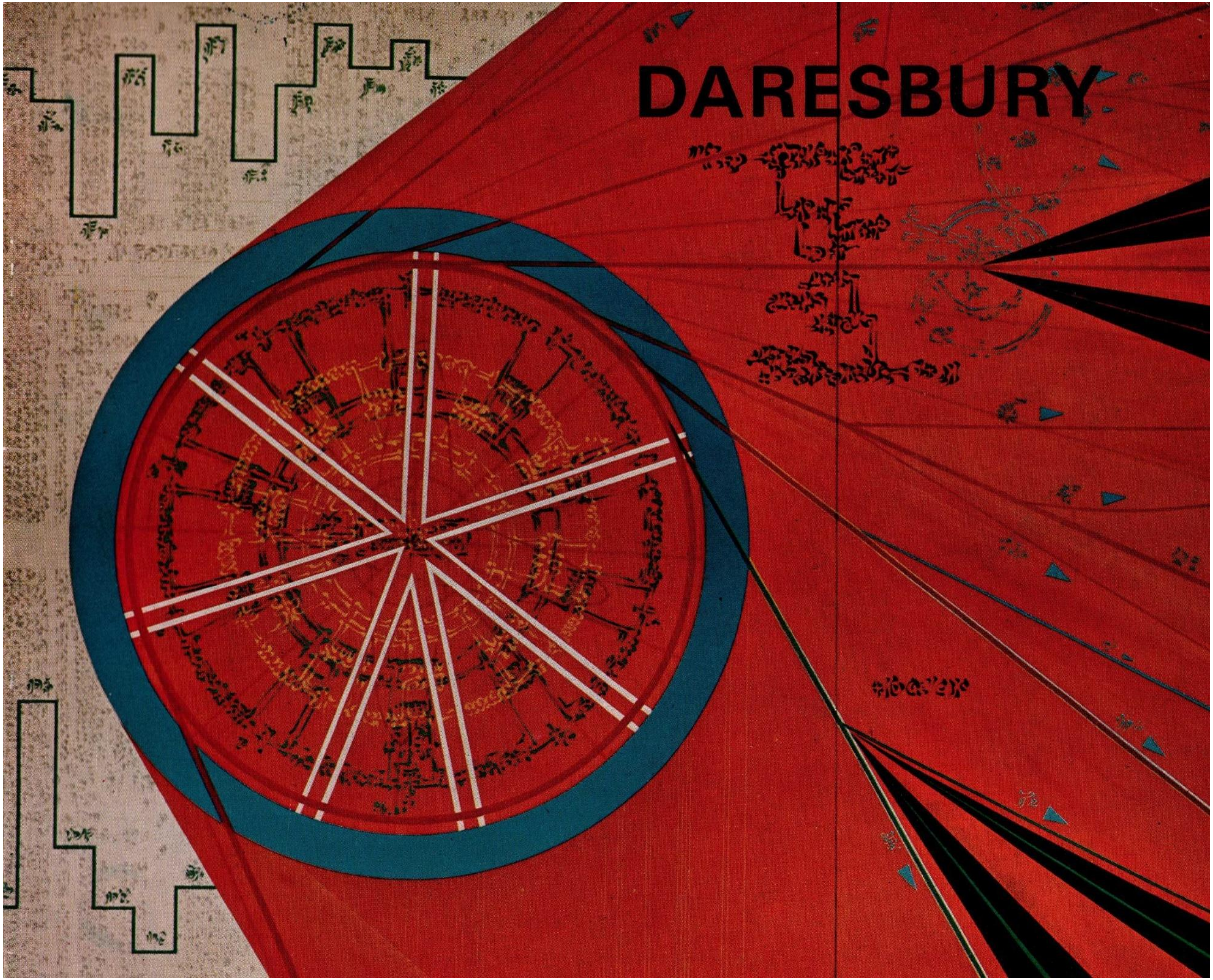
DARESBURY



SCIENCE RESEARCH COUNCIL

Daresbury Nuclear Physics Laboratory

In 1962 the National Institute for Research in Nuclear Science started to plan a second national laboratory for high energy physics at Daresbury. In order to complement the research at the 7 GeV proton synchrotron of the Rutherford Laboratory, it was decided to build at Daresbury a 4–5 GeV electron synchrotron. This machine is now known as NINA – National Institute Northern Accelerator. The Laboratory was intended primarily as a facility for physicists from the Northern Universities, especially those at Liverpool, Manchester and Glasgow, who also played a considerable part in the early design work. Teams of high energy physicists from these Universities, and others from Lancaster, Sheffield and Daresbury itself are currently performing experiments at the Laboratory. Daresbury physicists are also collaborating with groups from French and Italian Laboratories. NINA has been providing beams of high energy particles since it first became operational on 2nd December 1966, only 3 years after the start of construction.

Similar electron synchrotrons are in operation at Cambridge, Massachusetts and Cornell University, N.Y. in the U.S.A., at Hamburg in Germany and at Yerevan in Soviet Armenia.

This brochure is designed to give a pictorial guide to the scientific facilities of the Laboratory, from the accelerator itself to some of the experiments being currently performed, and to the general amenities which are available.

Text: R. E. Rand

Photography: A. J. Pickett

Magnet Support Pillars during Construction

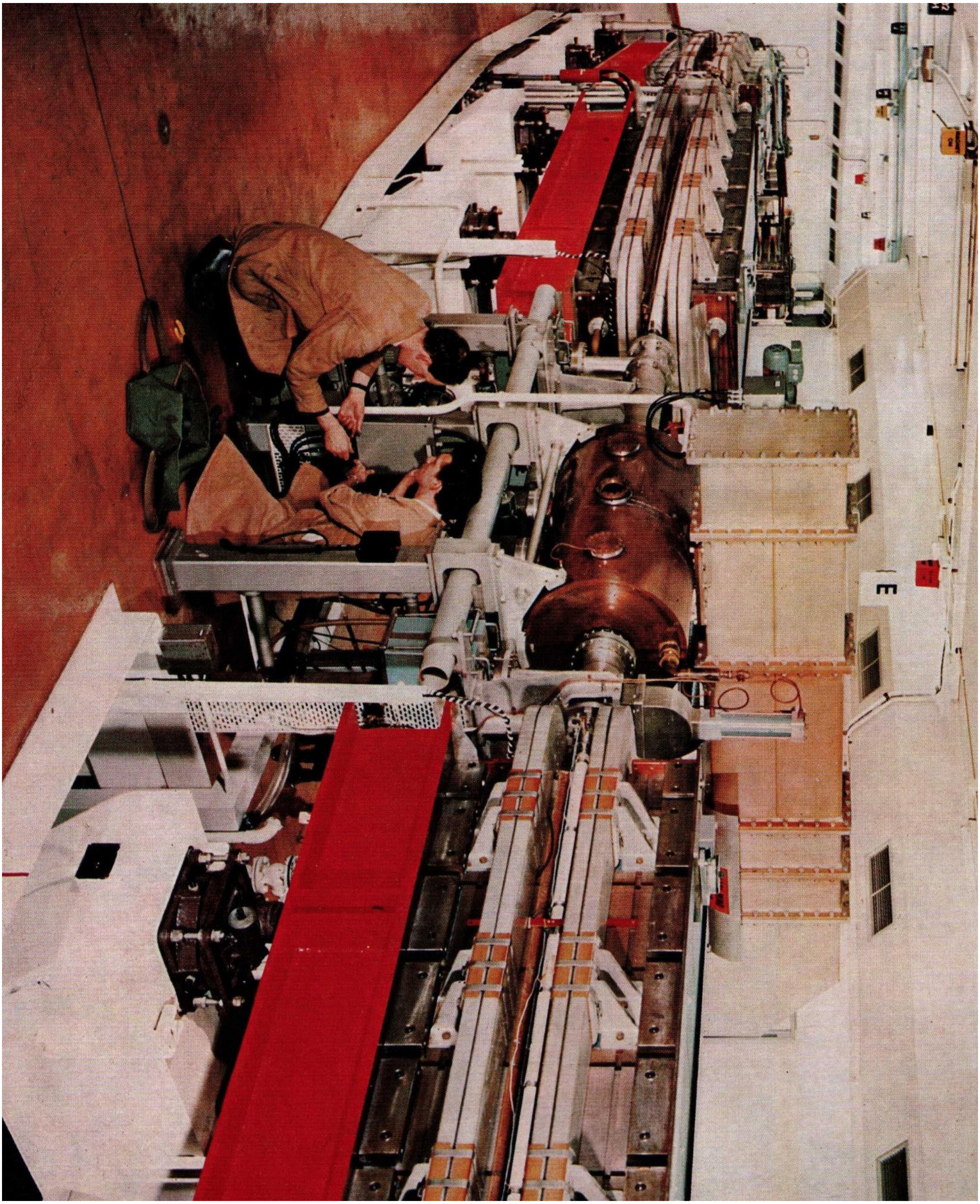
THE ACCELERATOR

An electron synchrotron consists basically of a ring of electromagnets whose magnetic fields confine the trajectories of the accelerating electrons to stable circular orbits. In the case of NINA the magnet ring is 70 metre in diameter and each magnet must be positioned to an accuracy of a few thousandths of a cm. The mechanical stability of the ring is thus crucial to the successful operation of the accelerator. The foundation for the magnets consists therefore of a reinforced concrete ring supported on pillars of concrete sunk deep into the underlying sandstone, for which the Daresbury site was chosen. This foundation is completely independent of that which supports the building around the accelerator.

There are 40 magnets in the ring, each formed from about 600 laminations. The magnet gaps are wedge shaped with the wedges facing inwards and outwards alternately around the ring. This arrangement produces "strong focussing" of the electron orbits and ensures that they are confined to a small aperture within the magnets.

The magnets in the ring are separated alternately by 1 metre and 3·5 metre long straight sections. In the longer straights the cavities for accelerating the electrons, and the inflection and beam extraction systems are located. They also contain diagnostic and control devices which provide fine adjustment of the operating conditions.

