POLARIZATION PROPERTIES OF DIFFRACTIVELY PRODUCED Λ_c^+

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The Pomeron-gluon-gluon interaction is considered in the QCD-based model for the charmed baryon production in the process Pomeron + $p \to \Lambda_c^+ + X$. Λ_c^+ polarization, $P_{\Lambda_c^+}(x_F, p_T)$, depends on the model parameter a=0÷1, and it appears to be sizeable in the wide range of a values: when a ranges from 0.1 to 1.0, the polarization $P_{\Lambda_c^+}(x_F, p_T)$ varies from –0.2 to –0.5 at $x_F \sim 0.5$ and p_T in the interval 1÷2 GeV/c.

We study the inclusive production of $c\bar{c}$ pair by the initial Pomeron in the process

$$p + \text{Pomeron} \to \Lambda_c^+ + X \tag{1}$$

(fig. 1). The underlying parton subprocess is shown in fig. 1 as the lowest-order heavy quark pair production by the gluon-Pomeron coupling:

$$g + \text{Pomeron} \to c + \bar{c}. \tag{2}$$

We neglect the charmed sea, so the leading order process c + Pomeron $\to$ $c + g$ does not contribute to the Λ_c^+ polarization. Also we neglect parton transverse momenta. The Λ_c^+ transverse momenta in (1) are taken in the region $p_T = 1 \div 2$ GeV/c.

Another assumption is the dominance of the Pomeron-gluon-gluon coupling constant g_{Pgg} compared to the Pomeron-quark-quark coupling g_{Pqq}, so that $g_{Pqq}/g_{Pgg} \ll 1$. Hence, at this level we exclude from the consideration the next-order subprocess q + Pomeron $\to q + c\bar{c}$ in which a valence quark q is excited by the Pomeron and it emits the $c\bar{c}$ pair.

The produced c quark recombines inclusively with the spectator ud diquark system thus forming the final Λ_c^+.

The Λ_c^+ polarization originates from the polarization of the produced c quark and is expressed in terms of the quark spin density matrix $\rho_Q^{\lambda\lambda'}$ by the following formula for the charmed baryon spin density matrix in process (1):

$$\rho^{\lambda\lambda'} E\frac{d^3\sigma}{dp^3} = \int \mathrm{d}x_{ud}\mathrm{d}x_g\mathrm{d}z\, f_g(x_g,Q^2)\;\; f_{ud}(x_{ud},Q^2)\,\varepsilon_Q \tfrac{d^3\hat{\sigma}}{dp_Q^3}\,\rho_Q^{\lambda\lambda'}(\vec{p}_Q,\mathcal{A}) \\ \times R(x_F,p_T,x_Q,x_{ud};z). \qquad (3)$$

Here $Q^2 = m_Q^2 + p_T^2$, R is the inclusive recombination function and $\rho_Q^{\lambda\lambda'}(\vec{p}_Q,\mathcal{A})$ is the quark spin density matrix in the external field $\mathcal{A}$.

Using (3) the Λ_c^+ polarization is written as $P_{\Lambda_c^+} = \mathrm{Tr}(\sigma\rho)/\mathrm{Tr}(\rho)$.

The inclusive recombination function is expressed as

$$R(x_F,p_T,x_Q,x_{ud};z) \;=\; const\cdot\frac{x_{\varepsilon_Q}x_{ud}}{x_{\varepsilon_Q}+x_{ud}}\cdot\frac{1}{z}\delta(z-1)$$

where $z = x_E/(x_{\varepsilon_Q}+x_{ud})$ and x_E is the reduced Λ_c^+ energy: $x_E = 2E/\sqrt{s}$. The normalization parameter *const* has not been specified since it drops down in the formula for polarization $P_{\Lambda_c^+}$.

