Note on Isospin Conservation in Strange-Particle Production*

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This paper reports the investigation of the reaction $\pi^+ + d \rightarrow K + \pi + \Lambda^0 + p_s$ at a bombarding energy of 7 GeV/c. A recent compilation of data concerning $\pi^- + p \rightarrow K + \pi + \Lambda^0$ showed a discrepancy in the decay $K^{*0}(890) \rightarrow K^+ + \pi^-$ and $K^0 + \pi^0$. The discrepancy was that too few of the latter decay modes were observed as compared with isospin predictions. This paper reports further investigation which shows a considerably smaller discrepancy than that previously found. The previously noted discrepancy must have been in part produced by a low scanning efficiency. The characteristics of these reactions are in other respects very similar to those observed at lower energies. The K^*'s seem to be produced by natural-parity exchange.

Last year we published data[1] gathered in a collaboration arising from several experiments studying 7.0-GeV/c π^--p interactions. The effect observed involved the decay of the $K^*(890)$ into $K^+\pi^-$ and $K^0\pi^0$. An apparent violation of isospin was observed in that too few K^0-π^0 decays were found.

Since that time we have done an essentially independent investigation which we report here. Since the original publication, a detailed check was made at lower bombarding energy by Crennell *et al.*[2] and no isospin violation was found. A possible explanation of the effect has also recently been proposed in a paper by Berger and Fox.[3] The theory presented gives a natural explanation of the destructive interference apparently observed. It is expected that the predicted effect would increase with bombarding energy.

The new data presented here came from the 30-in. MURA-ANL chamber filled with deuterium and exposed to 7.0-GeV/c π^+'s (600 000 pictures).

The reactions on neutrons (corresponding to the π^--p reactions) are

$$\pi^+ + n \rightarrow K^0 + \pi^+ + \Lambda^0 , \quad (1)$$

$$\pi^+ + n \rightarrow K^+ + \pi^0 + \Lambda^0 . \quad (2)$$

These two reactions should occur in a ratio of 2:1 if the $(K$-$\pi)$ system is in the $K^*(890)$. The topology of the two reactions is usually the same since the K^0 will appear a third or less of the time. The fact that both reactions can appear with the same topology is an important advantage over the previous investigations. Both reactions are usually fitted in a one-constraint class. The numbers observed in the deuterium experiment are as follows:

$$\begin{aligned} \pi^+ + n \rightarrow & (K^0) + \pi^+ + \Lambda^0 \quad (229 \text{ events}) \\ & K^0 + \pi^+ + (\Lambda^0) \quad (130 \text{ events}) \\ & K^0 + \pi^+ + \Lambda^0 \quad (50 \text{ events}) \\ \rightarrow & K^+ + (\pi^0) + \Lambda^0 \quad (194 \text{ events}), \end{aligned}$$

where (K^0) indicates that the K^0 was not observed

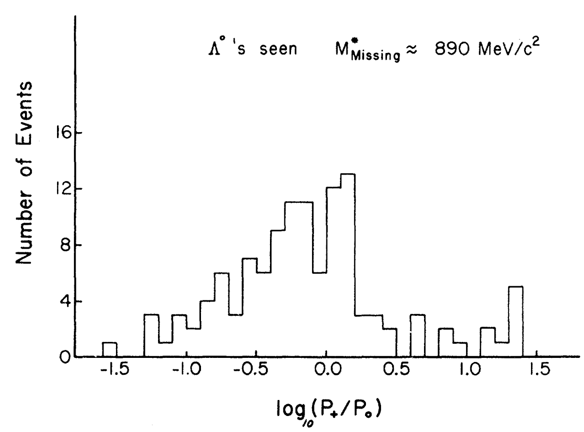

FIG. 1. Plot of the logarithm of the ratio of the momentum of the positive track to that of the neutral particle for events $\pi^+ + n \rightarrow \pi^+ + K^0 + \Lambda^0$ or $\pi^+ + n \rightarrow \pi^0 + K^+ + \Lambda^0$ for events with K-π masses in the $K^*(890)$ region.

