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PRODUCTION OF HYPERONS IN LEAD BY K_2^0 MESONS WITH A MEAN ENERGY OF ~100 MeV

D. V. NEAGU, É. O. OKONOV, N. I. PETROV, A. M. ROZANOVA, and V. A. RUSAKOV

Joint Institute for Nuclear Research

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Hyperon production in lead nuclei by K_2^0 mesons with a mean energy ~ 100 MeV was investigated using a cloud chamber in a magnetic field. The $\Lambda^0(\Sigma^0)$ hyperon production cross section in lead is estimated to be $\sigma(\Lambda^0 + \Sigma^0) = 200 \pm 70$ mb. The ratio of the cross sections for regeneration $K_2^0 \to K_1^0$ and creation of hyperons is appreciably less than unity ($\sim 5 \times 10^{-2}$).

HYPERON production by K_2^0 mesons has been observed by several groups of experimenters; however, at the present time no data exists concerning effective cross sections for these processes.*

We investigated hyperon production by K_2^0 mesons using a cloud chamber (in a magnetic field) in a beam of K_2^0 mesons from the proton synchrotron of the Joint Institute for Nuclear Research. A lead plate 5.8 g/cm^2 thick served as the target.

The experimental conditions were on the whole favorable for detecting Λ^0 hyperon decays because, as a consequence of the comparatively small energy of the particles created, an overwhelming portion of the charged hyperons did not escape from the lead plate because of ionization retardation.†

Upon exposure in the chamber containing the lead plate, 440 cases of V^0 events were recorded. Of these, we selected by visual means 39 events‡ in which one of the tracks was interpreted (from the density and curvature of the track) as that of a proton (see the figure).

The angular distribution of the Λ^0 hyperons emitted from the plate appears to be isotropic since the numbers of Λ^0 particles emitted "forward" and "backward" (in the laboratory coordinate system) with respect to the direction of motion of the K_2^0 mesons are practically identical ($N_f/N_b = 13/15$). A kinematical analysis of the selected events was carried out in order to identify the process conclusively. The difference $\Delta - C$ between the experimental quantity

$$\Delta = E_+E_- - p_+p_- \cos\gamma$$

and its calculated value* $C = 17.38 \times 10^4$ MeV^2 for the decay $\Lambda^0 \to p + \pi^-$, and also the experimental error $\delta\Delta$ (where E_+, E_-, p_+, p_- are, respectively, the experimentally measured total energy and momentum of the decay products, and γ is their divergence angle) were determined for 35 completely measured decays.

The selected events satisfy the kinematical properties of Λ^0 decay, as is seen from Table I. The average mass of the decaying particles, calculated for isolated decays, amounts to 1116 ± 8 MeV and is in good agreement with the most exact value for the Λ^0-hyperon mass, $M_{\Lambda^0} = 1115.45 \pm 0.12$ MeV.[3] The average energy of the detected Λ^0 hyperons was found to be 40 MeV, and the maximum was 80 MeV.

Thus, our analysis indicated that, under the conditions of our experiment, the selection of decays was made sufficiently reliably. Inasmuch as the probability for the imitation of Λ^0 particle decays by other possible reactions (e.g., production of negative pions in the cloud chamber gas by neutrons from the beam) is very small,† all 39 isolated events must be classified as Λ^0-particle decays in the mode $\Lambda^0 \to p + \pi^-$. In order to determine the true number of hyperons, corrections were introduced for the $\Lambda^0 \to n + \pi^0$ decay for decays inside the target and outside the illuminated

*Panofsky et al[1] determined the total cross section of K_2^0 mesons (with a mean energy of 130 MeV) in copper by measuring attenuation of the beam ($\sigma_{total} = 1120 \pm 250$ mb).

†The conditions and arrangement of the experiment have been described in detail previously.[2]

‡Among these, as indicated by a kinematical analysis, 11 hyperons were ejected from the walls of the cloud chamber and are henceforth excluded from the discussion.

*This quantity is an invariant and equals $C = (M_{\Lambda^0}^2 - M_p^2 - M_\pi^2)/2$.

†Altogether five cases of π^- production, consisting of many-pronged stars, were registered in the cloud chamber gas.

