THE $\Lambda K$ SYSTEM PRODUCTION IN THE HADRON INTERACTIONS

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The $A$-dependence is observed in $x_F$-distributions for the $\Lambda K^0$ system produced with the small transverse momentum in the neutron-nucleus interactions. For the $\Lambda$ hyperons similar dependence isn’t seen. The result is interpreted as an effect from intermediate excitative nucleon state, which decays into strange particles. Such interpretation is confirmed experimental data on $\Lambda K$ pair production in the pion-nucleon interactions.

Fig. - 8, References - 9

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The problems, connected to influence of the nuclear surroundings on production of hadrons and the nuclear transparency (or in the modern quantum mechanics - color shield and color transparency) is of great attention of the scientists in the last years [1-3]. The characteristics of producing leading particles are defined directly by evolution of quark system. The leader represents some kind of "transformation" of a primary particle, which characteristics reflect the history of hadron passage through target. So, the cross section evolution of the forming hadron can be possible to look on increasing (decreasing) of the secondary leading particles beam intensity of various nuclei in comparison with the hadron-nucleus interaction at appropriate kinematic intervals. The research of the leading particles properties, distinguished on quarks composition from the primary state, is of great interest. Avaricious experimental data demonstrates, that the behaviour of such particles at passage through nucleus differs from behaviour of the "kept" leaders. The change of passing ability (transparency) of nucleus as well as energy dependence is appeared to be brightly shown at initial energies in the order 10 Gev already.

The characteristic, transmitted "optical" properties of a nucleus in relation to hadron passage, is the effective number of nucleons, which represents the ratio of differential sections in the appropriate ranges of Feynman’s variable $x_F$ at reactions on nuclei and free nucleons:

$$N_{eff} = \frac{(d\sigma/dF)A}{(d\sigma/dF)N}.$$ 

The experimental data on inclusive production of pions and nucleons at initial energy of 100 GeV are in the consent with calculations on dual string model - the change of a nucleus passing ability for particles with different values of Feynman’s variable is observed. However, there is a reference for Λ-hyperons on some divergence of experimental data with calculations - probably, the passing ability of nucleus is identical for particles with different values of the Feynman’s variable [1].
At study of leading Λ-hyperons by neutrons with energy of 4 - 10 GeV, we showed, that the cross sections relation of hyperon’s production on nuclei of carbon and lead don’t depend from Feynman’s variable [4].

In the present work, we investigated production of the leading pairs ΛK⁰ by neutrons on carbon and copper nuclei in an angular range Θ < 8.5⁰ in relation of beam and supporting only neutral particles. The experiment was performed at KAON spectrometer on neutron beam of ITEP’s proton synchrotron [5]. As a target was used graphite by thickness of 6 cm and copper by thickness of 4 cm. Λ-hyperons and K⁰-mesons were registered by magnetic spectrometer KAON using wire spark chambers and system of the scintillation counters. The target was positioned on a beam, between the scintillation counters, connected in anticoincidence with other counters. Thus, the events accompanying by neutral strange particles were excluded, that has allowed to allocate half inclusive reaction:

\[ n + (C, Cu) \rightarrow \Lambda + K^0 + X^0. \] (1)

The decays of Λ and K⁰-particles, produced in target, were detected by spectrometer on base length of 40 cm. The decaying volume was filled by helium. The start of installation was carried out by the trigger from the circuits of fast electronic logic, using signals of scintillation counters. The trajectories of the charged particles were registered by groups of wire spark chambers.

The accumulated statistics was involved 349 pairs ΛK⁰, including 215 on carbon target, 134 - on copper target. The registration efficiency of ΛK⁰ pair was calculated by the software package GEANT.

The amendments on interaction, producing together with pair ΛK⁰ with neutrons and π⁰-mesons with target nuclei, were entered.

At realization of the experiment modeling, it was considered, that the reaction can be carried out as well on a nucleus neutron as on a proton. Therefore, the he contributions from four reactions were taken into account:

\[ n + n \rightarrow n + \Lambda + K^0, \] (2)
\[ n + n \rightarrow n + \Lambda + K^0 + \pi^0, \] (3)
\[ n + p \rightarrow p + \Lambda + K^0, \] (4)
\[ n + p \rightarrow p + \Lambda + K^0 + \pi^0. \] (5)

The relative contribution of reactions on proton and neutron was considered at conformity with the number of protons and neutrons in nuclei of
carbon and carbon. The contributions of three and four particles reactions were taken into account proportionally their cross section taken from the world data. Thus, the cross section of connected isotopically pp-reactions were used for reactions (2) and (3). The used modeling procedure has shown, that process take place on the neutrons of nuclei mainly. The reactions, proceeding on protons of a nucleus, are suppressed by inclusion of the anticoincidence counter. Nevertheless, the reaction on protons of a nucleus take place, because the secondary protons can stop in target or don’t hit in the counter of anticoincidence. The contribution from a four particles reaction is less than the contribution from a three particles, because electron-positron pairs, produced at conversion of γ-rays from π⁰-meson decay, can be a cause of counter’s operation.

The dependence of distribution on $x_F$ from the mass number of nucleus-target, characterized for the leading mesons, isn’t observed for leading Λ-hyperons. The distribution on Feynman’s variable for ΛK⁰-system produced on in a copper target is presented in Fig. 1, in Fig. 2 - for a carbon target. The relation R of differential cross section of ΛK⁰ pairs production, characterizing the passing ability of nuclei, is appeared to depend from Feynman’s variable (Fig. 3). This result can be understood, if heavy isobar is assumed to produced originally and decayed on a strange particles after that. On the other hands, the ΛK⁰-system at passage through a nucleus behaves as one unstrange meson but nor as two strange particles.