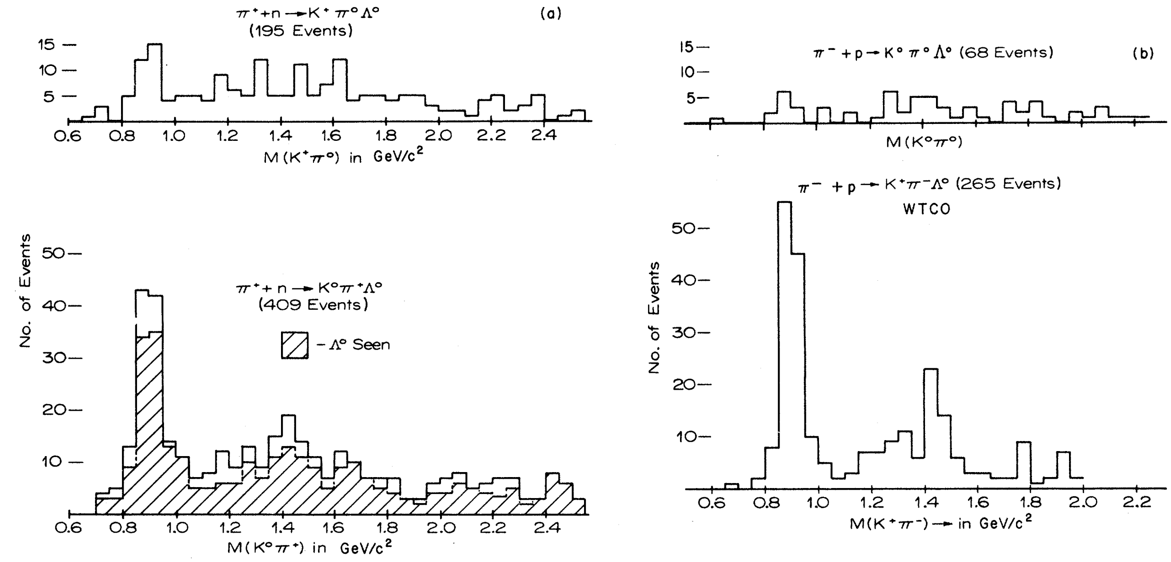

FIG. 2. (a) Mass spectra of $K^+\pi^0$ and $K^0\pi^+$ from $\pi^+ + n \to \pi^+ + K^0 + \Lambda^0$ and $\pi^+ + n \to \pi^0 + K^+ + \Lambda^0$. (b) Mass spectra of $K^0\pi^0$ and $K^+\pi^-$ from the corresponding π^--p interactions.

to decay. The events in which the K^0 and Λ^0 are both observed to decay are the least difficult to identify. The one-constraint categories in which a K^0 is not seen requires justification. These events are classified by hypothesis test. There is sometimes subsidiary information available which helps to decide classification of events; for example, occasionally the identification of the positive track can be determined by ionization. There were converting tantalum plates on the downstream side of the chamber which converted high-energy γ's (i.e., forward moving) with fairly high efficiency (~90%). Thus if one or two high-energy γ's were observed and an ambiguity existed in the hypothesis test, the event was categorized as a $K^+\pi^0\Lambda^0$ type. To check on the accuracy of the hypothesis test, we looked at events $\pi^-p \to K^+\pi^-\Lambda^0$ and removed momentum information on one of the two charged particles. An attempt was made to fit the event with the remaining charged particle misidentified. It

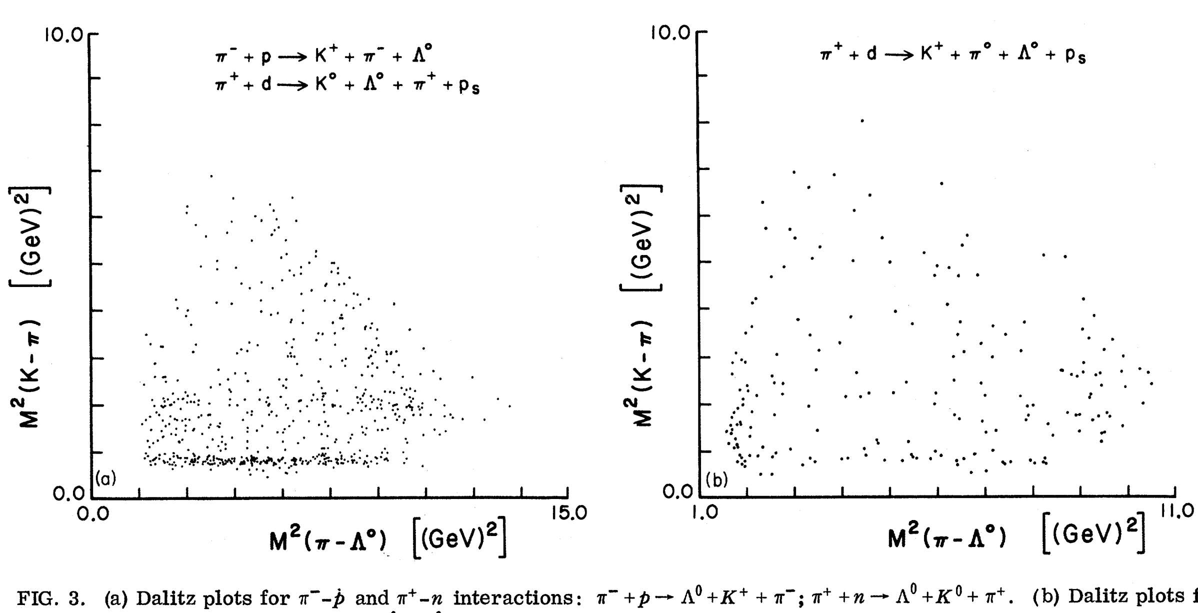

FIG. 3. (a) Dalitz plots for π^--p and π^+-n interactions: $\pi^- + p \to \Lambda^0 + K^+ + \pi^-$; $\pi^+ + n \to \Lambda^0 + K^0 + \pi^+$. (b) Dalitz plots for products of the reaction $\pi^+ + n \to K^+ + \pi^0 + \Lambda^0$.

was found that a wrong fit could be obtained 10–20% of the time. With our checks on hypothesis as indicated above, 10% should represent a maximum error. The feature that helps with the classification is that the K is three times as massive as the pion and in the case of the decay of the K^* in the laboratory frame the K has on the average twice the momentum of the π. In Fig. 1 we show a plot of $\log_{10}(P_+/P_0)$ from events in which the K-π mass was in the $K^*(890)$ mass range. This is compared to the plot of $\log_{10}(P_+/P_-)$ for the corresponding reaction ($K^+\pi^-\Lambda^0$) in hydrogen. One observes a preponderance of fast neutrals in the case of the deuterium events. These are events in which the Λ^0 is seen.

