K^-$$

Many properties of these particles have still to be found and the high statistics of the experiment should help to pin-point some of them. To take just one example, the f° which belongs to the same SU3 octet as the A2°, may be 'split' like the A2 — the high mass resolution in the experiment will detect any such split.

The detection system consists of scintillators, spark chambers, a large aperture magnet and a PDP9 on-line computer. The spark chambers are wire chambers with magnetostrictive readout. Tests have been carried out on one of area 330×90 cm^2 and nine of area 50×50 cm^2. They have been shown to have an efficiency of 98 % for the track triggering the chambers (with no significant difference between one and two tracks) and a measuring accuracy of 0.25 mm in the small chambers.

S92

A CERN team is carrying out a survey of proton-proton interactions at high energies. Using the e7 slow ejected beam directly onto a hydrogen target the survey will extent to 24 GeV, and to large values of the 'four momentum transfer'.

The experiment uses a fixed double focusing spectrometer about 60 m long. Two movable septum magnets close to the target, together with a fixed magnet, can be set to select particles emerging from the target over an angular range from 12 mrad to 140 mrad. The spectrometer carries out momentum analysis bringing the particles to a focus where they are detected by counters. The whole system is controlled by a Hewlett Packard 2116A computer on-line and it is possible to select the momentum and angle of interest by simply typing the figures into the computer. The resulting data consists of momentum spectra at many angles over the energy range available.

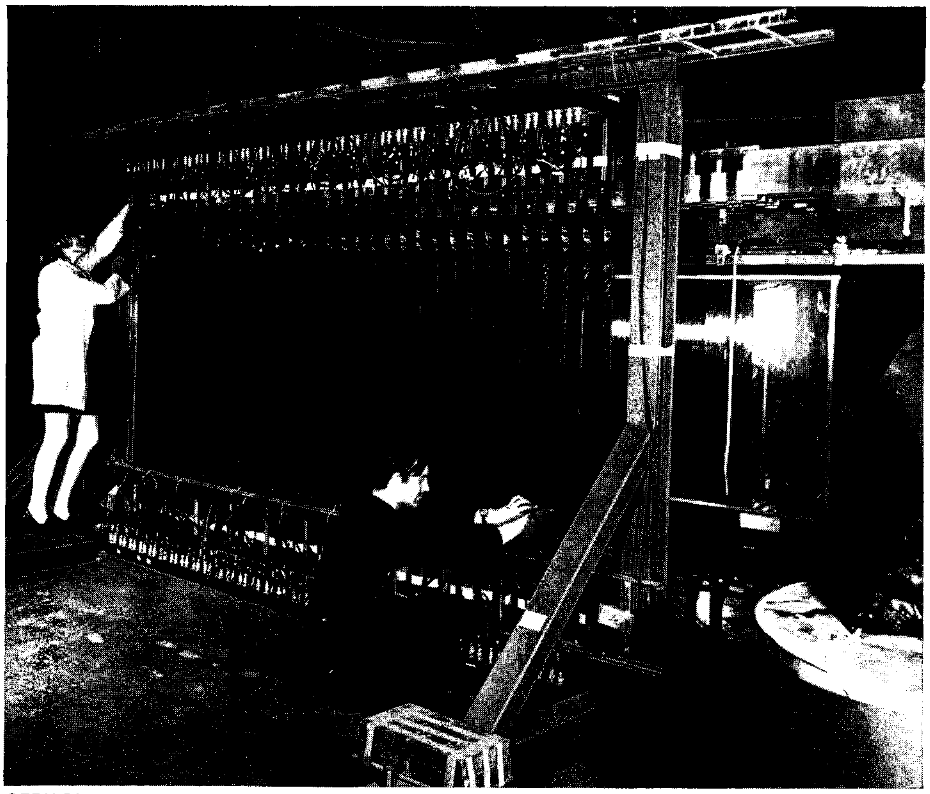
The survey is being taken further by installing a deuterium target in order to study proton-neutron interactions at high energies. It has been shown that it is possible to extract the proton-neutron cross-section from the proton-proton and proton-deuterium data.

Nuclear structure experiments

It is indicative of the growing interest of nuclear structure physicists in access to higher energies (sufficient, for example, to produce a high flux of kaons) that there are two experiments using, alternately, a beam of negative kaons, k12, in the East Hall.

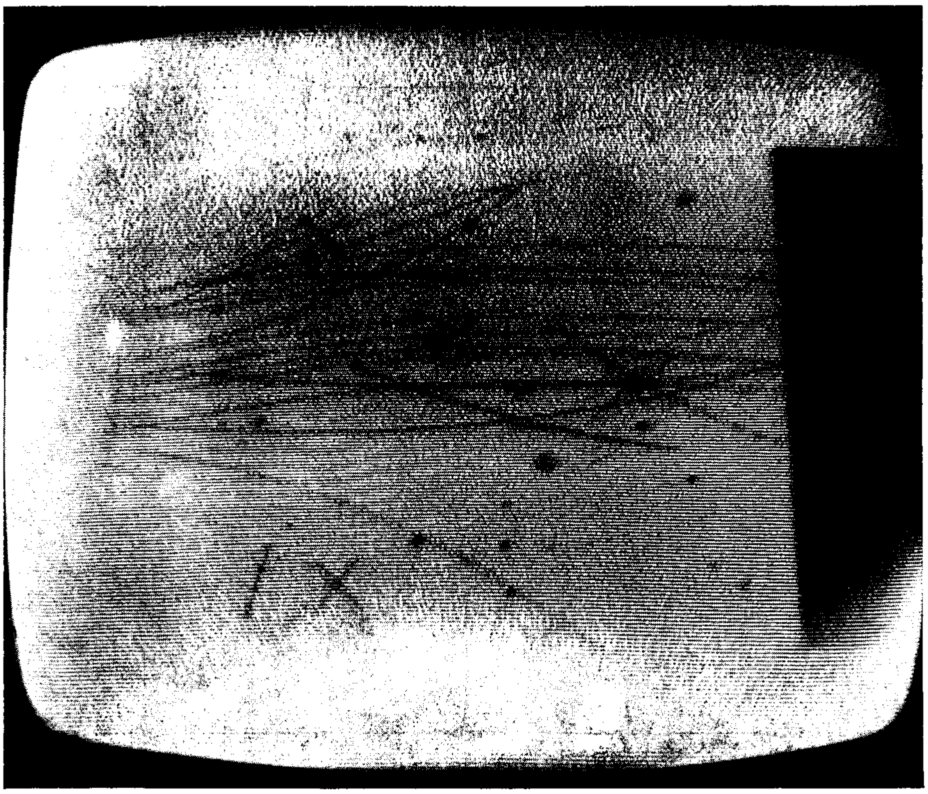
P6

A CERN, Heidelberg, Warsaw collaboration is looking at gamma rays emerging from 'hypernuclei'. A hypernucleus is one in which a lambda hyperon is added to the usual configuration of particles in the nucleus. This phenomenon was first found in nuclear emulsion experiments by a Warsaw team. Studying nuclei in which such conditions prevail gives further



CERN/PI 690.4.70

The 'picket fence' of scintillation counters used to select two-particle events in the CERN, Munich experiment (S94) studying bosons. Just behind the fence can be seen the last of the magnetostrictive wire chambers used to detect the particle paths. A large aperture spectrometer magnet is obscured by the wire chamber.



Keeping track on the tracks. The 81 cm hydrogen bubble chamber is fitted with a closed circuit television system so that experimenters can have a rough check, in the course of operation of the chamber, on the quality of the data they are storing on film. A burst of particles into the chamber, as transmitted by the camera, is shown in the photograph. The performance of the chamber and the beam-line feeding it can thus be roughly monitored 'on-line'.

CERN/PI 207.3.70

information on nuclear structure and on the interaction between the nucleon and hyperon.

In the experiment the lambda hyperon is produced in the interaction of a negative kaon with a proton. The kaon is of low energy such that it 'stops' in the target and the resulting lambda has therefore a good chance of being captured in a nucleus. With a lithium target, for example, lithium 7 can be formed consisting of three protons, three neutrons and a lambda. The detection system then monitors the gamma rays which emerge as the nucleus falls from its excited state through the various energy levels which it can assume down to its ground state.

P7

A CERN, Karlsruhe, Heidelberg collaboration is studying K-mesic atoms, extending a very successful series of experiments on mu-mesic atoms and pi-mesic atoms which has been conducted at the 600 MeV synchro-cyclotron over the past few years.

When a low energy negative meson approaches a nucleus it can be captured into an orbit around the nucleus in the same way as the normal atomic electrons. The heavier mesons take up orbits much closer to the nucleus than the electrons, their orbits can even pass through the nucleus. Thus the energy levels associated with the orbits are very sensitive to the structure of the nucleus. As the meson falls through a series of orbits it emits X rays corresponding to the difference in the energy levels. Observing these X rays measures the energy levels from which information on the nuclear structure can be extracted. Mu-mesic X rays have given detailed information on the electric charge distributions in nuclei. Pi-mesic X rays have shown additional effects due to the strong interaction between the pion and the nucleus.

K-mesic X rays will give new information about the interaction of kaons with nuclear matter and will provide a sensitive test for the nuclear structure — particularly the surface of the nucleus. First investigations on K-mesic atoms have been carried out at Berkeley. The present experiment on the more powerful kaon beam from the PS has already achieved a substantial improvement. For the first time the natural line width of a K-mesic X ray transition has been observed which provides a direct measurement of the absorption of the kaon by the nucleus (in this case sulphur). Futhermore a precise determination of the energy of this transition was possible and it indicates a negative energy shift which is caused by a repulsive interaction for kaons with nuclei at low energies.

Bubble chamber experiments

81 cm hydrogen

The 81 cm hydrogen bubble chamber is occupied with its final experiments. The chamber has been operating at CERN since 1961 (initially on loan from the Saclay Laboratory) with exceptional reliability. When its present programme is completed the chamber will close down.

T175, T176

A CERN, Heidelberg collaboration is using a negative kaon beam, k13, of momentum between 0.6 and 0.8 GeV/c to study kaon-proton interactions. They will take 800 000 pictures with the chamber filled with hydrogen (experiment T175) and change to operation with the chamber filled with deuterium to take another 800 000 pictures to study kaon-neutron interactions (experiment T176).

With these two complementary experiments the strange hyperon resonances with masses in the region 1600 to 1700 MeV will be studied with a significant increase in statistical precision compared with previous investigations.

1.2 m heavy liquid

Experiments with the 1.2 m heavy liquid bubble chamber were described last month (vol. 10, page 116).

T167

The m10 beam-line is providing positive pions of 3.5 GeV/c for an experiment carried out by a Bergen, Ecole Polytechnique, Madrid, Orsay, Stockholm collaboration. The aim is to take half a million pictures in a propane/freon mixture to study pion-pion interactions by an indirect method.

The interaction which is measured is :

$$\pi^+ + p \rightarrow N^{*++} + \pi^\circ + \pi^\circ$$

the neutral pions being seen by their decay into gammas which materialize as electron-positron pairs. The existence of $\pi\pi$ resonances will be investigated to see if one exists associated with a charge-exchange interaction. One is anticipated around 750 MeV with zero isotopic spin.

2 m hydrogen

T173

At the beginning of May, the 2 m hydrogen chamber was being fed with antiprotons of momentum 1.5 to 2 GeV/c for an experiment being carried out by a Glasgow, IPN Paris, Lausanne, Liverpool, Neuchâtel collaboration. 380 000 pictures are scheduled.

The experiment is designed to study the properties of the U meson which has a mass of 2380 MeV. It will also serve to fill in a gap in the existing knowledge of antiproton-proton annihilation interactions.

T174

When the present programme with the 2 m filled with hydrogen is completed, the chamber will be filled with deuterium for a series of experiments. The first, T174, will continue to use the k8 beam to provide negative kaons in the energy range 1.15 to 1.75 GeV/c taking 300 000 pictures for a Birmingham, Edinburgh collaboration.

The experiment will study the negative kaon-neutron interaction in the centre of mass energy range from 1.8 to 2.25 GeV in particular looking at the interactions

$$K^- + n \rightarrow \pi^- + \Lambda^\circ$$

$$\text{and } K^- + n \rightarrow \pi^\circ + \Sigma^- \text{ or } \pi^- + \Sigma^\circ$$

but also measuring the interactions where three or four particles emerge.

The beam feeding the chamber will then be changed to the u5 r.f. separated beam for the following experiments in deuterium.

T152. A Bari, Bologna, Florence, Paris collaboration using a negative pion beam of momentum 9 GeV/c to take 300 000 pictures. The experiment intends to study boson resonances (with high statistics) — their decay properties, branching ratios and production mechanisms. Of particular interest is the study of the interaction

$$\pi^- + d \rightarrow p + p + \pi^- + \pi^- + \pi^\circ$$

in order to check and provide more information on, a $\varrho^-\pi^-$ resonance around 1.3 GeV.