Initially a model for the final-state quark polarization expressed in terms of $\rho_Q^{\lambda\lambda'}(\vec{p}_Q,\mathcal{A})$ was formulated in [1]. The expression for ρ_Q is deduced from the following considerations. By definition $\rho_Q^{\lambda\lambda'} = \sum L^{\lambda\mu}\overset{*}{L}{}^{\lambda'\mu}$ where $L^{\lambda\mu}$ is the quark transition amplitude in the gluon field $\mathcal{A}$. The following traces relate to the basic formula (3): $\mathrm{Tr}(\sigma\rho_Q) = -2\mathrm{Im}\,\rho_Q^{+-} = 4\mathrm{Im}\,(L^{++}\overset{*}{L}{}^{+-})$ and $\mathrm{Tr}(\rho_Q) = 2(|L^{++}|^2+|L^{+-}|^2)$. Under the space parity conservation the relations $L^{++}=L^{--}$ and $L^{+-}=-L^{-+}$ hold.

The normalized spin-flip transition amplitude squared $|L^{+-}|^2$ has the sense of probability to make quark spin-flip in the external field. It seems natural to think that it increases with the quark mean range. Henceforth, it grows with increasing quark energy, ε_Q, since at hadronization the mean range of a fast quark is proportional to ε_Q/M^2 where M^{-1} is of order of the confinement radius. Thus, we accept the equality $|L^{+-}|^2/(|L^{++}|^2+|L^{+-}|^2) = a\varepsilon_Q/\varepsilon_Q^{max}$ with the supression parameter $0< a <1$. The normalization ε_Q^{max} depends, of course, on the kinematics, however, for the simplicity we take it equal to $\sqrt{s}/2$.

Taking these straightforward considerations into account the quark polarization is parametrized as follows:

$$P_Q \;=\; \mathrm{Tr}(\sigma\rho_Q)/\mathrm{Tr}(\rho_Q) = \frac{2\mathrm{Im}(L^{++}\overset{*}{L}{}^{+-})}{|L^{++}|^2+|L^{+-}|^2} = 2\sqrt{ax_\varepsilon(1-ax_\varepsilon)}\sin\Delta\phi, \quad (4)$$

where $x_\varepsilon = \varepsilon_Q/\varepsilon_Q^{max}$, and $\Delta\phi$ is the phase difference of the amplitude L^{++} and L^{+-}.

In the Regge approach the Λ_c^+ polarization in reaction (1) is due to the interference of the exchange diagrams with D^* and D^{**} exchange trajectories [2]. Neglecting the small-t contribution, we obtain $\Delta\phi = \pm(j_* - j_{**})\pi/2 = \pm\pi/2$. Here the starred j's correspond to the spins of the exchange trajectories. The sign $\pm$ reflects the non-uniqueness of this procedure. The negative sign has been chosen to justify the sign of the strange Λ^o polarization in the similar approach.

The only undetermined quantity is still the suppression factor a in formula (4). The numerical calculations were made for two far-distant values a=0.1 (small polarization) and a=1 (largest polarization) using two sets of the leading-order parton distributions CTEQ4L and GRVLO [3]. The results for x_F dependence of the Λ_c^+ polarization $P_{\Lambda_c^+}(x_F, p_T)$ at p_T= 1.5 GeV/c are shown in fig. 2. At x_F= 0.5 the small and the largest polarizations differ in magnitude by a factor of ∼2.5. With growing x_F from 0.2 to 0.9, both the small and the largest polarizations increase by a factor of 2.

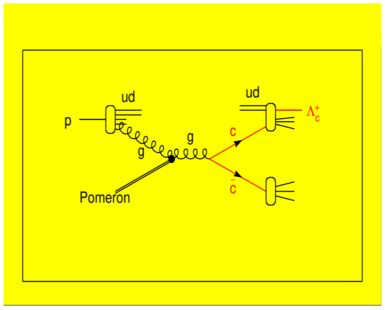

Figure 1: The leading-order parton subrocess in reaction p + Pomeron $\rightarrow \Lambda_c^+ + X$.

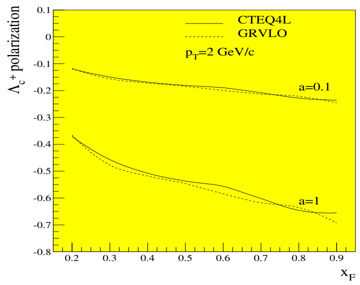

Figure 2: x_F dependence of the Λ_c^+ polarization.

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