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NOTE ON THE ASSOCIATED PRODUCTION OF HYPERONS AND K MESONS

Saul Barshay

August 1956

NOTE ON THE ASSOCIATED PRODUCTION OF HYPERONS AND K MESONS

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There are now several pieces of experimental evidence indicating definite asymmetries in the angular distributions of Δ^0 and K^0 particles that are produced in association in pion-nucleon and nucleon-nucleon collisions.^{1, 2, 3, 4} Experimental evidence also exists for asymmetries in the angular distributions of Σ^- and K^+ particles produced in pion-nucleon collisions.^{1, 2, 3, 4} This note concerns a suggestion for a possible interpretation of these asymmetries in terms of a coupling between pions and K mesons and a coupling between pions and hyperons. These remarks were considered originally in connection with an experiment performed by Osher and Moyer,⁵ in which they observed the angular distribution of neutral unstable particles, produced by bombarding a copper target with protons of various energies ranging from 2 to 6.2 Bev. The angular distribution of the K^0 produced in the reaction $p + n \rightarrow Y + K + N$ was fitted with a $\cos^{14} \theta$ in the center-of-mass system, at all energies in the range. This very high power of the cosine is difficult to understand in terms of the angular momentum states available to the system at the lower energies, if the interaction radius is considered to be on the order of $(m_K)^{-1}$. A longer-range interaction that will give strong forward and backward peaking of the hyperons and K mesons is needed. The production mechanisms suggested are shown diagrammatically in Fig. 1. The processes represented by graphs (a) and (b) involve the pion-nucleon coupling constant, G ; the nucleon-hyperon-K-meson coupling constant, G_{YK} ; and a pion-K-meson coupling constant, $G_{\pi K}$.

¹ Fowler, Shutt, Thorndike, and Whittemore, Phys. Rev. 93, 861 (1954).

² Fowler, Shutt, Thorndike, and Whittemore, Phys. Rev. 98, 121 (1955).

³ Report of the Sixth Annual Rochester Conference, 1956.

⁴ Budde, Chretien, Leitner, Samios, Schwartz, and Steinberger, Nevis Report-27, Columbia University, 1956.

⁵ J. Osher, π^0 Modes of Heavy-Meson and Hyperon Decay (Thesis), UCRL-3449, July 1956.

The π -K interaction is assumed of the form $K_e^+ \tau_a K_0 \pi_a$, where $K_e(K_0)$ represents the field operator of the K meson of spin and parity $0^+(0^-)$, the π_a represent the pion field operators, and the τ_a are the Pauli i-spin matrices. The processes represented by graphs (c) and (d) involve G , $G_{\pi K}$, and a pion-hyperon-hyperon coupling constant, $G_{\pi \Sigma}$. It should be noted that if one is to allow K mesons of either parity to be emitted in either even or odd angular momentum states, then there must be Σ and Δ particles with both positive and negative parity relative to the nucleon. Thus, for example, the nucleon-lambda-K-meson interaction will be of the form $\bar{N} \Delta_e K_e + \bar{N} \gamma_5 \Delta_0 K_e + \bar{N} \Delta_0 K_0 + \bar{N} \gamma_5 \Delta_e K_0$ and the sigma-sigma-pi-meson interaction will have the form $\bar{\Sigma}_{e(0)} \gamma_5 \tau_a \Sigma_{e(0)} \pi_a + \bar{\Sigma}_{e(0)} \tau_a \Sigma_{e(0)} \pi_a$. The γ_5 dependence of these vertices leads nonrelativistically to a dependence on the momentum of the bosons which tends to enhance peaking effects.

Processes of graphs (a) and (c) of Fig. 1 lead to a peaking of the K mesons forward, while those for (b) and (d) lead to a peaking of the K mesons backward. The peaking of the K mesons is most pronounced in the processes of graphs (c) and (d), because the K carries much of the momentum of one of the initial nucleons forward or backward respectively, in the center of mass. The production process may also occur through the mechanisms indicated in graphs (e) and (f). These mechanisms can lead to backward and forward peaking respectively, for both the Δ^0 and K^0 . If we have $G \approx G_{\pi K}$ or $G_{\pi \Sigma}$, the processes shown in these graphs may make a large contribution to the total cross section. The question arises as to what is the relative contribution to the peaking of the processes in graphs (a) and (b) on the one hand, and in (c) and (d) on the other. If we look now at the production of Δ^0 and K^0 in pion-nucleon collisions we get a partial answer. What has been observed in π^- -p collisions is a very strong peaking of the Δ^0 backward and the K^0 forward.⁴ The production processes are shown diagrammatically in Fig. 2. That of graph (a) leads to an essentially isotropic distribution; that of graph (b),⁶ involving

⁶ The possibility of the production mechanism pictured in diagram (b) of Fig. 2 was suggested by Dr. M. Goldhaber in connection with his compound models of unstable particles, Phys. Rev. 101, 433 (1954). Professor Schwinger has suggested a π -K interaction in his dynamical theory of the unstable particles; (unpublished material).

