Polarization of Σ^+ hyperons in π^+p interactions at 3.6–4.2 GeV/c

V. Yu. Batusov, A. G. Drutskoi,* V. I. Mikhailichenko,* I. L. Kiselevich,* S. Yu. Panitkin, A. K. Ponosov, F. M. Sergeev, M. Yu. Tel'nov, and K. V. Filimonov

Moscow Engineering-Physics Institute, 115409 Moscow, Russia

* *Institute of Theoretical and Experimental Physics, 117259 Moscow, Russia*

(Submitted 25 March 1993)

Pis'ma Zh. Eksp. Teor. Fiz. **57**, No. 9, 518–520 (10 May 1993)

The transverse polarization of Σ^+hyperons produced in π^+p interactions at 3.6–4.2 GeV/c was measured: $P_\Sigma = 0.49 \pm 0.09$. A correlation was established between the polarization of the hyperons and the production of $K^*(890)$ vector mesons. It is shown that the polarization of the Σ^+hyperons increases in the reactions in which a $K^*(890)$ vector meson is produced. At small 4-momentum transfer the Σ^+ hyperons produced in K^- and π^+beams are oppositely polarized; at large 4-momentum transfer the difference becomes insignificant.

Experiments on deep inelastic scattering of polarized muons by polarized protons have led to a situation known as "spin crisis."[1] This circumstance has increased interest in spin physics, in general, and in polarization of strange particles, in particular. It is of interest to measure the polarization of cumulative baryons.[2]

Data on the polarization of Λ hyperons in hadron–hadron and hadron–nucleus interactions have been analyzed systematically in Refs. 2 and 3. There are significantly fewer data on polarization of Σ hyperons.[4–6]

The results presented below were obtained on the proton synchrotron at the Institute of Theoretical and Experimental Physics, using the 2-meter hydrogen bubble chamber method. The production of strange particles in π^+p interactions at 3.65 and 4.23 GeV/c was studied.

The seven main exclusive reaction channels, in which Σ^+ hyperons are produced in the final state, were investigated: Σ^+K^+, $\Sigma^+K^+\pi^0$, $\Sigma^+K^0\pi^+$, $\Sigma^+K^+\pi^+\pi^-$, $\Sigma^+K^0\pi^+\pi^0$, $\Sigma^+K^+\pi^+\pi^-\pi^0$, and $\Sigma^+K^0\pi^+\pi^+\pi^-$. A fit of the reaction channel was made for each event. Cases in which two or more neutral pions were produced were excluded. The statistical sample consisted of 1265 events.

The decays $\Sigma^+ \to p + \pi^0$ and $\Sigma^+ \to n + \pi^+$ were recorded. However, the second decay channel is ineffective for measuring polarization, because the channel decay parameter is too small. This channel was employed for making methodological adjustments.

The polarization of the Σ^+ hyperons was determined from the asymmetry in the decays $\Sigma^+ \to p + \pi^0$ with respect to the hyperon production plane. The angular distribution of protons in the Σ^+ rest frame is

$$f(\cos\theta) = \tfrac{1}{2}(1 + \alpha P \cos\theta),$$

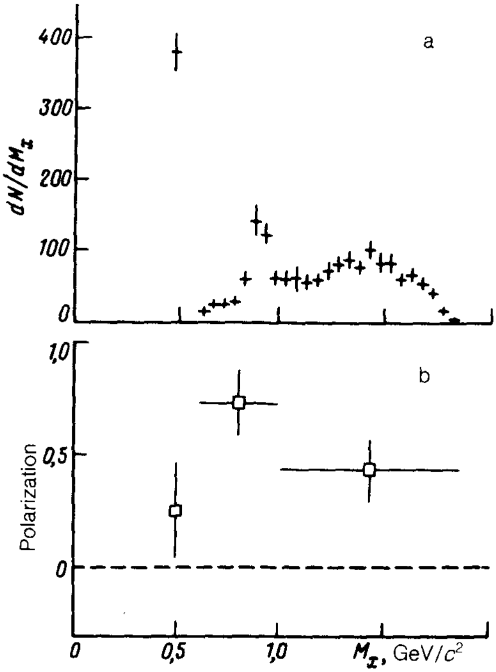

FIG. 1. (a) Σ^+-hyperon missing-mass distribution and (b) the polarization as a function of the missing mass.

where $\alpha = -0.979 \pm 0.016$ is the decay parameter, P is the polarization, and θ is the angle between the direction of emergence of the proton in the Σ^+ rest frame and the direction identified in space.

The following coordinate system was used for determining the polarization: the **Y** axis was oriented along the vector normal to the hyperon production plane; the **Z** axis was oriented along the hyperon momentum vector in the laboratory system; and $\mathbf{X} = \mathbf{Y} \times \mathbf{Z}$. The normal to the Σ^+ hyperon production plane is defined as

$$\mathbf{n} = [\mathbf{P}_\pi \times \mathbf{P}_\Sigma] / |[\mathbf{P}_\pi \times \mathbf{P}_\Sigma]|,$$

where $\mathbf{P}_\pi$ is the beam momentum vector, and $\mathbf{P}_\Sigma$ is the hyperon momentum vector. The polarization was calculated using the weighted formula

$$P = \frac{3\Sigma W_i \cos\theta_i}{\alpha \Sigma W_i} \pm \frac{1}{\alpha}\sqrt{\frac{3 - \alpha^2 P^2}{N}},$$

where N is the number of events, and W_i is the weight of the ith event, which takes into account the efficiency with which particles are recorded in the bubble chamber.

