RUTHERFORD CENTENARY

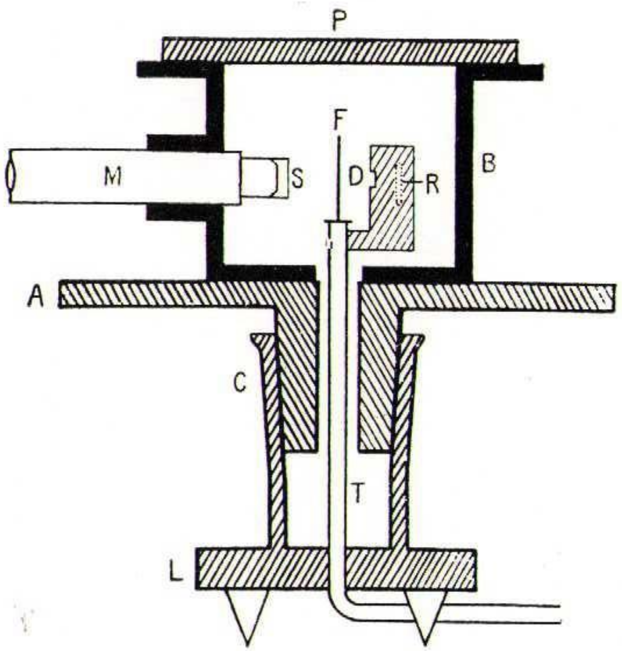
Royal Society Celebrations

Visit to the

RUTHERFORD HIGH ENERGY LABORATORY

29th October, 1971

A view from the North-West of the Rutherford High Energy Laboratory, the largest of the Science Research Council's research establishments. The Laboratory's research programme