The absolute value of the rate of this new process is important for the understanding of the Fermi couplings of hyperons.[4] Clearly, an isolated event does not permit an answer to this question. We are pursuing a systematic analysis of our pictures towards a determination of the absolute $\Sigma^{\pm}$ β-decay rates.

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[1]J. Hornbostel and E. O. Salant, Phys. Rev. 102, 502 (1956).

[2]F. Eisler et al., Phys. Rev. 112, 979 (1958); J. Leitner et al., Phys. Rev. Letters 3, 186 (1959).

[3]It may be noted parenthetically that the event is quite possibly an example of the production of the newly discovered K' [M. Good (private communication); M. Alston, Conference on Strong Interactions at Berkeley, December, 1960 (unpublished)], $\pi^- + p \rightarrow K'^+ + \Sigma^-$. From the K^0 and π^0 momenta, we find $m_{K'}c^2 = 933 \pm 33$ Mev for this event.

[4]See, for instance, R. P. Feynman and M. Gell-Mann, Phys. Rev. 109, 193 (1958); L. Okun', Annual Review of Nuclear Science (Annual Reviews, Inc., Palo Alto, California, 1959), Vol. 9, p. 61.

PROPERTIES OF THE Y^* AS OBSERVED IN THE INTERACTION $K_2^0 + p \rightarrow \Lambda^0 + \pi^+ + \pi^0$ *

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An investigation by Alston et al.[1] of the reaction $K^- + p \rightarrow \Lambda^0 + \pi^+ + \pi^-$, at a K^- momentum of 1120 Mev/c, has shown that strong momentum correlations exist among the reaction products. They concluded that these correlations were due to the existence of a strangeness -1, isotopic spin 1, baryon state, Y^*, which decays by strong interactions into a $\Lambda^0 + \pi$. Analyses of their data indicated to them that the mass of this state was 1384 Mev and the width was 63 Mev.

We are reporting on similar analyses of the products of the related reaction $K_2^0 + p \rightarrow \Lambda^0 + \pi^+ + \pi^0$. The K_2^0 mesons were produced by a chain of reactions initiated by the external beam of the Brookhaven Cosmotron. Three-Bev protons from the external beam were focused on a steel target to produce π^- mesons which in turn were momentum-analyzed and focused on a polyethylene target. The K_2^0 mesons produced in the forward direction by reactions such as $\pi^- + (p \text{ or } n) \rightarrow (\Lambda^0 \text{ or } \Sigma) + K_2^0 + (0, 1, \text{ or } 2)\pi$, passed through a lead absorber and a magnetic clearing field designed to eliminate charged particles and γ rays, and into a 14-in., 20-liter, liquid hydrogen bubble chamber 10 ft from the target. An average flux of 7×10^9 protons per pulse incident upon the meson target produced an intensity of about 3×10^5 π^- mesons with a momentum of 1.60 Bev/c and a spread of 7%. At these π fluxes, we estimate, from consideration of the number of K_2^0 decays observed and the measured lifetime, that the K_2^0 flux through the chamber was about 1.5 per pulse. Maximum intensities about three times these values were achieved. For each event of the type $K_2^0 + p \rightarrow \Lambda^0 + \pi^0 + \pi^+$, measurements of the momentum of the associated π^+ and the Λ^0 produced in the chamber, together with the knowledge of the direction of the incident K_2^0, allowed the determination of the momentum of the π^0 and the K_2^0. This momentum distribution for the 60 analyzable events reported here can be described adequately as a Gaussian distribution centered at 975 Mev/c with a half-width of 100 Mev/c. From charged Σ and 3-prong events we estimate that about 15% of these events are $\Sigma^0 + 2\pi$ and $\Lambda^0 + 3\pi$ events.

Any interaction of a K_2^0 with a proton which produces a hyperon and π mesons must be initiated by the strangeness -1, $\bar{K}^0$ part of the K_2^0. Since the third component of the isotopic spin of the $\bar{K}^0$ is $+\frac{1}{2}$, the interaction with the proton takes place wholly in the $T=1$ state. As the Λ^0 has an isotopic spin of zero, the two π mesons, of the reaction products $\Lambda^0+\pi^++\pi^0$, will have isotopic spin one, and the final space wave function will only change sign upon exchange of the two mesons. Therefore, if the interaction is charge independent, any description of the distribution of reaction products must not depend upon the charge of the π meson. Conversely, an observed symmetry of this kind is evidence for charge independence in interactions involving strange particles.