Part of the Magnet Ring



One of the Accelerating Cavities

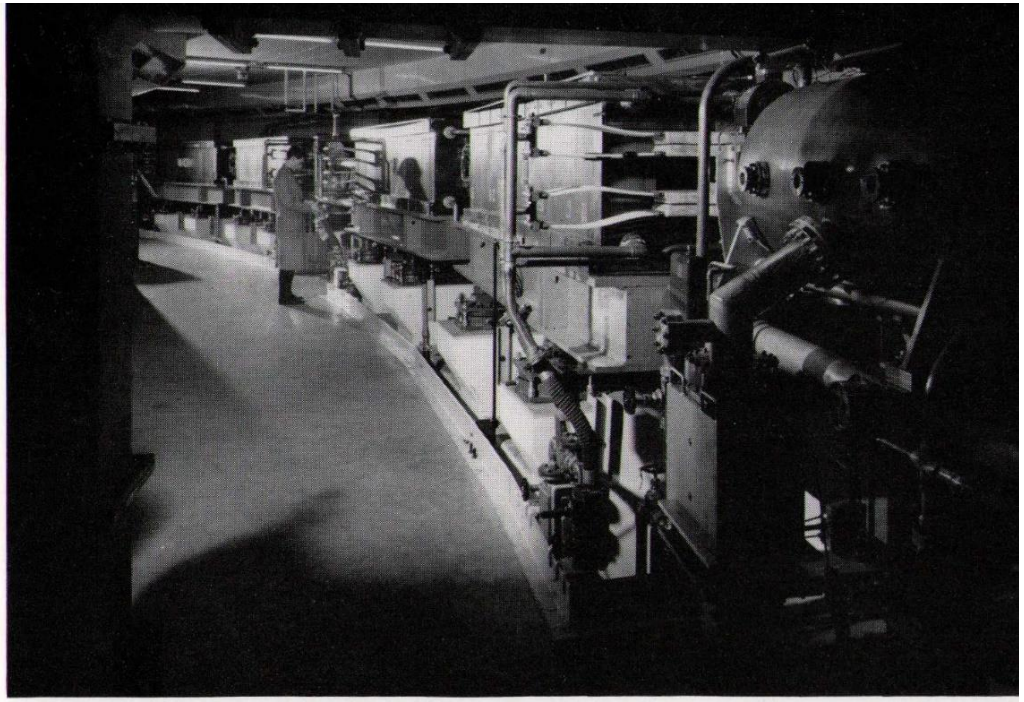
Electrons are injected into the synchrotron after acceleration to 40 MeV in a linear accelerator or linac. This consists of a loaded waveguide in which the electrons are continuously accelerated by a travelling electric wave. Power is fed into the wave-guide by two 30 megawatt klystrons at a frequency of 2856 Mc/s. Electrons from the linac are directed into the ring first by bending magnets and then by a pulsed electro-magnetic inflector.

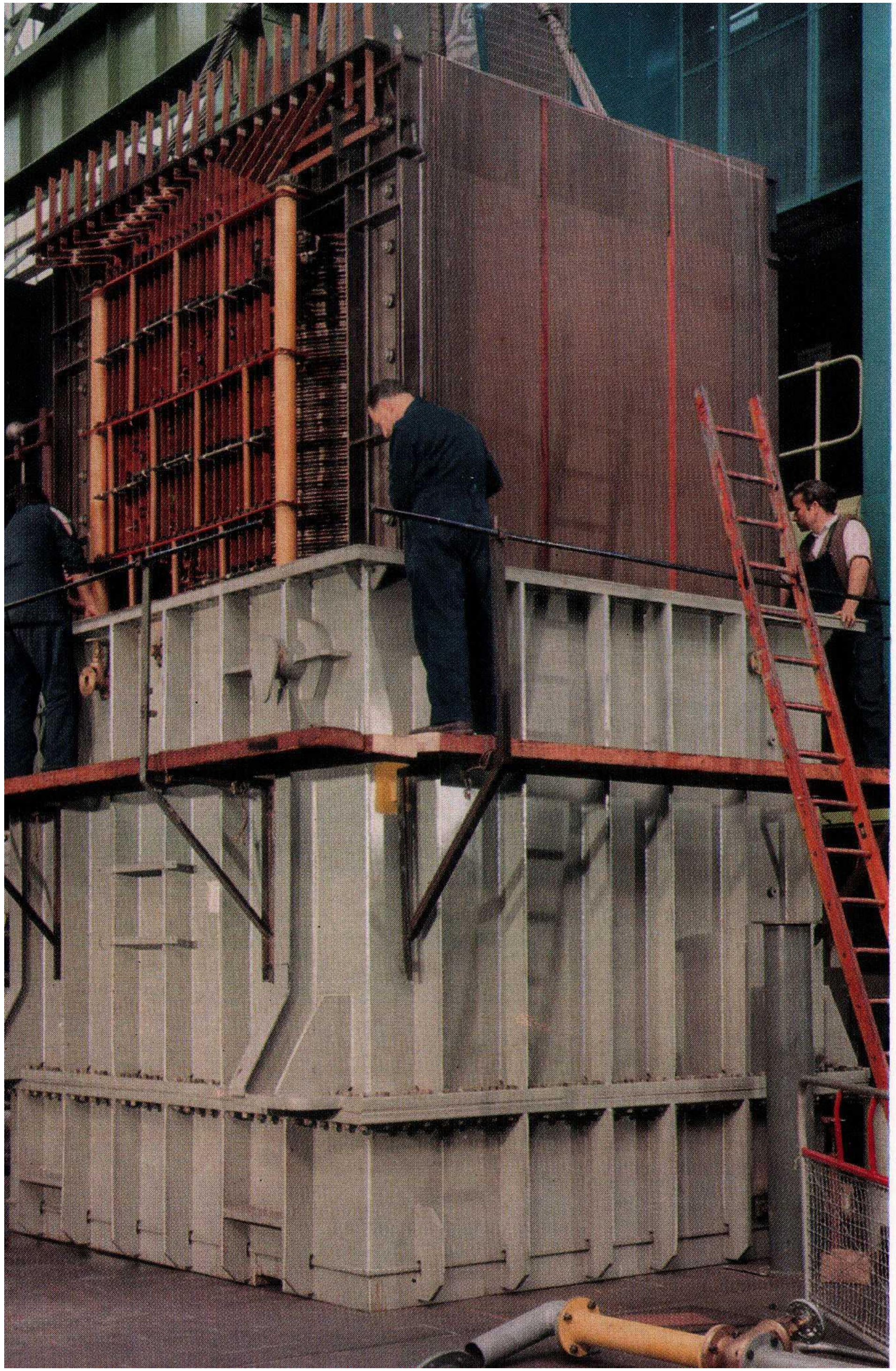
The orbiting electrons are accelerated by the oscillating electric fields in five resonant cavities around the ring. The operating frequency of these cavities is 408 Mc/s, exactly 300 times the circulating frequency of the electrons. Microwave power is fed to these cavities by a high power triode amplifier, controlled by an 80 kilowatt tetrode. The average power required to accelerate a 10 microampere beam to 4 GeV is about 150 kilowatt with a peak power of 500 kilowatt.

During the acceleration process the electrons must remain in a region of high vacuum. The original stainless steel and epoxy-resin vacuum chambers have now been replaced by new ceramic chambers in which it is possible to maintain a far better vacuum.

The Linear Accelerator

A Ceramic Vacuum Chamber



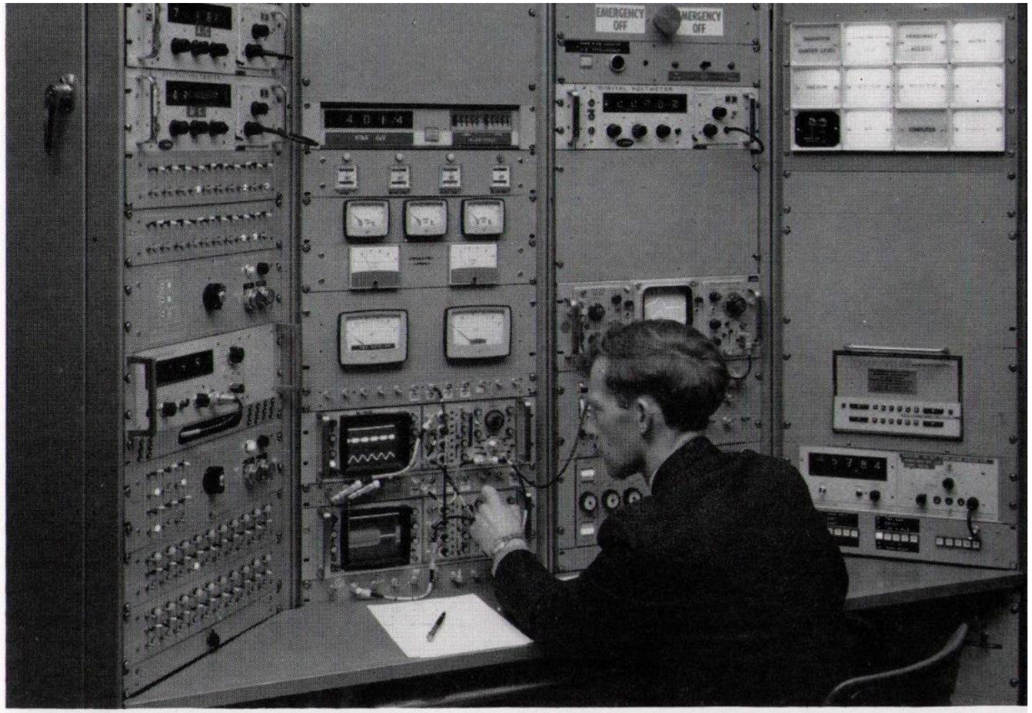


Immediately after injection, the electrons circulate in a stable orbit, defined by the ring magnets and are accelerated by the electric fields in the cavities. As the energy of the electrons increases the magnetic field must also rise in order to maintain a constant orbit radius. This variation in magnetic field is achieved by making the magnet coils part of a resonant circuit which oscillates at 50 c/s. A d.c. bias is also applied to the magnets to control the rate of rise at injection. The electrons are injected into the ring soon after the magnetic field passes its minimum value. The field and electron energy then increase to their maximum values in about 1/100th of a second. The beam is extracted at its maximum energy and the field falls again for the next acceleration cycle.

In order to make up for power losses, energy must be fed into the resonating system. This is achieved by connecting groups of magnet coils to the secondary windings of an energy storage choke whose primary windings are supplied with the necessary power in the form of short pulses. At maximum excitation the magnet coil currents are 680 ampere d.c. and 480 ampere r.m.s. a.c., and the power consumed is about 1 megawatt.

