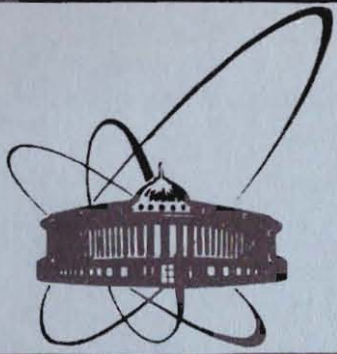

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POLARIZATION OF CHARMED Λ_c^+ BARYONS PRODUCED IN NEUTRON-CARBON INTERACTIONS

Collaboration BIS-2

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An observation and a study of the polarization of hadronically produced charmed baryons are of obvious interest. Such a study could clarify some features of the hadronic production of charmed quarks and allowed one to investigate deeper the effect of a large polarization of inclusively produced Λ° and other hyperons by unpolarized hadron beams observed in a number of experiments [1-13]. The hyperon polarization increases with increasing transverse momentum and practically does not depend on beam energy or target material. The polarization of Λ° is conditioned by the polarization of s-quark, and consequently it is directly associated with the mechanism of strange quark production in hadron interactions. Qualitative explanations of this effect are given in a variety of models [4, 14-20]. Some of them [16,18] predict the dependence of the polarization on the type of the quark produced.

The polarization of a baryon manifests itself as an asymmetry in the emission of secondary particles via a weak decay. The angular distribution of the decay probability $W(\cos\theta)$ for a decaying baryon with spin 1/2 depends on the polarization $\mathcal{P}$ as follows

$$W(\cos\theta) = \frac{1}{2}(1 + \alpha \cdot \mathcal{P} \cdot \cos\theta), \qquad (1)$$

where α is the decay asymmetry parameter and θ the angle between the polarization axis and the decay analyzer, e.g., the direction of flight of a secondary baryon in the rest frame of the parent particle.

In this report we present results of a search for the polarization of the charmed Λ_c^+ baryons produced inclusively in neutron-carbon interactions. Preliminary results of this study have been reported in [21]. The experiment was carried out in the neutron beam of the Serpukhov 70 GeV proton synchrotron using the BIS-2 spectrometer [22]. The registration of the Λ_c^+ produced by neutrons over the momentum range between 40 and 70 GeV/c was due to the acceptance of the spectrometer. The Λ_c^+ were registered via the decay

$$\Lambda_c^+ \to \bar{K}^\circ p\pi^+\pi^- \qquad (2)$$

and

$$\Lambda_c^+ \to \Lambda^\circ\pi^+\pi^+\pi^-. \qquad (3)$$

These decays were identified as statistically significant narrow peaks in the corresponding invariant mass spectra. A detailed description of all experimental conditions and event selection was given elsewhere [23-26].

As the Λ_c^+ production is a parity-conserving process, the Λ_c^+ polarization vector should be perpendicular to the production plane. Therefore the polarization axis has been chosen along the normal to this plane $\vec{n} = \vec{P}_n \times \vec{P}_c / |\vec{P}_n \times \vec{P}_c|$, where $\vec{P}_n$ and $\vec{P}_c$ are the momentum vectors of the incident neutron and the Λ_c^+ in the laboratory system, respectively. The direction of flight of the emitted particle, having momentum $\vec{p}$ in the Λ_c^+ rest frame, is characterized by $\cos\theta = \vec{p} \cdot \vec{n} / |\vec{p}|$. The decay asymmetry is defined as

$$A = \frac{N(up) - N(down)}{N(up) - N(down)}, \qquad (4)$$

where N(up) and N(down) are the numbers of Λ_c^+ emitting the analyzing particle in the "up" ($\cos\theta > 0$) and "down" ($\cos\theta < 0$) directions, respectively. Using (1), the asymmetry (4) can be related to the polarization by

$$\alpha \cdot \mathcal{P} = 2 \cdot A. \qquad (5)$$

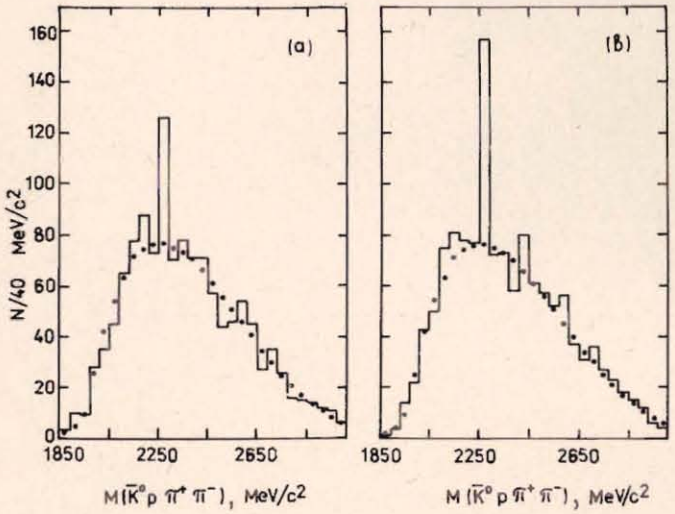

Fig. 1. The invariant $\bar{K}^\circ p \pi^+\pi^-$ mass spectra obtained for events with the proton emitted in the "up" (a) and "down" (b) directions. The dotted curves represent the fit to the spectra by the background function.