When the observation of final-state interactions is important, it is useful to consider the distribution of Q values as calculated between pairs of particles. This is illustrated in Fig. 1, where the distribution of Q values is plotted for (Λ^0, π^+), (Λ^0, π^0), and for the lesser of the two values for each event. Independent of any detailed assumptions concerning the origin of the peaks near 130 Mev, the similarity of the (Λ^0, π^0) and (Λ^0, π^+) distributions is evidence of the charge independence of the interaction. This sharp Q-value peak suggests again the existence of the Y^* state previously postulated. About 40 events can be assigned to the peak, 22 Y^+ and 18 Y^0, the Y^0 not having previously been observed. While alternative explanations of this anomaly can be offered,[2] we shall proceed in the rest of this discussion on the assumption that the explanation in terms of the existence of a state, Y^*, is correct.

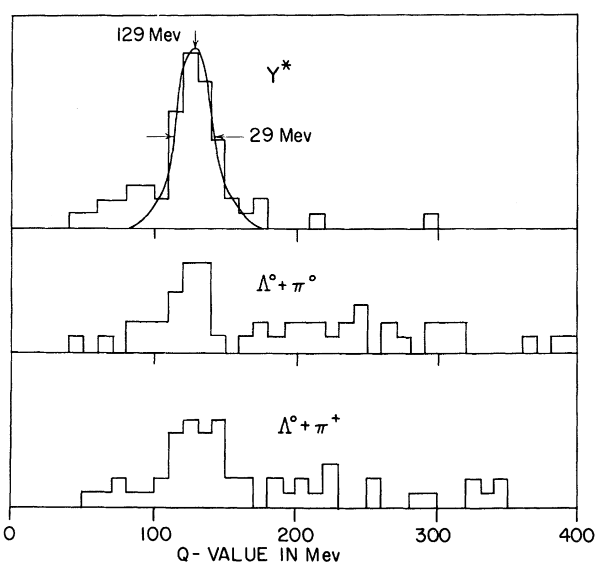

FIG. 1. Histograms representing Q-value distributions. The lower histogram shows the distribution of Q values calculated for the Λ^0 and π^+, the center histogram represents the same plot for $\Lambda^0+\pi^0$, and the upper histogram shows a plot of the lower of the two Q values plotted for each event. Sixty events are represented.

The experimental width of the state, as seen in Fig. 1, is about 29 Mev. This measured width will be approximately equal to the square root of the sum of the squares of the natural width and the experimental resolution. From a study of our errors we conclude that the full width of the resolution function cannot be less than 20 Mev and is more likely near 30 Mev. The value of the natural width is then, $0 \leq \Gamma \leq 20$ Mev, which is quite different from the value of 63 Mev quoted by Alston et al.[1]

Information concerning the spin and parity of the state may be derived from analysis of angular distributions of Y^* and Λ^0 decays. The Y^* produced at small angles with respect to the K beam will decay preferentially in the beam direction[3] if the spin is greater than $\frac{1}{2}$. Of the 17 events such that $|\cos\theta| > 0.7$, where θ is the production angle, the fraction 0.50 ± 0.15 decayed such that $|\cos\phi| > 0.5$, where ϕ was the decay angle, in agreement with the value 0.5 to be expected for $J=\frac{1}{2}$, and about 1.3 standard deviations from the value 0.69 for $J=\frac{3}{2}$. For any angle of production there will be some alignment, if the spin is greater than $\frac{1}{2}$, and the direction of the alignment will vary slowly with angle. Therefore, the examination of correlations between the directions of decay of Y^* states produced at nearly the same production angle will be informative.[2] The quantity $C=\Sigma_i\Sigma_j P_2(\cos\theta_{ij})$ was evaluated, where P_2 is the Legendre polynomial normalized over the interval 0 to 1, and θ_{ij} is the angle between the decay of the Y^* event i and event j. The sum i is over all events, the sum j over all events such that $|\cos\phi_i - \cos\phi_j| \leq 0.3$, in this case, where ϕ is the production angle of the Y^*. The value of C from this experiment was -0.03 ± 0.10 which is to be compared to expected values of 0 for $j=\frac{1}{2}$, and 0.09 for $j=\frac{3}{2}$.

