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REACTION $\Sigma^- + {}^4\mathrm{He} \rightarrow \Lambda^0 + n + {}^3\mathrm{H}$ †

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When Σ^- hyperons are absorbed at rest in helium the only possible final state, apart from hyperfragment production, is $\Sigma^- + {}^4\mathrm{He} \rightarrow \Lambda^0$ + nucleons, Σ^0 production being forbidden by energy considerations. We have examined such events obtained in an exposure of the Northwestern University helium bubble chamber[1] to a stopping beam of K^- mesons. The analysis was restricted to events with a π^+ meson and a highly ionizing track at the K^- vertex. This topology can occur only for Σ^- production, and permits an unbiased count of Σ^- interactions regardless of their topology.

Those events having a charged stub with projected length greater than 0.5 mm at the Σ^- interaction vertex and a visible Λ^0 were kinematically fitted to the hypothesis

$$\Sigma^- + {}^4\mathrm{He} \rightarrow \Lambda^0 + n + {}^3\mathrm{H}.$$

135 events were analyzed, 104 of which had a stub satisfying the length criterion. 93 gave a satisfactory fit to the hypothesis $\Lambda^0 + n + {}^3\mathrm{H}$, with the Σ^- assumed to interact at rest. Of the remainder, five were interactions in flight, and six represented breakup of the triton. Figures 1, 2, and 3 show the experimental momentum spectra of the final-state particles.

The predominance of the three-body final state indicates that a description in terms of the impulse model is appropriate. This model has been investigated by several authors[2] for K^- absorption in deuterium, and by Block[3] for K^- absorption in helium. Similar calculations[4] for Σ^- absorption in helium assuming a general S-wave interaction of the form

$$H_{\mathrm{int}} = A + B\vec{\sigma}_Y\cdot\vec{\sigma}_N + C\{(\vec{\sigma}_Y\cdot\vec{q})(\vec{\sigma}_N\cdot\vec{q}) - \tfrac{1}{3}(\vec{\sigma}_Y\cdot\vec{\sigma}_N)q^2\},$$

where the subscripts Y and N refer to the hyperon and nucleon, respectively, and $\vec{q}$ is the relative Λ^0-n momentum, yield the theoretical

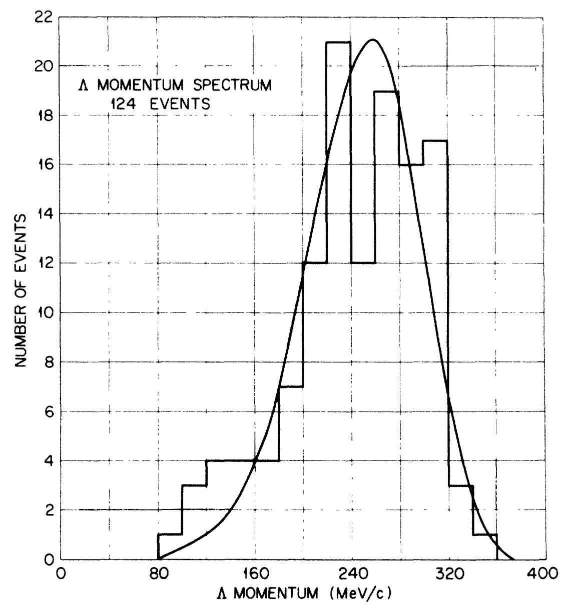

FIG. 1. Λ momentum spectrum. The solid curve represents the predictions of the impulse model.