is based on the 7 GeV proton synchroron Nimrod, which is located beneath the circular mound in the centre foreground.



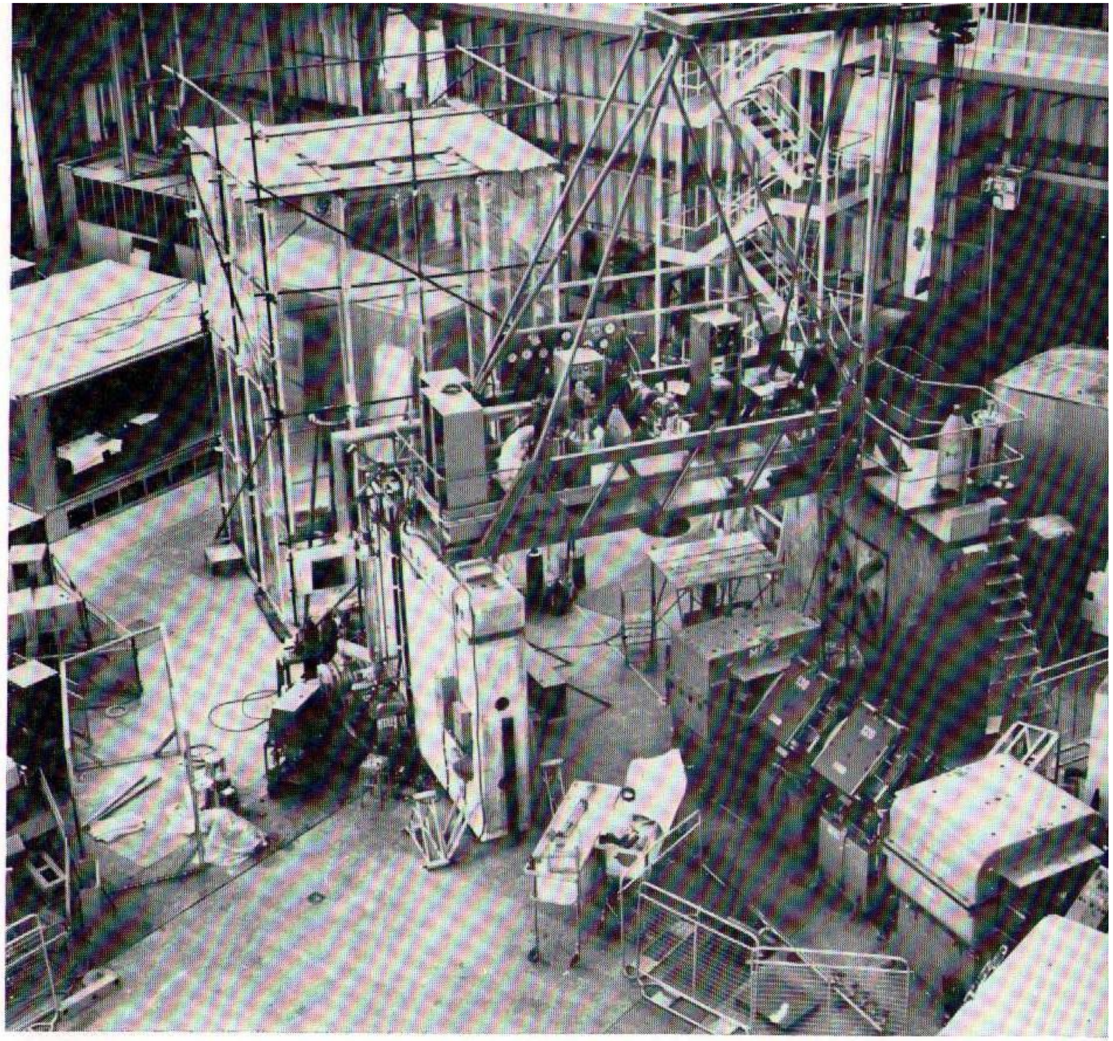
Geiger and Marsden's alpha scattering apparatus. R is the alpha particle source, F the metal foil target, and S the scintillating screen observed through the microscope M.