The Energy Storage Choke

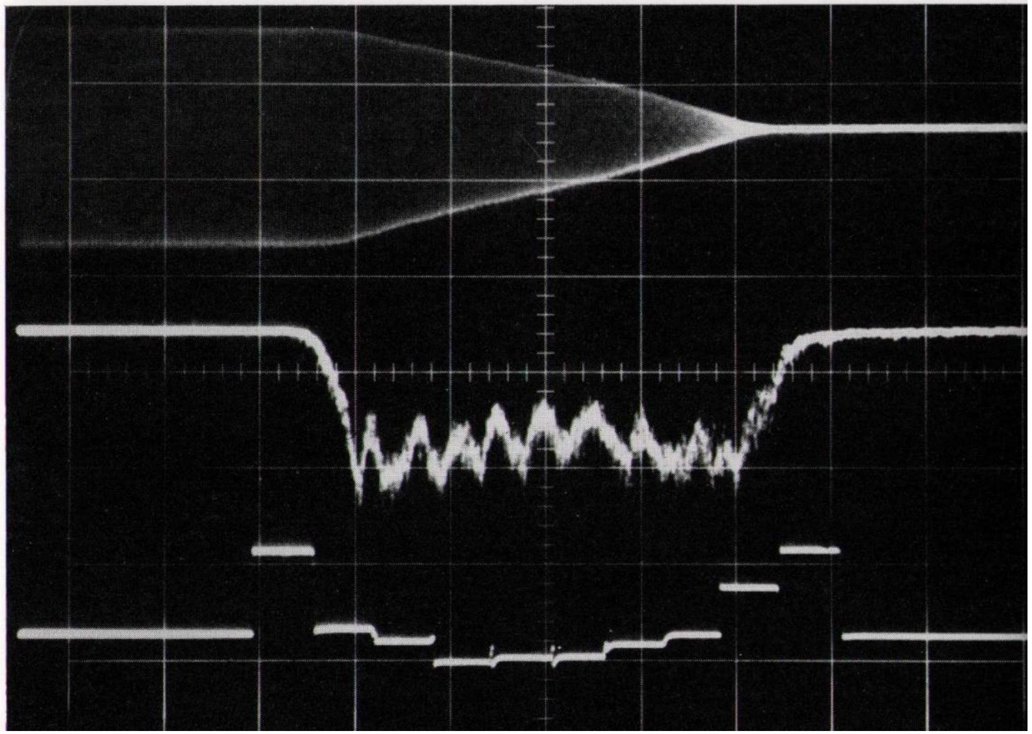
The Main Control Consul



The electron beam itself may be extracted from the machine by means of a pulsed current strip which, with an appropriate orbit distortion, "peels off" the electrons over a period of about 800 microseconds. Alternatively the electrons may be caused to collide with a tungsten wire target, in the ring vacuum chamber, thus producing a beam of photons by the bremsstrahlung process. This beam leaves the machine tangentially. The "spill" may be up to 2 milliseconds in duration each acceleration cycle. The oscilloscope photograph on this page shows the circulating beam envelope, the ejected photon beam (as observed by a scintillation counter) and the pulse which controls the ejected beam.

Beams of photons or electrons may be ejected from the machine at three points around the ring. The pulses used to produce these beams can be programmed in such a way that successive beam pulses may be fed to different experimental areas. Thus up to three high energy experiments may be performed simultaneously.

Operation of the machine is directed from the main control room, where, as well as manual controls, there is an IBM 1800 computer which monitors many variables, diagnoses faults and will shortly control certain critical parameters of the accelerator.

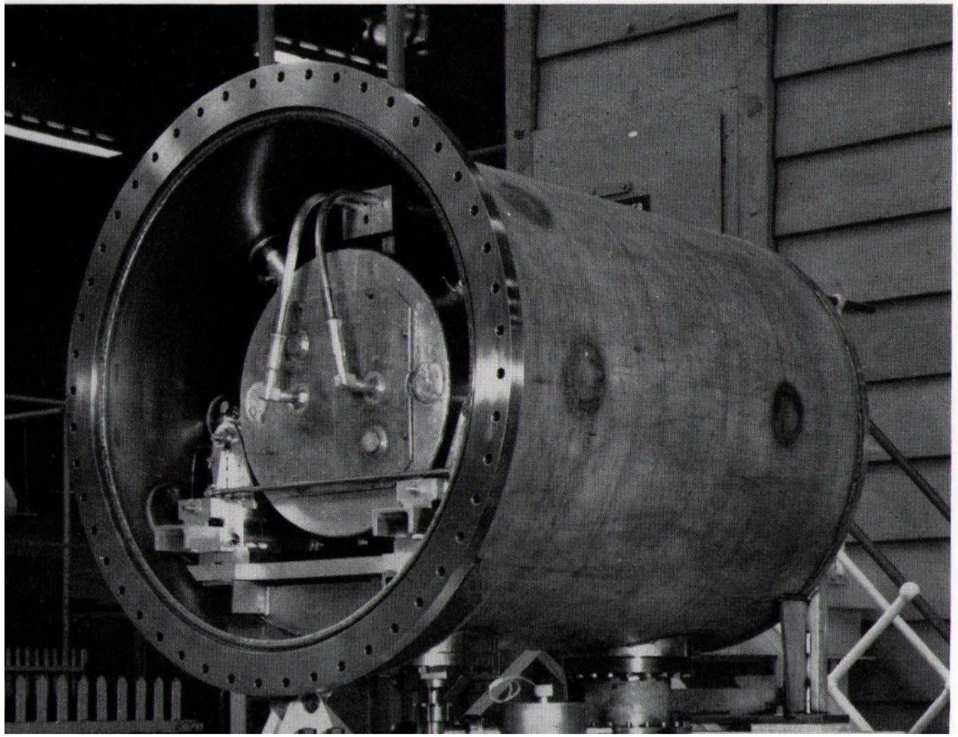


Circulating and
Ejected Beams

Scintillation Counters

EXPERIMENTAL FACILITIES

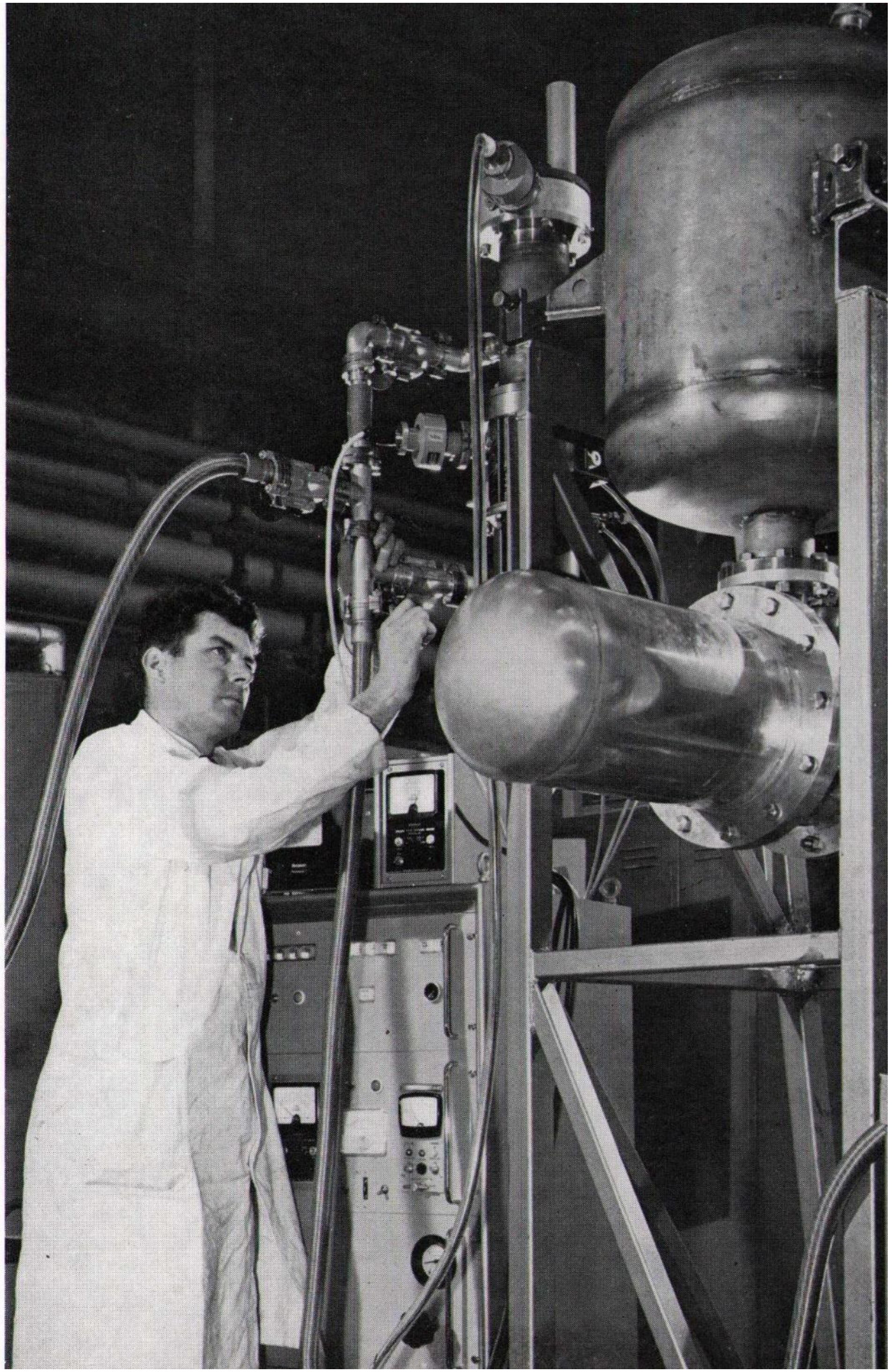
Beams of particles from the accelerator are transported to the various areas in the experimental hall. Photon beams cannot, of course, be deviated but they must be collimated and cleared of charged particle contamination, by passing them through the fields of "sweeping" magnets, before they reach an experimental target. Electron beams may be directed along any desired path by using uniform field magnets, while quadrupole magnets are used to focus the beams as required. Photon and electron beams are monitored by quantameters and Faraday cups respectively. Each of these devices enables the experimenter to calculate the number of primary particles which have passed through his apparatus. In almost every high energy physics experiment, charged particles are detected by scintillation counters. These generally consist of a sheet of clear plastic scintillator in which a flash of light is produced whenever a charged particle passes through. This light is transmitted through a perspex light guide to a photomultiplier where it is converted into an electrical pulse. These pulses are transmitted through cables to a counting room where they are analysed and recorded.



