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ELASTIC SCATTERING OF Λ-HYPERONS AND K_1^0-MESONS ON HYDROGEN

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Abstract

Elastic scattering of Λ -hyperons and K° -mesons was investigated. The elastic scattering cross sections have been estimated on the basis of the 20 observed events of the reaction $\Lambda + p \to \Lambda + p$ and of the 16 events of the reaction $K_1^{\circ} + p \to K_1^{\circ} + p$. The angular and momentum distributions of the scattered particles are presented. The experimental data on 500-1500 MeV/c Λ-hyperon scattering are compared with the theoretical calculations.

Λ-hyperon -nucleon scattering has been so far treated in the only experimental paper[1] which presents the data concerning two events of inelastic and four events of elastic scattering.

In this paper an attempt is made to investigate elastic Λ-hyperon and K-meson scattering on protons. There were used Λ and K_1^0 particles produced in the interaction of 7-8 BeV/c π^--mesons with hydrogen and carbon in the propane bubble chamber[2] placed into the permanent magnetic field 13700 oersted in strength.

Scanning and Selection of Events

There have been scanned 70000 photographs. All of them have been twice scanned - once only with the aim of finding the events of elastic Λ and K_1^0 scattering. The detecting efficiency of the events required turned out to be 81%. After the results of the measurements have been analysed, there were selected 20 events satisfying the kinematics of elastic Λ-p scattering and 16 events satisfying the kinematics of elastic K_1^0-p scattering* (Fig. 1). The contribution of the reactions which under definite conditions may imitate the elastic scattering of Λ and K_1^0 particles (background reactions) has been estimated. For instance, one can consider the following reactions to be background

$$n + p \rightarrow \begin{cases} p + K^0 + \Lambda(\Sigma^0) \\ n + K^+ + \Lambda(\Sigma^0) \end{cases} \qquad (1)$$

when Λ particle decays in the chamber, K^+ cannot be distinguished from a proton, while the neutral particles carry away a small amount of energy (the K^0 decays outside the chamber). By assuming that the cross section for strange particle generation in n-p interactions does not exceed 0.2 mb[3], it has been obtained that there must be observed not more than 10 events of reaction (1) on 70000 photographs. The momentum spectra of neutrons and K^0 mesons from reaction (1), calculated according to the statistical theory have such a form that only 2% of all Λ-p scattering events may be admixture from reaction (1). At the same time, one can neglect the admixture of the reaction

$$\Lambda + p \rightarrow p + \bar{K}^0 + n$$

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* All the scattered Λ hyperons and K_1^0 mesons were produced in the chamber. There have been found 8 events of Λ hyperon and 5 events of K_1^0 meson scattering, Λ hyperons and K_1^0 mesons being produced outside the chamber. These events are presented on the graphs by the dashed lines.

if a large threshold energy of Λ particles necessary for this reaction, as well as the neutron spectrum after the reaction are kept in mind. The recoil particles in the selected events of elastic scattering mainly acquire the momenta of less than 1 BeV/c and are identified reliably as protons. Therefore, the reactions of the type

$$K^{\circ} + p \to \Lambda + \pi^{+}$$

$$K^{\bullet} + p \to K^{\circ} + \pi^{+} + n$$

$$\Lambda + p \to \Lambda + \pi^{+} + n$$

cannot be background with respect to the processes under investigation. The kinematics of the reaction $K^{\circ} + (np) \to \Lambda + p$ is strongly different from that of elastic scattering and, hence, this reaction will not be a background one either.

The probability has been estimated of random appearance of a combination of particles imitating elastic $\Lambda - p$ or $K_1^{\circ} - p$ scattering. It turned out to be $1{,}2 \cdot 10^{-9}$ per picture. For elastic scattering events of Λ and K_1° particles generated outside the chamber, this probability is much greater and equal to $1.6 \cdot 10^{-5}$, i.e., 1-2 events out of those identified as elastic scattering of Λ and K_1° particles having no generation points in the chamber are the background ones. There have been constructed the integral distribution of hyperons by their time of flight after scattering (Fig. 2). This indicates that there are no essential systematic missings of the events.

Cross Sections. Angular Distributions

To determine the flux of Λ and K_1° particles the cross sections for strange particle production in $\pi^- - p$ interactions have been used[4]. Λ hyperons and K_1° mesons which decay via neutral modes, as well as K_2° particles were not taken into account. The cross section for Λ and K° production on carbon was taken proportional to $A^{2/3}$, what is in good agreement with our preliminary results on the Λ - hyperon production cross section.