High Energy Physics is concerned essentially with studying the forces between elementary particles. One of the most powerful methods of investigating these forces is to perform scattering experiments, which measure the deflections suffered by fast particles striking other particles in a target.

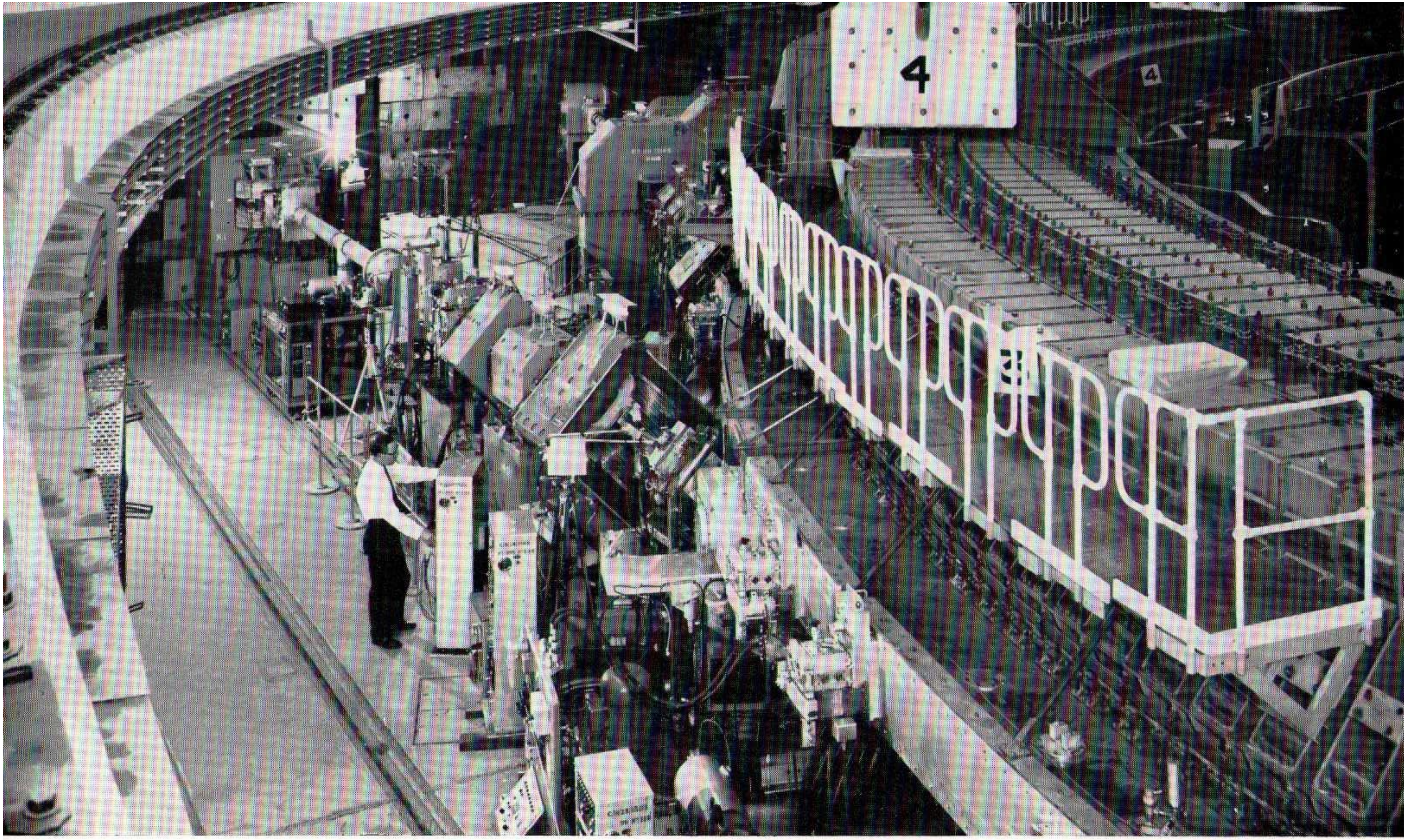
This technique was pioneered under Rutherford's guidance by Geiger and Marsden with their milestone experiment on the scattering of alpha particles by nuclei. The three key components of such an experiment are the source of incident particles, the target and the particle detectors; in the Geiger and Marsden experiment these were an alpha particle source, a metal foil and zinc sulphide screens.

In modern High Energy Physics the same 3 components are still present; the source is now a particle accelerator, the target is frequently liquid hydrogen, and the detectors are fast electronic devices. The main changes since the Rutherford era are in the scale of experiments rather than in their basic strategy. Apparatus is physically larger, experiments need more physicists for longer periods, while data collection rates are much more rapid thanks to modern electronics.

One of the Rutherford Laboratory's current experiments, which is a collaboration with Birmingham University, will be on show. It is investigating kaon-nucleon interactions.