T179. A Birmingham, Durham, Rutherford collaboration using a positive pion beam of momentum 4 GeV/c to take up to 400 000 pictures. The purpose of the experiment is to study the production of neutral meson resonances in the interaction

$$\pi^+ + n \rightarrow p + X^\circ$$

and, in particular, resonances containing a single neutral particle which is inaccessible to study in the charge symmetric interaction

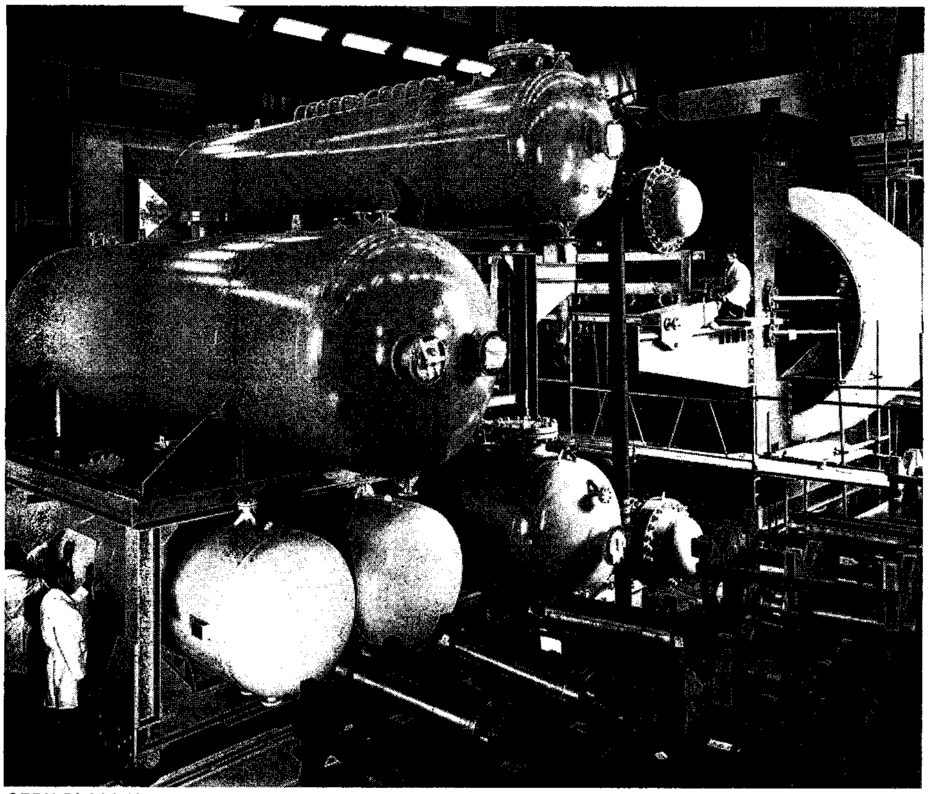
$$\pi^- + p \rightarrow n + X^\circ$$

T182. An Oxford experiment using a positive kaon beam of momentum 5.6 GeV/c to take 250 000 pictures to study the K^* resonance of mass 1400 MeV and the 'Q' enhancement in the K $\pi\pi$ resonance.

T169. A Strasbourg experiment using an antiproton beam of momentum 9 GeV/c to take 150 000 pictures to study (in conjunction with results already obtained at 5.5 GeV/c by the same Laboratory) the energy dependence of different final states produced in antiproton-neutron interactions and for a study of coherent particle production (that is interactions which leave the deuterium nucleus intact).

T162. An Alma-Ata experiment using a proton beam of momentum 20 GeV/c to take up to 75 000 pictures to investigate proton-neutron interactions at high energy.

The one remaining experiment, *T180*, in the approved programme for the 2 m chamber will revert to hydrogen using the u5 beam providing negative pions of momentum 9 GeV/c to take 250 000 pictures to study resonances with G = ±1, looking with high statistics at their production mechanisms in the pion-proton interaction and their decay properties. This experiment (which is complementary to that carried out at the same momentum in hydrogen) is a Bologna, Florence, Genova, Milan collaboration.



CERN/PI 95.9.69

A view of the tanks of the pressure system for the Gargamelle bubble chamber installed in the South-East Hall. The system is currently being tested pulsing with a dummy chamber while awaiting the arrival of the chamber body which is now due at CERN about the end of June.

300 GeV Project

In the last issue of CERN COURIER we reported (page 107) such information as was then available about the latest moves towards realizing the 300 GeV project. New proposals, which have come to be known as 'Project B', were announced on 18 April. They were then presented for discussion to European scientists and to the twelve Member States of CERN. There have been further developments and we outline some of them here. To realize their significance and implications we need to recap the headlines of the history of the project.

1963 The European Committee for Future Accelerators (ECFA) urges the construction in Europe of a new high energy accelerator — its main features to be an energy of about 300 GeV, high proton beam intensity and high capacity for exploitation.

1964 A design study for such a machine, carried out at CERN, is completed. Major parameters are — peak energy of 300 GeV with a beam intensity of 10^{13} protons per second from a main-ring diameter of 2.4 km using 'combined-function' magnets with a peak field of 12 kG; several ejected beams; design and construction time of ten years; cost (transposed to 1969 prices) 1902 million Swiss francs.

1965 At the end of the year other recommendations of ECFA in connection with the installations at CERN-Meyrin are approved by the CERN Council. These consist of an extensive improvement programme for the 28 GeV proton synchrotron and its experimental facilities and the construction of intersecting storage rings.

1966 ECFA is reconvened to examine again the situation with regard to future accelerators for Europe.

1967 ECFA presents its second report endorsing its previous recommendations and urges European governments to approve the 300 GeV project on the basis of the 1964 CERN design.

Approval is received in the USA for the construction of an accelerator in the hundreds of GeV range. Design studies begin in the Summer under the direction of R.R. Wilson and the preliminary design for a 200 GeV machine, having potential for extension up to 500 GeV, is presented at the International Accelerator Conference in September.

First operation of the 76 GeV proton synchrotron at Serpukhov in the USSR occurs in October taking over from the CERN PS and the Brookhaven AGS as the highest energy accelerator in the world.

1968 The UK government announces in June that it will not join the 300 GeV project. In an attempt to ensure that the financial burden on other Member States is not thereby greatly increased, the 300 GeV project is revised to bring the cost to 1431 MSF (1969 prices) mainly by a reduction in the initial facilities for experiments.

The total of countries declaring their willingness to participate in the project grows to six — Austria, Belgium, Federal Republic of Germany, France, Italy and Switzerland thereby assuring sufficient financial contributions for the project to begin.

1969 The CERN Council accepts the 'Programme for Construction and Bringing into Operation of the CERN 300 GeV Laboratory'. The Programme envisages development of the accelerator in stages beginning with an energy not less than 200 GeV and a construction period of eight years which might be reduced to seven. J.B. Adams having taken up his appointment as Director of the 300 GeV project initiates a rethink on the design. This rethink leads to a 'missing magnet' design (described in the last issue of CERN COURIER) and a programme beginning with a 250 GeV machine, within the same budget, with conventional magnets taking up half the circumference of a 3 km diameter ring. Filling up the circumference with conventional magnets would later give 500 GeV. If superconducting magnets are mastered, there is the alternative of inserting them in the free half of the circumference to give 650 GeV and eventually filling the ring with superconducting magnets to give 1300 GeV. This is 'Project A' which could be built on any of the five sites (Doberdo-Italy, Drensteinfurt-Federal Republic of Germany, Focant-Belgium, Gopfritz-Austria, Le Luc-France) offered by States ready to participate. The problem of site selection, however, brings the project to a standstill at the end of the year.

It was in this situation, during the first months of 1970, that Project B was born.

Several other factors influenced the form of Project B. A most important one was that the CERN Organization looked like being divided in two with only six Member States supporting the 300 GeV project. Project B is of a scale and form such that all Member States have a strong incentive to join. A further factor was the consideration of the long-term use of CERN-Meyrin facilities when the new 300 GeV Laboratory got under way. Finally, Project B attempted to come more into line with the finance which might reasonably be anticipated in the future, where the growth rates of expenditure on high energy physics in the past are unlikely to be sustained.

As first presented for discussion, the major features of Project B read like this: The main ring would be about 2 km in diameter; a missing magnet design would be adopted giving 300 GeV energy with all magnets in place at a peak field of 18 kG and 150 GeV with half these magnets. With superconducting magnets it could finally reach about 800 GeV. The cost of the 150 GeV stage of the project would be 1100 MSF; the construction time was put at eight years. A significant aspect is that such a machine could be built not only on any of the five sites offered but also adjoining the existing Laboratory at CERN-Meyrin. If it were constructed adjoining CERN-Meyrin further savings become possible in cost and manpower so that the 'new' money that participating States would have to find would be considerably less than 1100 MSF over the eight years of construction.

Project B meets the requirements of the machine that has been under discussion for so many years and (as discussed below) offers the possibility of advancing the date of operation with potential for ultimately reaching much higher energies. What would be built is a machine of at least 300 GeV. Filling half the ring for 150 GeV initially would enable the conversion to 400 GeV by filling the other half with superconducting magnets to be done with little disruption to the physics programme. An additional 70 MSF could alternatively fill the entire ring with conventional magnets for 300 GeV from the word go. The machine would give high intensity and would have potential for extensive exploitation.

In the discussions in the scientific community during the past month emphasis has been put on several implications of Project B and some suggested variants, within the same physical and financial boundary conditions, are receiving attention.

To cover the variants first, the most interesting is the suggestion that with the new accelerator next door the existing CERN PS could, at least initially, serve as injector. Proton beams could be accelerated to 10 GeV in the PS and transferred to the 300 GeV (involving some spacing out of the PS bunches to redistribute them around the larger circumference of the 300 GeV where they would be debunched and then rebunched). This would eliminate the Booster from the initial construction programme, saving time and money, adding instead the construction of a beam transfer line from the PS to the 300 GeV. The PS would then have a heavier work load which might be distributed per day something like this — one hour for filling the intersecting storage rings, remaining time shared 50/50 between 28 GeV physics and injection into the 300 GeV. This would mean about one pulse per four seconds from the 300 GeV at about 10^{12} protons per pulse.

In addition, the first experimental area for physics at 150 or 300 GeV energy could be the existing PS West Hall. By the time of first high energy beams, this Hall will be exceptionally well equipped, including the 3.7 m European hydrogen bubble chamber and the 'Omega project' for counter physics. Again there is saving of time and money in the initial 300 GeV construction programme, cutting out a new experimental hall and equipment while adding a beam transfer line to the West Hall.

Later, new experimental areas would be added and a separate injection system could be built, but the exciting thing about this modification of Project B is that it opens up the possibility of physics at higher energies by the beginning of 1976 (if the project can go ahead in 1971) rather than several years later, while still requiring the same rate of spend during the first years of construction. What is clear however, is that the use of the PS and its experimental facilities (without quite special financial arrangements) assumes that all the Member States currently participating in CERN-Meyrin can eventually be attracted into the new project.

To turn now to a few points which have been underlined in the course of the discussions — the peak energy of the machine of Project B should be at least 300 GeV. As emphasized above, this is met by the proposals already put forward. What is not clear is how best to play the card of the missing magnet design en route. It depends particularly on timescales. For example, the project cannot wait to be absolutely sure that superconducting magnets are mastered; therefore it must begin with a design using conventional magnets. If it does not go 'missing magnet' (leaving half the ring clear) it would be necessary to cut out over a year's physics in converting later to superconducting magnets. There is a good chance, however, that with the present rate of developments on superconducting technology, the option on superconductivity can be taken by the end of 1973. The project might therefore begin planning a conventional magnet half-ring and decide on superconductivity, one way or the other, in midstream.

Since the diameter of the machine, once construction begins, is a parameter which can no longer be played with but is a parameter which dictates ultimate peak energy, it is something which should be as large as possible, within the limits of what is practicable.

Finally, the European science community wishes assurance that the contribution which would come from the CERN-Meyrin Laboratory towards the construction of the new machine would not substantially reduce the growth in the physics research programme based on the existing facilities and those shortly to come into service, on which so many European physicists depend.

The discussion is continuing but already much has crystallized out. It is recognized that it is of supreme importance to move quickly if particle physics in Europe is to retain in the coming decades the excellent standing it has now.

CERN News

ECFA new Chairman

The European Committee for Future Accelerators has elected a new Chairman and Secretary who took office for the first time at a Plenary Meeting held on 9 May. The Chairman is T. G. Pickavance, Director of Nuclear Physics at the Science Research Council (UK) and formally Director of the Rutherford Laboratory. The Secretary is D. Harting (Netherlands).

Dr. Pickavance opened the Plenary Meeting recording the great appreciation of the European particle physics community to E. Amaldi (the former Chairman) and A. Citron (the former Secretary) for the devotion with which they had lead ECFA for many years. Professor Amaldi was elected President of the CERN Council last December.

Protons towards ISR

On 22 April a beam was ejected from the CERN proton synchrotron towards the intersecting storage rings for the first time. It was taken about 35 m along the beam-transfer line through several quadrupoles and bending magnets into a copper 'beam-dump'. Several periods of machine time since then have been used to check the behaviour of the ejection and the first section of the beam-line. The performance meets the design expectations.

