Rutherford Laboratory

Technical Leaflet

B9

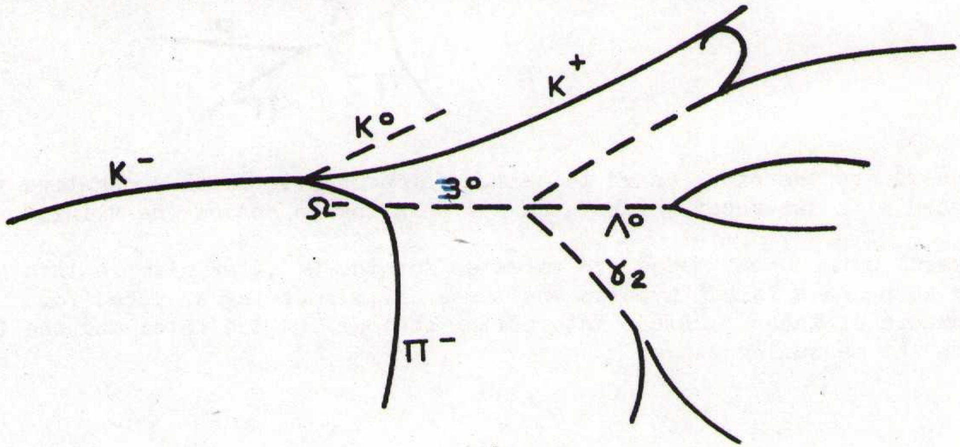
THE WORK OF SCANNING AND MEASURING LABORATORIES

In a typical bubble chamber experiment several hundred thousand photographs are taken containing an average of two or three interactions per picture. In each case three stereographic 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 measurement and computing.

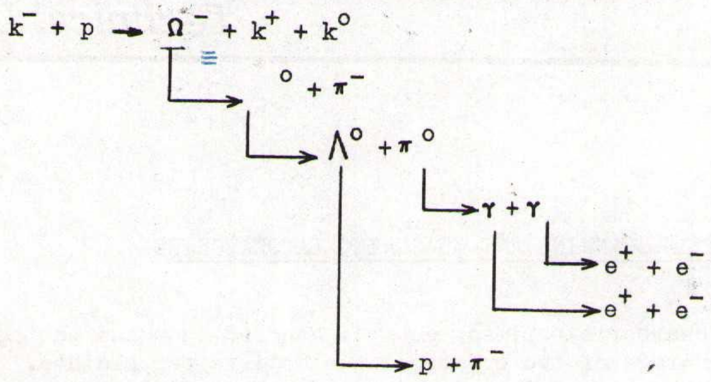
It is not possible to analyse all of the interactions occurring in a particular experiment because this would take several years with the conventional equipment. It is therefore necessary for the physicist to specify in some detail the interactions of interest. He may wish for example to study events in which one particular type of unstable particle is produced and detected. If this is so then the photographs are first scanned for interactions which might be interpreted as the production of this particle.

As an example we have recently been searching for reactions in which the newly discovered Ω^- particle is produced. The particle is expected to be 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. The omega minus is expected to have several decay modes. The event observed at Brookhaven is a decay into a neutral cascade hyperon (Ξ^0) and a negative pion (π^-). The neutral cascade particle subsequently decays into a lambda hyperon (Λ^0) and a neutral pion (π^0). 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^0. The neutral pion decays very quickly into two γ rays which in turn convert into electron 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.

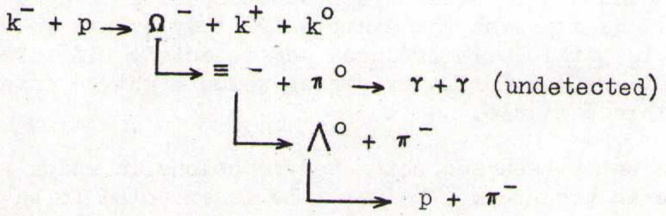


The production and decay reaction is therefore:



