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PROTON PENCIL BEAM STUDIES

There is still very little known about the Ξ particle apart from its mass, the total world sample (in hydrogen and heavy liquids) being about 50 events. There seems to be some rule which depresses their production by an order of magnitude below the 0.1 mb predicted by the statistical theory. The $\tilde{\Xi}$ production is at least another order of magnitude less.

A possible way of producing Ξ particles is by passing an intense "pencil beam" through a hydrogen chamber. Materialisation gives too much background in a large heavy liquid chamber.

The beam should give as many production interactions as possible without obscuring the chamber with secondaries. We calculated that this corresponds to about 150 particles for the 30 cm chamber, which was borne out by experiment (see B) below).

An exposure of a hydrogen chamber in a proton pencil beam would give many times the present world total of Ξ events and so give the following information:

a) Lifetime (to $\pm \sim 25$ o/o).
b) Asymmetry parameter α_{Ξ} α_{Λ}
c) An upper limit for other decay modes of the Ξ.
d) $\tilde{\Xi}$ events (or an upper limit of 0.1 μb for the cross-section).

In addition a sample of $\hat{\Lambda}^0$ events similar to the Ξ sample should be obtained.

B) A high energy proton pencil beam

An exposure of the Hahn 16 cm chamber was made on Feb. 14th. 1961 to check the possibility of producing a pencil beam by collimating the "Berne-Cocconi" beam of 25 GeV protons. Counters were also placed in the beam to check the intensity.

The beam was defined by two iron collimators C_1 and C_2 with machined holes 2 mm x 2 mm, accurately aligned. They were placed on both sides of a shielding wall, which had a 25 mm x 25 mm hole to allow passage of the beam.

Tests were also made with C_2 only, but this was found to be unsatisfactory. The distance d was varied and it was found that it should be small ($\sim$ 1 metre) for best beam definition (i.e. few scattered particles from the collimator). The beam divergence was, however, less than 1 mb (i.e. $<$ 1 mm/metre spearation). This agrees with the finding of Evans (CERN) and Cjivanovitch (Berne) who have exposed emulsions in similar beams.

The counters showed that with a circulating current of 2.10" protons, and bending magnet set for maximum intensity, about 450 particles per pulse passed through the collimators (i.e. 100 per sq. mm). This is four times more than is necessary for the bubble chamber, so that a proton pencil beam could be used in a parasitic run. This is equal to the incident intensity quoted by Cocconi, so that losses in the collimators were negligible, and the alignment was within 0,1 mm.

The shortest beam pulse available during the run was about 10 mS so that the bubble chamber could not be operated under optimum conditions. However even with a long pulse, the pictures obtained showed a well-defined pencil beam 3 mm wide at entry. Secondary particles were wide of the beam and easily distinguishable. It was also found that even with the very high bubble density in the beam and long growth time, the vapour formed did not interfere with the operation of the chamber, even with 450 particles/pulse. The chamber was filled with C_3F_8, which has an interaction length of 140 cm, about 8 times shorter than in hydrogen (the entrance window was 2 mm Al, negligible compared with the freon). Thus, as regards spreading of the beam due to interaction in the chamber, a picture in C_3F_8 with 20 particles is equivalent to the proposed operating conditions in hydrogen (150 particles/ pulse). A consecutive set of such pictures is attached, and show that most of the strange particles produced would be easy to see and measure. The background dots are probably due to recoils produced by slow neutrons, and possibly γ-rays, which would not appear in a magnet bubble chamber because of the shielding afforded by the magnet itself.

c) <u>Estimation of required machine time</u>

In the 32 cm chamber a run of 10^5 pictures with 100 particles in the pencil beam would give about 100 observable Ξ - decays (10 cm decay length). In the 80 cm chamber, where the probability of observing the decays is about 3 times higher, $\sim$ 300 Ξ decays should be seen, in which case there is a good chance of observing the anti Ξ . The details of these estimated figures are quoted in the appendix.

The feasibility of a high energy pencil beam is demonstrated above with the diffracted Berne beam, which provides a very suitable beam of protons with a density of 4.10^4 particles/cm^2.

For the actual experiment we probably would choose an energy of 15 GeV as being well above threshold for $\Xi + \bar{\Xi}$ production while still allowing a 2 second machine pulse rate. From the experiment with 16 GeV π^- we expect most of the Ξ 's to be produced at angles of 15 to 20 degrees, with momenta about 3 GeV/c in the lab. system. Only 5 o/o of their decay length is obscured by the pencil beam.

The machine time required for 10^5 pictures with a 2 sec rep. rate would be 56 hours (9 shifts). The experiment could probably be done as a parasiting run since we need only 5.10^{10} protons circulating current.

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APPENDIX

a) Hypothetical momentum and angular distribution of Ξ^-'s.

The following graphs have been obtained with

$$\bar{p}^*_{\Xi^-} = \bar{p}^*_{\Sigma,\Lambda} = 1 \text{ GeV/c} \qquad \text{(see 16 GeV } \pi^- \text{ experiment)}$$

The angular distribution has been obtained by assuming a symmetrical B-F symmetry with the same degree of peaking as has been found for Σ's and Λ's from 16 GeV π^- interactions.

This gives at 25 GeV proton energy

$$\langle p_{\Xi^-} \rangle = 5 \text{ GeV/c} \qquad \langle \theta_{\Xi^-} \rangle = 10^\circ$$

Lowering the primary energy to 15 GeV

$$\langle p_{\Xi^-} \rangle = 3 \text{ GeV/c} \qquad \langle \theta_{\Xi^-} \rangle = 15^\circ$$

b) Decay probability of Ξ^-'s.

The fig. 2 gives the probability detecting a Ξ^- decay when the Ξ^- has been produced inside the chamber.

N_{Ξ^-} number of observable Ξ^- decays with Λ-decay (both decay modes) inside the chamber. For detection of $\Lambda \to p + \pi^-$ one has to multiply

$$N_{\Xi^-} \text{ by } \frac{\Lambda \to p + \pi^-}{\Lambda(p\pi^-) + \Lambda(n\pi^0)} = 0.67$$

L effective chamber length

λ decay length of Ξ^- and Λ (assumed to be equal)

λ_i interaction length for producing Ξ^-'s. (for 10 μb cross-section $\lambda_i = 3.10^5$ cm H_2 liq.)