A Faraday Cup

Each experiment has a target in which high energy reactions induced by the primary beam take place. This target may be of any desired material but consists usually of liquid hydrogen. This is chosen since the nucleus of the hydrogen atom is a single elementary particle – the proton. Reactions between the incident beam and protons are simpler to observe experimentally and analyse theoretically than those involving complex nuclei. Hence the importance of hydrogen as a target material. The liquid phase is used to pack as much hydrogen as possible in a given volume. In order to produce the hydrogen targets required by the experimental groups a large cryogenic workshop and laboratory has been established. The targets are of two types based respectively on the principles of the vacuum flask and the refrigerator. In the latter case, the working substance of the refrigerator is helium – the only gas which does not liquify at liquid hydrogen temperatures. Shown on this page is a typical hydrogen target of the vacuum flask type.

A Liquid Hydrogen Target



The Laboratory maintains a large mechanical workshop where much of the experimental equipment is produced. Large or heavy items are manufactured by outside firms but usually the workshop staff are responsible for the final assembly. The muon range counter shown here is a typical mechanical product.

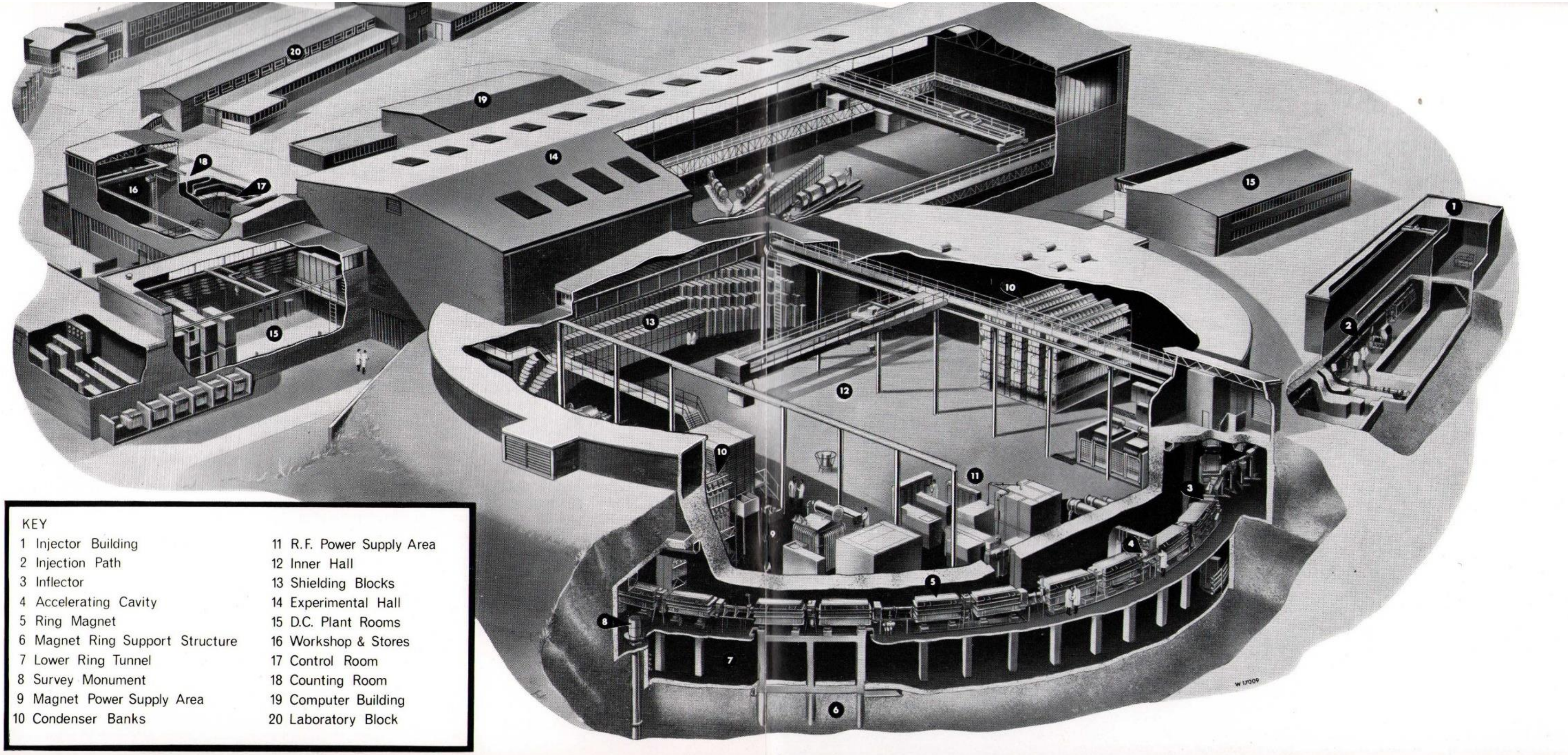
This apparatus is used to detect muons in the presence of a strong contamination of electrons and pi-mesons or pions. It uses the fact that muons are able to penetrate very much greater thicknesses of material than other elementary particles. The apparatus consists of two iron wedges, one of which slides against the other forming an iron slab of variable thickness. Behind this slab are mounted arrays of scintillation counters. When a beam of particles is incident on the front face of the range counter, only muons penetrate the iron and these are recorded by the scintillation counters.

Muon Range Counter

The Central Computer Facility

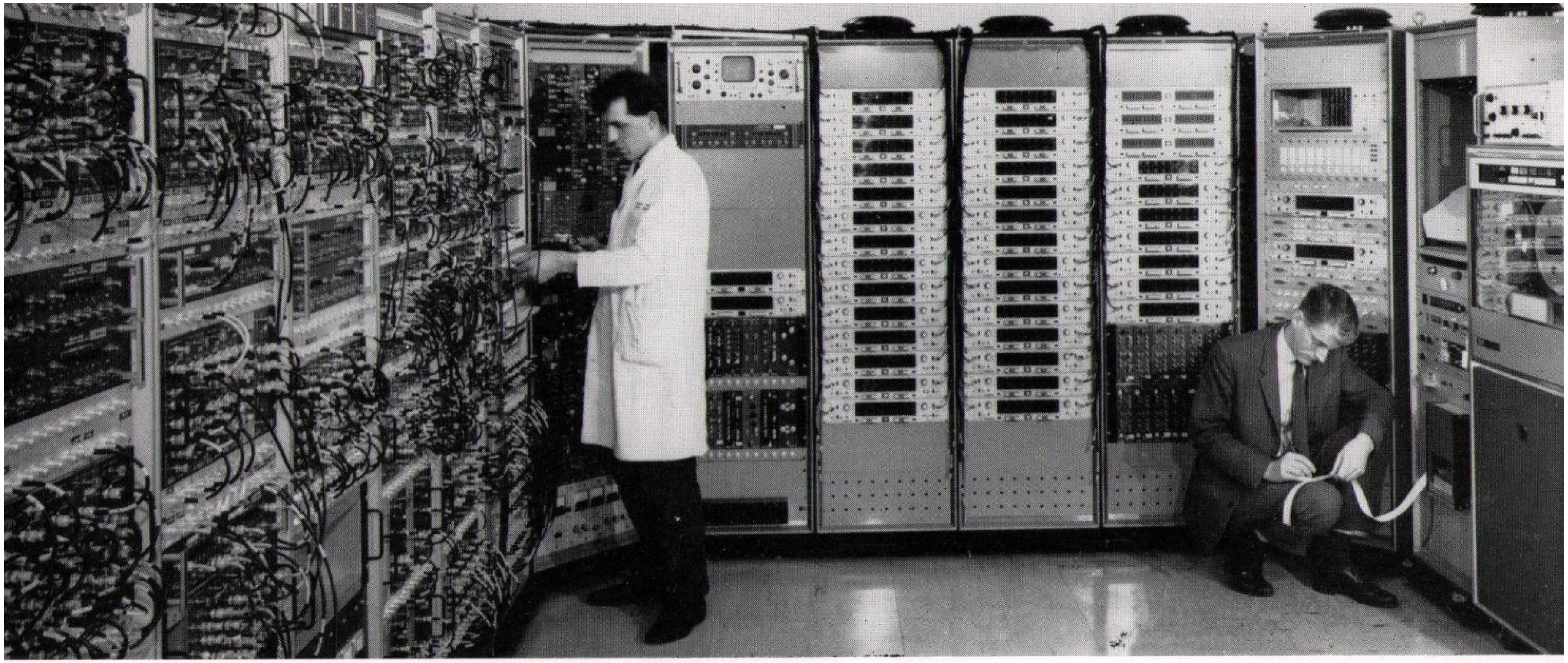
COMPUTING

The complexity of data from modern high energy experiments requires the use of a computer in the analysis of results. The laboratory maintains an IBM 360/65 installation for the use of experimentalists, theorists and others such as applied physicists and engineers. Several experimental groups are using small "on-line" computers in association with their counting equipment to process and analyse data as it is produced. These small computers are inadequate by themselves for many such tasks so that they may be linked to the IBM 360/65 for more complex calculations. The latter is able to deal with data from several such links as well as perform other independent calculations virtually simultaneously. Some experiments store data on magnetic tapes. These may also be processed by the main computer. A particular facility available on the IBM 360/65 is the visual display unit. This may be used to reconstruct experimental events, trace particle tracks through magnets, etc. The form of the display is chosen by the programmer. He also has the facility of erasing or writing on the display at will by use of a "light pen".