The number of elastic $\Lambda - p$ and $K_1^{\circ} - p$ scattering events has been determined with account of the correction for the probability of Λ and K_1° particle detection after their scattering over the effective region of the chamber and for the scanning efficiency. Systematic missing of the events with slow (150 MeV) recoil protons restricts the detection of small angle elastic scattering events (less than 18°

for Λ hyperons and 12° for K^0 mesons in the center-of-mass system, for the mean momentum of the incident particle being 1 Bev/c).

The number of Λ -hyperon and K_1^0 meson events of scattering on quasi-free carbon protons has been estimated in a manner like in paper[5], which was devoted to the study of elastic $\Sigma^{\pm}$ hyperon scattering on hydrogen in the propane bubble chamber. The error in the Λ -hyperon scattering angle is in our case 1.5°, the error in the K_1^0 scattering angle is 1° and, therefore, the admixture from Λ-(p) scattering is 10% of all elastic Λ - p scattering events, while K_1^0-(p) scattering constitutes 7% of the elastic K_1^0- p -scattering events.

With account of the above-mentioned corrections, the cross sections for elastic scattering of Λ and K_1^0 particles on hydrogen averaged over all the momentum spectrum are equal to

$$\sigma\ (\Lambda + p \to \Lambda + p) = (36 \pm 14)\ mb$$

$$\sigma\ (K^0 + p \to K^0 + p) = (22 \pm 9)\ mb.$$

By making use of the distribution by the momenta of the Λ -particles produced in $\pi^- - p$ interactions (Fig. 3a), as well as of the preliminary data on the Λ -hyperon production in π^--C interactions we have obtained, it is possible to estimate the cross sections for elastic scattering of Λ -particles averaged over smaller intervals of the scattered particle momenta

$\sigma_1 = (42 \pm 16)\ mb$ — interval: from 0.4 up to 1.5 BeV/c with the mean momentum of 1 BeV/c

$\sigma = (30 \pm 15)\ mb$ — interval: from 1.5 up to 2.5 BeV/c with the mean momentum of 2 BeV/c.

The angular distributions of Λ -hyperons and K_1^0 - mesons in the c.m.s. are shown in Fig. 4. As is seen, K_1^0-mesons show a sharp maximum in the forward scattering (Fig. 4b). In the angular distribution of Λ -hyperons the predominant role belongs to Λ particles which are flying in the backward direction (Fig. 4a).

If the events in which the Λ -momentum is large are neglected, the distribution becomes more anisotropic; out of 16 hyperons which have the momenta of less than 1500 MeV/c, 13 after scattering are flying backward and 3- forward. (Fig. 4a,c,d). These magnitudes are given without corrections for the detecting efficiency.

Discussion

π and K -meson forces may give the contribution to elastic Λ- p scattering. Both the π-meson pole and the exchange of two π-mesons in the resonance state with $T = 1$, $J = 1$ are absent in this case. Elastic Λ- p scattering with the π-meson exchange has been treated in /6/. By making use of the hypothesis of the 'global' symmetry for Λ -particles with an energy of about 270 MeV, the authors have obtained the total cross section of 30-40 mbs and the angular distribution with the preferential scattering of Λ -hyperons in the forward direction. Thus, even if a part of the small angle (up to 18° in the c.m.s.) Λ- p -scattering events is lost, the angular distribution of Λ -hyperons in the c.m.s. obtained on the basis of the hypothesis stating that during the elastic scattering process a Λ-particle exchanges pions with a proton, is not in agreement with the experimental distribution.

Since, for Λ -hyperon momenta of less than 1.5 BeV/c, the magnitudes of the momenta transferred from a proton to a Λ-hyperon are, in the main, small (up to 600 MeV/c), then it is reasonable to consider the model of peripheral interactions in which the $T = 1/2$ strange particle is exchanged (Fig. 5). The importance of taking into account such an exchange is indicated also by the experiments on Σ scattering against protons /5/. Let us analyse the contribution to the elastic Λ-hyperon scattering which is due to the exchange of K or K' mesons /7/ for different values of parities and spins of these particles. The calculations of such interactions were made for 1 BeV/c hyperons in the lab.system. As the calculations show, for the pseudo-scalar K-meson, the angular distribution in the c.m.s. must be asymmetrical: most of the hyperons must fly forward. The total cross section is found to be $\sigma = 0.1 \left(\frac{g_p^2}{4\pi}\right)^2$ mbs.

When the scalar K-meson is exchange there must be o strong asymmetry in the angular distribution of Λ -hyperons flying mainly backward in the c.m.s., whereas the total cross section for elastic Λ-hyperon scattering on protons must be equal to $\sigma \approx 24 \left(g_s^2 / 4\pi \right)^2$ mbs. In this case, both the angular distribution and the total cross section (by assuming the coupling constant to be $g_s^2 / 4\pi \approx 1$) are in agreement with the experimental results obtained in the given note.

