ON THE POSSIBLE EXISTENCE OF THE Ξ^0-HYPERON

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It is suggested that the appreciable difference between the mean lifetime of the Λ^0 particle as measured in cosmic ray or in accelerator work is due to the existence of the Ξ^0 hyperon. Based on this assumption a rough estimate is made of the lifetime and relative production probability for the Ξ^0 hyperon.

In spite of the large volume of phase space available, the decay $\Xi^- \rightarrow n + \pi^-$ has not as yet been observed. The absence of this decay has led Gell-Mann and Pais to suggest that decays involving strongly interacting particles are governed by the $|\Delta S| = 1$ selection rule, which forbids decays in which "strangeness" changes by two units.[1] This rule requires the "strangeness" of Ξ^- to be -2, since it decays into Λ^0 and π^- of total strangeness -1. It then follows from the well known relation $Q = I_Z + N/2 + S/2$ that the Ξ-hyperon is an isotopic doublet, i.e., that besides Ξ^- $(I_Z = -\frac{1}{2})$ there also exists Ξ^0 $(I_Z = +\frac{1}{2})$. The main mode of decay of this particle will apparently be $\Xi^0 \rightarrow \Lambda^0 + \pi^0$, which is hard to observe. However, as was already noted by Okun and Pontecorvo[2] the selection rule $|\Delta S| = 1$ is no more than a working hypothesis. The apparent validity of this rule is a natural consequence of the fact that all known strange particles (with the exception of Ξ) are assigned the values $S = \pm 1$ and consequently $|\Delta S| = 1$ is the only possible change in strangeness in the decay into "usual" particles. It should also be noted that within the framework of the Gell-Mann and Nishijima scheme the possibility exists of assigning a strangeness $S = -3$ to the cascade particle which would lead to an isotopic singlet. In such a case the selection rule would have to be changed to permit decays with $|\Delta S| = 1, 2$ and forbid $|\Delta S| = 3$.

Consequently the observation of the Ξ^0 hyperon is of particular interest since it would, in a sense, confirm the selection rule $|\Delta S| = 1$.

In connection with the possible existence of the Ξ^0 hyperon we want to call attention to the appreciable difference between the mean lifetime of the Λ^0 particle as measured in cosmic ray work: $\tau'_{\Lambda^0} = (3.5^{+0.2}_{-0.1}) \times 10^{-10}$ sec, and as measured in accelerator work: $\tau_{\Lambda^0} = (2.8 \pm 0.1) \times 10^{-10}$ sec.* In the first case it is possible that in addition to Λ^0 particles produced directly, Λ^0 particles from the invisible decay $\Xi^0 \rightarrow \Lambda^0 + \pi^0$ are also registered. Furthermore, as a rule, the primary reaction is not observed and so the two types of Λ^0 particles cannot be distinguished. It is clear that this circumstance will cause an apparent increase in the measured τ'_{Λ^0} as compared with the true lifetime, the increase depending on the relative production probabilities (followed by decay) of Ξ^0 and Λ^0 particles. At the same time, Λ^0 particles produced artificially by accelerators are "pure" since the production of Ξ^0 particles is energetically impossible. It is to be noted that in those few "cosmic" events for which the primary interaction is strongly coplanar with the Λ^0 decay as seen in the chamber, the measured τ_{Λ^0} has also turned out to be markedly smaller: $(2.14^{+0.8}_{-0.5}) \times 10^{-10}$ sec.[3] However, coplanarity cannot be used as a criterion for "purity" of the Λ^0 at high energies, since in such a case the Λ^0 from the decay of Ξ^0 will be very nearly collinear with the parent Ξ^0-hyperon.

The probability that a Λ^0 resulting from the decay of Ξ^0 will be observed in a given time interval dt_i (or in a corresponding distance dl_i) is given by

$$dp_i = f_i\,dt_i = B_i \frac{\tau_{\Lambda^0}}{\tau_{\Xi^0} - \tau_{\Lambda^0}} \left[\exp\left(-\frac{t_i}{\tau_{\Xi^0}}\right) - \exp\left(-\frac{t_i}{\tau_{\Lambda_0}}\right)\right] dt_i,$$

where τ_{Λ^0} and τ_{Ξ^0} are the mean lifetimes of the Λ^0 and Ξ^0 hyperon, respectively, and B_i is a normalization coefficient. In this manner, without go-

*These numbers represent a weighted average of results published in 1958: τ_{Λ^0} from 425 analyzed events, τ'_{Λ^0} from 207 events. The latter number does not include 25 events published in reference 3, for reasons given below (their inclusion would have almost no effect on our results anyhow.)