KEY

1 Injector Building
2 Injection Path
3 Inflector
4 Accelerating Cavity
5 Ring Magnet
6 Magnet Ring Support Structure
7 Lower Ring Tunnel
8 Survey Monument
9 Magnet Power Supply Area
10 Condenser Banks
11 R.F. Power Supply Area
12 Inner Hall
13 Shielding Blocks
14 Experimental Hall
15 D.C. Plant Rooms
16 Workshop & Stores
17 Control Room
18 Counting Room
19 Computer Building
20 Laboratory Block



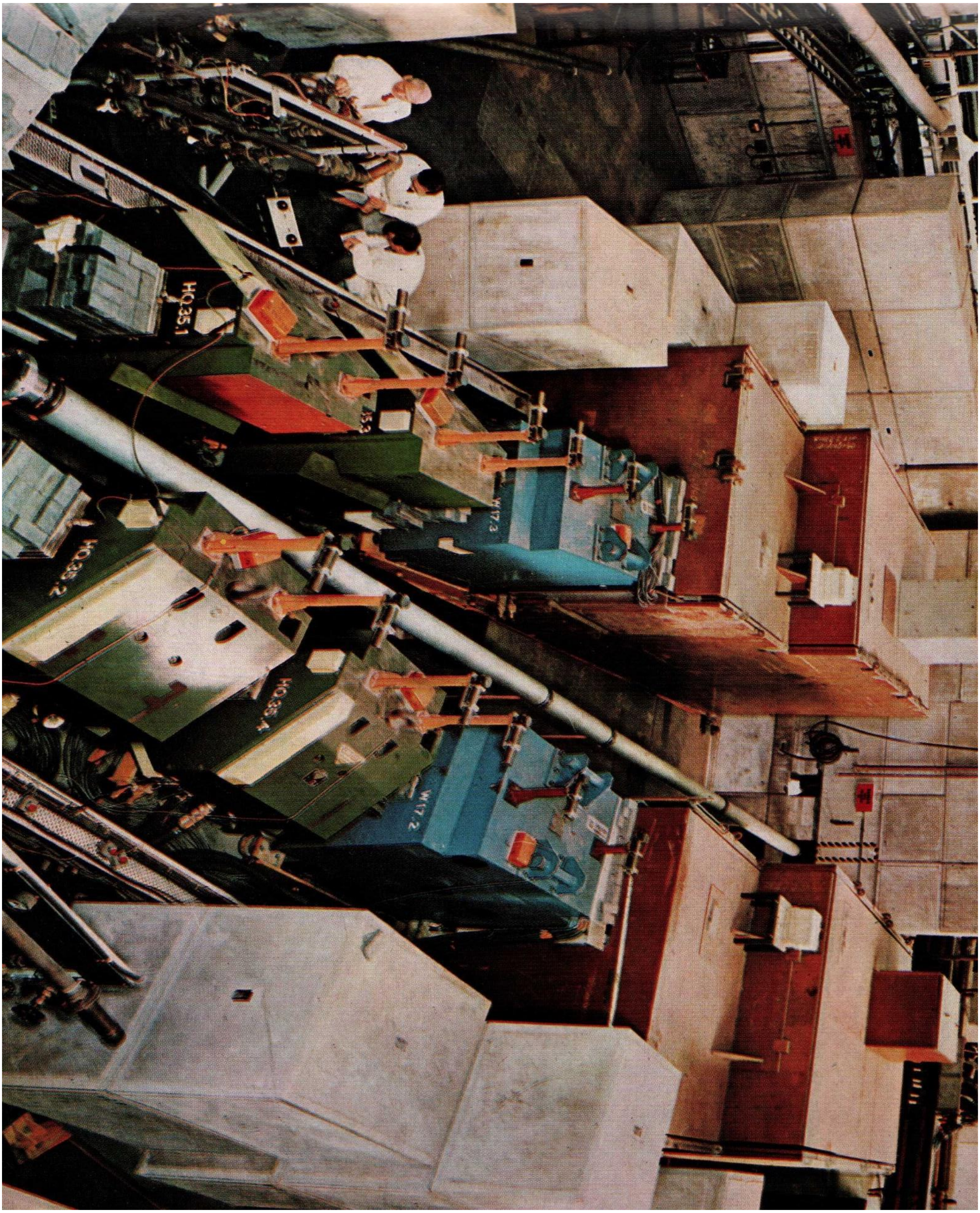
The Counting Room

WIDE ANGLE ELECTRON PAIR PRODUCTION

A group of Daresbury physicists is engaged in a series of experiments involving the photo-production of electron-positron pairs in hydrogen and other targets. By observing electron pairs at characteristically wide angles (5°–7°), and high energies, it is possible to test the validity of current theories of electrodynamics when the interaction occurs over very short distances ($\backsim 10^{-14}$ cm).

The apparatus consists of two identical but mirror image spectrometers, mounted on platforms which may be rotated about a pivot at the target. Each spectrometer comprises two focussing quadrupole magnets and a bending magnet to analyse the momentum spectrum of the electrons. Particles are detected by arrays of scintillation counters or hodoscopes. Electrons are distinguished from other particles by Cerenkov and shower counters. Electrical pulses from the various counters are fed to the counting room where true electron pair events are selected by the logic circuits. The data describing each event are written on magnetic tape for later analysis by the IBM 360/65 computer. Results have shown that quantum electrodynamics is a valid theory in the energy region investigated.

The Spectrometers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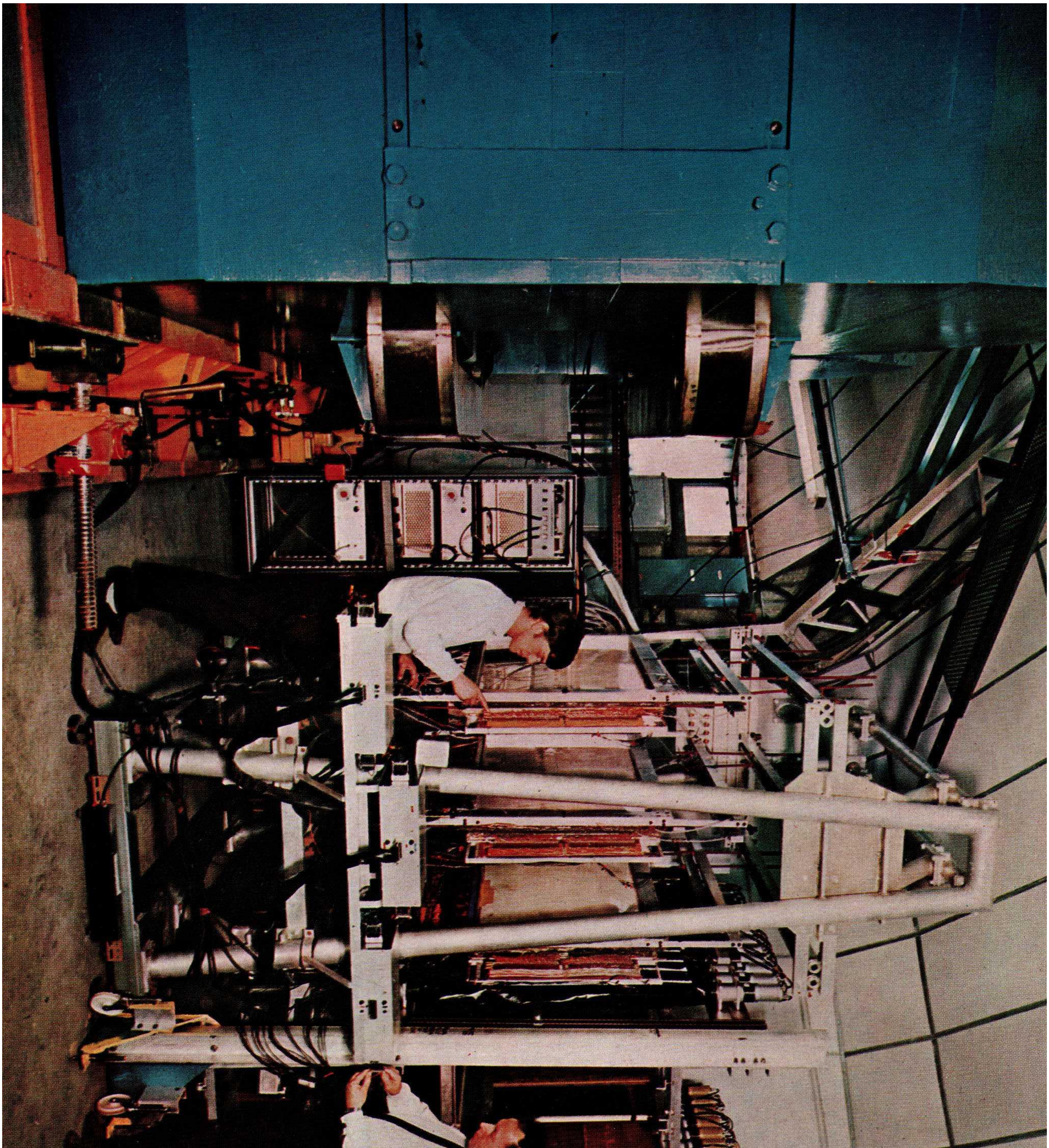
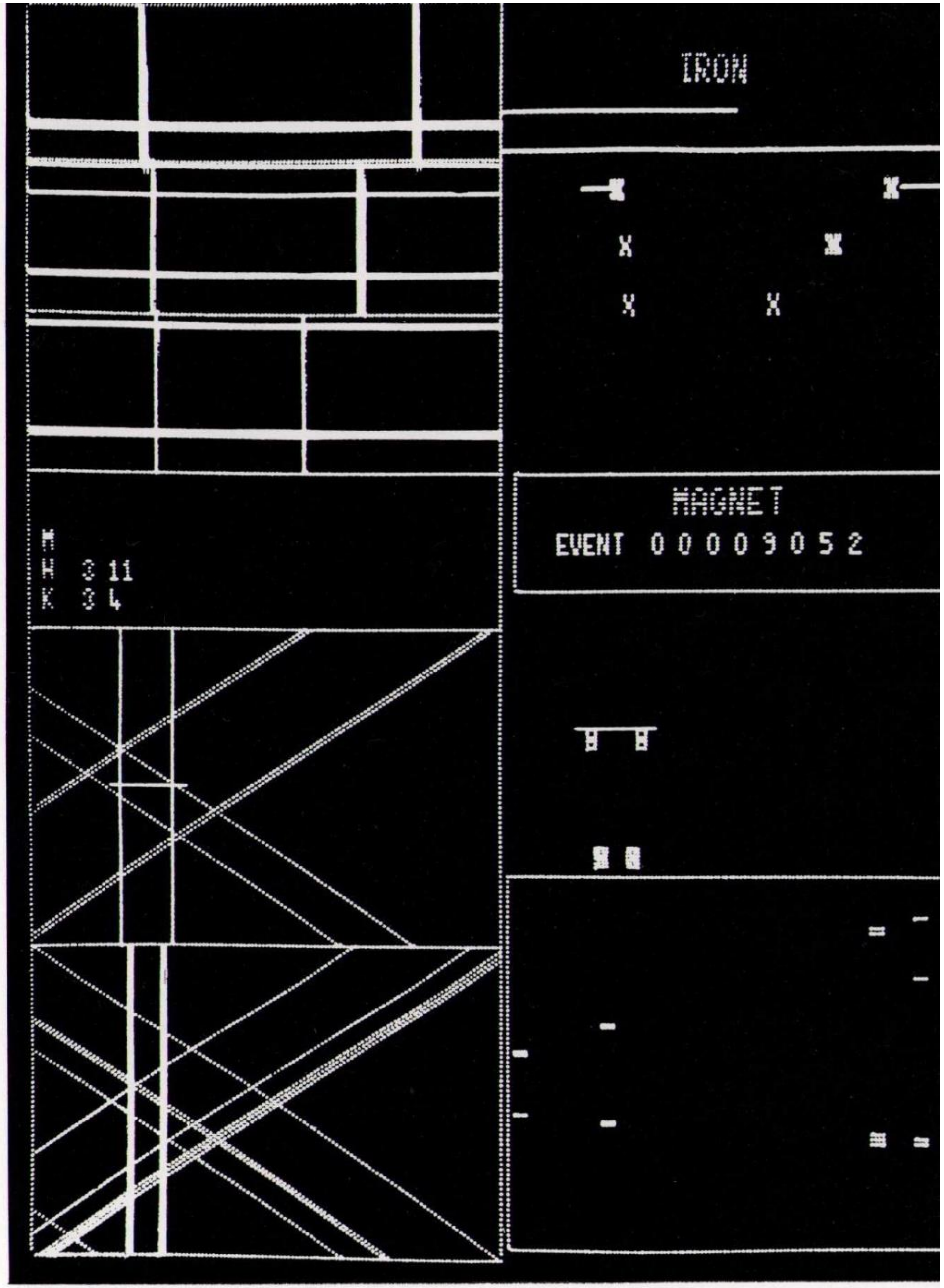