The fast ejection from the PS involves a fast kicker magnet, positioned in straight section 97, which bends the beam into two septum magnets, in straight section 16, which complete the ejection from the ring. Two 'bump magnets' (an innovation at the PS) also play a part in the ejection. They serve to distort the beam orbit in the ring so that the beam passes very close to the first septum. When the kicker magnet comes on, it then has less work to do in bending the beam into the aperture of the septum magnet. The ejection system has worked well providing beams through the first part of the beam-line with remarkable stability. Ejection efficiencies have been over 90 %.

The first tests have been carried out using four, or all, of the twenty bunches of protons in the synchrotron. However, it has proved possible to carry out the tests taking only two out of the twenty bunches leaving the rest of the beam for experiments. Also, to fit in with the requirements of the experimental programme of the PS, the tests have been carried out with at 15 GeV (they will later be taken to higher energies).

A variety of methods were used to observe the ejected beam including pick-up electrodes, grid type secondary emission monitors and closed circuit television observation of screens (consisting of grids of fluorescent glass fibres) placed in the path of the beam.

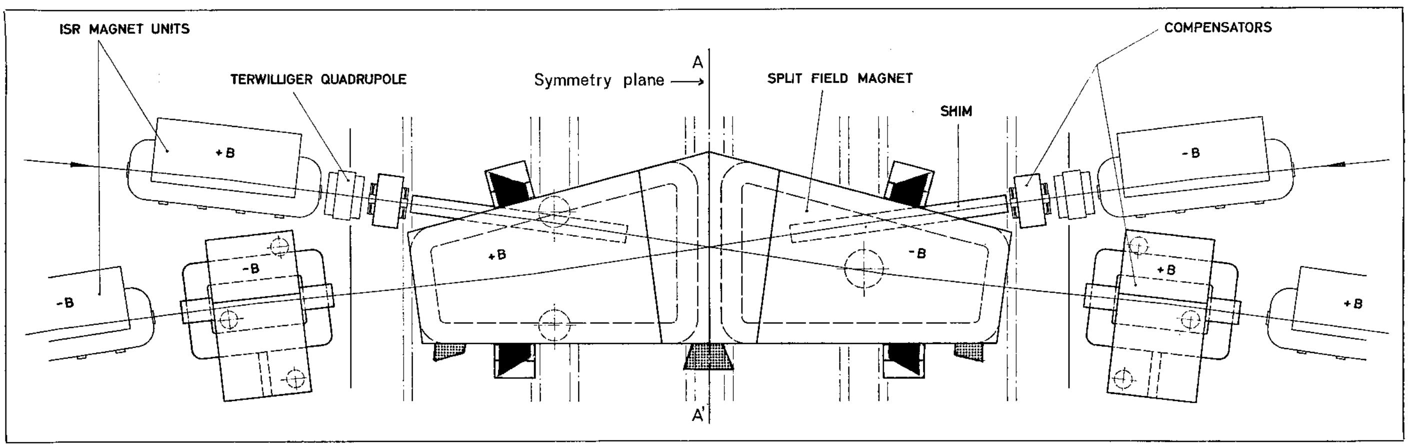
At the moment all the control and monitoring is carried out from the 'Y building' (where the beam-lines to the ISR fork to take protons to one storage ring or the other). This will soon be transferred to the SRC (Storage Ring Control Room) and the control computer will be brought into action in the setting up of magnets and the processing of information from the beam monitors. When this stage is complete there should be little problem in extending it to the whole of the beam-lines to the ISR.

Another major event in the ISR project occurred on 13 May. The last of the bending magnets for the two rings was moved into place completing a steady programme of installation which began at the end of 1968. Altogether 264 bending magnets (72 short units and 60 long units for each ring) have been assembled, tested and installed.

Split field magnet

The problems of carrying out experiments with the ISR are very different from those at conventional accelerators. For example, the magnetic fields required for the analysis of the momentum of the collision products must cover the intersection regions for many experiments and thus can also affect the protons which continue to travel around the rings. These protons must emerge from the interaction region unaffected by any magnet system used in the region.

A 'split field' magnet has been adopted for interaction region I 4 (see CERN COURIER vol. 9, page 102) and the Magnet Group of the ISR Department is responsible for its construction. The original proposal (put forward by J. Steinberger)



A diagram of the split field magnet with its compensating magnets to be installed in intersection region I 4 of the ISR. The main magnet, designed to provide the longest possible trajectory for the high-energy secondary particles subject to the field, is symmetrical in relation to the plane AA'. At the level of the median plane, the magnetic field lines are directed towards the top on one side of the plane of symmetry and to the bottom on the other. The trajectories of circulating protons will remain undisturbed outside the intersection region. The main spacers are shown in black; the lower two could be replaced by four smaller ones (cross-hatched) to facilitate certain experiments.

The fifth-scale model of the split field magnet which is being tested in Hall E1. One test concerns the measurement of the magnetic field by means of a probe, the arm of which may be seen protruding from the aperture. The main purpose of the model is to perfect the system of shielding the beam against the effect of the end fields. The beams enter at a wide angle and experience focusing forces, due to the end effects, which is countered by arranging magnetic screens (the shape of which has yet to be decided) around the beams.

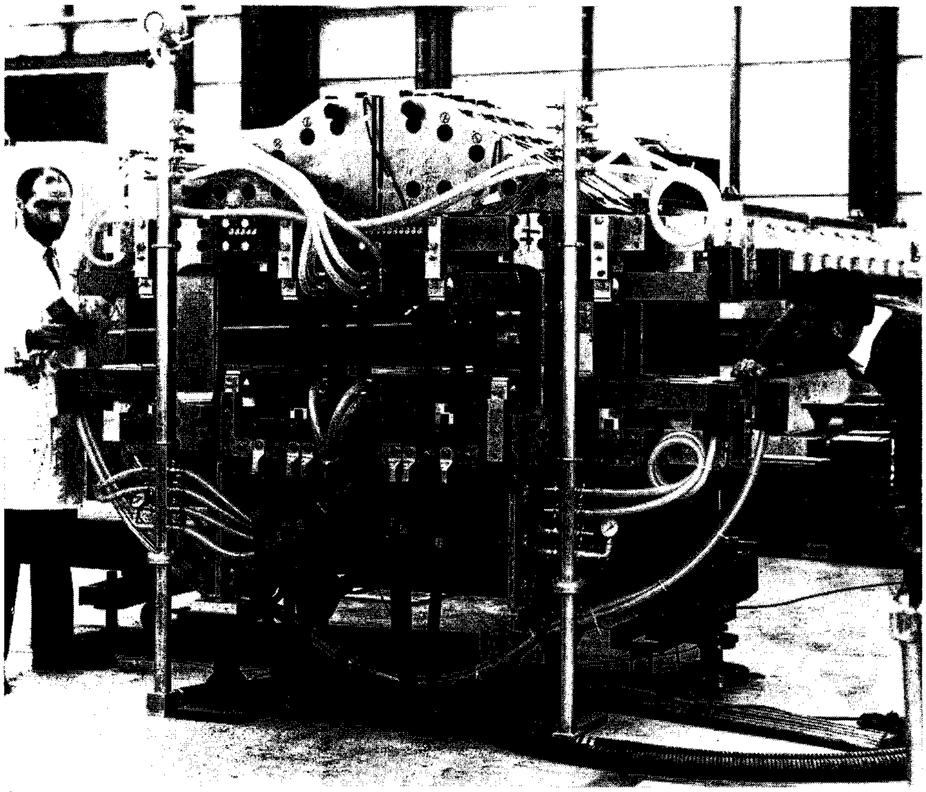
was modified to take account of suggestions from A. Minten and other CERN physicists. In this magnet, the vertical field will be of opposite polarity on either side of the point of intersection of the beams hence the name 'split field'. The features of the system were determined adequately enough for invitations to tender to be issued in January and the contracts are about to be placed, so that the magnet can be installed during the second half of 1972.

. A fifth-scale model was completed in March and is being used to plot a complete field map, to measure certain stresses on the most heavily loaded parts of the structure, to decide on possible modifications to the shape of the yoke and, in particular, to check the characteristics of magnetic screens. The model was made in the CERN workshops in the record time of six months. It has high current density in the coils (30 A/mm^2) and the amount of power dissipated is 650 kW.

Screening the beam

The magnet has to satisfy several requirements — fields as high as compatible with reasonable running costs, a field volume in which the largest possible number of detectors (for example, proportional wire chambers — see page 151) can be installed, and no overall effect on the protons which continue to circulate in the rings. On this last point, there are two factors to be taken into consideration — horizontal deflections and focusing effects.

To obtain a zero horizontal deflection, the structure of the magnet has been made such that it is divided by a radial vertical plane into two symmetrical parts where the vertical component of the field is in opposite directions. Thus a circulating proton is deflected, first to the left until it reaches the point of interaction, and then to the right, which brings it back towards the trajectory on which it was travelling in the absence of the field. (This sequence is, of course, reversed in the case of the other beam.) In practice, two compensating magnets must be added both upstream and downstream of the split field magnet giving the proton an S-shaped trajectory.



CERN/PI 45.4.70

The most satisfactory solution to the focusing problem has been found to be the installation of sleeve-shaped screens at the point where the beams enter the split field magnet. They shield the beam from the considerable asymmetrical end effect where the beams enter the magnet at a large angle.

Main features

The split field magnet will be 10.2 m long, with a maximum width of 3.2 m providing a useful field volume of 28 m^3 with an aperture of 1.1 m. Each half-yoke weighs 400 tons, divided into components weighing not more than 60 tons each to allow their transport by the ISR cranes. Each of four coils weighs 13 tons and passes a peak current of 6250 A with a power dissipation of 4 MW. The field in the median plane is about 12 kG, and is higher near the poles. The field is not uniform, and thus the field maps must be very accurately made to be fed into computer programmes for determining particle momenta.

ESONE General Assembly to be held at CERN

The General Assembly of ESONE (the Committee for European Standards of Nuclear Electronics) will be held at CERN from 13 to 16 October 1970. The Assembly meets each year at one of its member organizations; CERN has offered sponsorship for this year's conference.

About 40 representatives from the member organizations and some observers from other organizations in Europe and from the USA will meet to discuss and programme their activities in the field of electronics. The main topic will be 'CAMAC', a system (mechanical and logical) for data handling (see CERN COURIER vol. 8, page 314).

Other topics may include the general rules applicable to membership of ESONE and to the Executive group, applications for membership from various Laboratories, and collaboration with the NIM committee (which is concerned with the 'NIM' standard electronics). The various activities of the working groups may also be discussed in the frame of general policy and also the problem of the 'central bureau' intended to coordinate administration and technical activities between all the members.

An informal exhibition of CAMAC instrumentation will be held at the same time (12-16 October) illustrating the commercial activity in the field.

An indication of the speed at which the CAMAC system is receiving wide acceptance is that the USA Atomic Energy Commission NIM Committee, meeting in Washington in March, endorsed the CAMAC system as a 'complementary system to NIM', and as 'the only dataway system that seems likely to receive wide acceptance by the Laboratories at this time'.

Details of the CAMAC system proposed by the ESONE Committee in which CERN participated can be found in a EURATOM document EUR 4100e.

Installation of ISR r.f. cavities

In the normal process of injection into the ISR, the momentum of the injected protons must be increased so that they move out of the injection orbit leaving it free for the next pulse from the proton synchrotron. This acceleration is brought about by six r.f. cavities in each ring. These cavities have now been installed in ring No. 1 and testing is under way.

The main features of a cavity are: r.f. voltage variable from 12 V to 3.3 kV; frequency adjustable in relation to the injection energy from 9.25 to 9.55 MHz corresponding to an energy range of from 3 to 28 GeV for the injected protons. In view of the accelerating frequency, their unit length should be 7.5 m (a quarter of the wave-length, corresponding to a frequency of 9.5 MHz). It is possible, however, to reduce their length to 1.3 m using a fixed capacitor of 1000 pF for each cavity.