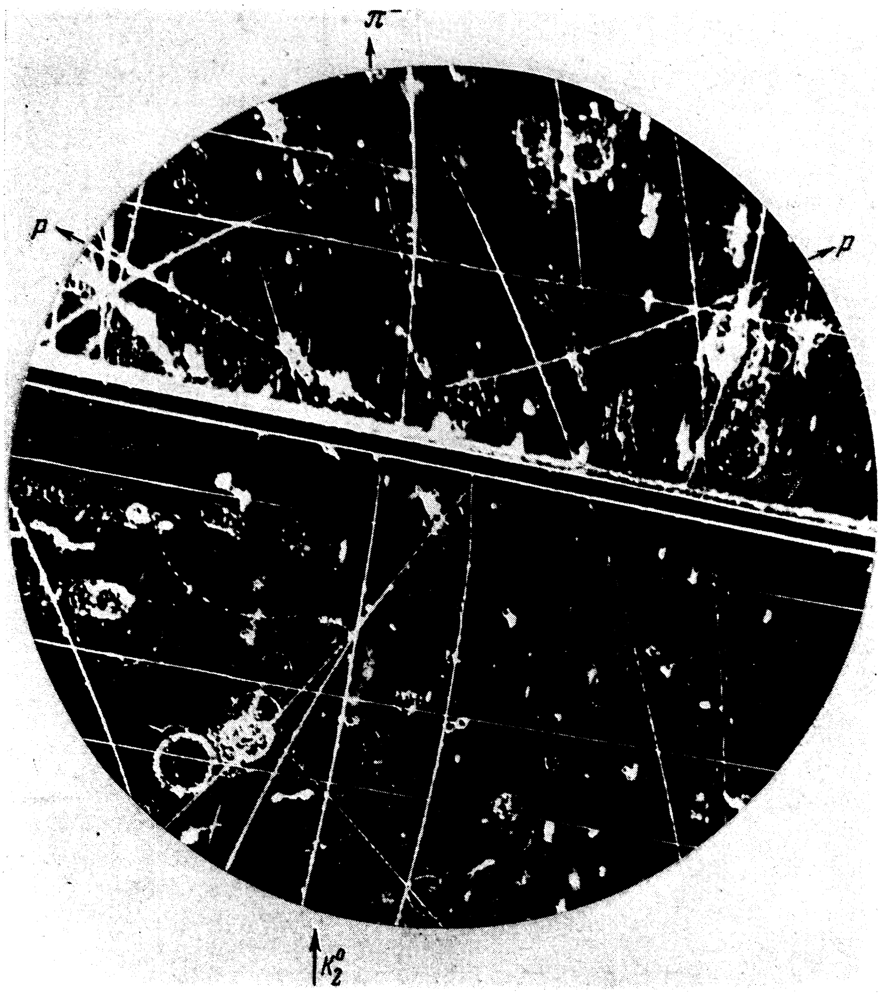

Table I. Distribution of the number of Λ^0 hyperons by value of $(\Delta - C)/\delta\Delta$

Target	$(\Delta - C)/\delta\Delta$				
	0–1	1–2	2–3	>3	Total
Lead	21	6	1	0	28
Lead + glass	24	8	2	1	35

For the conditions of the experiment $\delta\Delta/\Delta \sim 7\%$.

portion of the chamber, and for the Λ^0-hyperon detection efficiency which depends (as the measurements indicated) on the position of the decay plane with respect to the photographing direction.

After introducing all corrections, the adjusted number of Λ^0 hyperons escaping from the plate amounts to 133 ± 23 (the uncertainty includes both the statistical spread and the uncertainties associated with the introduction of the corrections).

The total incident K_2^0 meson current is determined from the number of K_2^0 decays recorded in a well-scanned region of the chamber under the assumption that the K_2^0 mesons have an energy 100 MeV, which is close to their previously determined[2] mean energy. Taking into account the corrections for detection efficiency and for the $K_2^0 \to 3\pi^0$ decay,* the number of K_2^0 mesons passing through the plate was found to be $(41 \pm 10) \times 10^3$. The main reason for the large uncertainty in the current is connected with the inaccuracy in the determination of the mean K_2^0 life-time [$\tau(K_2^0) = (6.1^{+1.6}_{-1.1}) \times 10^{-8}$ sec[4]].