PHOTOPRODUCTION OF K° MESONS

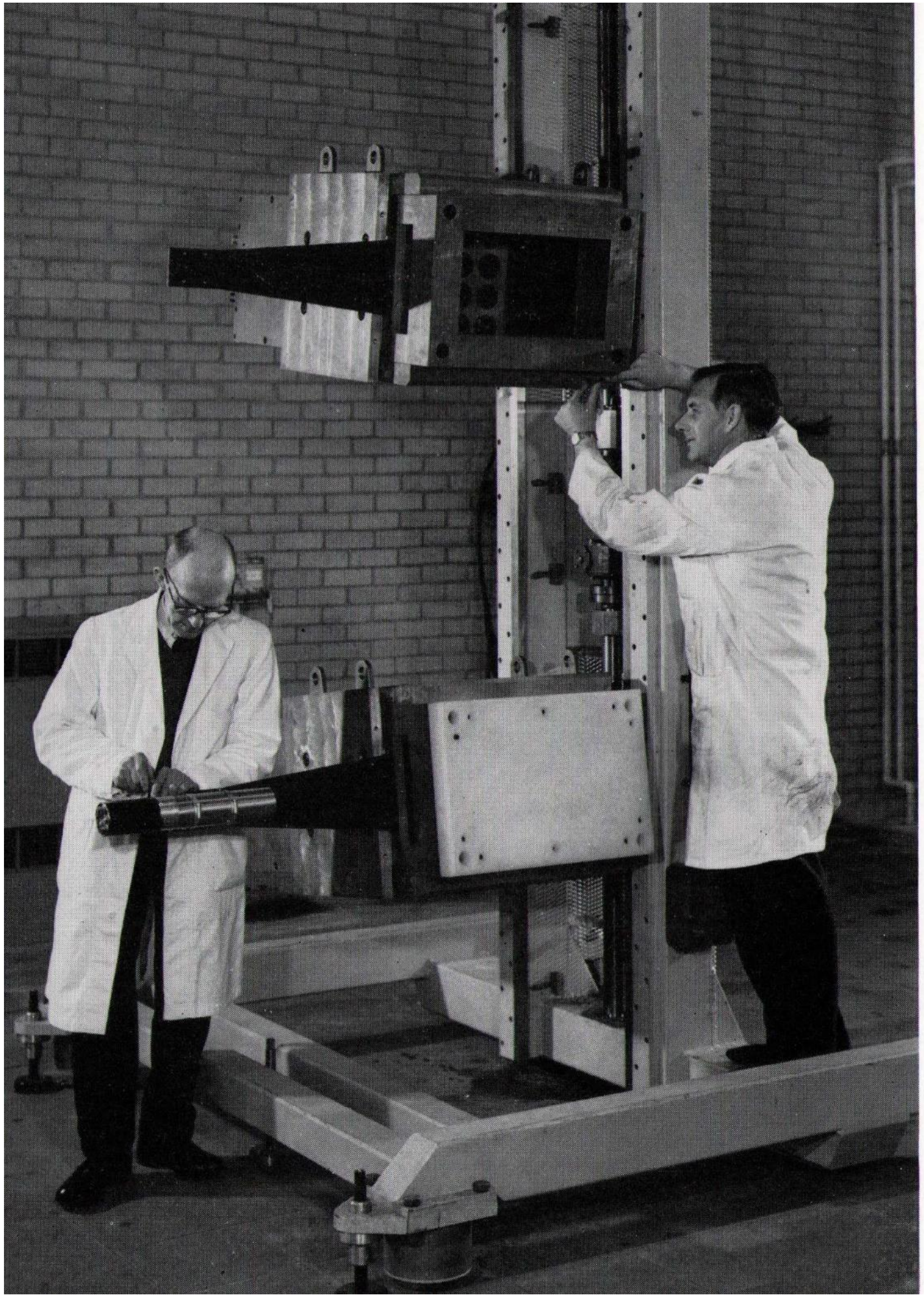
The electrically neutral K° meson is probably the most unique and fascinating of the elementary particles. Once a beam of K°'s has been produced it is found to consist of two distinct but intimately related types of K°, the long- and short-lived. These two particles have slightly different masses and individual modes of decay into lighter particles. If one observes the composition of such a beam of K°'s as it varies with distance from the production target, the short-lived K°'s very soon decay, leaving a beam of almost pure long-lived K°'s. If the beam is then passed through some heavy material however, short-lived K°'s are "regenerated" and may again be observed.

A group from Manchester University has observed photoproduction of K°'s using a bremsstrahlung beam from NINA. The beam of K°'s from the experimental target (hydrogen or beryllium) is observed by detecting pairs of charged pions from the decays of short-lived K°'s, regenerated 40 metre from the target. The pions are detected by scintillation counter hodoscopes and spark chambers arrays in conjunction with a large bending magnet. The output from the spark chambers is fed to a small PDP8 computer operated "on line". This instrument reconstructs each event and decides whether the particles observed are due to a true K° decay. The group has now set up a long-lived K° beam to study the decay modes of this particle.

Magnet and Spark Chambers



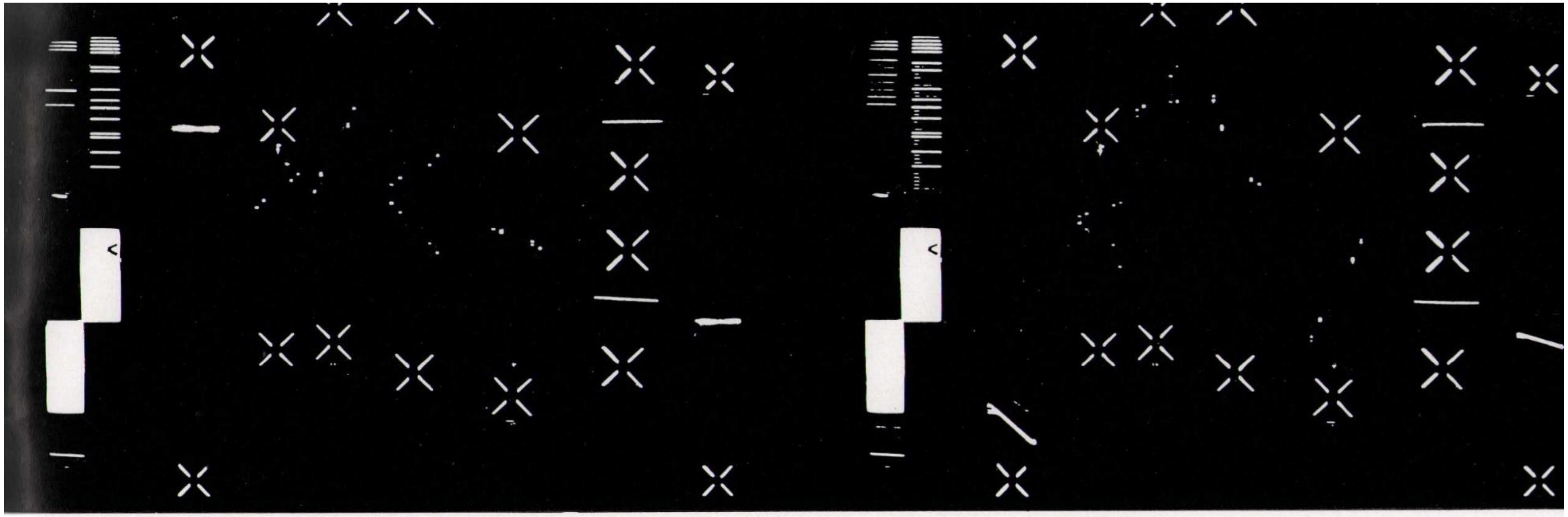
Computer Display of K° decay into two Pions



PHOTOPRODUCTION OF π° and η MESONS

The Liverpool University Group is studying the photoproduction of neutral pions and eta mesons. These particles have extremely short life times and must be detected by observing one or both of the γ-rays into which they decay. This is achieved by means of an array of lead-glass Cerenkov counters in which the γ-rays are detected by the electromagnetic showers they produce. The π° and η mesons are created by interactions between incident photons and protons in a liquid hydrogen target. In the first part of the experiment, only one of the decay γ-rays was observed and the process was identified by detecting the recoiling proton, whose energy was measured by a range counter. A modified apparatus is now being set up in which both decay γ-rays from the meson are measured by the double array of lead-glass Cerenkov counters shown here. The results of the experiment may be compared to various predictions of "symmetry" theories of elementary particles and are also of interest in observing excited states of the proton. Evidence for a new excited state has already been produced. Further work in this field will make use of a polarised proton target now being developed.