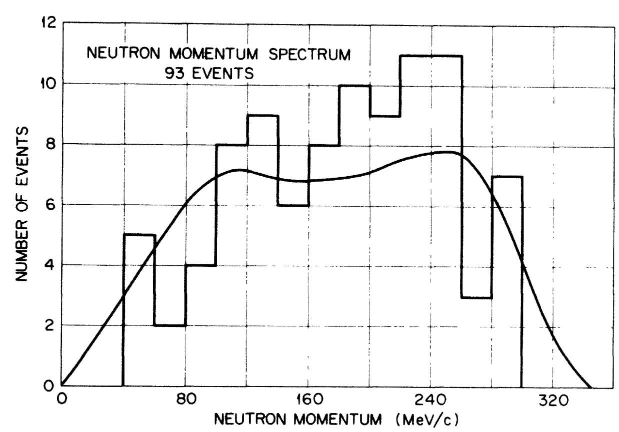

FIG. 2. Neutron momentum spectrum. The solid curve represents the impulse-model prediction and takes into account the experimental cutoff in the measurability of the triton momentum.

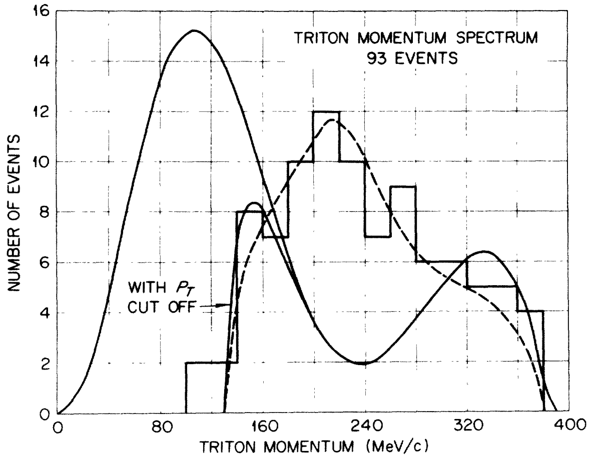

FIG. 3. Triton momentum spectrum. The solid curve is the impulse-model prediction normalized to the total number of events: 93 fit events and 31 events for which the triton stub was too short to be measured. The dashed curve represents impulse model and resonance ($\Gamma = 20$ MeV/c^2) combined.

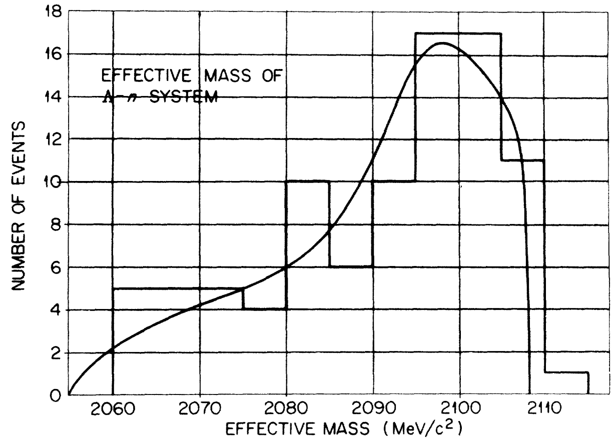

FIG. 4. Effective-mass distribution of the lambda-neutron system. The solid curve represents the combined effects of a resonance at 2098 MeV/c^2 with $\Gamma = 20$ MeV/c^2 and impulse model and takes into account the experimental cutoff in the triton-momentum measurability.

curves shown in Figs. 1, 2, and 3. A final-state wave function specifically taking into account the effects of the Pauli principle was used, and the experimental resolution has been folded in. The effect of the experimental cutoff in the triton momentum is included in the neutron curve (Fig. 2). These curves represent the equivalent phase space for Σ^- capture at rest in helium. The results are insensitive to choice of the parameters A, B, and C.

The shapes of the observed lambda and neutron spectra are not in disagreement with the predictions of the impulse model, but there is clearly a peak in the spectator triton momentum that cannot be accounted for. In addition, the model predicts that our sample should yield 65 events with triton stub length less than 0.5-mm projected length as compared to an observed number of 31. A similar situation has been observed in K^- absorption in helium,[5] where the reaction $K^- + {}^4\text{He} \rightarrow \Sigma^\pm + \pi^\mp + {}^3\text{H}$ agreed with the predictions of the impulse model, but where Y_1^*(1385 MeV/c^2) formation in the final state, $\Lambda^0 + \pi^- + {}^3\text{He}$, displaced the ^{3}He momentum peak to higher values. The position of the peak in the spectator momentum depends sensitively on the mass of the resonance. If the viewpoint is adopted that the anomaly in the triton spectrum in our reaction is due to a resonance in the Λ^0-n system, the peak in the triton spectrum yields a mass value of 2098 $\pm$ 6 MeV/c^2.