The following results were obtained for the polarization with respect to the coordinate axes:

$$P_x = 0.038 \pm 0.097, \quad P_y = 0.491 \pm 0.094, \quad P_z = 0.058 \pm 0.097.$$

These results allow us to conclude that the transverse polarization of the Σ^+ hyperons is substantial.

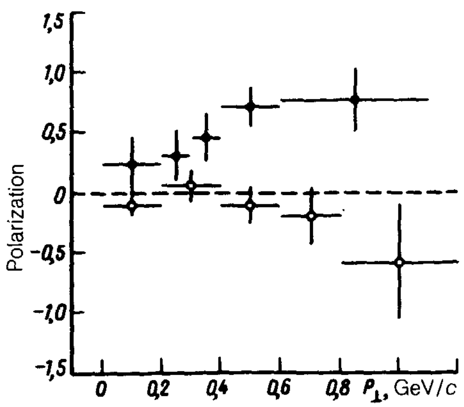

FIG. 2. Polarization of Σ^+ hyperons (●) and Λ hyperons (○) as a function of the transverse momentum.

The Σ^+-hyperon missing-mass distribution is shown in Fig. 1a. In addition to the peak corresponding to the K^+ meson, we clearly see the signal from $K^*(890)$. It follows from Fig. 1b that the polarization of Σ^+ hyperons is maximum for reactions in which vector mesons are produced. Taking into account the background for reactions in which $K^*(890)$ is produced, the Σ^+ hyperons are found to be almost completely polarized. We thus conclude that at moderate energies the hyperon polarization depends on the nature of the accompanying mesons.

Figure 2 is a plot of the polarization as a function of the transverse momentum. Our previous results, obtained by the same method for the Λ hyperon,[7] are shown for comparison. The Σ^+-hyperon polarization is higher in Absolute magnitude and opposite in sign to the Λ-hyperon polarization. Qualitatively, a weak Λ-hyperon polarization could be due to hyperon production through intermediate states. The fact that Λ and Σ^+ hyperons are oppositely polarized can be understood on the basis of their quark composition.

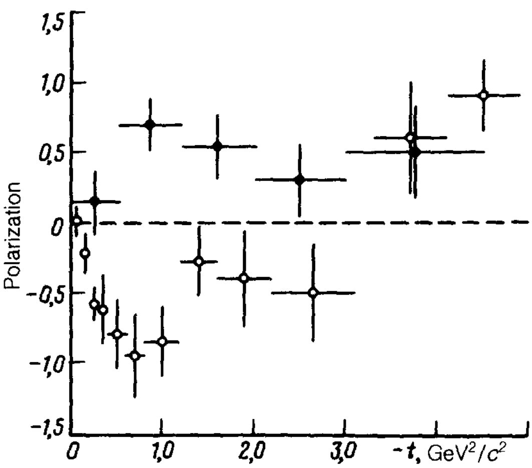

FIG. 3. Σ^+-hyperon polarization as a function of the square 4-momentum transfer. (●)—Our data; (○)—data of Ref. 4 for the reaction $K^- + p \to \Sigma^+ + \pi^-$ (4.2 GeV/c).

In Fig. 3 the polarization of Σ^+ hyperons produced in pion beams is plotted as a function of the square 4-momentum transfer and compared to the polarization of Σ^+ hyperons produced in negative kaon beams for the same initial momenta. We see that the plots differ sharply in the region up to 1.5 $(\text{GeV}/c)^2$, and that they converge at large 4-momentum transfer. This behavior of the polarization can be explained by taking into account the fact that in the case of the pion beam the strange quarks arise from the quark sea and must be accelerated, while for the beam of negative kaons the strange quark is a structural quark which already carries a large momentum.[8]

We thank M. T. Stybaev for assistance in data analysis.

[1] J. Ashman, B. Badelek, G. Baum *et cl.*, Phys. Lett. B **206**, 364 (1988).
[2] L. S. Vorob'ev, V. B. Gavrilov, N. A. Goryainov *et al.*, Yad. Fiz. **53**, 732 (1991) [Sov. J. Nucl. Phys. **53**, 458 (1991)].
[3] A. Panagiotou, CERN-EP/89-131.
[4] P. A. Baker, J. S. Chima, P. J. Dornan *et al.*, Phys. Rev. Lett. **40**, 678 (1978).
[5] V. V. Glagolev, A. A. Kuznetsov, G. D. Pestova, and M. Sabéu, Yad. Fiz. **22**, 1008 (1975) [Sov. J. Nucl. Phys. **22**, 525 (1975)].
[6] Yu. D. Aleshin, G. A. Artyunyants, I. L. Kiselevich *et al.*, Preprint ITÉF-42, Institute of Theoretical and Experimental Physics, Moscow, 1976.
[7] A. I. Amelin, A. S. Belokurov, I. L. Kislevich *et al.*, Yad. Fiz. **55**, 2945 (1992) [Sov. J. Nucl. Phys. **55**, 1647 (1992)].
[8] T. A. DeGrand, J. Markkanen, and I. Miettinen, Phys. Rev. D **32**, 2445 (1985).

Translated by M. E. Alferieff