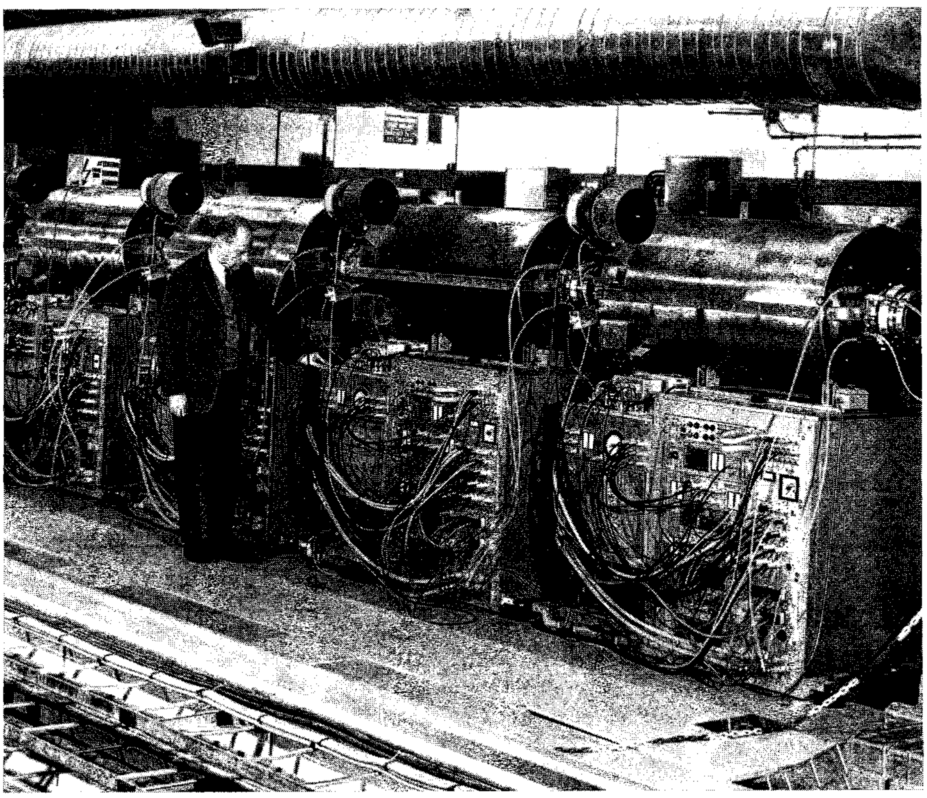
A variable capacitor (giving a range of 10 to 110 pF, added to the fixed capacitance) is used to vary the resonant frequency. This cavity tuning system can be used because of the small frequency range (3 %). In the PS or the Booster, on the other hand, the frequency variation range is much larger, and it has been necessary to use ferrites whose permeability (which controls the resonant frequency of the cavities) can vary over a wide range.

The ISR cavities are primarily water-cooled, although there is a supplementary air-cooling system. The power amplifiers, the main component of which is a water-cooled tetrode, are housed in the base of the cavities. They can be removed by remote-controlled manipulators to reduce handling time. A phase-lock system similar to that of the PS will be used in acceleration, although in this case there is the complication that the system must select the bunches which have just been injected *and remain bunched under the effect* of the r.f., from the debunched proton beam already stored in the machine.

One of the main difficulties presented to the r.f. system is beam-loading in the cavities. This is being handled by a combination of two techniques. The first involves a wide-band feed-back system reducing the impedence seen by the beam. The second uses a signal proportional to beam intensity derived from the beam to compensate the effect of the beam current. These techniques decrease the effective impedence to less than ten ohms per cavity.

The power supplies and some of the r.f. cavity controls will be installed in two of the eight auxiliary buildings located at the centre of the rings 150 m from the tunnel, while the whole assembly will be controlled from the main ISR control room.

Tests on the cavities are scheduled for completion by August of this year.



Four r.f. cavities installed in the ISR; seven cavities are scheduled for each ring (in one group of three and one of four). Six will be in use for acceleration, while the seventh is in reserve as a spare. Tests on the installed cavities are now under way.

CERN/PI 2.4.70

Proportional chambers

Simplified circuit diagram for an amplifier processing unit such as is used for a single wire in a multiwire proportional chamber. The pulse from the wire enters on the left and is amplified by a factor of about a 1000, shaped, and delayed while a 'decision' is taken by all the electronic circuitry as to whether the information should be stored. If the decision is positive, a 'gate' opens to store the information in the computer. The information is transferred sequentially for groups of wires (32, or sub-multiples of 32, wires).

Progress in particle physics has been closely linked with the development of particle detectors. The invention of new detectors has progressively provided observations and measurements which were previously impossible. Development has then taken place rapidly from the prototype table to giant systems using the advantages of the detector to the full; the evolution of bubble and spark chambers are cases in point.

Multiwire proportional chambers may be undergoing a similar development. After a modest start, using a few tens of wires in 1968, chambers with 10 000 wires are now being prepared for experiments, and chambers with more than 100 000 wires are planned for the not too distant future.

The multiwire proportional chamber in its modern form was invented at CERN (see CERN COURIER vol. 9, page 174) and this article will trace its development over the past two years. We first review their principle of operation, their advantages and disadvantages in relation to other electronic detectors.

The ancestor of the proportional chamber was the proportional counter, which has been in use since 1936, but which has undergone little development since then. It consists of a gas-filled metal cylinder through which a wire passes axially, held at a positive potential of several thousands of volts in relation to the cylinder. When an ionizing particle passes through the gas in the cylinder, it generates positive ions and electrons. The electrons are attracted by the wire and, over the last few microns of their trajectory, are so accelerated that an avalanche is produced, giving a pulse of a few millivolts on the wire.

If the applied voltage is between certain values (of the order of a few thousand volts) the current is proportional to the ionization produced by the particle, regardless of its distance from the wire. If this current is amplified, it is possible not only to detect a particle, but also to measure its ionizing power. The major defect of the counter, which led to its replacement in most cases by the scintillation counter, is that its resolution time is almost 1 microsecond.

Since 1943, multiwire proportional counters have nevertheless been constructed for special purposes. Here, a plane of parallel wires held at alternately positive and negative potentials was stretched across the gap between two electrode planes. The aim in alternating the voltage was to stop capacitive coupling between adjacent wires at the same potential. The spatial resolution with a wire spacing of 3 mm was 6 mm which leads also to a poor time resolution. For these reasons such chambers could not compete with spark chambers and it had limited applications.

G. Charpak and his group at CERN discovered, in 1968, that there is no need to alternate the potentials of the wires. If the main pulse is negative, weaker positive pulses will be received on the neighbouring wires. All that is necessary is to have the amplifiers insensitive to the positive pulses in order to identify the wire receiving the electron avalanche.

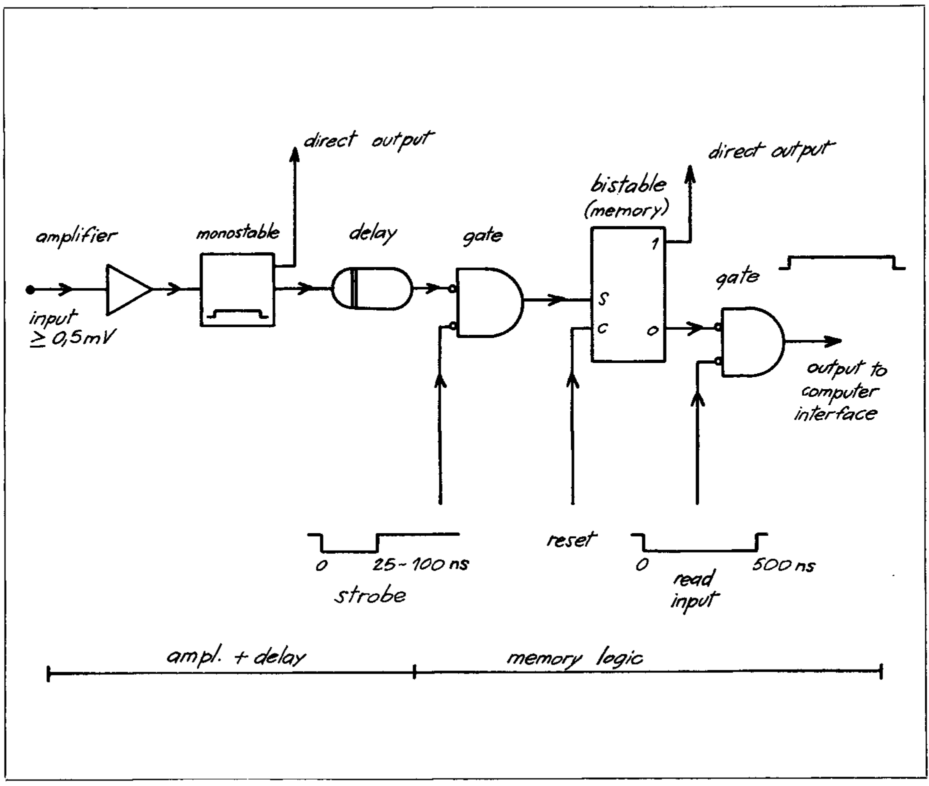
The resolution thus improved by a factor of two. With all the wires in one plane at the same potential, it is easier to place them very close together. One could thus reach resolutions of a millimetre, as in spark chambers. Small detectors using this principle were built at CERN in 1968 and christened multiwire proportional chambers.

Their advandages are:

1) Unlike spark chambers, they need not be pulsed; the voltage is continuously applied and, as the passage of a particle brings no appreciable voltage drop, any number of particles can be detected at the same time.

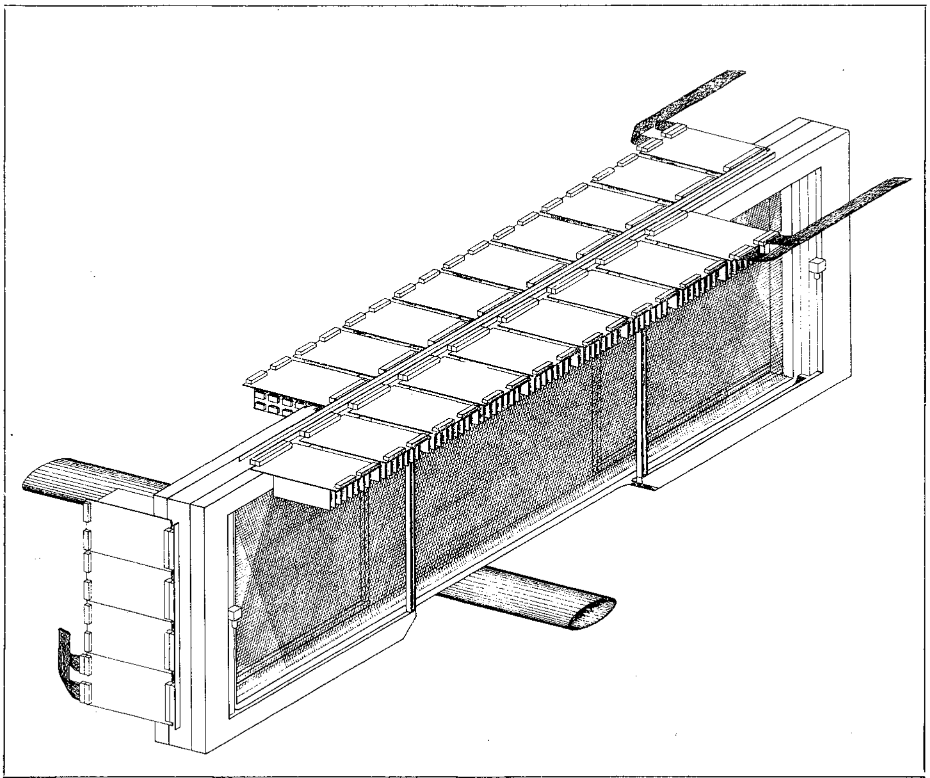
2) The 'dead time' is determined by the electronic circuits. It is zero for two pulses affecting two different wires and less than 100 ns for the same wire. Count rates per wire have been attained which are very high compared to those from spark chambers (of the order of a few MHz). This is a great advantage at a time when beam intensities are climbing significantly higher and when 'high statistics' experiments are becoming more important.

3) The resolution time mainly dependent on the distance between the wire and the trajectory is thus a function of the wire spacing (24 ns for 2 mm and 36 ns for 3 mm). This represents an increase of 10



Section of a multiwire proportional chamber with three detection planes which will be mounted inside the split field magnet at the intersection region I4 of the ISR (see also page 148 of this issue). The pitch of the wires is 2 mm. For maximum utilization of the useful gap volume the frame which carries on each side amplifiers and data processing units must be of minimum thickness.

Three planes of wires can be seen: 1 vertical and 2 oblique, a system which allows the position of simultaneous events to be resolved.



to 30 over that of spark chambers. This is a major advantage.

4) The proportional chamber is virtually unaffected by a magnetic field. This is another major advantage since detectors are needed in a strong magnetic field for many experiments. (Other methods involving spark chambers in intense fields are being developed also, particularly the capacitive storage method put forward by E. Quercigh.)

5) Detection efficiency is between 99.5 and 99.9 % for any number of particles. The chambers are therefore suitable for the analysis of certain complex events, until now the exclusive province of optical chambers.

6) The chambers give less accurate ionization measurements than the proportional counter, but the accuracy is sufficient to allow particles of clearly differing energy to be separated.

7) Finally, neither the efficiency nor the spatial resolution is affected by the angle of incidence of the particles, contrary to spark chambers.

Their disadvantages are:

1) The spatial resolution is a function of the gap between the wires. On large chambers now in operation, a resolution of ±0.6 mm is being attained, which is still twice as high as that of the best wire spark chambers. However, there is still the possibility of improvement.

2) The cost of proportional chambers is high. The signals have to be amplified and processed independently for each wire which at present involves a cost of about 60 Swiss francs per wire. The price thus becomes prohibitive where chambers with large numbers of wires are wanted. The technology of electronics is, however, advancing rapidly and, as will be discussed later, large-scale integrated circuits offer opportunities for cost reductions.