On the basis of the observed $\log_{10}(P_+/P_0)$ distribution a ratio of $N_{0(K^0\pi^+)}/N_{0(K^+\pi^0)}$ is estimated to be 88/26.

The observed mass spectra are shown in Fig. 2 for the sample of events with a Λ^0 seen. The various events have been classified either by hypothesis test or by using subsidiary information (ionization, γ ray, observation of a K^0 decay). The ratio of $K^0\pi^+/K^0\pi^+$ is appreciably greater than 2/1 for each selection of the data. We believe that the classification of events is indeed good to about 10%. The most serious error probably has to do with the ($K^0\pi^+$) events being mistakenly put into the $K^+\pi^0$ category. We thus view the result as a lower limit on the $K^0\pi^+/K^+\pi^0$ ratio.

Figure 3 shows Dalitz plots for the hydrogen $K^0\pi^0$ events and $K^+\pi^-$ as well as the deuterium events. For the deuterium experiment the ratio $K^+\pi^0/K^0\pi^+$ in the $K^*(890)$ region is 22/71 if we make an estimate of the phase-space background. The ratio of $K^0\pi^0/K^+\pi^-$ for the WTCO (Wisconsin-Toronto-Colorado-Ohio) data[1] is 8/100. The discrepancy is considerably smaller than in our previous publication. The $K^+\pi^0/K^0\pi^+$ ratio is expected to be 1/2 from isospin considerations. The observed ratio for the deuterium data differs from the expected value by a little more than 2 standard deviations. The hydrogen data should give a ratio 1/6 and seems to be low but it is apparent that the statistical accuracy is not great. The most likely explanation of the previous results has to do with scanning losses. Such an effect may be seen also in our inefficiency in finding $K^0\pi^+\Lambda^0$.

TABLE I. Spin density-matrix elements.

$\pi^+d \to p\pi^+K^0\Lambda$	$792 < M(\pi^+K^0) < 992$ MeV/c^2
$\rho_{00} = 0.176^{+0.072}_{-0.061}$	
$\rho_{1\,-1} = 0.264^{+0.070}_{-0.086}$	
$\mathrm{Re}\rho_{10} = 0.066^{+0.048}_{-0.054}$	
$\pi^-p \to \Lambda\pi^-K^+$ [a]	$650 < M(\pi^-K^+) < 1150$ MeV/c^2
$\rho_{00} = 0.182 \pm 0.071$	
$\rho_{1\,-1} = 0.227 \pm 0.068$	
$\mathrm{Re}\rho_{10} = -0.066 \pm 0.039$	

[a] From A. Peekna, W. D. Walker, B. Y. Oh, M. A. Thompson, D. R. Clear, D. N. Hoa, and J. Prentice, Nucl. Phys. B27, 605 (1971).

Our results are consistent with the $K^+\pi^0/K^0\pi^+$ being low by 20–30% which would be consistent with the model of Berger and Fox as calculated by Sivers.[4] Probably less sophisticated interference effects could also produce such an effect. At this level of discrepancy the results are not particularly disturbing (or exciting). In other respects we find results rather similar to those found by Crennell *et al.*[2] at 4.5 and 6 GeV/c. We find that the Λ^0 produced in association with the $K^{*0}(890) \to K^+ + \pi^-$ or $K^{*+} \to K^0 + \pi^+$ is strongly polarized [(55 ± 27)% down]. The density matrix elements for the K^* are given in Table I. These indicate the dominance of natural parity exchange. The presumption is of course that K^* exchange is the dominant exchange responsible for the process. If this were the case, the polarization would be small. Thus we must assume that there are other natural-parity exchanges present or that absorption effects are large in the case of K^* exchange. The latter possibility seems reasonable to the authors. The events showing $K^{*+} \to K^+ + \pi^0$ have a Λ^0 polarization consistent with zero. The Λ^0's from the $K^*(1400)$ seem to have the opposite polarization [$P_\Lambda = (66 \pm 40)$% up].

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[1] J. Lynch *et al.*, Phys. Letters 35B, 457 (1971).

[2] D. J. Crennell, H. A. Gordon, Kwan-Wu Lai, and J. Michael Scarr, Phys. Rev. D 6, 1220 (1972).

[3] E. L. Berger and G. Fox, Phys. Letters 36B, 389 (1971).

[4] D. Sivers (private communication).