When the K^1 -particle is exchanged, the cross section has a much weaker angular dependence what is due to a large value of the K' mass /7/. At the same time the cross sections for the vector and scalar variants are, respectively:

$$\sigma_v = 7 \left(f_v^2 / 4\pi \right)^2 \text{ mbs}$$

$$\sigma_s = 5 \left(f_s^2 / 4\pi \right)^2 \ mbs.$$

The interaction constants of the K' with nucleons and Λ-hyperons can be estimated [8] by making use of the data on the reaction $\pi^- + p \to \Lambda + K^0$

$$f_v^2 / 4\pi = 0{,}3 - 0{,}5 \quad and \quad f_s^2 / 4\pi = 5 - 10 .$$

For these values of the constants, the magnitudes of the total cross sections disagree with the experimental data.

Thus, out of the variants we have considered, the assumption on an exchange of the scalar K-meson in the course of the Λ-particle scattering on hydrogen, is in best agreement with the experimental results. On analysing the process $\pi + N \to \Lambda + K + \pi$ the authors of [9] have drawn a similar result. However, this hypothesis contradicts the experiments in which the K meson is likely to behave as a pseudo-scalar particle [10]. This contradiction can be avoided if we assume the non-conservation of parity in ΛNK -interaction i.e., take a mixture of a scalar and pseudo-scalar in this interaction. A similar hypothesis has been treated in [11]. To bring these results into agreement with experiment provided that the exchange is occuring via the pseudo-scalar K-meson one should assume that there is a great contribution from the non-pole graphs.

For large momenta of Λ -hyperons (for instance, more than 1.5 BeV/c) (Fig. 4d) the scattered Λ-hyperons are more likely to fly forward. This can be explained if the diffraction scattering is taken into account which must play an essential role at high energies and give a small contribution in the region where the inelastic processes are absent.

In view of poor statistics and a wide energy range of Λ -hyperons undergoing the scattering, the above mentioned considerations concerning the theoretical interpretation of the experimental data on elastic $\Lambda^- p$ -scattering are only illustrative.

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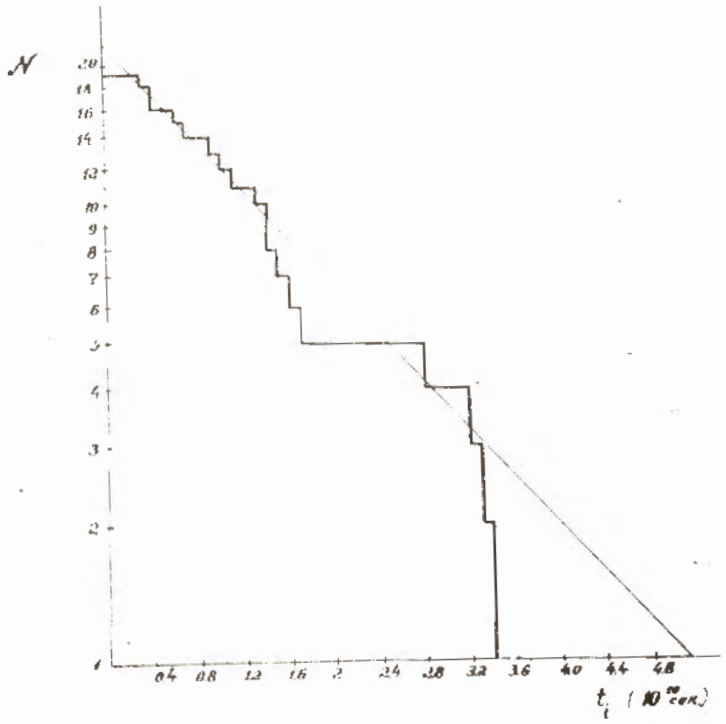
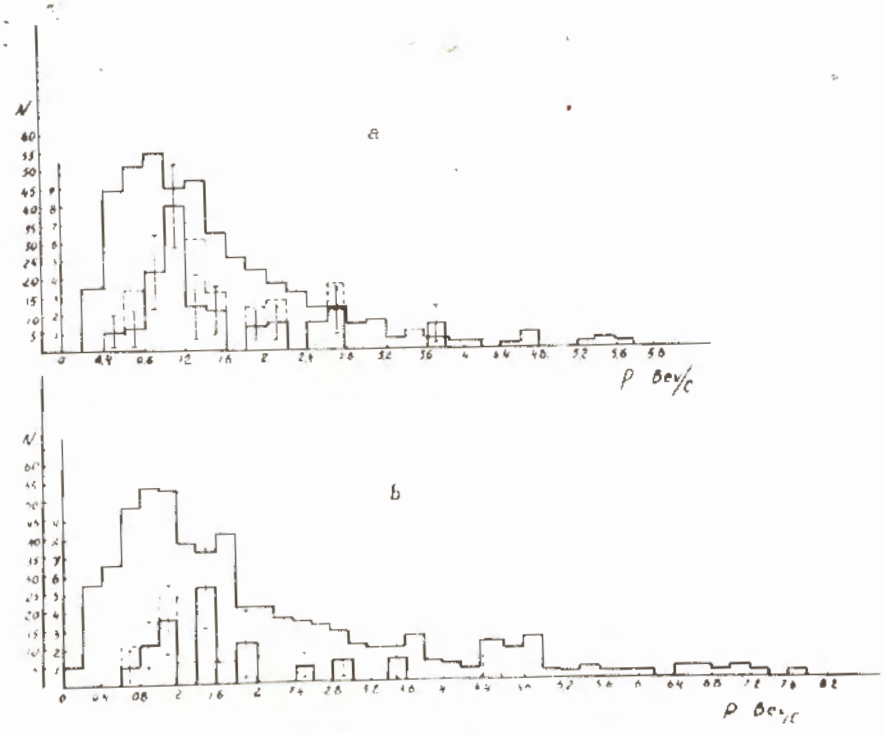
a