ing into the details of the statistical method of determination of τ_{Λ^0},[4] it can be shown that the starting probability distribution of all particles will actually be not

$$dP = \prod_{i=1}^{n} A_i \exp\left(-\frac{t_i}{\tau'_{\Lambda^0}}\right) dt_i,$$

as was assumed in the analysis, but rather

$$dP' = \prod_{i=1}^{n} A_i \exp\left(-\frac{t_i}{\tau_{\Lambda_0}}\right) dt_i$$

$$\times \prod_{i=1}^{m} B_i \frac{\tau_{\Lambda^0}}{\tau_{\Xi^0} - \tau_{\Lambda^0}} \left[\exp\left(-\frac{t_i}{\tau_{\Xi^0}}\right) - \exp\left(-\frac{t_i}{\tau_{\Lambda^0}}\right)\right] dt_i,$$

where n and m are the number of Λ^0's produced in the primary interaction and resulting from decays of Ξ^0, respectively.* At the same time, the mean lifetime was determined on the assumption that the time dependence of the Λ^0 decays is given by a pure exponential. Clearly, the exponent of the exponential best approximating the true distribution function will depend on the relative number of Ξ^0 particles ($q = m/n$) and on their lifetime. A rough estimate of q and τ_{Ξ^0} can be obtained from a comparison of τ'_{Λ^0} with the true lifetime as measured in the accelerator work.

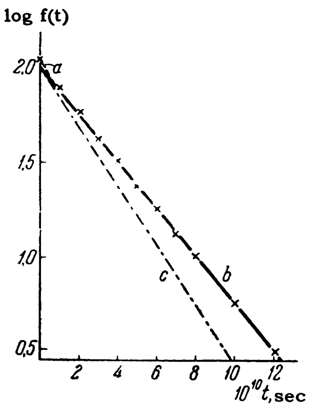
For this purpose we find those values of q and τ_{Ξ^0} which make the distribution function

$$f'(t) = \exp\left(-\frac{t}{\tau_{\Lambda^0}}\right) + q \frac{\tau_{\Lambda^0}}{\tau_{\Xi^0} - \tau_{\Lambda^0}} \left[\exp\left(-\frac{t}{\tau_{\Xi^0}}\right) - \exp\left(-\frac{t}{\tau_{\Lambda^0}}\right)\right] \qquad \text{(a)}$$

approximate as well as possible the exponential

$$f(t) \sim \exp\left(-\frac{t}{\tau'_{\Lambda^0}}\right) \qquad \text{(b)}$$

(see figure) (the effect of the normalizing coefficients A_i and B_i has been ignored). The values of q and τ_{Ξ^0} obtained in this manner turn out to be reasonable: $q = 0.1$ to 0.2, and $\tau_{\Xi^0} = (4 \text{ to } 6) \times 10^{-10}$ sec. Indeed, there is at present no reason why the production cross sections of Ξ^- and Ξ^0 should differ drastically. On the other hand, it is known that the number of Ξ^- produced in cosmic rays amounts to 0.1 of the number of Λ^0 observed under similar conditions,[5] which agrees in order of magnitude with q. As regards τ_{Ξ^0}, one would expect, from an analysis of the isotopic spin states produced in the decays of Ξ^- and Ξ^0, that $\tau_{\Xi^0}/\tau_{\Xi^-} = 2$ if the decay interaction transforms in isotopic spin space as a tensor of rank $\frac{1}{2}$, or that $\tau_{\Xi^0}/\tau_{\Xi^-} = \frac{1}{2}$ if the transition is pure $|\Delta I| = 3/2$.[6] Consequently the value for τ_{Ξ^0} is reasonable since experimentally $\tau_{\Xi^-} = 4.6 \times 10^{-10}$ sec.[7] it is our opinion that the above-mentioned fact favors the existence of the neutral cascade hyperon Ξ^0, although, understandably, the possibility of some systematic error cannot be excluded.



Λ^0-decay distribution function a) $f'(t)$, $q = 0.2$, $\tau_{\Xi^0} = 4 \cdot 10^{-10}$ sec b) $f(t) \sim \exp(-t/\tau') = 3.5 \cdot 10^{-10}$ sec c) $f(t) \sim \exp(-t/\Lambda^0)$, $\tau\Lambda^0 = 2.8 \cdot 10^{-10}$ sec.

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*We ignore the small difference in the velocities of the Ξ^0 and the Λ^0 produced in the decay.

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