Polarization in inclusive processes

A. V. Turbiner

Institute of Theoretical and Experimental Physics
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Formulas are derived within the framework of the reggeized one-pion exchange for the polarization of an investigated particle in inclusive processes in the fragmentation region. The reaction $pp\to\Lambda X$ is investigated at high energies and a nonzero polarization of the Λ hyperons is predicted.

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It is known that the study of polarization is one of the critical tests of strong-interaction models. This paper is devoted to an investigation of the polarization of the final particles in inclusive reactions within the framework of the reggeized one pion exchange model (OPER).[1,2] By way of example, we consider the reaction

$$pp\to\Lambda X \quad (1)$$

in the fragmentation region. We use in the calculations the parameters and the form factor obtained in the description of one-particle inclusive spectra of hyperons in pp collisions.[2] The OPER model makes it also possible to study the dependence on the polarization of the initial particles.

1. The fragmentation region of the reaction (1) is described in the OPER model by the diagram of Fig. 1. We write down the amplitude corresponding to this diagram, assuming factorization of the departure of the upper and lower blocks from the mass shell[1])

$$M=\bar{u}_\Lambda(a+b\hat{q})u_p\,\eta_\pi(t)F(t;\,s,\,s_1,\,s_2)M_{\pi p\to\,any}\,, \quad (2)$$

where $\hat{q}=\gamma_\mu(p_\Lambda-p_p+2p_k)_\mu$; u_Λ and u_p are the Λ-hyperon and proton amplitudes; $\eta_\pi(t)$ and F are the signature

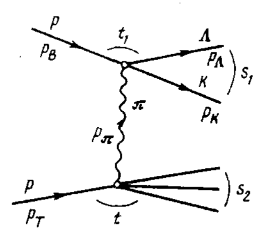

FIG. 1. Diagram of the process (1) in the fragmentation region in the OPER model.

factor of the π trajectory and the form factor that includes the departures of the blocks from the mass shell and the pion propagator; $M_{\pi p\text{-any}}$ is the amplitude of the πp transition into any final state; a and b characterize the process $\pi p\to K\Lambda$. After squaring (2), averaging over the polarization states of the initial protons, integrating over the phase space of the particles of the lower block, and summing over the possible final states of the lower block, we arrive at an expression for the differential cross section of (1)

$$d\sigma=\frac{I_1}{I_0}\,\sigma^T_{\pi p}(s_2)|\eta_\pi(t)F(t;s,s_1,s_2)|^2\left[\frac{32\pi^2 s_1 Q(s_1,m^2,\mu^2)}{Q(s_1,m^2_\Lambda,m^2_K)}\right.$$
$$\left.\times\left(\frac{d\sigma}{d\Omega}(\pi p\to K\Lambda)+\vec{\zeta}_\Lambda\vec{\zeta}_d\,\frac{d\sigma}{d\Omega'}(\pi p\to K\Lambda)\right)\right]\frac{Q(s,s_1,s_2)}{2\pi\sqrt{s}}\,\frac{d\Omega}{4\pi}\,\frac{d\Omega'}{4\pi}\,\frac{ds_1}{2\pi}\,\frac{ds_2}{2\pi},\tag{3}$$

where $\vec{\zeta}_d$ is a vector that determines the direction separated by the detector; $\vec{\zeta}_\Lambda$ is the polarization vector of the Λ hyperon obtained in the reaction $p\pi\to\Lambda K$ and is directed along $\mathbf{N}_1=\mathbf{p}_\pi\times\mathbf{p}_K$ in the Λ rest system; $\sigma^T_{\pi p}(s_2)$ is the total πp-scattering cross section; $d\sigma/d\Omega'(\pi p\to K\Lambda)$ is the differential cross section of the reaction $\pi p\to K\Lambda$; Ω' and Ω are the solid angles in the c.m.s. of ΛK and in the c.m.s. of the upper and lower blocks; $Q(x,y;z)=\sqrt{(x-y-z)^2-4yz/2\sqrt{x}}$, $I_0=Q(s,m^2,m^2)\sqrt{s}$, $I_1=Q(s_2,m^2,\mu^2)\sqrt{s_2}$; m, μ, m_Λ, and m_K are the masses of the proton, pion, Λ hyperon and kaon, respectively. From (3) we obtain a final formula for the inclusive polarization of the hyperon in the direction of $N=p_B\,p_\Lambda$[3]

$$P_\Lambda=\int I_1\sigma^T_{\pi p}(s_2)|\eta_\pi F(t;s,s_1,s_2)|^2 s_1\frac{Q(s_1,m^2,\mu^2)}{Q(s_1,m^2_\Lambda,m^2_K)}P_\Lambda^{\pi p\to K\Lambda}\cos\phi\,\frac{d\sigma}{d\Omega}$$
$$\times(\pi p\to K\Lambda)\frac{Q(s,s_1,s_2)}{\sqrt{s}}\,\frac{d\Omega}{4\pi}\,\frac{d\Omega'}{4\pi}\,ds_1\,ds_2\Bigg/\left[\begin{array}{l}\text{analogous integral with the}\\ \text{substitution } P_\Lambda^{\pi p\text{-}K\Lambda}\cos\phi\to 1\end{array}\right]\tag{4}$$

where $p_\Lambda^{\pi p\to K\Lambda}$ is the polarization in the direction of N_1 in $\pi p\to K\Lambda$, and ϕ is the angle between $\mathbf{N}$ and $\mathbf{N}_1$ in the

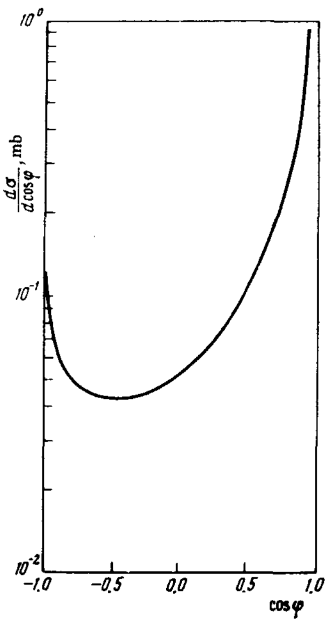

FIG. 2. The distribution of $d\sigma/d\cos\phi$.