Information concerning the parity of the Y^* can be obtained if the Y^* is produced such that it is polarized. Assuming that the spin is $\frac{1}{2}$, if the Y^* decays by S wave the Λ will be polarized in a direction perpendicular to the plane of production and will decay with an angular distribution of $1+A_S\cos\theta_S$, where θ_S is the angle between the decay direction and the normal to the plane of production $(\vec{P}_K \times \vec{P}_Y)/(|\vec{P}_K||\vec{P}_Y|)$ and $A_S = P\alpha$;

P is the degree of polarization of the Y^* and α is the usual asymmetry parameter in the decay of the Λ which is about +1. If the decay is by P wave, the distribution will take the similar form $1+A_p \cos\theta_p$, where A_p is again $P\alpha$ but θ_p is the angle between the Λ-decay direction and a vector which lies in the plane formed by the production-plane normal and the Y^*-decay direction, and whose angle with the normal is twice that of the Y^* decay. The measured values of the quantities A_p and A_S are correlated; for an S decay, $A_p = -\frac{1}{3}A_S$, while for a P decay, $A_S = -\frac{1}{3}A_p$. Our results, using 37 events, are $A_S = -0.38 \pm 0.25$, $A_p = 0.19 \pm 0.25$, which suggests that the decay is S-wave. Statistically more significant results, in accord with these, have been reported by Ferro-Luzzi et al.[4]

If these spin and angular momentum assignments are valid, and if the K-meson parity is odd, this state can be expected to be the state related to the $(a-)$ K^--p scattering length solution of Dalitz and Tuan,[5] $a = (-1.0+0.18i)$ fermi. It is then interesting to calculate the threshold behavior of the K^--p system under the assumptions that a single-level resonance formula[6] dominates the situation, and the Σ-Λ parity is odd. The scattering length will then be equal to $\gamma_K^2/(E_\lambda - \frac{1}{2}i\Gamma) - R$, where $\Gamma_i = 2ki\gamma_i^2$ is the width for channel i for S wave and $\Gamma_i = 2k\gamma^2(kR)^2/[1+(kR)^2]$ for P wave, Γ is the total width equal to $\Gamma_K + \Gamma_\Lambda + \Gamma_\Sigma$, where K, Λ, and Σ represent the $\Lambda+\pi$, $\Sigma+\pi$, and K^-+p channels, respectively, E_λ is the Y^* resonance energy, and R is an interaction radius, taken here as $\hbar/M_Kc$. From the Y^* widths taken as $\Gamma_\Lambda = 16$ Mev and $\Gamma_\Sigma = 4$ Mev,[7] we find $\gamma_\Lambda^2 \approx 7$ Mev f, and $\gamma_\Sigma^2 \approx 45$ Mev f. We choose $\gamma_K^2 = 30$ Mev f to fit the real part of the scattering length. With these numbers, $a = (-1.0+0.32i)$ f and the ratio of Σ to Λ production at threshold in the $T=1$ state is about 0.75, not greatly different than results of the analysis of Dalitz and Tuan.[5] Even Λ-Σ parity results in a much poorer fit to the Σ-Λ production ratio.

It is interesting to note that the sum of the reduced widths, about 80 Mev f, is, within the very rough estimates made here, consistent with the Wigner sum rule,[8] $\Sigma_S \gamma_S^2 \approx \hbar^2/MR \approx 200$ Mev f, where the sum is over all channels open or closed.

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[6]E.g., E. P. Wigner and L. Eisenbud, Phys. Rev. 72, 29 (1947).

[7]Preliminary investigations of the $\Sigma + 2\pi$ production from this experiment, by B. Musgrave, suggest that $\Gamma_\Sigma/\Gamma_\Lambda$ may be about 1/4.

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