b

F i g. 1a, b. Examples of elastic scattering events a) Λ-hyperons, b) K_1^0-mesons on protons. At the point 'A' either Λ or K^0 particles are produced; at the point 'D' they collide with protons B; at the point 'C' Λ or K_1^0-particles decay.



F i g. 2. *The integral time of flight distribution of Λ -hyperons scattered on protons.*



F i g. 3. *The momentum distributions of elastic events in the lab. system: a) Λ- p b) K_1^o - p -scattering.*

The histogram envelope presents the momentum distributions a) of Λ-hyperons and b) K_1^o -mesons produced in π^- - p -collisions.

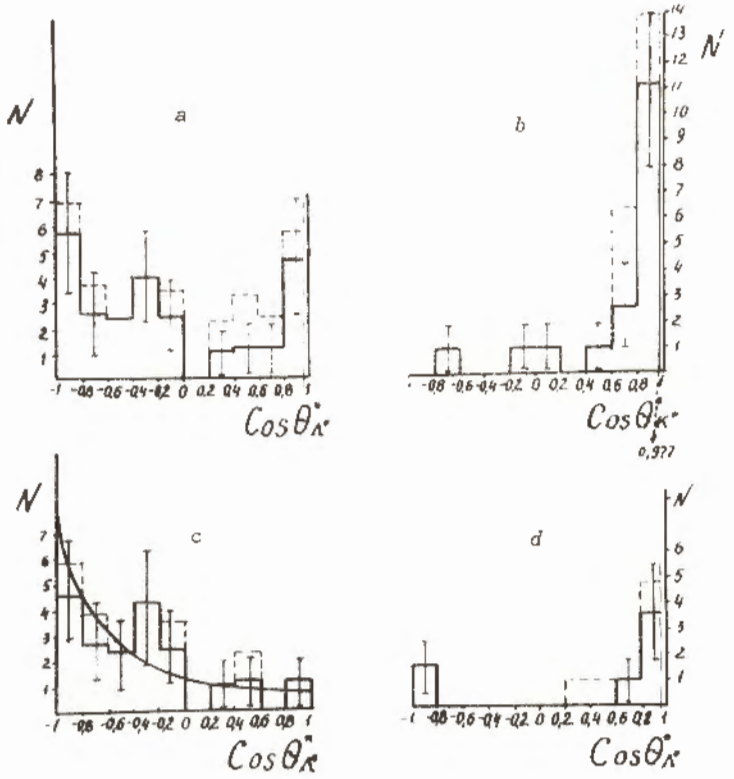


Fig 4. *The angular distributions in the c.m.s. a) of Λ hyperons scattered on protons, b) of K_1^0 mesons, c) of Λ -hyperons, having the momenta between 500 and 1500 MeV/c, d) of Λ -hyperons having the momenta of more than 1.5 BeV/c before the scattering.*

In Fig. c) a curve is plotted obtained on the basis of the model of the peripheral collisions with the exchange of a scalar K-particle.

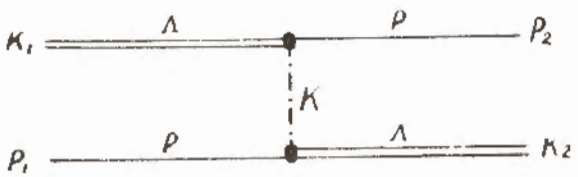


Fig. 5.