The dashed curve in Fig. 3 represents an admixture of impulse model and a Breit-Wigner-shaped resonance in the effective-mass spectrum (Fig. 4), and takes into account the experimental momentum cutoff. A best fit is obtained for a width of 20 MeV/c^2 and resonant-term contributions of 55 %, although satisfactory fits are obtained for widths ranging from 15 to 35 MeV/c^2 with corresponding resonant-term contributions of 45 % to 65 %, respectively. It should be noted that the experimental resolution and the kinematic limits affect the shape of the spectrum in such a way that the width is not measured in a sensitive manner. On the basis of the above fitting procedure a width assignment $\Gamma = 20_{-5}^{+15}$ MeV/c^2 is appropriate.

Using the effective-range formalism to describe the n-n force, Chen[2] has investigated the effect of an n-n final-state interaction for Σ^- capture in deuterium. The Λ^0 spectrum is shown to differ drastically in shape from the plane-wave result.in a narrow region near the upper kinematic limit. Examination of the neutron and Λ^0 momentum spectra in the helium case yields no evidence for the presence of appreciable Λ^0-triton or neutron-triton scattering in the final state due to ordinary $\Lambda^0 n$ or nn forces. Such scattering seems unlikely, therefore, to account for the observed anomaly in the triton spectrum.

With the exception of evidence for Λ^0-nucleon resonances reported by Jain[6] and Piroue,[7] no such resonance has been observed in other reactions that exhibit a lambda and a nucleon in the final state.[8,9] It should be noted, however, that the reaction $\Sigma^- + \text{He}$ is particularly suited to reveal such a resonance. The lambda is directly produced, and the nucleon in the final state cannot be considered a spectator to the initial interaction; nor does the reaction involve a pion that can distort the spectrum through Y^* formation.

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EXAMPLE OF DECAY $\Omega^- \to \Xi^- + \pi^0$†

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The existence[1] of the Ω^-, a baryon of mass[2] 1676 MeV and strangeness -3, has been predicted from SU(3) invariance of the strong interactions. This prediction was beautifully confirmed by three examples[3] found in the 80-in. hydrogen bubble chamber in a separated 5.0-BeV/c K^- beam at the AGS accelerator at Brookhaven National Laboratory. We have found another example of an Ω^-, which decays into a Ξ^- and π^0. The three previous examples have exhibited the decay modes $\Omega^- \to \Xi^0 + \pi^-$ and $\Omega^- \to \Lambda + K^-$ (two examples).

The exposure for this experiment was carried out at Brookhaven National Laboratory using the 80-in. hydrogen bubble chamber. A mass-separated beam of 4.2-BeV/c K^- mesons from the AGS was incident on the bubble chamber. We have scanned 25 000 pictures for events initiated by an incident-beam track and containing at least two (charged or neutral) V particles.

Figure 1 shows the complete event reported on here. This event is interpreted to be

$$K^- + p \to \Omega^- + K^+ + K^0 \quad \text{(1a)}$$
$$K^0 \to \pi^+ + \pi^- \quad \text{(1b)}$$
$$\Omega^- \to \Xi^- + \pi^0 \quad \text{(1c)}$$
$$\Xi^- \to \Lambda + \pi^- \quad \text{(1d)}$$
$$\Lambda \to p + \pi^-. \quad \text{(1e)}$$

Both the Λ decay (1e) and the K_1^0 decay (1b) give excellent fits to the reactions indicated. All alternative hypotheses, such as alternate origins or mass assignments, fail to fit. For the Ξ^- decay (1d) we also obtain a good fit.