$G_{\pi K}$ peaks the K^0 strongly forward; however, process (c), involving $G_{Y\pi}$, peaks the K^0 strongly backward. That the latter effect is not observed, indicates that we have $G_{Y\pi} < G_{\pi K}$. The coupling of the pion to the isotopic bosons Δ and Σ must be smaller than that of the pion to the isotopic fermions K_e and K_0 if this picture of the production mechanism is to be consistent for both π -N and N-N collisions.

A detailed calculation is in progress to see if the angular distribution of the Osher experiment can be fitted with the matrix element from graphs (e) and (f) and the graphs involving $G_{\pi K}$ in Fig. 2. If not, the question is then how much of the process involving $G_{Y\pi}$ can be introduced consistent with the absence of the backward peak in π -N collisions.

Finally we note that the production of Σ^- and K^+ in π^- -p collisions occurs through the processes shown in Fig. 3. Experiment indicates that the K^+ tend to go backward and the Σ^- forward in the center of mass. This is consistent with the mechanism in graph (b). The smaller number of $\Sigma^- K^+$ events⁴ than of $\Delta^0 K^0$ events is consistent with the absence of the production mode involving $G_{\pi K}$ in π^- -p collisions. If $G_{\pi K} > G_{Y\pi}$, the Σ^- produced in π^- -p collisions should come off predominantly backwards in the center of mass.

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LEGENDS

Fig. 1. Feynman graphs for the process $p + \pi^0 \rightarrow \Lambda^0 + K^0 + p$.

Fig. 2. Feynman graphs for the process $\pi^- + p \rightarrow \Lambda^0 + K^0$.

Fig. 3. Feynman graphs for the process $\pi^- + p \rightarrow \Sigma^+ + K^+$.