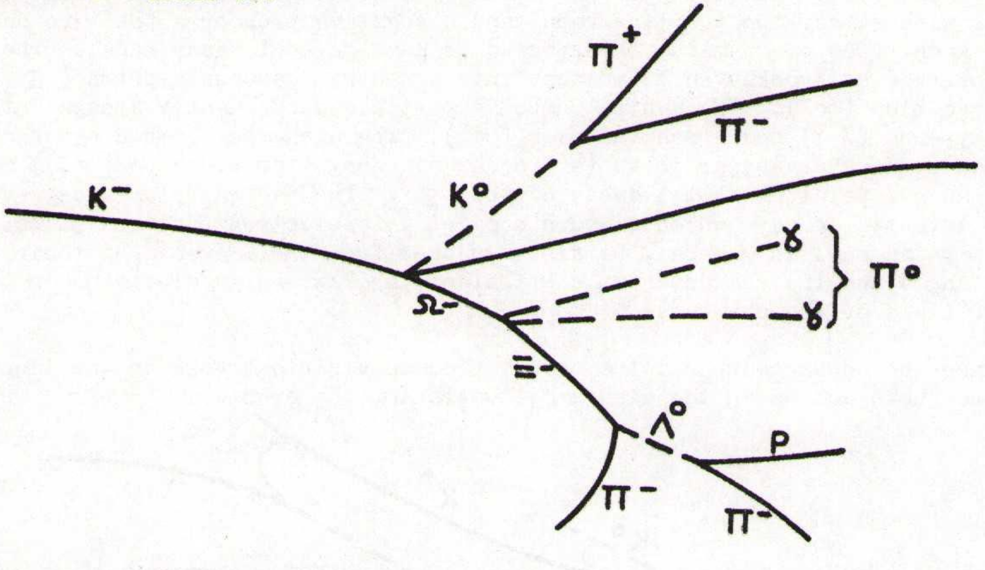
$$k^- + p \rightarrow \Omega^- + k^+ + k^o$$
$$\Omega^- \rightarrow \Xi^o + \pi^-$$
$$\Xi^o \rightarrow \Lambda^o + \pi^o$$
$$\pi^o \rightarrow \gamma + \gamma$$
$$\gamma \rightarrow e^+ + e^-$$
$$\gamma \rightarrow e^+ + e^-$$
$$\Lambda^o \rightarrow p + \pi^-$$

We are also searching for the alternative decay mode of the Ω^- into a negative cascade particle and a neutral pion. The identification of this sequence does not necessitate detection of the γ ray conversion to electron positron pairs (which has a low probability in hydrogen). Thus we would hope to observe the production and decay chain



$$k^- + p \rightarrow \Omega^- + k^+ + k^o$$
$$\Omega^- \rightarrow \Xi^- + \pi^o \rightarrow \gamma + \gamma \text{ (undetected)}$$
$$\Xi^- \rightarrow \Lambda^o + \pi^-$$
$$\Lambda^o \rightarrow p + \pi^-$$

Such an event would be:



The scanners are therefore asked to search for events in which a negative track is produced with two decay "kinks" and a V pointing to one of the "kinks".

Several other decay modes are expected for the Ω^-, for example into a negative kaon and a lambda hyperon and these are also being searched for. The frame numbers of these possible interesting photographs are noted and the film passes to the measuring stage.

The measuring machines are designed to make accurate two-dimensional measurements on the photographs of interest. The image of the chamber is projected onto a screen. The measurer drives a cross along the images of the tracks and co-ordinates are taken at intervals of a few centimetres. These co-ordinates are punched in binary form on paper tape suitable for feeding to the computer. Although the measuring device is itself very complex, its operation is comparatively simple and fast.

The data from the measuring machine passes to the computer which is programmed to reconstruct the event in three dimensions from the two-dimensional measurements on the stereoscopic views. The output of this "geometry" program is in the form of the angles and momenta of the tracks in space and the special co-ordinates of the vertices (interaction or decay points) together with the errors on these quantities. This data is used as input for a program which tests the event against the particular hypotheses suggested by the experimenter. For example we may wish to test our V production events against the hypothesis that the V was a Λ^0 coming from the interaction. If this hypothesis is correct then the momenta and angles of the tracks involved must satisfy certain equations. The program tests the measured values to see if they satisfy the equations and yields a value of the probability that the measured event agrees with the hypothesis.

Having found in this way a sample of events satisfying a particular hypothesis the experimenter may begin his real work of analysis. One may hope to learn something of the properties of the elementary particles from the ways in which they are produced and in which they decay. For example we note that in many cases our Λ^0 production events have additional charged π-mesons and that in many cases the Λ^0 and π appear to be related in the sense that if we calculate the mass of the system we always get the same answer. Physicists have therefore been led to believe that in fact a particle is produced in the initial reaction which decays exceedingly quickly, i.e. so that it only travels a very small distance compared with a bubble diameter, into a Λ^0 and a charged π meson.

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