Lead-glass Cerenkov Counter Array

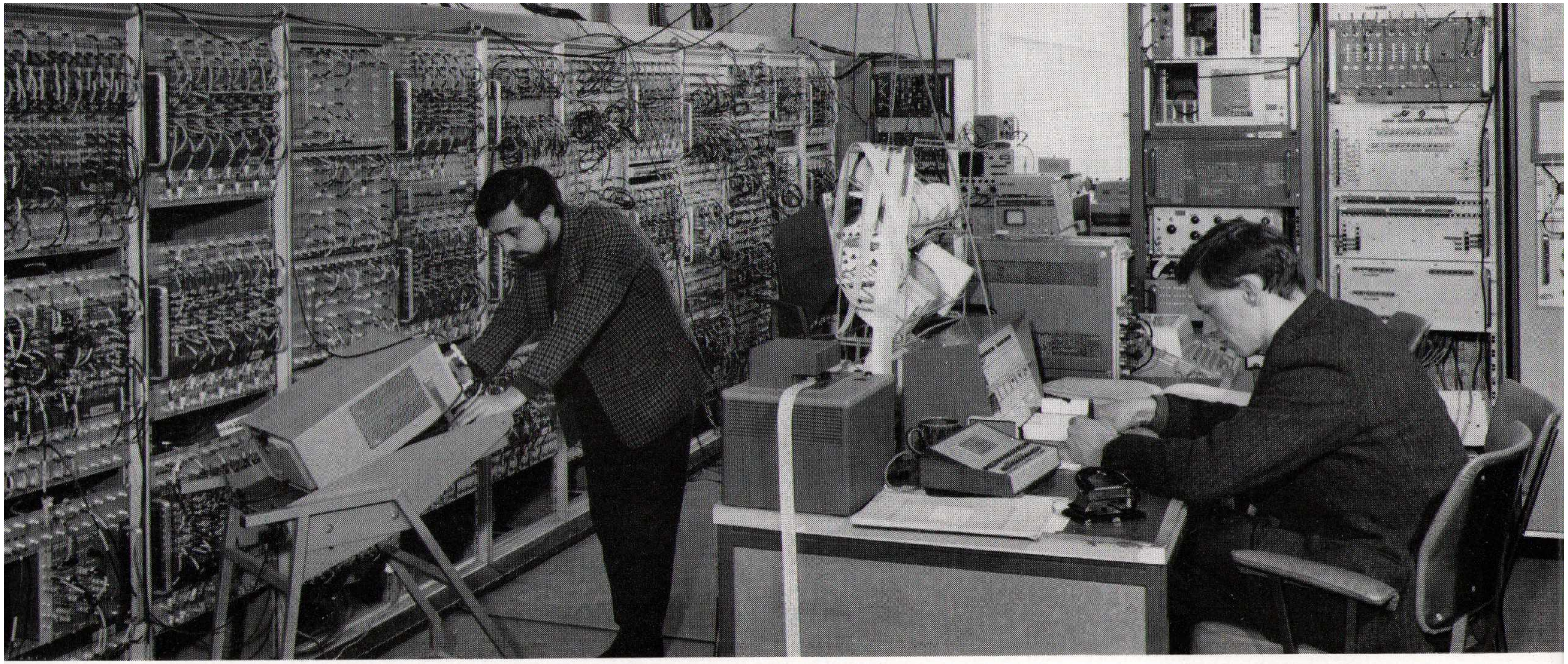


Spark Chamber Photographs

POLARISATION IN ELASTIC ELECTRON-PROTON SCATTERING

The electromagnetic interaction which occurs when a high energy electron scatters from a proton is apparently well described by assuming that the electron and proton "exchange" a single photon. Theoretically, however, it is also possible for the particles to exchange two or more photons. The presence of a two-photon contribution to the process may be detected by observing whether the recoiling proton is polarised, i.e. whether its spin axis is preferentially aligned in a certain direction. Such an experiment has been performed at Daresbury by a group from Glasgow and Sheffield Universities. An electron beam is passed through a liquid hydrogen target. Electrons and protons are then detected in coincidence in two magnetic spectrometers.

Another hydrogen target in the proton spectrometer is used to scatter the protons a second time. Polarisation of the protons may be observed as a left-right asymmetry in this second process. The scattered protons are observed by optical spark chambers. The tracks of the protons are measured from stereo-photographs such as those shown above. Digital information describing the event is also recorded on the film which is analysed by an automatic scanner.

