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4 PM Auditorium Bldg. 50

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I GENERAL

Several of the cloud chambers used in cosmic ray research are discussed in terms of their application as measuring instruments at Bevatron energies. Some of the limitations of these instruments are revealed.

II TYPES OF EXPERIMENTS

Cloud chambers can be used at Bevatron energies both as exploratory devices and as measuring instruments. Ordinary mesons, heavy mesons, and hyperons have already been studied in this energy range in cosmic ray work; but the statistics are poor.

With cloud chambers one should be able to measure with care the mass lifetime, production cross sections polarization, and multiplicity of heavy particles. Although these measurements could also be obtained from plates cloud chambers present a larger field of view.

III SCANNING

A scanning group will be necessary if the cloud chamber is to be utilized effectively. Many thousands of photographs must be read if one hopes to see rare events. For example, at Brookhaven 30 V-particles have been observed in approximately 20,000 pictures

IV TYPES OF CLOUD CHAMBERS

A. Continuously Sensitive Cloud Chambers

A continuously sensitive high pressure cloud chamber has been used by the Brookhaven group for the dynamic analysis of heavy particle events. Even at 20 atmospheres of hydrogen the number of events is still rare as the number of hydrogen atoms per cc is still small. The advantage of using hydrogen in chambers is that the events once seen can be analyzed in great detail. The disadvantage of this chamber is that the field of view is restricted. The tracks are short so that the resolution of momentum, which goes as the square of the track length is poor. One can use a trick to circumvent this difficulty if the Q-values of the particles are known with sufficient accuracy.

Other gases such as air, argon or even xenon could be used in a continuously sensitive cloud chamber. One could, for example, investigate the cross section for heavier nuclei, or look at argon stars.

B. Expansion Cloud Chambers

Expansion cloud chambers are ideally suited to operation with a pulsed machine. The maximum operating rate of the expansion chamber (determined by the limits on permissible thermal distortion as set by the desired momentum accuracy) is of the order of one pulse per minute. This means that one pulse in 20 can be studied by the expansion chamber while the other 19 pulses can be utilized for plates and other exploratory instruments. The expansion chamber only requires that one pulse in the group be reduced in intensity whereas the continuously sensitive chamber requires that all beam pulses be at low intensity. Although hydrogen could be used in the expansion chamber, the density would be so low as to render events extremely improbable. One can however, use exterior or interior producing layers of liquid hydrogen or hydrogenous material such as polyethylene. By placing the expansion chamber in a strong magnetic field, say 20,000 gauss, one can get accurate measurements of momentum, Q-value, and velocity.

One can combine multiplate chamber with a hydrogenous layer and analyze the particles by their scattered tracks. This technique might be utilized, for example in the rapid measurement or production cross section of heavy particles in different materials. Such a technique would be expected to increase the probability of seeing pairs. It could also be adapted to measure lifetimes.

V SOME LIMITATION ON CLOUD CHAMBER Q-MEASUREMENTS

The deviation of a track from a straight line thru the path ends is

$$\delta = \frac{\ell^2}{8\rho} \sim H\ell^2$$

For a 3Bev/c proton and 20,000 gauss, a 30 cm track will yield a 2.5 mm deviation. Since the cloud chamber need not be expanded until approximately 50 milliseconds before a beam pulse, the tracks should be sufficiently sharp to allow δ measurements as small as 0.1 mm.

According to Leighton's* recent paper, the accuracy in Q-values determined from momentum measurements are as follows:

$$\frac{\partial Q}{\partial p_+} = -0.1 \text{ to } +0.2$$

$$\frac{\partial Q}{\partial p_-} = -0.3 \text{ to } 1.0$$

$$\frac{\partial Q}{\partial \theta_T} = -0.5 \text{ to } 3$$

Thus a 10 percent uncertainty in momentum for p_+ at 1 Bev will introduce a 20 Mev uncertainty in Q-values.

VI THERMAL DISTORTION

Thermal distortions will produce spurious radii of curvature in tracks. These effects may not be as large for a chamber operated with the pulsed machine, as pictures can be taken within 50 milliseconds of beam time. If the temperature across the chamber can be held to 0.01° C then $\rho_{sp} \sim 200$ meters are possible. The value of ρ_{sp} must be determined for every cloud chamber. It is obtained from the statistics of track measurements without field.

The magnitude of ρ_{sp} sets an upper limit on the accuracy with which Q-values can be measured. For example, consider a 3Bev/c proton track for a typical chamber in which $\rho_{sp} \sim 100$ meters. At 20,000 gauss $\rho = 500$ cm so that p is known to

* Leighton, Phys Rev, January 1, 1953

5 percent, or 150 Mev The computed Q-value for a Λ^0 is then uncertain to 15 percent.

VII IONIZATION MEASUREMENTS

A Minimum Ionization Estimation

With some experience one can visually estimate the ionization in cloud chamber tracks within a factor of two. This will not permit differentiation between tracks of K and p particles but will allow resolution of π and p particles.

B. Drop Counting Technique

By allowing the tracks to diffuse, the number of droplets can be counted to yield the ionization loss to the order of 20 - 25 percent. Helium, or a mixture of helium and argon can be used so that the ionization will not be too heavy. A stereoscopic camera and microscope can be used to count drops. Once this technique is calibrated the resulting ionization measurements are good to ~ 25 percent.

VIII LIFETIME MEASUREMENTS

Since the time dilation is energy dependent, the measurements of particle lifetime requires the knowledge of the time available to the particle in terms of the useful volume of the cloud chamber. This number must be obtained for each particle for each cloud chamber. It is determined as follows. From a geometric definition of the available length of path in the chamber d_i ; obtain for a given particle the time:

$$t_i = \frac{d_i}{\gamma_i \, v_i}$$

where γ_i is the time dilation factor.
Then on the average

$$t_{av} = \frac{d_{av}}{\gamma_{av} \, v_{av}}$$

The lifetime is then given by the expression

$$\tau = \frac{1}{N} \sum_i \left[t_i + \frac{t_{av}}{\exp(-t_{av}/\tau) - 1} \right]$$

This is solved by trial for τ . Typical lifetimes are:

$$\Lambda^0 \sim 3.3 \begin{pmatrix} +0.9 \\ -0.5 \end{pmatrix} \times 10^{-10} \text{ sec}$$

$$\Theta^0 \sim 2 \, (\pm 1) \times 10^{-10} \text{ sec}$$

$$\tau, K, \chi \sim 10^{-8} \text{ to } 10^{-9} \text{ sec}$$

IX SUGGESTED MEASURING TECHNIQUES

A. Double Cloud Chambers

K-particles are hard to identify by ionization measurements but are relatively easy to identify in plates. It is suggested that an expansion cloud chamber with a magnetic field and hydrogenous producing layer, etc., be followed by a packet of photographic plates. From these results one may be able to tell whether or not K-particles are nuclear interacting.

B. Multiplate Chambers

The use of multiplate diffusion chambers with hydrogenous materials for plates and a magnetic field should be investigated. If materials of different Z are substituted, one can accumulate production cross section measurements rapidly.

C Helium and Argon Chambers

Helium and argon might well be substituted for hydrogen in the continuously sensitive chambers.