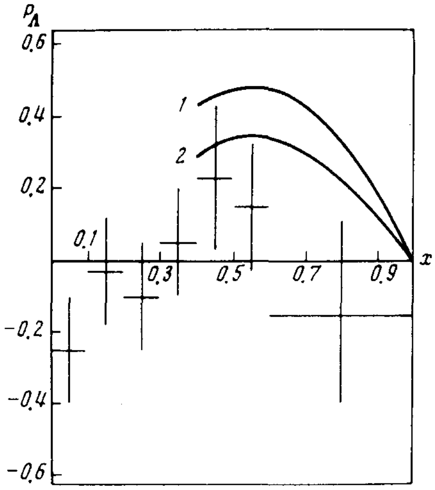

FIG. 3. The polarization p_Λ in the process (1): 1—polarization in $pp\to\Lambda X$, 2—contribution to the polarization in $pp\to\Lambda(\epsilon^0)X$ from the reaction $pp\to\Lambda X$.

Λ-hyperon rest system. The form factor $F(t,s,s_1,s_2)$ coincides with that used in[2] to describe the spectra of (1). We note that formulas (3) and (4) are valid, in particular, for the reactions $NN\to\Sigma^{\pm,0}X$.

2. The diagram of Fig. 1 contains as the upper block the reactions[2)]

$$\pi^-p\to K\;\Lambda^\bullet,\tag{5}$$

$$\pi^\bullet p\to K^+\Lambda^\bullet,\tag{6}$$

The differential cross section (5) was taken from the experimental data (see[2]). To find the Λ-hyperon polarization in (5) in the direction of $\mathbf{N}_1$, use was made of the expansion

$$P_\Lambda^{\pi^-p\to K^\bullet\Lambda^\bullet}\frac{d\sigma}{d\Omega'}(\pi^-p\to K^\bullet\Lambda^\bullet)=\sum_{l=1}^{7}B_l(s_1)P_l^1(\theta'),\tag{7}$$

where p_l^1 are associated Legendre functions of the first kind, and θ' is the angle between π and K in the ΛK c.m.s., the coefficients B_l were taken from the corresponding reductions of the experimental data[4–6] and tabulated. Unfortunately, the information on B_l is limited to $s_1\lesssim 9$ GeV^2. At $s_1>9$ GeV^2 the values of B_l were assumed equal to zero (see below). The experimentally unobservable reaction (6) was obtained from the isotopic relations

$$d\sigma_{\pi^\bullet p\to K^+\Lambda^\bullet}=\frac{1}{2}\,d\sigma_{\pi^-p\to K^\circ\Lambda^\bullet},\qquad P_\Lambda^{\pi^\circ p\to K^+\Lambda^\bullet}=P_\Lambda^{\pi^-p\to K^\bullet\Lambda^\bullet}.\tag{8}$$

3. We proceed now to discussion of the results. Since the polarization of the Λ hyperon produced in reaction (5) or (6) is directed along the normal $\mathbf{N}_1$, the factor $\cos\phi$ arises in the recalculation in terms of the normal $\mathbf{N}$ to the "plane" of the inclusive reaction (1). Figure 2 shows the distribution of $d\sigma/d\cos\phi$. We see that the bulk of the cross section lies in the region where the "planes" of the reactions (two-particle and inclusive) almost coincide.[3)] *Consequently, the sign*

of the polarization in the fragmentation region will be the same as the sign of the polarization in the two-particle reaction, averaged over the energy.

The experimental situation is still uncertain. Figure 3 shows the behavior of the polarization in the direction of **N** in (1)[4] as a function of $x = p_\Lambda^\parallel / p_\Lambda^{max}$ at a momentum 19 GeV/c[8] The model predicts a definite sign of the polarization, which increases with decreasing x and has a maximum at $x \sim 0.55$. The investigation of the region of x from 0.85 to 1, in which (5) and (6) make the main contribution at large s_1, would lead to conclusions concerning the polarization of (5) at large s_1, and would make it possible, in particular, to check on the hypothesis that the K^* and K^{**} trajectories describing the forward peak in (5) or (6) at high energies are strongly degenerate. A 300 GeV/c it was found that $P_\Lambda = 0.34 \pm 0.29$,[9] and the model predicts $P_\Lambda \sim 0.2$ in the fragmentation region.

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1) The kinematic variables are defined in Fig. 1.

2) Summation over both channels of the reaction (1) is implied, in (3) and (4), respectively.

3) An analogous conclusion was drawn by Fox[7] for reactions of the type $NN \to NN\pi$.

4) In the experimental data there is no distinction between the Λ obtained in (1) directly and the Λ obtained from the decay $\epsilon^0 \to \Lambda\gamma$, i.e., in the reaction $pp \to \Lambda^0 X$.

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