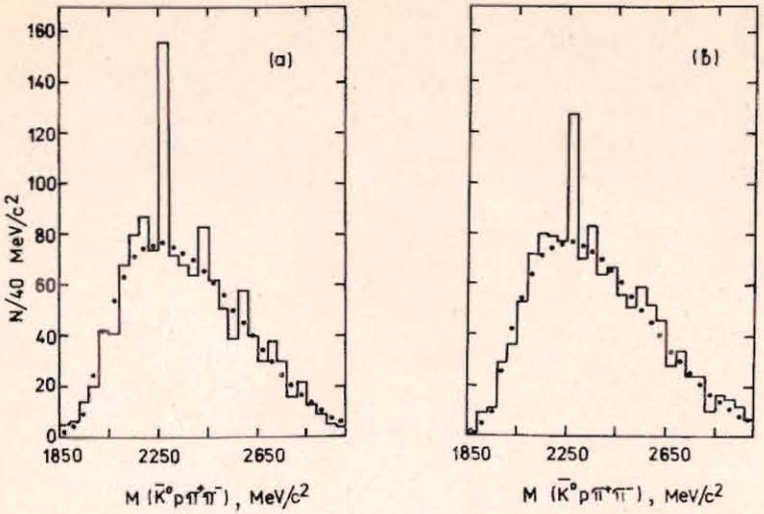

Fig. 2. The invariant $\bar{K}^\circ p \pi^+\pi^-$ mass spectra obtained for events with the $\bar{K}^\circ$ emitted in the "up" (a) and "down" (b) directions. The dotted curves represent the fit to the spectra by the background function.

Figures 1a and 1b present the invariant $\bar{K}^\circ p \pi^+\pi^-$ mass distributions [28] of events with the proton emitted in the "up" and "down" directions, respectively. In both distributions clear signals of the Λ_c^+ decay (2) are seen as narrow peaks at the appropriate mass. The background spectra (dotted curves) have been obtained by fitting the distributions by a polynomial function. These spectra in figs. 1a and 1b are identical within the errors estimated. The efficiency of Λ_c^+ registration calculated using the Monte-Carlo method does not depend on the direction of flight ("up" or "down") of secondary particles. The results of this calculation are completely confirmed by the background behaviour. A total of (130±18) Λ_c^+ events has been registered. The difference of the Λ_c^+ numbers observed in figs. 1a and 1b leads to the asymmtery

$$A(p) = -(0.24 \pm 0.13). \qquad (6)$$

Considering the $\bar{K}^\circ$ as an analyzing particle, two invariant $\bar{K}^\circ p \pi^+\pi^-$ mass spectra have been plotted in fig. 2 as well. Figures 2a and 2b present the spectra of events with the $\bar{K}^\circ$ emitted in the "up" and "down" directions, respectively. The background behaviour (dotted curves in fig. 2) is independent of the direction of flight ("up" or "down") of the $\bar{K}^\circ$ emitted. The corresponding asymmetry obtained

$$A(\bar{K}^0) = (0.22 \pm 0.13) \qquad (7)$$

is naturally opposite in sign to A(p).

The invariant $\Lambda^0\pi^+\pi^+\pi^-$ mass spectra for events with the Λ^0 emitted "up" and "down" are shown in figs. 3a and 3b, respectively. Narrow peaks consistent with the experimental resolution are seen at the Λ_c^+ mass in both spectra. These peaks indicate the registration of the Λ_c^+ decays (3). The background estimation (dotted curves in fig.3) leads to (57±14) Λ_c^+ registered. The asymmetry obtained from these distributions is

