Rutherford Laboratory

Technical leaflet

B12

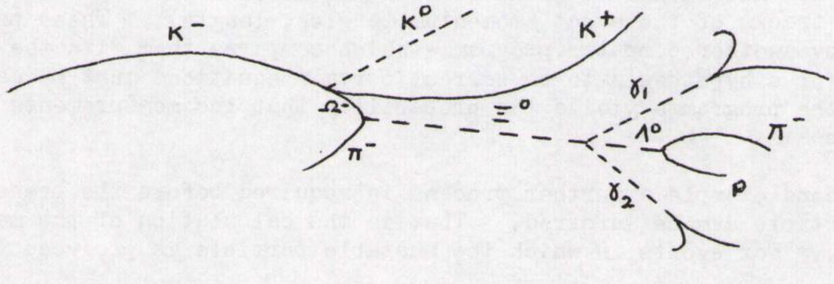
THE WORK OF SCANNING AND MEASURING LABORATORIES

In a typical bubble chamber experiment several thousands of photographs are taken containing up to two or three interactions per picture. In each case stereoscopic views of the chamber are produced. To handle this quantity of film in a reasonable time it is necessary to have a rather complicated procedure of scanning, measuring and computing.

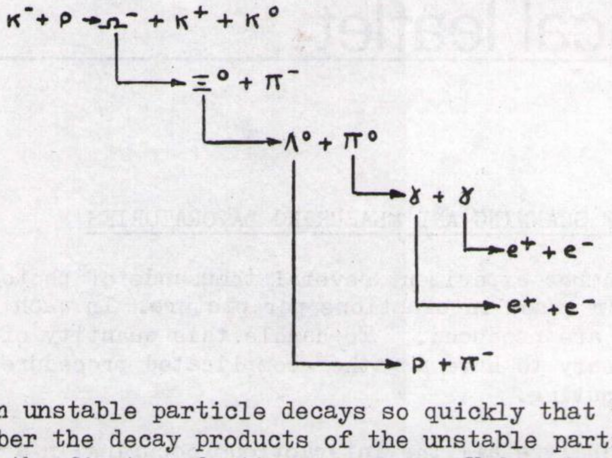
It is not possible to analyse all the interactions occuring in a particular experiment because this would take several years with conventional equipment. It is therefore necessary for the physicist to specify in some detail the interactions of interest. He may wish, for example, to study events in which one particular unstable particle is produced and detected, or he may wish to search for the presence of some unstable particles which cannot be detected directly but can be shown to exist by looking for correlations between the outgoing particles of the interaction.

In the case of detected particles the film is scanned for events which have distinctive patterns. An example of this is the case of the Ω^- particle. This particle is produced from interactions of high energy negative K mesons with the protons of the hydrogen Bubble Chamber. Because of its strangeness properties it is produced together with either two positive kaons and a negative pion or a positive and a neutral kaon (see diagram). The omega minus is expected to have several decay modes, one is a decay into a neutral cascade hyperon (Ξ^o) and a negative pion (π^-). The neutral cascade hyperon subsequently decays into a lambda hyperon (Λ^o) and a neutral (π^o). The uncharged lambda hyperon decays into two charged particles (a proton and a negative pi-meson (π^-)) and appears as a V pointing to the decay of the Ξ^o. The neutral pi-meson decays very quickly into two gamma (γ) rays which in turn convert into electrons-positron pairs. These electron pairs can, in general, be distinguished from the V events by their small opening angle and the characteristic spiral of the low energy electrons in the magnetic field of the chamber.

Since the uncharged particles do not produce visible tracks in the liquid these are shown dotted in the diagram illustrating the event.



The production and decay reaction is therefore:-



When an unstable particle decays so quickly that it cannot produce a track in the chamber the decay products of the unstable particle appear as simple products of the first production process. Under these conditions it is not possible at the scanning stage to distinguish this type of event from events of similar configuration which do not involve an unstable particle.

An example of this type of situation is the production of the K^{*-} meson. The particle is produced in the interations of K^- mesons with protons together with a proton. However, the K^{*-} meson decays very rapidly into a neutral Kaon (K^0) and a negative pion (π^-). The production interaction is

$$K^- + p \longrightarrow K^{*-} + p$$
$$\hookrightarrow K^0 + \pi^-$$

or

$$K^- + p \longrightarrow K^0 + \pi^- + p$$

In each case the appearance of the event on the scanning table is the same.

Before any analysis can take place it is necessary to test events against particular hypotheses in order to establish the nature of the produced particles. This is achieved by making co-ordinate measurements on the three, two dimensional stereoscopic views of the events. These co-ordinates are punched in binary form on paper tape suitable for feeding to a computer.

The data is read by the computer which is programmed to reconstruct the event in three dimensions and to produce a further record of the parameters describing the tracks of the event (momentum, angles, length). These parameters are then used by another computer programme which compares them with the possible hypotheses. For a hypothesis to be correct certain equations must be satisfied. If this is so the programme yields the probability that the measurements agree with the hypothesis.

In the second example a further process is required before the presence of an unstable particle can be inferred. That is the calculation of the mass of the $K^0 + \pi^-$ system. For events in which the unstable particle is produced the mass is always the same whereas in the case of events in which no unstable particle is produced the mass varies over a wide range.

In this way the existance of new particles can be inferred even though they can never be directly detected.

Scanning and Measuring Machines

The scanning is carried out on machines designed at Imperial College. The machines consist, essentially, of three projectors of about X12 magnification placed side by side projecting onto a flat table. The two outside projectors have adjustable lenses so that any two views may be superimposed and advantage taken of the stereoscopic effect.

In order to maintain a high rate of scanning the machines are fitted with a fast film drive.

The measuring is carried out on two types of machine. One, developed by Imperial College, London, projects an image onto two screens, a general view of the whole photograph at X6 magnification and a smaller portion of the photograph at X30 magnification. The movement of the image in two perpendicular directions is made by moving the stage holding the film for one direction and by moving the projecting lens for the other. Each of these movements are digitised using Ferranti Moiré Fringe Gratings. The digitisations are then counted and this record of the stage position punched out on paper tape.

The second type of measuring machine was developed at University College, London. This machine can produce two images of X6 and X50 on to a screen. A small shutter obscuring the image not in use.

The film is clamped to the upper stage of two stages which move in perpendicular directions. These two stages have their position encoded by rotary disc encoders.

Both types of machine are under complete operator control. The operator adjusts the stages so that the image of a point on the track lies on a fixed fiducial mark on the screen. When this operation is complete the position of the stage is punched out onto paper tape in binary form. This operation is repeated several times for each track and for any other information which is required.

The machines have an output of up to two hundred events per week depending on the complexity of the types of event being measured.

A second generation machine, the H.P.D. which is described in Technical Leaflet (C9) will increase the measuring output by one or two thousand events per week. The increased speed and accuracy of this machine will allow the physicist to see much more detail in the analysis of the various interactions.