A distinction has to be drawn between costs related to amplification and costs related to signal processing. For the latter, the prices will be directly determined by electronics and even if they remain high, they may be justified compared with prices of similar systems in other spark chambers because the price includes the selection of the particle and rejection of unwanted events — processes which, in other chambers, give rise to considerable expenditure. The cost of pulsed high voltage generators and that of special gas are also saved.

A new development has recently altered the problem of amplification considerably. Studies on the correlation between the nature of the gas filling the chamber and the amplification of the avalanche resulted in the discovery of a 'magic mixture' in which the amplification factor is multiplied by almost 100. (An article has been submitted to 'Nuclear Instruments and Methods' by the group working on the split field magnet detector.) This development, is still too new for any precise analysis of its effects to be made, but it is heartening to note that progress is still possible in such an old technology. In spite of the accepted theoretical limit of 10^6 for the gain, 10^8 has been achieved in practice.

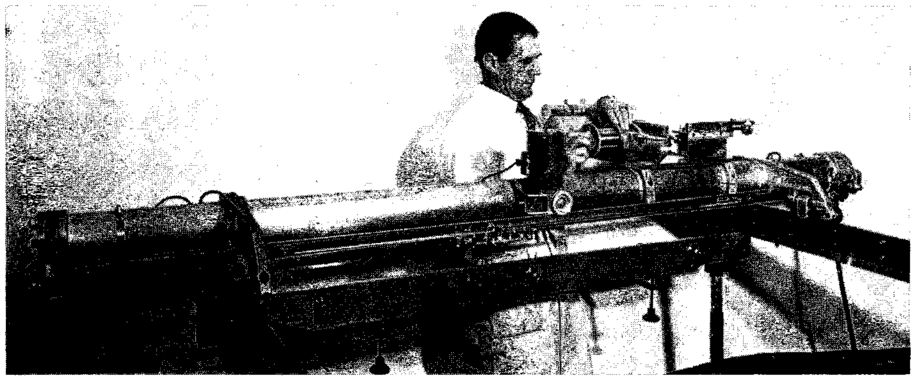
Construction of proportional chambers

The construction of large chambers must be undertaken with great care, especially when the gap between wires is small. CERN workers have developed a machine for 'weaving' the wires so that the tension on each wire is uniform. When the wires are very long, however, unique problems occur which have never been met on spark chambers. They are due mainly to electrostatic phenomena which have been carefully examined particularly by the CERN-Heidelberg group.

To simplify assembly, chambers made up of frames of wires capable of being stacked one on top of the other are now being constructed. The high voltage frames consist of grids of parallel wires or of very thin aluminium foils (a few microns thick) which are highly transparent to particles.

The main problem involved in reducing the spacing between wires is that the charge per wire is reduced, for a given voltage. It can be compensated by increasing the voltage, but a limit is set by flashovers. Nevertheless, some authors claim to have built chambers with two wires per millimetre.

Several automatic machines, developed in the West workshop at CERN, are available to 'weave' wire chambers of all kinds. These machines stretch the wires on a frame and keep both the wire tension and the gap between the wires constant. The latter is maintained constant by toothed racks between which travels a shuttle fitted with a servo-mechanism for adjusting the tension (between 10 and 50 g). The wire leaves one rack, passes around a tooth on the opposite one, and then returns. Racks are available, with pitches varying from 1 to 3 mm; gaps of less than 1 mm can also be produced by means of a special device. A wire can be woven over a width of 1.20 m in about 7 s.



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Associated electronics

An amplification of about a thousand has to be provided. Conventional transistor amplifiers were used in the first chambers but the move is now towards industrial mass-produced integrated circuits. With the new gas mixtures it will be possible to multiply the signal voltages by about a hundred, and the cost of the amplifier will drop to a point at which it will have little financial weight.

. To turn to signal processing, it has been found necessary to design special read-out circuits which select the pulses, store them and feed them into the computer. Very compact circuits fulfilling both amplification and data handling functions, have been perfected on the basis of discrete integrated circuits. There is a tendency to unite circuits for several wires (a group of four initially, eight now and possibly thirty-two in the future) on a single wafer. The circuits of several wires (for example, eight at a time) can be contained within the same unit with an area of a few square millimetres, and at a price hardly higher than that for one single wire.

The circuit logic varies from experiment to experiment particularly with regard to pulse selection and the grouping of coincidence and anti-coincidence signals, gate opening times, etc. Only one output to the computer is needed per group, considerably reducing the number of connections and the cost.

'Polyvalent' circuitry is virtually the sine qua non for proportional chambers with very large numbers of wires (more than 10 000).

Specifications have been sent to industrial firms but, so far, European and American industry is reluctant to invest in the manufacture of such circuits. While technically they are perfectly feasible, considerable investment would be required and a reasonable profit could be made only if very large numbers were ordered. Collaboration between Laboratories to standardize specifications is essential and is helped by the close contacts existing between CERN and the other European Laboratories.

Proportional chambers in use

The first multiwire proportional chambers were tested in an experiment carried out on the synchro-cyclotron by the Charpak group. Since then, a number of others have been built:

1) Beam profile analyser (G. Amato, G. Petrucci).

The first, built in 1968, was a small beam analyser (see CERN COURIER vol. 9 page 175) comprising two planes of wires which was used to find the horizontal and vertical profile of a beam.

2) Beam analyser

Shortly afterwards, a CERN/Imperial College group built a set of seven similar chambers. They were used in various experiments to find the position and momentum of particles in different incident beams. They differed from the previous ones in adding to the amplifier stage an integrated-circuit processing stage. They have proved reliable and easy to operate.

3) Beam diagnostic equipment

A set of six small chambers connected to a computer with a display system was constructed to specifications provided by a NP Division group (Petrucci et al.) to monitor the beams to experiments (phase space divergence, and energy spectra measurements). They have been in use since February 1970 and have proved extremely simple diagnostic tools enormously facilitating the control of the beam-lines. Certain operations, previously thought unreasonable because they would have taken several days' beam time are now carried out in less than an hour.

4) Chambers for physics experiments

Chambers are now being built by a CERN, Caen group to be used in an experiment measuring kaon-neutron scattering due to begin at the PS about the beginning of 1971. There will be an assembly of nine planes of wires, the largest measuring 1.20 × 0.80 m^2.

5) Large chambers

The largest multiwire proportional chambers are at present under construction for a CERN, Heidelberg experiment. Two of the planes of wires measure 2.85 × 0.90 m^2. This experiment is scheduled for the end of 1970 and will study the decay of the neutral kaon. It will be the first extensive physics experiment with chambers of this type to make use of their high counting rate, which will make it possible to use beams five to ten times more intense than is possible with spark chambers. Up to 2000 decays per synchrotron pulse may be detected. In addition, the accuracy of measurement will be increased by a factor of ten by comparison with a similar previous experiment.

6) Detector for the ISR

A second large project concerns the construction of the chambers to be installed in the split field magnet of the ISR (see page 148). Here, the conditions are different:

a) The detector must be capable of use in as wide a variety of experiments as possible. The electronics must, therefore, be very versatile.

b) The magnetic field volume must be used to the full, and thus the structure and the electronics must be designed for maximum space-saving.

The planes of wires will measure 150 × 50 cm^2, with a total of 10 000 wires initially. Further sets of wires could be added later to increase this total to up to 100 000, so that complex events can be analysed.

The future of multiwire proportional chambers is largely dependant on the possibility of reducing their price. If, because of a lack of demand, advantage may be taken only of progress made in the actual construction of the chambers (gas amplification for example) the chambers will probably find wide-spread use as triggers for optical or automatic chambers, but not very much more. However, if the cost barrier can be overcome, it would be possible to build colossal detectors capable of replacing the best methods of detection now available.

Around the Laboratories

Director of the 300 GeV project, J. B. Adams, visited several USA Laboratories in April. He is photographed here boarding a helicopter on 17 April for an aerial view of the progress of construction of the 200-500 GeV accelerator at Batavia. With him, on the right, is F. T. Cole, Assistant Director for Technical Affairs.

(Photo NAL)

CORNELL
Slow ejected beam

The most recent addition to the experimental facilities at the Cornell 10 GeV synchrotron has been a slow ejected electron beam. Using the resonant ejection technique, a pulsed quadrupole magnet in the synchrotron moves the betatron oscillation frequency from 10.68 per turn toward the half-integer resonance at 10.5. An octupole magnet provides the non-linearity that makes the frequency a function of oscillation amplitude, thus enabling one to spill the beam slowly. The beam jumps a septum 0.8 mm thick, passes through two more septum magnets, emerging through the fringe field of the synchrotron and a special port in the yoke of the ring magnet. Outside the synchrotron it passes through an achromatic system of d.c. magnets with quadrupoles to match the beam optics to experimental requirements.

The ejection system and beam transport worked perfectly almost immediately. Ejection efficiency is about 75 % and the spill can be spread to 2 ms (the repetition rate is 60 Hz). The beam focuses to a spot less than 1 mm^2 with a divergence less than 1 mrad in both planes. No collimation is used and the halo seems to be negligibly small.

A successful measurement of elastic electron-proton scattering has been made as a check of the performance of the beam and of a recently constructed 10 GeV/c spectrometer system. An experiment on coincidence electroproduction in the deep inelastic region is now beginning.

Within a month a fifth r.f. accelerating section will be installed, increasing the maximum energy of the synchrotron by the factor $(1.25)^{1/4}$, giving about 10.6 GeV. Actually, the most important effect will be the increase in reliability of operation, since only four of the five sections will be needed for energies between 9 and 10 GeV.

A programme to raise the synchrotron energy to 15 GeV is now in progress. The radiation losses at 15 GeV will be 50 MeV per turn instead of the present 10 MeV per turn at 10 GeV. This enormous increase in the need for r.f. power at the end of the acceleration cycle will be met by a superconducting r.f. accelerating section. A test cavity of niobium has been operated S-band with an unloaded Q value of 6×10^8 and the effect of intense radiation on the cavity has been investigated. The completion of the superconducting system is planned for 1972.

The synchrotron began operating for experiments about two and a half years ago. In this period, the accelerator has behaved very well indeed providing about 7000 hours of scheduled experimental time during the last year. The programme has consisted of experiments on quantum electrodynamics and photoproduction of pions, kaons, and vector mesons. Most of these experiments have been done by Cornell groups, but some have been performed by an outside group or outside collaborators.

As the operation has become more stable, the Laboratory is now better prepared to accommodate a larger number of outside users. The curtailment of experimental programmes at other Laboratories (particularly at the Cambridge Electron Accelerator Laboratory — see CERN COURIER vol. 10, page 120) has led to an increased interest in the use of the Cornell machine. Cornell encourages this interest and welcomes the experimental proposals. Such increased user activity will help maintain a healthy and well-balanced programme at the accelerator.

TRIUMF
News from Annual Report

Some items of information from the latest Annual Report of the 500 MeV cyclotron project, TRIUMF, under construction at British Columbia in Canada.

A unique feature is being fed into the design of the accelerating system. Because of the simple rectangular shape of the r.f. resonator it is comparatively easy to add the 3rd harmonic to the waveform. This has been confirmed in model studies. The result is a flat-topped waveform giving a 'square wave' accelerating voltage, which has advantages such as increased phase acceptance and subsequent improvement in energy spread and duty factor.

To improve focusing and to reduce the electric stripping of the negative hydrogen ions by using a lower average magnetic field, the machine diameter has been increased to 314 inches. The magnet contract has been placed (covered in CERN COURIER vol. 10, page 88). Work on the ion source and injection system, the beam dynamics, vacuum system, and extraction areas is well advanced.

Five Users Groups (Meson, Radiochemistry, Slow Neutron, Radiobiology and Radiotherapy, and Proton) are contributing particularly to the evolution of the experimental facilities. Together with the Operating Committee they are now discussing a schedule for the availability of the various proposed beams from the cyclotron.

A layout for the meson area has been prepared. It involves the use of two targets — a thin target feeding two beam lines (one to take pions in the energy range 100-250 MeV, one for pions of lower energy) and a thicker target for the production of 'stopped' pions and muons and a high intensity, low energy pion beam for bio-medical use.

The radiochemistry users have a 'Chemistry Annex' of 4000 sq ft designed with two hot cells for handling very active materials.

The slow neutron users expect a minimum flux of thermal neutrons equivalent to $7.6\ 10^7$ per cm^2 per second for a 2 degree cone. There will be five neutron beam ports — two corresponding to different energy peaks (thermal and 1500° K) to be used for neutron diffraction studies of magnetic structure, one for studies of crystal structure, one for neutron capture gamma ray spectroscopy and one for neutron scattering spectroscopy.

A large Radiobiology-Radiotherapy Laboratory has been designed. This research will use a negative pion beam which is under study. (The work is supported by such bodies as the National Cancer Institute, the Health Resources Fund and the British Columbia Cancer Treatment and Research Foundation.)