The values found for the actual number of Λ^0 hyperons and the K_2^0 meson current through the plate yield the following estimate for the Λ^0-hyperon production cross section in Pb nuclei:

$$\sigma = 200 \pm 70 \text{ mb}.$$

However, this may turn out to be an underestimate because, in the determination of corrections, we may not have taken complete account of decays which have a very small probability of being detected (e.g., decays of hyperons with momenta that make a small angle with the plate).

Taking into consideration the fact that the detected Λ^0 hyperons may have been formed both as the result of the direct interaction of a K_2^0 meson

*According to our data,[2] the relative probability of this decay amounts to ~ 20%.

with a lead nucleus and as the result of the decay of a Σ^0 hyperon which was also created in a direct interaction, it is necessary to attribute this cross section to Λ^0 and Σ^0 hyperon production.

In order to obtain information about the hyperon production mechanism, we investigated the nature of the charged particles emitted from the plate together with the Λ^0 hyperons. In six cases (out of 28) either a π^+ meson or an electron-positron pair was emitted jointly with the Λ^0. In nine other cases the emission of the Λ^0 was accompanied by the emission of a proton, and in these cases no correlation was observed in the divergence angles of the Λ^0 and the proton, whereas in the case of K_2^0 absorption by two nucleons it is natural to expect that divergence angles close to 180° should predominate. The cited data indicate that, under the conditions of our experiment, K_2^0 meson absorption by two nucleons (as also in the case of the absorption of K^- mesons in flight[5]) is not predominant.

Among the V^0 events in which one track emerges from the plate, one case of $\Sigma^- \to \pi^- + n$ decay was identified by its kinematical characteristics and by the measured ionization. Although the efficiency for detecting such a decay is small ($\sim 15\%$), the observation of only one charged hyperon points to a low yield in comparison with the Λ^0 particles. At the same time, the yields of neutral and charged hyperons for K^- interactions in deuterium are comparable in magnitude. The low yield of charged hyperons is apparently due in the present case to strong absorption within the Pb nucleus.

In the analysis of the V^0 events that might be decays of K_1^0 mesons emitted from the plate, we observed one event that satisfied, within the limits of one standard deviation, the kinematics of the $K_1^0 \to \pi^+ + \pi^-$ decay, by which the ratio of the cross sections for $K_2^0 \to K_1^0$ regeneration and for hyperon production in lead is far less than unity ($\sim 5 \times 10^{-2}$). In this connection it is necessary to mention that, according to the calculations of Biswas,[7] this ratio (for the K_2^0-p interaction at an energy of 100 MeV) has a value from 0.2 up to 5 for the four possible K^--p scattering amplitudes found by Dalitz and Tuan.[8]

In conclusion, we mention that we determined for Λ^0 decays the ratio of the numbers of decay protons emitted forward and backward in the center-of-mass system of the Λ^0, and also the ratio of the same particles emitted upward and downward relative to the Λ^0 production plane. The results are presented in Table II, where values of the asymmetry coefficients are given

Table II

Asymmetry	Number of Hyperons	Target	$a \pm \Delta a$
Forward-Backward	28	Pb	-0.22 ± 0.34
	11	Glass	-0.39 ± 0.50
	39	Pb + glass	-0.27 ± 0.29
Up-Down	28	Pb	-0.11 ± 0.34
	11	Glass	-0.42 ± 0.51
	39	Pb + glass	-0.19 ± 0.28
Right-Left	39	Pb + glass	$+0.24\pm0.27$

$$a \pm \Delta a = \frac{3}{N} \sum \cos\theta_i \pm \sqrt{\frac{3-a^2}{N}}$$

(N is the number of events, θ denotes the angle of emission of the proton; the summation is with respect to the number of events). It is necessary to say that in the present instance one does not expect a strong polarization of the Λ^0 particles upon production, since the interaction apparently takes place for the most part in the S state. Besides, possible asymmetries may be blurred by the motion of the nucleons within the nucleus.

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