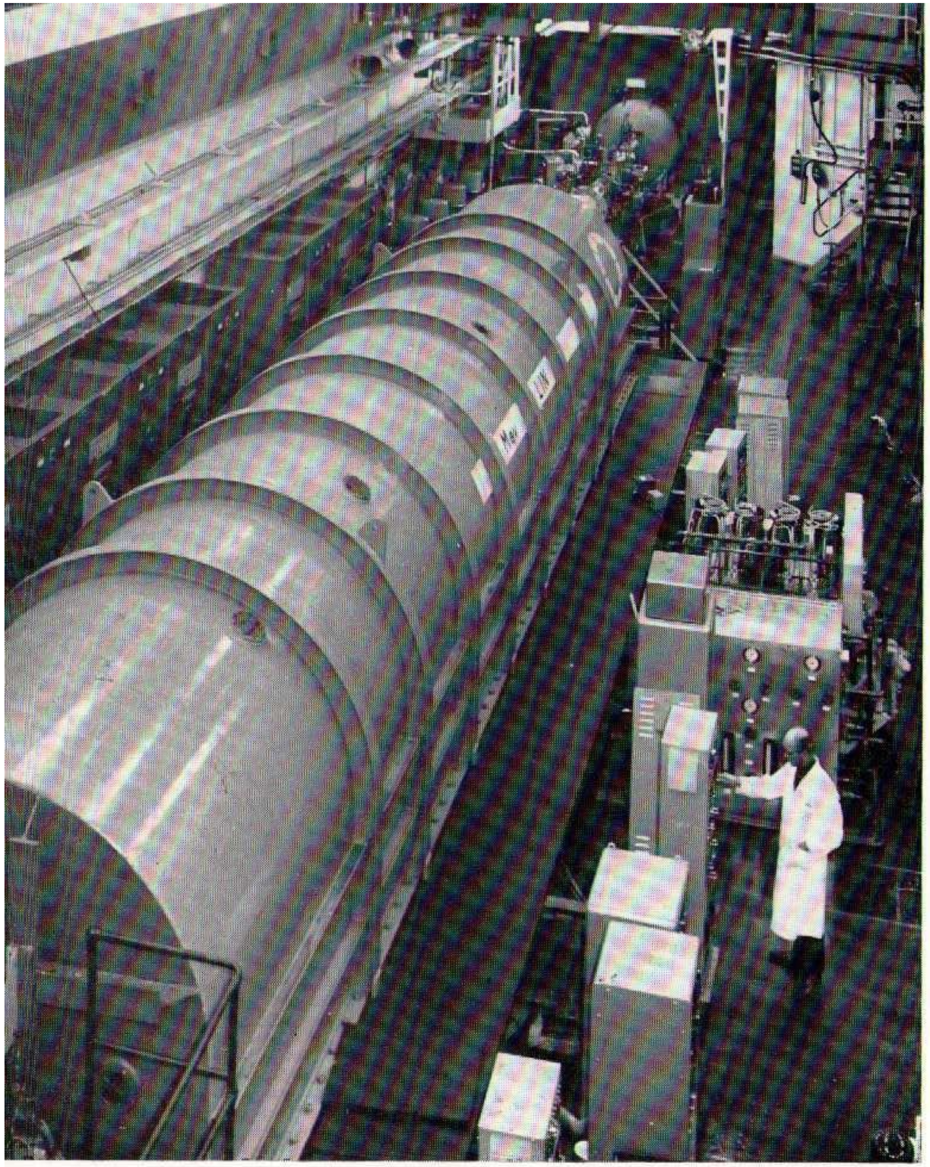
Apparatus for a pion-proton scattering experiment being installed in Experimental Hall 3 at the Rutherford Laboratory.



Part of the main ring magnet of Nimrod, in the region where the beam lines lead off to Experimental Hall 1.

Natural alpha-particles have been superseded as the incident beam in scattering experiments by artificially accelerated particles. The high energy beams required for elementary particle physics are obtained from proton synchrotrons. The Rutherford Laboratory machine is known as Nimrod (after the mighty hunter of Genesis), and has a primary proton beam energy of 7 GeV. Depending upon the interaction to be studied, the protons can either be used directly as the incident particles, or can be used to produce other particles (e.g. pions, kaons) which then form the incident beam.

The main physical feature of Nimrod is an annular electromagnet, 160 feet in diameter. The proton beam circulates on an orbit of constant radius within a toroidal vacuum vessel located between the magnet pole pieces, and is accelerated to its final energy of 7 GeV by means of a radio-frequency unit which imparts a 7 keV energy increment to the beam on each of its one million revolutions. This acceleration process takes approximately three-quarters of a second, during which the magnetic field and the frequency of the accelerating voltage are increased to keep step with the rising proton energy. When the protons are at full energy, they are utilised for high energy physics, and the magnet is de-energised ready for the next acceleration cycle some $2\frac{1}{2}$ seconds later.