Proposed experimental facilities for the proton area include: a scattering chamber with time-of-flight extension arms for heavy-particle identification and the study of high isobaric spin states in fission fragments and other charged particle reactions; hydrogen and deuterium targets for the production of secondary beams of unpolarized and polarized neutrons and of polarized protons; a pion spectrometer to study pion production by neutrons and protons; a high resolution proton spectrometer to exploit the extremely good energy resolution (ultimately expected to be ± 25 keV) of the primary proton beam. The proton area will be divided into two regions: one accepting proton beams of up to 10 μA, the other limited to a maximum intensity of 1 μA.

CAMBRIDGE

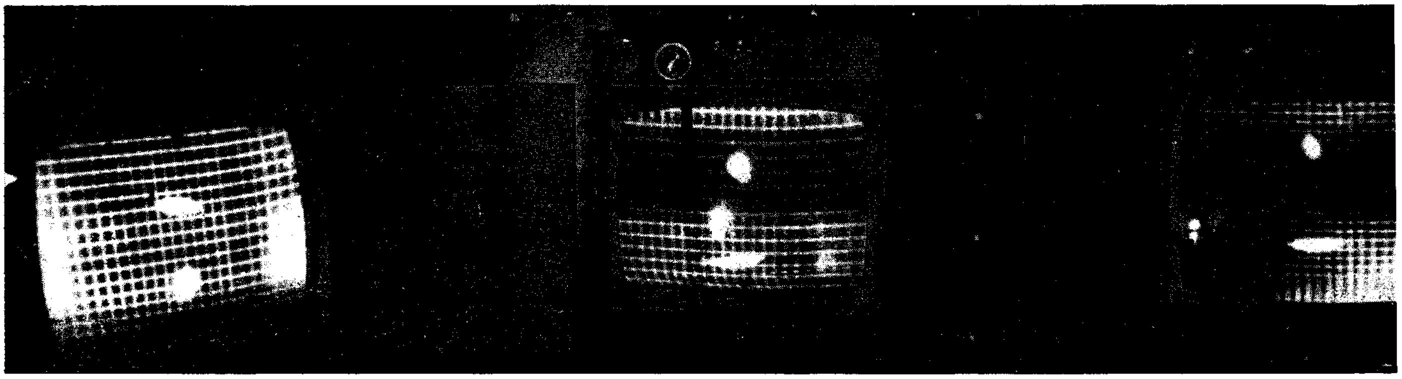
Electron and positron beams stored simultaneously

On 11 April 'Project Bypass' at the Cambridge Electron Accelerator Laboratory took another important step towards its goal when electron and positron beams were stored simultaneously for the first time. The colliding beam facility (described in CERN COURIER vol. 8, page 289) now has top priority in the Laboratory following the budget cuts which are leading to the curtailment of the conventional research programme at the 6 GeV electron synchrotron.

The photograph shows three TV views (from cameras mounted adjacent to straight sections) of the synchrotron radiation in the visible range emitted by the electron and positron beams. The beams are of course travelling in opposite directions and mirrors are used to bring the light to a single camera. The beams were coincident since the electrostatic separation system was not powered and the separation of the visible spots was arranged arbitrarily by adjusting the angle of the mirrors. The beam energy was 2 GeV and the beam intensity of the order of 1 mA.

General progress on the project in April was as follows: Multi-cycle injection of positrons has been improved using a modified off-axis inflector positioned on the inside of the orbit. Positron beams of 11 mA peak and 4 mA average have been achieved with a 1/e filling time of 20 s and a beam decay time of 1.5 m. The best results were obtained at 2.1 GeV peak energy. Multi-cycle injection of electrons at 240 MeV achieved 25 mA peak.

Both beams suffered from instabilities, which were current dependent, when changing to d.c. operation at the top of the acceleration cycle. For example when the positron beam was non-uniformly distributed, the high current portions suf-



First simultaneous storage of electrons and positrons in the Cambridge Electron Accelerator. The television screens show the cross-sections of the beams observed at three different points in the ring. Each view is provided by a camera receiving (via two oppositely facing mirrors) synchrotron radiation from electrons travelling counter-clockwise and from positrons travelling clockwise. Each camera sees two differently shaped cross-sections because the beam segments emitting the light are in magnets of different type. The separation of the two spots is a consequence of adjusting mirror tilt so as to show the two spots separately. The beams were actually coincident, since the electrostatic separation system was not powered.

(Photo CEA)

fered most and finished with especially low current. This applied for currents in excess of 1 mA and peak stored currents were 3 mA for positrons and 10 mA for electrons. Work is now under way to control the effects using an octupole lens and beam-widening techniques.

Control of the separation between horizontal and vertical oscillations using Panofsky type ferrite-cored quadrupoles is installed and working well. The electrostatic plate system for vertical separation of the beams has been improved and tested. Also tests have begun on computer control of the bypass magnets. Finally, work is under way on the two linacs, the converter and the injection systems so as to be able to switch from electron filling to positron filling in less than 30 s.

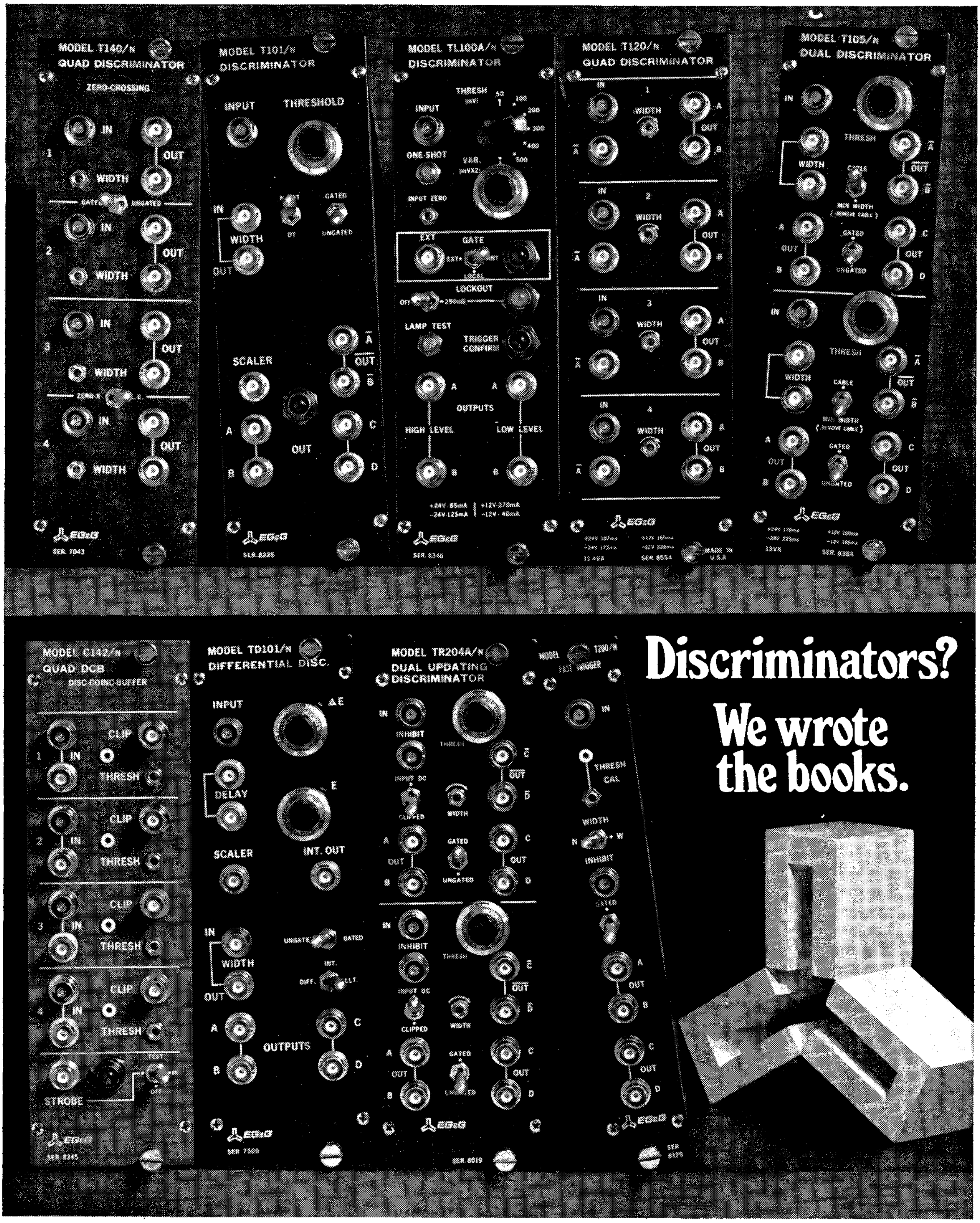
BERKELEY

Discovery of element 105

It was announced on 28 April that a team of scientists at the Lawrence Radiation Laboratory, led by A. Ghiorso, have produced atoms of element 105, the heaviest yet discovered. They have proposed the name 'hahnium' (symbol Ha) in memory of the German scientist Otto Hahn.

The element was made in bombarding a target of californium-249 (element 98) with a beam of nitrogen ions accelerated to 84 MeV in the Laboratory's Heavy Ion Linear Accelerator (HILAC). Hahnium-260 was formed and was found to have the unexpectedly long half-life of 1.65 s. Alpha particles of characteristic 9.1 MeV energy are emitted in the decay.

This new work adds another feather to the already highly decorated cap of the Lawrence Radiation Laboratory. They have a strong claim to the first identification of all the heavy elements from plutonium (element 94) to hahnium (element 105).



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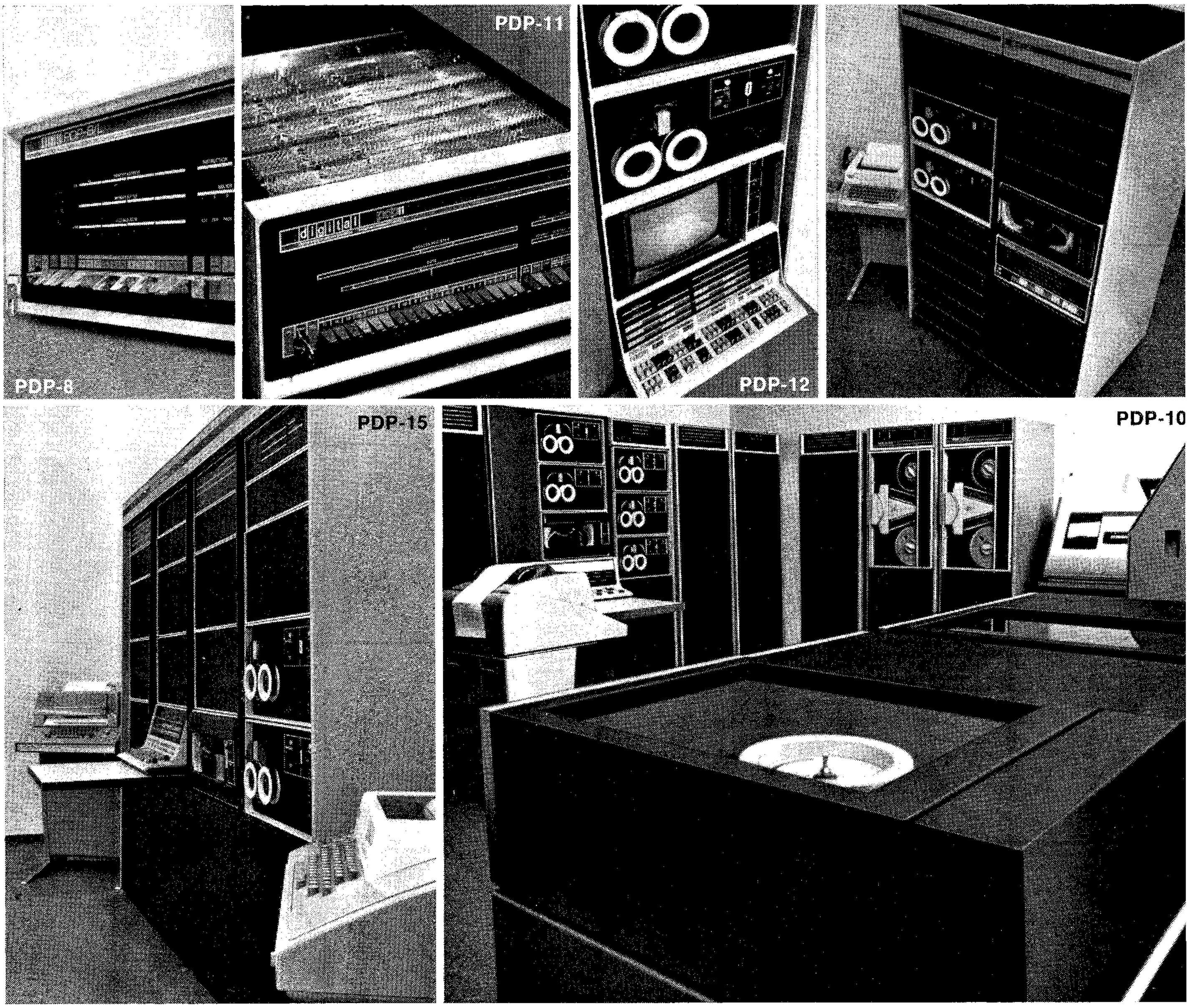