$$A(\Lambda^0) = (0.30 \pm 0.22). \qquad (8)$$

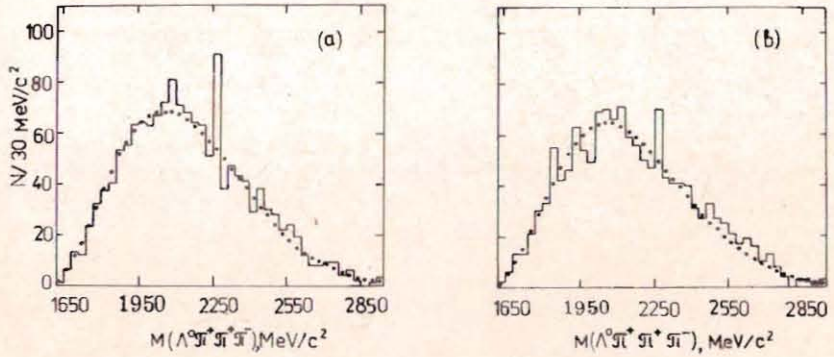

Fig.3. The invariant $\Lambda^0\pi^+\pi^+\pi^-$ mass spectra obtained for events with the Λ^0 emitted in the "up" (a) and "down" (b) directions. The dotted curves represent the fit to the spectra by the background function.

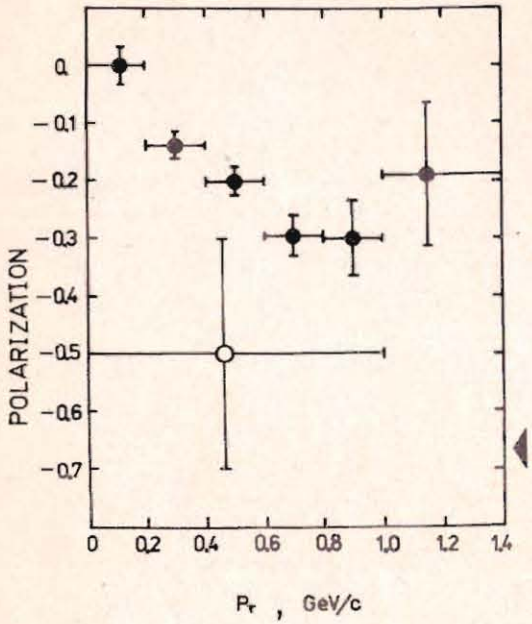

Fig.4. The dependence of the Λ^0 polarization on transverse momentum P_T obtained in [1] (•) and the limit for the Λ_c^+ polarization measured (○).

The asymmetries (6) and (8) observed for the decays (2) and (3) indicate the polarization of the Λ_c^+ as well as the presence of both parity-conserving and parity-violating amplitudes inherent in weak decays. Values of the decay asymmetry parameter α are unknown and possibly different for the decays (2) and (3). Different models [27-30], which calculate the parameters $\alpha(p)$ and $\alpha(\Lambda^0)$ for the two-particle decays $\Lambda_c^+ \to p\bar{K}^0$ and $\Lambda_c^+ \to \Lambda^0\pi^+$, respectively, are in contradiction. In the particular model [27], opposite signs of the α's are predicted. Our data indicate the opposite signs of $\alpha(p)$ and $\alpha(\Lambda^0)$ for the decays observed. Taking this indication into account, we average the absolute values of the asymmteries (6) and (8) and obtain the limit for the Λ_c^+ polarization:

$$|\mathcal{P}|_{min} = (0.5 \pm 0.2). \qquad (9)$$

The transverse momentum of the Λ_c^+ registered does not exceed 1.0 GeV/c and has a mean value of 0.43 GeV/c. To compare the Λ_c^+ polarization with Λ^0 data, we have plotted in fig.4 the result (9) (open circle) and the polarization of the Λ^0 (shaded circles) obtained in the same experiment [1]. This comparison indicates that the Λ_c^+ polarization increases steeper and is larger than the polarization of the Λ^0 as predicted in some models, e.g., refs. [16,18].

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Поляризация очарованных барионов Λ_c^+, рожденных в нейтрон-углеродных взаимодействиях

В эксперименте, проведенном с помощью спектрометра БИС-2 на серпуховском 70 ГэВ протонном синхротроне, измерена асимметрия в распадах Λ_c^+, рожденных в нейтрон-углеродных взаимодействиях. Средняя величина поперечного импульса зарегистрированных Λ_c^+ составляла 0,43 ГэВ/с. Изучались распады $\Lambda_c^+ \to \bar{K}^0 p \pi^+ \pi^-$ и $\Lambda_c^+ \to \Lambda^0 \pi^+ \pi^+ \pi^-$. Асимметрии вылета барионов при распаде относительно плоскости рождения Λ_c^+ равны $A(p) = -/0,24 \pm 0,13/$ и $A(\Lambda^0) = /0,30 \pm 0,22/$. Из этого следует, что минимальная абсолютная величина поляризации Λ_c^+ равна $/0,5 \pm 0,2/$.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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