The 15 MeV linear accelerator, which acts as an injector for Nimrod, seen from its input end.

Nimrod will not accelerate protons from rest, and the beam is therefore injected at an energy of 15 MeV, obtained from a linear accelerator. This is of the Alvarez type, with drift tubes along the axis of a horizontal 115 MHz cylindrical copper resonator. This accelerator also will not handle protons at rest, and is therefore fed with a 600 keV beam from a d.c. generator.

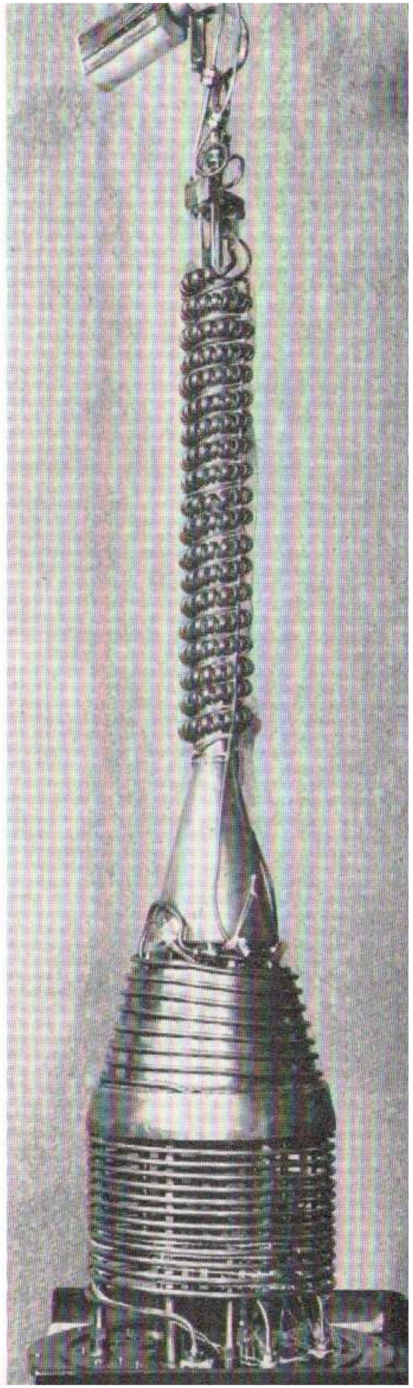
The whole of the Nimrod installation will be open for inspection, including the beam lines leading from Nimrod to the experimental areas. These beam lines embody magnets, lenses, slits and electrostatic separators to momentum analyse, focus and collimate the beam and to filter out unwanted particles.