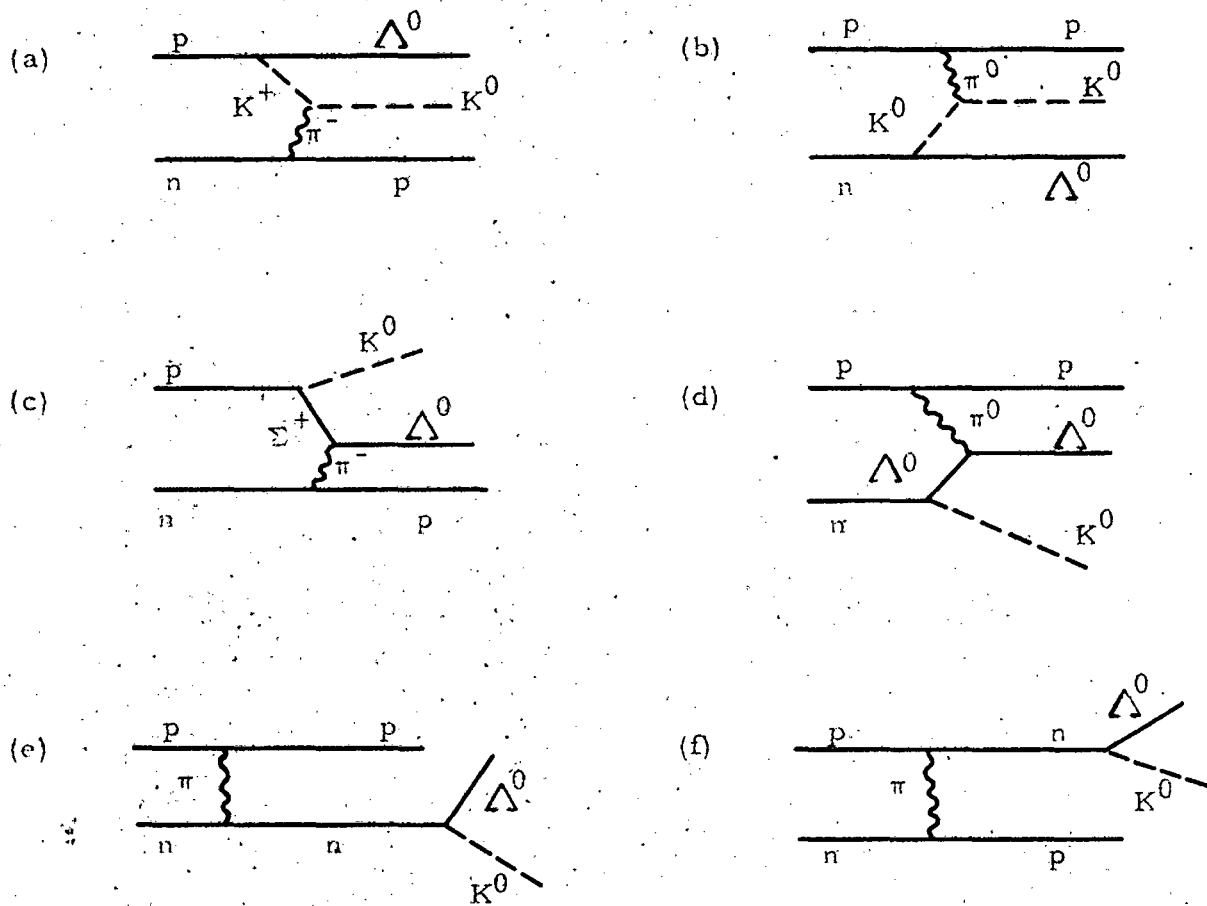


Fig. 1. Feynman graphs for the process $p + n \rightarrow \Lambda^0 + K^0 + p$

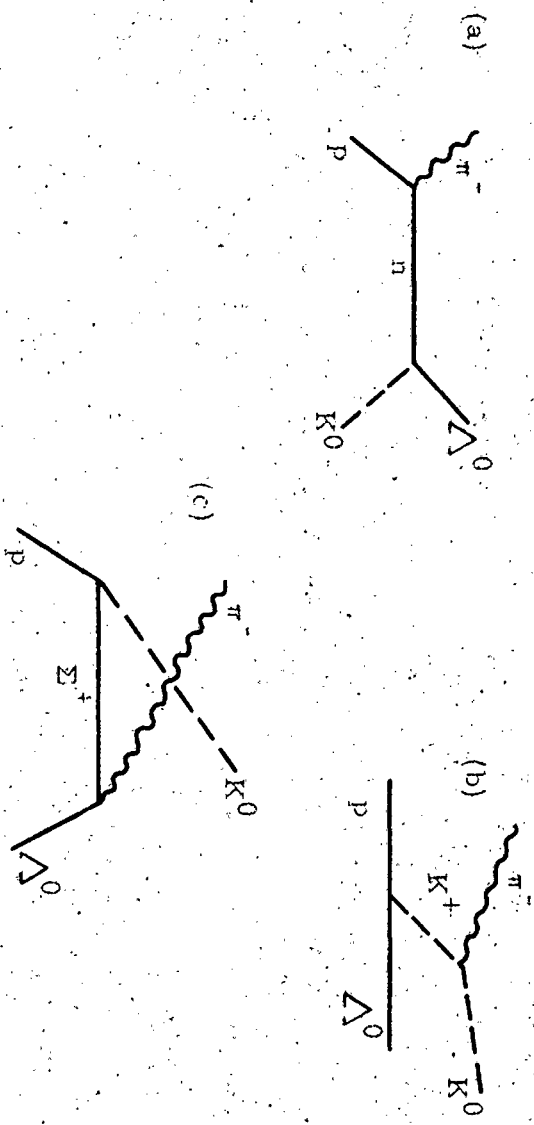


Fig. 2. Feynman graphs for the process $\pi^- + p \rightarrow \Lambda^0 + K^0$.

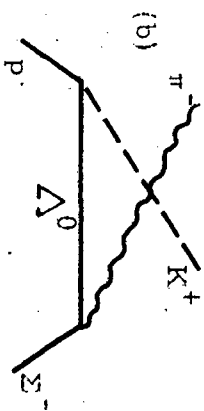
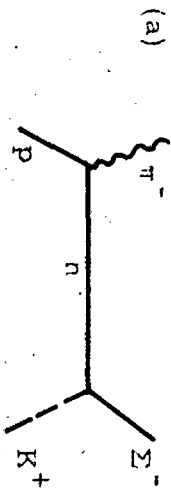


Fig. 3. Feynman graphs for the process $\pi^- + p \rightarrow \Sigma^- + K^+$