The limited statistics does not allow to analyze spectra of effective mass of ΛK⁰ system at detail. However, it should be noted, that spectrums of effective mass, obtained on a carbon and copper target, are different, i. e. the nuclear surroundings influences on kinematical characteristics of formed particles even under the condition of cascade processes suppression.

The spectrums of the effective masses were approximated by the sum of Breit-Wigner distributions and phase volume. The results of approximation are submitted in figures by a continuous line and given in Table 1. The essential increase of statistical accuracy is necessary for more detailed study of the effective mass spectrums.
Table 1. The approximation results of the invariant mass spectrums of $\Lambda K^0$-system for carbon and lead targets.

| Parameter | Target C       | Target Cu       |
|-----------|----------------|-----------------|
| $M_0$, eV/c$^2$ | 1797 ± 6   | 1743 ± 13      |
|          | 176 ± 25     | 72 ± 21         |
| $\chi^2$/degrees of freedom | 9.7/7    | 6.3/8          |

It is necessary to essentially increase the statistical accuracy for quantitative results. At the same time the confirmation assumption of an intermediate isobar role can serve the data, obtained at the analysis of the secondary particles effective mass spectrums in $\pi^+ p$-interactions with production of the strange particles.

II

The resonance production in $\pi^+ p$-interactions at an initial momentum of 4.23 GeV/c with strange particles production was investigated by us on a material of 2-meter by hydrogen camber of ITEP at three channels using rather large section:

$$\pi^+ + p \rightarrow \Lambda + K^+ + \pi^+, \quad (6)$$
$$\pi^+ + p \rightarrow \Lambda + K^+ + \pi^+ + \pi^0, \quad (7)$$
$$\pi^+ + p \rightarrow \Lambda + K^0 + \pi^+ + \pi^+. \quad (8)$$

Due to analysis the events were used, where beam momentum, founded from the balance of energy, differed from average no more than 75 MeV/c - experimentally determined beam dispersion. It is made to elimination of the badly balanced events, which presence can deform mass spectrums that, will have an effect on adjustment results.

The hypotheses of resonance production, number of events, obtained on the full statistics, and cross sections of channels, performed at simultaneous adjustment by multiparametrical function, containing resonance amplitudes generated by a method of Monte-Carlo, their mutual reflections and phase volumes to experimental distributions on effective mass, are presented in Tables 2-4. Due to this procedure the effects of resonance reflections for all mass spectrums were taken into account.

The minimization was carried out by the method of least squares with help of program MINUIT [7]. The errors in cross sections are statistical.
Effective masses and widths of well known resonances *(892), Σ(1385) and ρ were taken from the table of elementary particles, and an appropriate parameters of isobar and resonances Σ(1560), Σ(1670) and Σ(1849) were defined by minimization process.

The value of the invariant mass of isobar positioned in the region closely to 1.7 GeV/c\(^2\), width - about 100 MeV/c\(^2\). Due to this region a little close located isobars are known, that does not given an opportunity to identify unequivocally the discovered resonance. Most likely, it should be identified with \(N^*(1710)\) 1/2\(^+\)-isobar having the high probability of decay into \(Λ\) and \(K\). Due to the benefit of such assumption the close location to isotropic angular distribution of Λ-hyperons according direction of ΛK momentum in thier system of rest is testify. The given results testify about the large contribution to cross section channels with resonance production in \(π^+p\)-interactions at 4.23 GeV/c. More than 80% of the investigated reactions take place through resonance production.

The experimental distribution (histograms) on effective masses of ΛK together with curves, obtained as fitting result, are presented in Fig. 6-8 for an illustration of the fitting quality.

**Table 2.** Cross section of resonances production for the channel Λ\(K^+π^+\)

| Number of events | Hypothesis       | Cross section, cb |
|------------------|------------------|------------------|
| 387              | Λ\(K^+π^+\)      | 26,6 ± 1,6       |
|                  | Σ(1385)\(K^+\)  | 21,2 ± 1,4       |
|                  | Σ(1670)\(K^+\)  | 10,6 ± 1,0       |
|                  | \(N^*(1710)\)π^+| 5,8 ± 0,8        |
The data about heavy isobar, decaying into strange particles were obtained from the analysis of the effective mass spectra in reaction (6) in works, performed on the chamber of Alvarezt [8,9].

The basic results of the present work are following.

1. The dependence of Feynman’s variable distribution from mass number of nucleus target is observed in reaction of $\Lambda K^0$ production by neutrons on carbon and copper nuclei. Qualitatively, this dependence is coordinated to calculation of B.Z. Kopeliovich on the dual string model for inclusive hadrons production.
2. The observable dependence can be explained by production of intermediate isobar, decaying on a strange particles.
3. This interpretation proves to be true by experimental data, obtained by us from the analysis of effective masses spectra in $\pi^+p$-interactions with generation of strange particles. More than 80% of these reactions at an initial moment of 4.2 Gev/c carry out through production of resonances.

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Figure 1: The distribution on Feynman’s variable for $\Lambda K^0$ system produced on a copper target.
Figure 2: The distribution on Feynman's variable for $\Lambda K^0$ system produced on a carbon target.
Figure 3: The ratio of differential sections of pair production $\Lambda K^0$ on copper and carbon targets depending on Feynman’s variable.
Figure 4: The spectrum of effective masses of $\Lambda K^0$ system produced by neutrons on copper target.
Figure 5: The spectrum of effective masses of $\Lambda K^0$ system produced by neutrons on carbon target.
Figure 6: The spectrum of effective masses of $\Lambda K^+$ system produced in reaction (6).
Figure 7: The spectrum of effective masses of $\Lambda K^+$ system produced in reaction (7).
Figure 8: The spectrum of effective masses of $\Lambda K^0$ system produced in reaction (8).