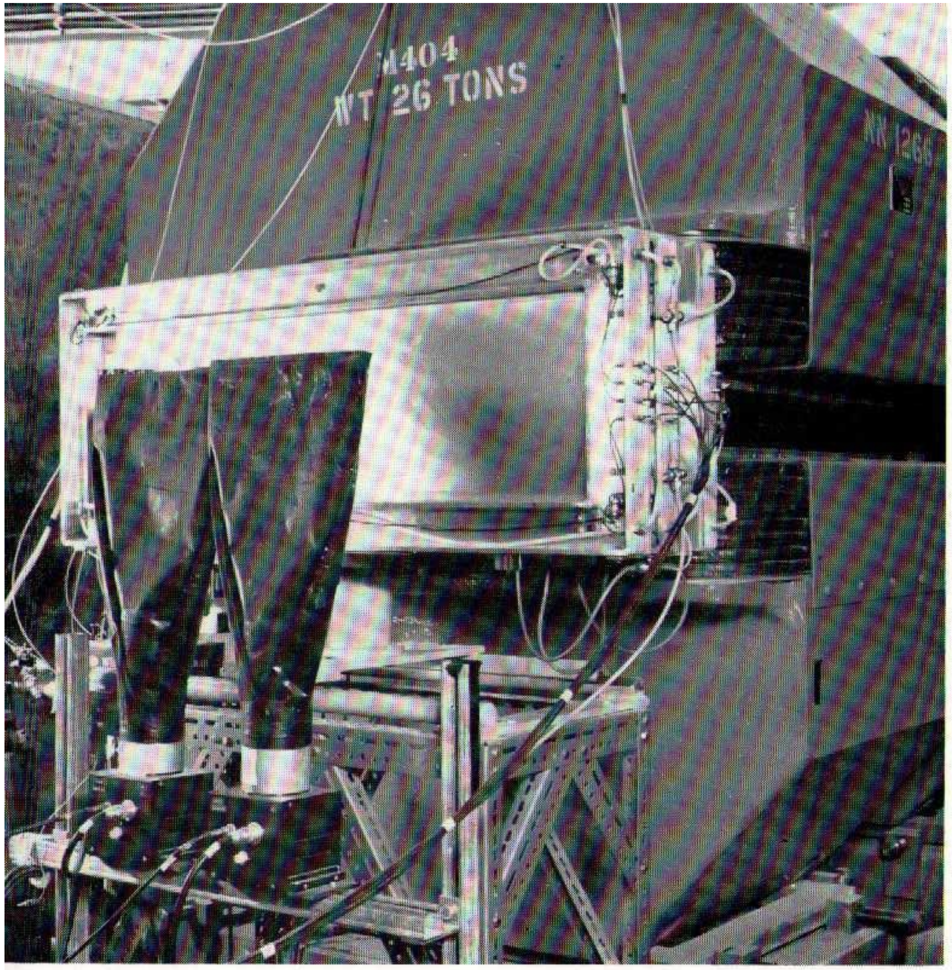
Since High Energy Physics is concerned with the interactions between one elementary particle and another (as opposed to the physics of nuclei which are large assemblies of particles), the scattering targets are usually the simplest possible substances, hydrogen and deuterium. These are frequently used in liquid form so as to give a high density target. Cryogenic techniques are therefore involved. Substantial effort goes into target design, for instance, to ensure that container vessel walls are as thin as possible so as to minimise background effects.

Most elementary particles possess intrinsic angular momentum or spin, and there is therefore considerable interest in measuring polarization effects, that is to say the dependence of scattering effects on the relative spin directions of the incident particles and those in the target. Without special attention both are randomly oriented and spin effects cancel out. Polarized targets, using microwave pumping to populate selectively certain spin states, have been employed in several Rutherford Laboratory experiments.

A selection of target components will be on display.

Tailpiece of a polarized target cryostat, showing cooling coils and, at the top, the microwave cavity containing the actual target.