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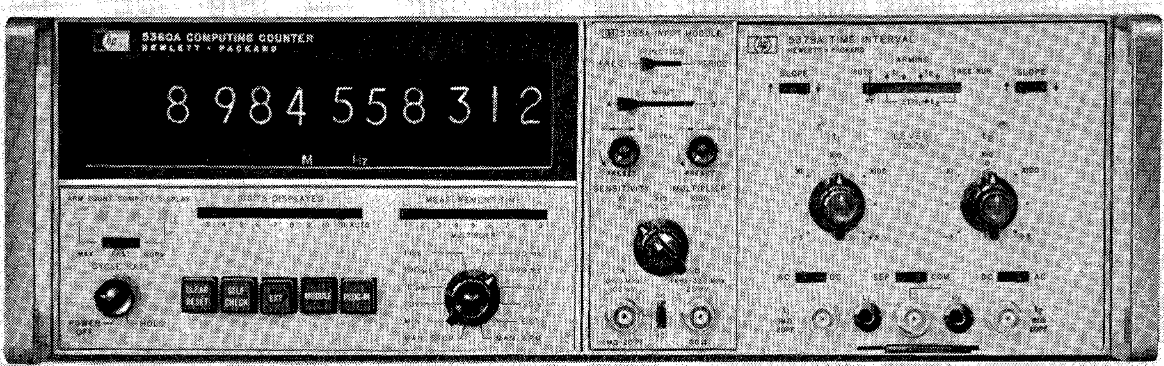

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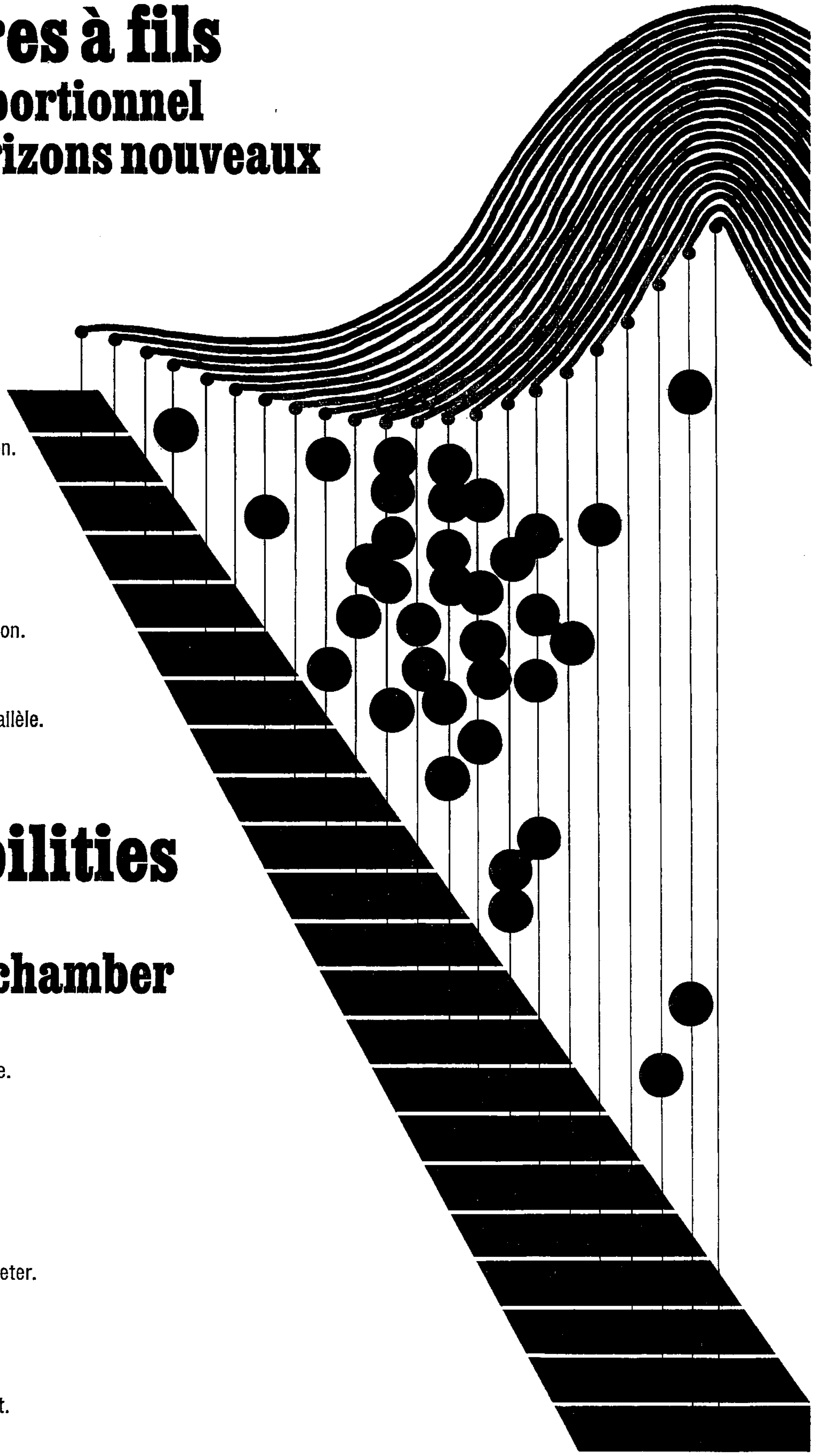

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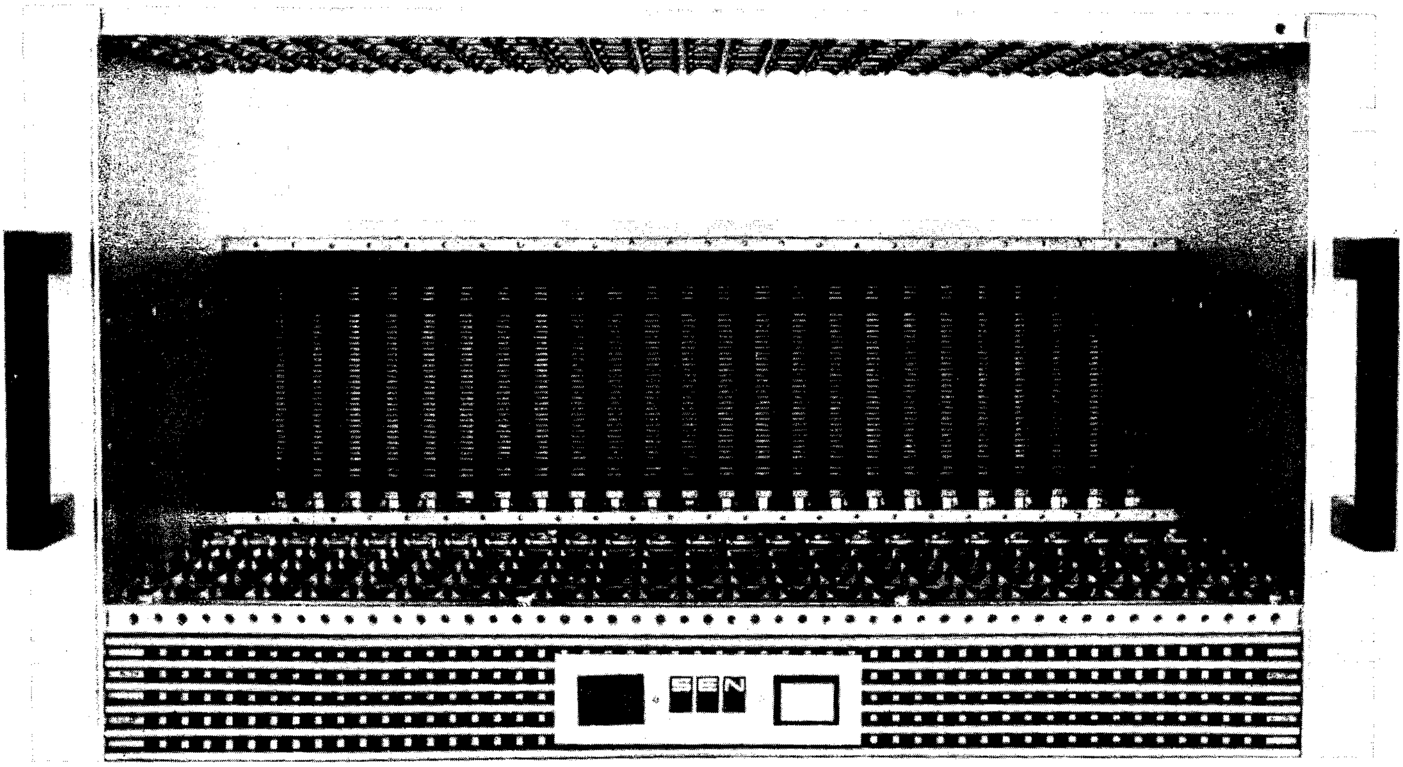

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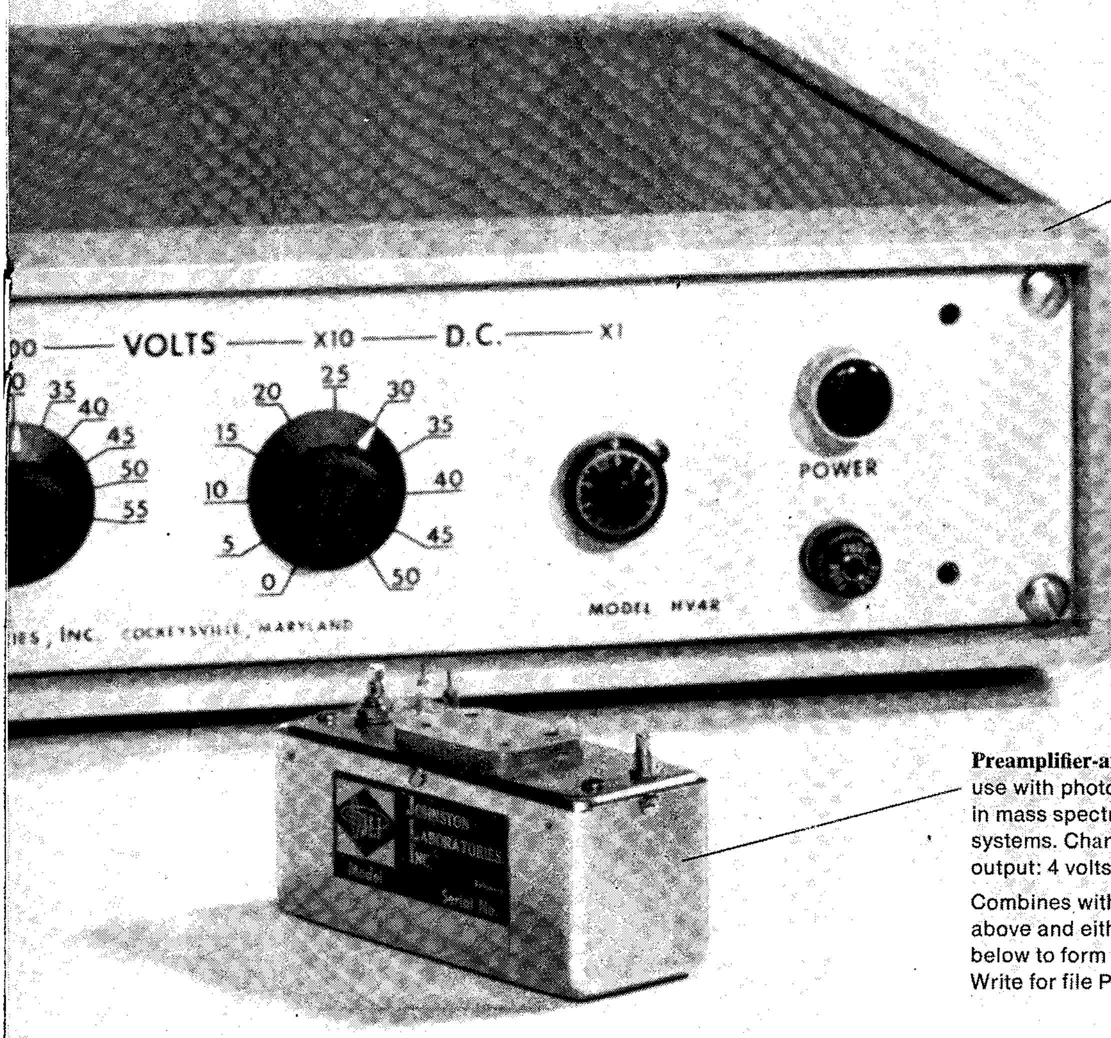

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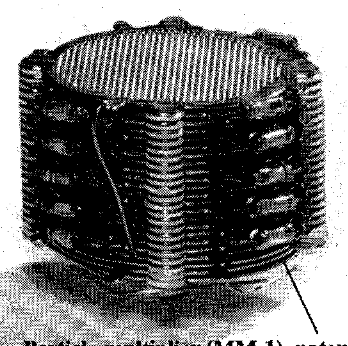