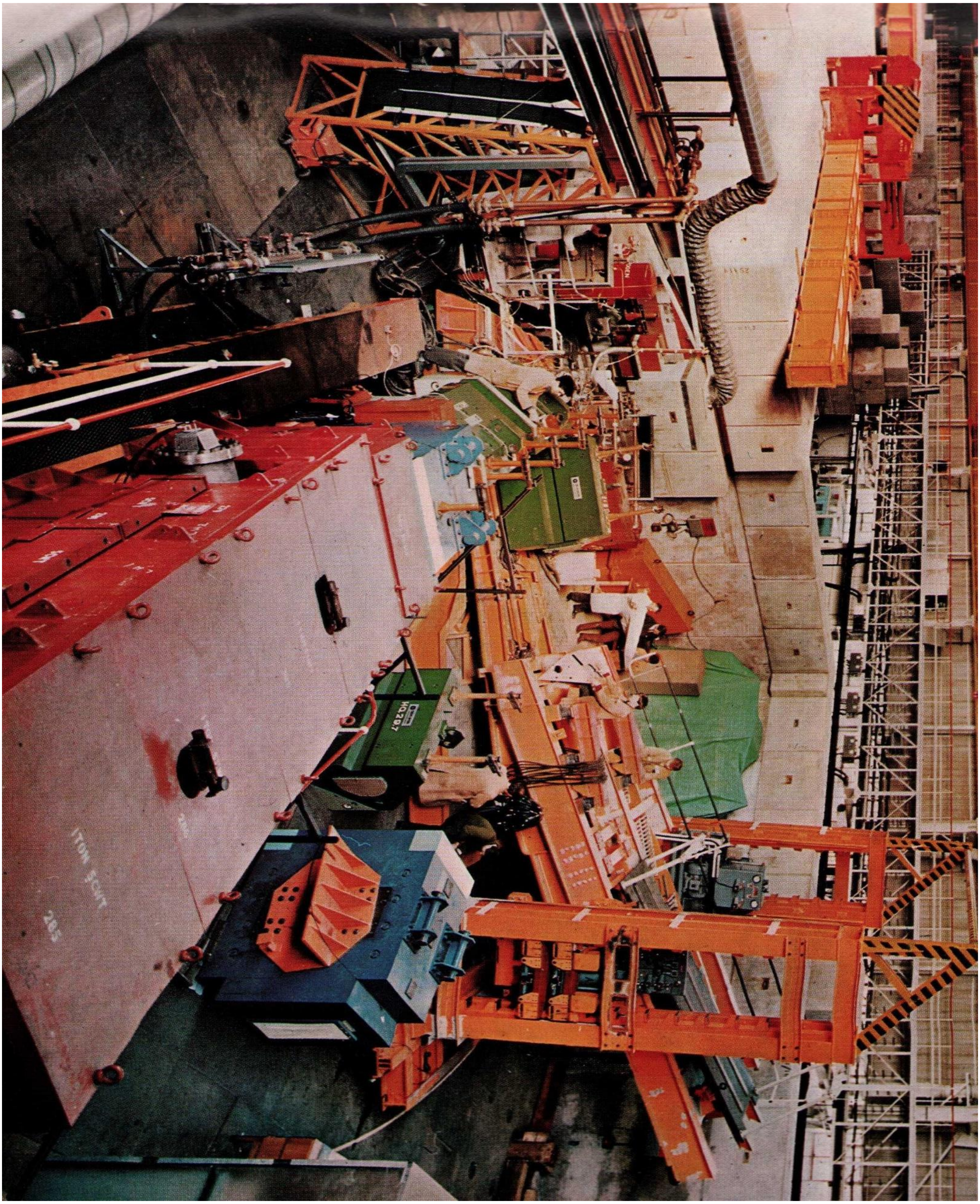


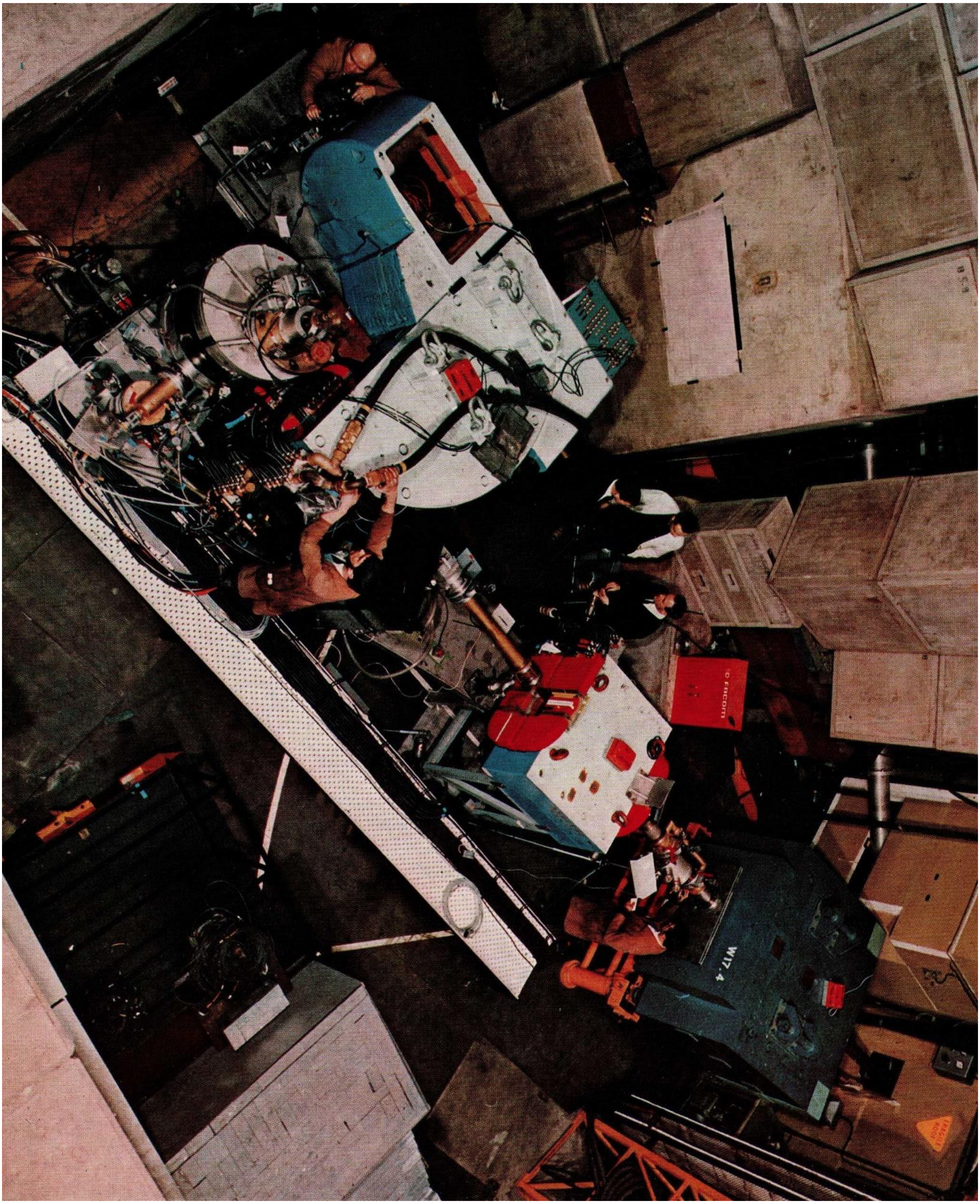
The Counting Room

INELASTIC ELECTRON SCATTERING

A group from Lancaster and Manchester Universities is setting up an experiment to observe inelastic electron-proton scattering in which the proton is effectively left in an "excited" state (known as a nucleon isobar), which subsequently decays into a proton and a pion. Again the primary interaction occurs in a hydrogen target through which passes an electron beam. Scattered electrons and protons from the decay of the isobar are detected in magnetic spectrometers. A special feature of this experiment however is that the proton spectrometer may be tilted at angles up to 30° as well as rotated about the pivot at the target. This enables the physicists to determine the complete angular distribution of the protons produced by decay of the isobars. Information from each event is recorded by a small "on-line" computer which provides the experiment with an instant analysis of the experiment as it proceeds.

The Spectrometer and Experimental Hall

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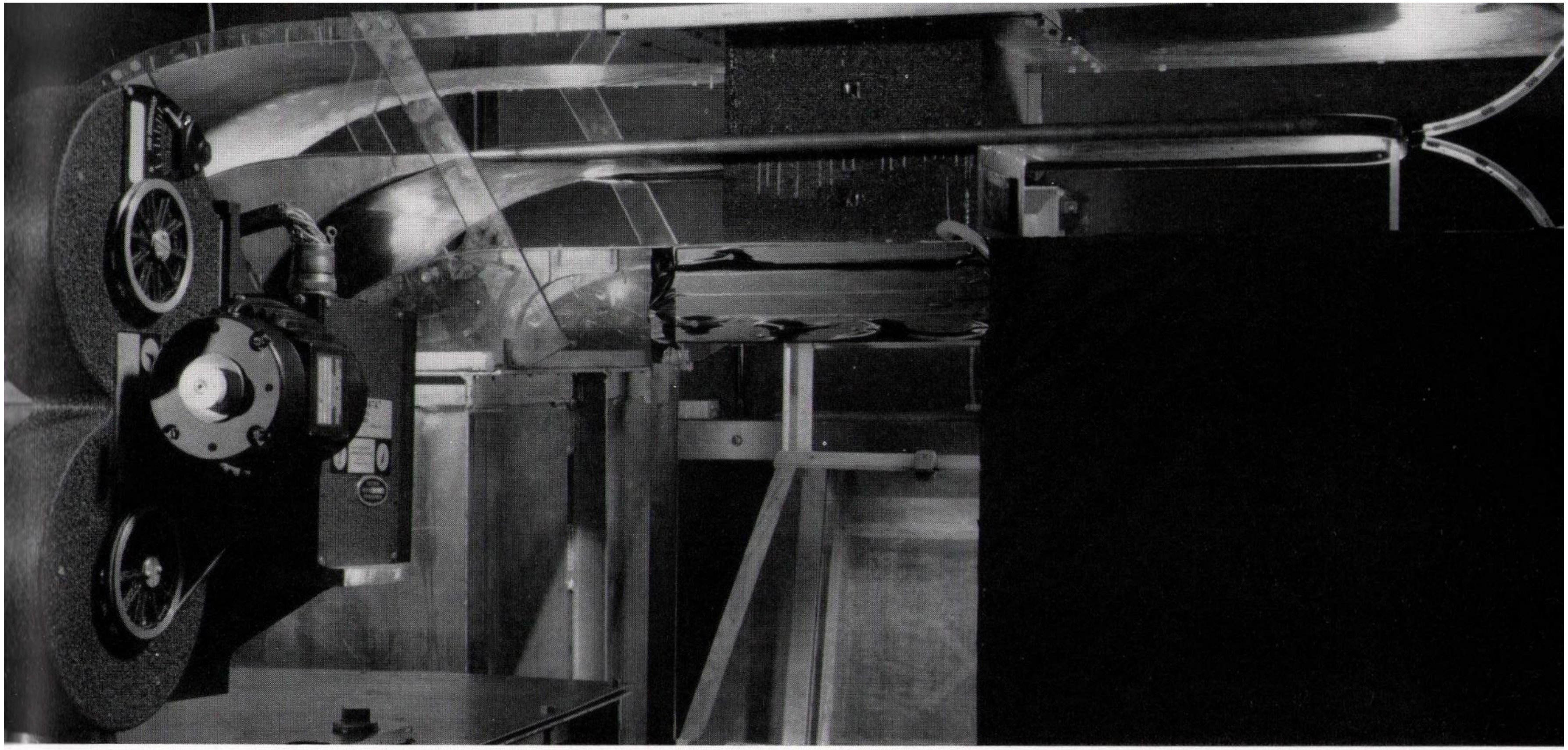
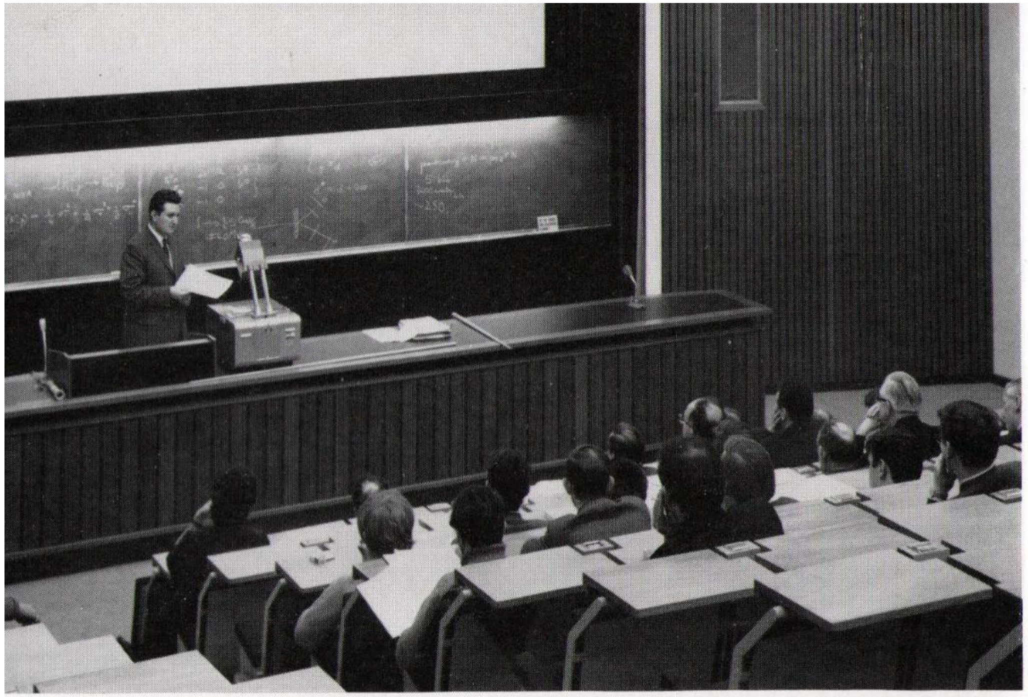


Experimental Streamer Chamber

The Daresbury Laboratory is engaged in many other experimental projects. Among these is a collaboration with Strasbourg University and the Orsay Laboratory near Paris. This group is studying the photoproduction of π^+ mesons from protons in a configuration in which the π^+ is emitted travelling against the direction of the incident beam. The pions are observed and their momenta measured by a double focussing magnet using a spark chamber as detector. This process will provide information on the electromagnetic interactions of nucleon isobars.

Orsay Experiment on π^+ Photoproduction

As a general purpose experimental facility the Laboratory is developing a streamer chamber to be installed in the 75 cm gap of a large electromagnet. At the centre of the chamber will be situated a liquid hydrogen target. In such a chamber many high energy processes may be observed with high efficiency. Tracks of particles in the chamber will be recorded photographically and a group is being set up to analyse the large amount of data expected.



The Lecture Theatre

As well as its experimental activities, Daresbury also supports a theoretical high energy physics group. Experimental and theoretical physicists from the Laboratory and associated Universities meet regularly to discuss and interpret their results. The scientific and engineering staff are served by a reference and lending Library which stocks text books, journals and reports from other Laboratories.

Altogether about 500 people are employed at Daresbury. As well as the scientists, this staff includes Laboratory technicians, craftsmen and general workers and administrative, clerical and secretarial personnel.

The employees enjoy the services of the Laboratory canteen, which provides lunch and other meals, and a coffee lounge where they may relax in a pleasant and congenial atmosphere. They may also take advantage of the various social and sporting activities organised in the Laboratory.

The Coffee Lounge

The Library

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