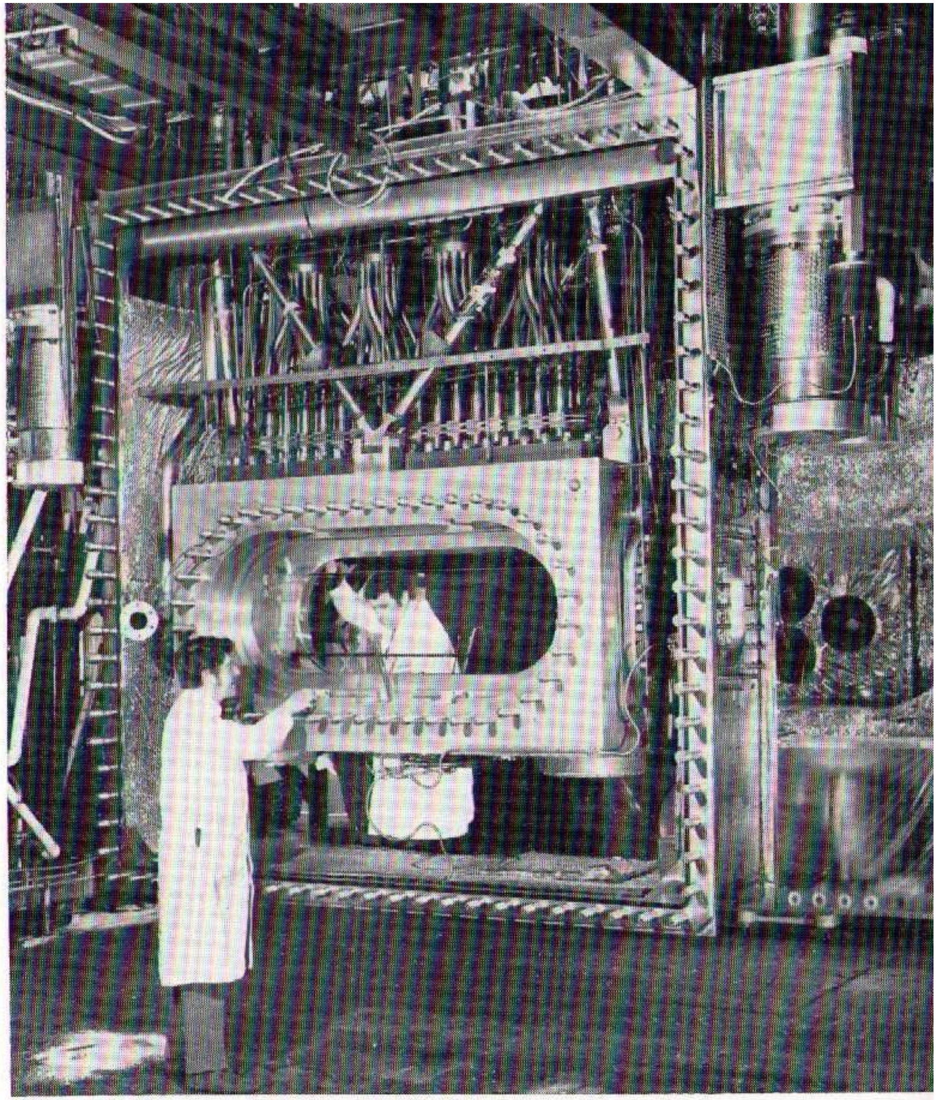


Spark chambers and scintillation counters seen at the exit end of a spectrometer magnet.

It is necessary to determine and record the directions (and usually the momenta) of particles leaving the target as well as counting their numbers. They may be incident particles which have been scattered, target particles recoiling or, in inelastic collisions, newly-created particles. The passage of a particle is detected (with a time precision of a nanosecond or less) by scintillation counters, the signals from which are processed by fast electronic logic circuits. Triggering signals may then be fed to spark chambers, which can measure particle position with great accuracy; this enables deflection angles and (by use of spectrometer magnets) particle momenta to be determined. After preliminary processing by means of a small local computer, the data is written on to magnetic tape for subsequent analysis.

A display of scintillation counters, spark chambers, Cerenkov counters and scaling circuits has been arranged. Adjacent to this display the K12A kaon-nucleon experiment will be on show; it incorporates all the above detection techniques.

The other major high energy physics particle detection device is the bubble chamber, in which the trajectories of charged particles are seen as trails of tiny bubbles in a momentarily superheated liquid. The liquid, frequently liquid hydrogen, functions as both target and detector. Stereoscopic photography enables particle interactions to be reconstructed in three dimensions from measurements of projected angles and radii of track curvature. These parameters are extracted from the photographs largely by means of computer controlled flying spot measuring machines. Since bubble chamber experiments produce hundreds of thousands of pictures, automated methods are needed to give results both quickly and accurately. A complex computer installation is needed to control these on-line devices, and to process the vast amounts of data arising from them and from counter experiments. The heart of the system is an IBM 360/75, shortly to be replaced by a 360/195.



The body of the 1.5 metre Liquid Hydrogen Bubble Chamber. The large square frame is part of the thermally insulating vacuum vessel. When in use, the chamber is surrounded by a 240-ton electromagnet.

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