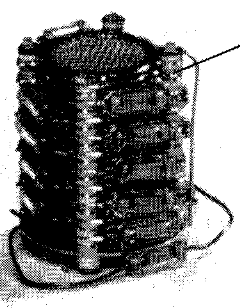

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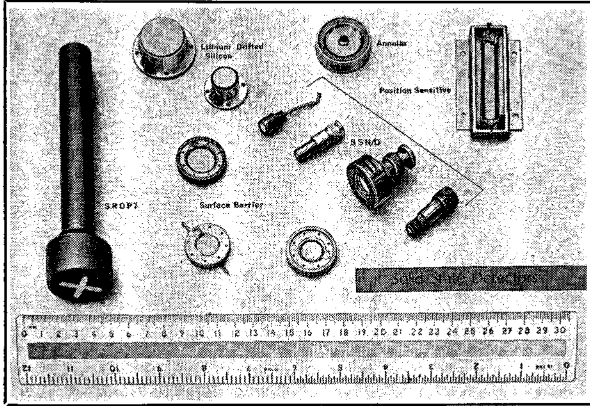

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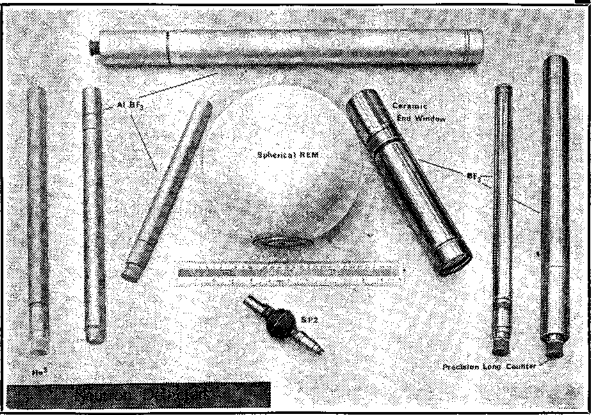

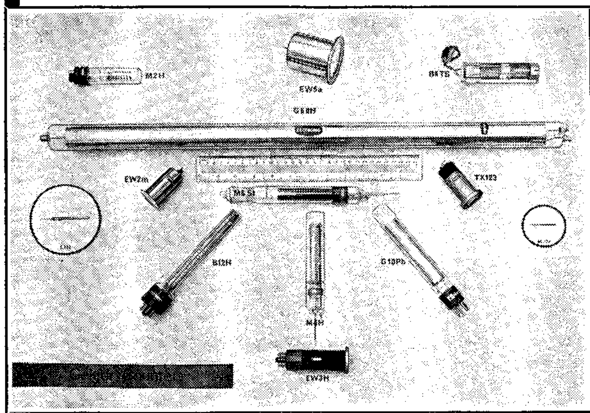

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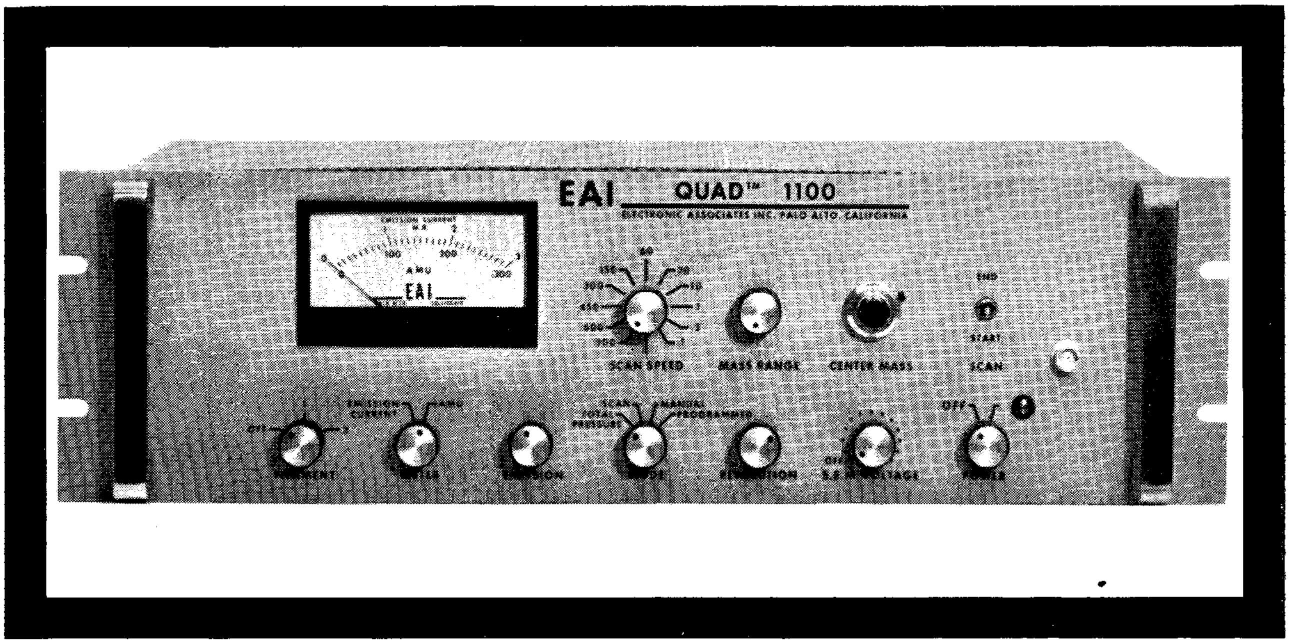

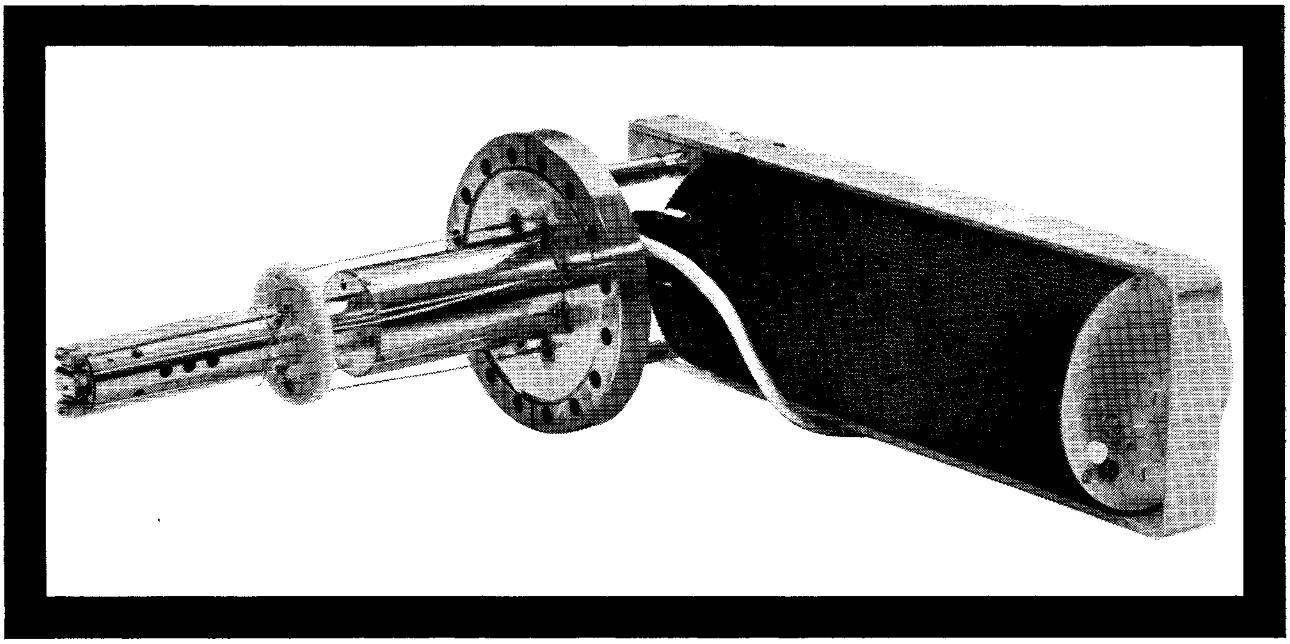

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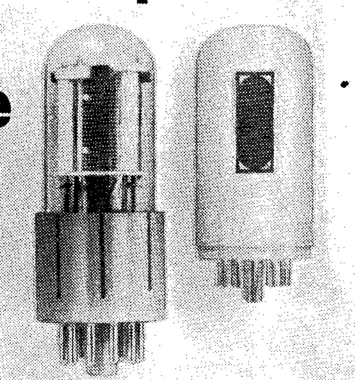

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C31025C	(1) 200 – 940 (2) 280 – 720	37 @ 450 nm	13.1% @ 300 nm 6.4% @ 632.8 nm 1.9% @ 860 nm	0.5 @ 2A/lm
C31025D	(1) 200 – 760 (2) 290 – 640	61 @ 450 nm	21% @ 350 nm 8.6% @ 632.8 nm	0.5 @ 2A/lm
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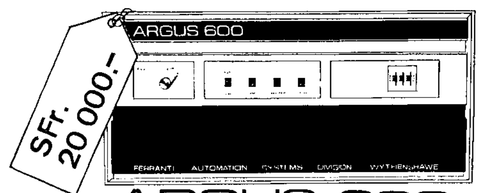

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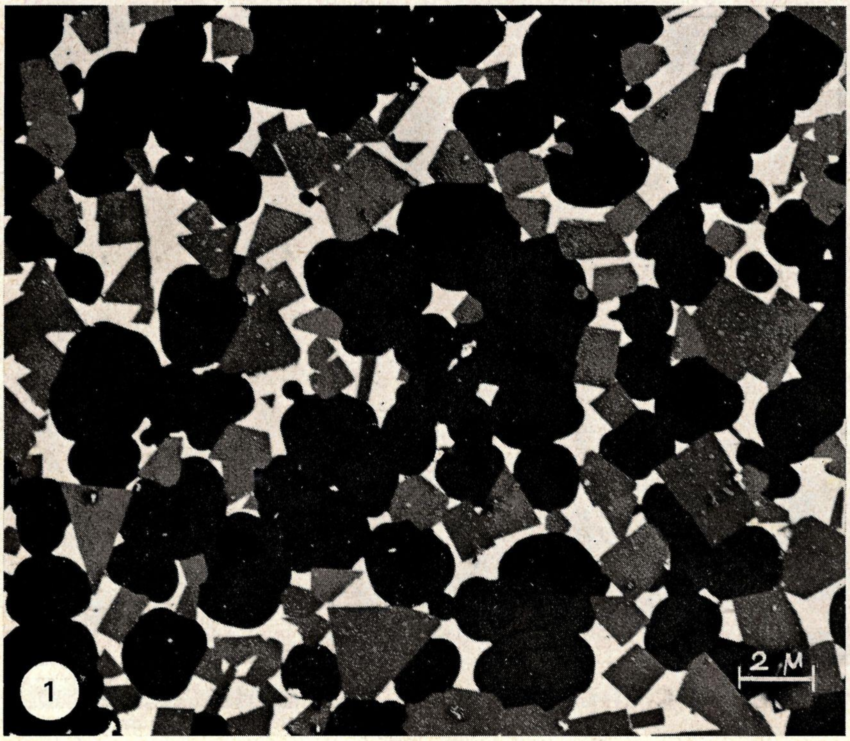
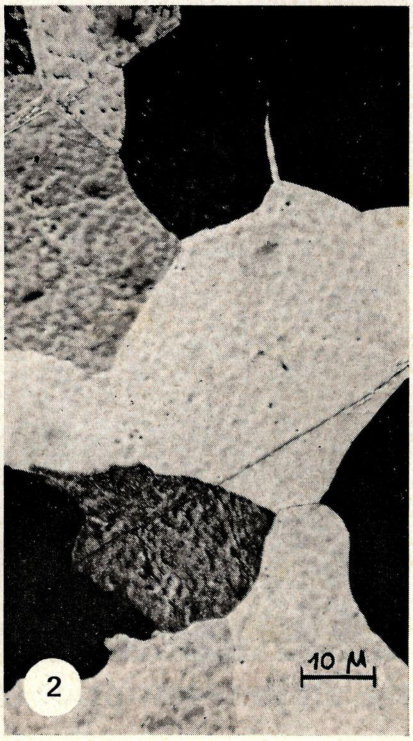
Surfaces of solids with optimum contrast and high resolution at room temperature and at high temperatures too

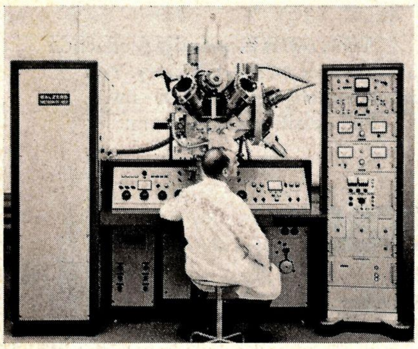




Two examples:

(1) Cemented carbide mechanically polished photoemission micrograph at room temperature. 5000 x

(2) Ferritic structure of silicon-iron during recrystallization photoemission micrograph at 675°C. 1000 x



... and this

is the instrument needed for such studies: The photoemission electron microscope METIOSCOPE KE 3 BALZERS.

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