LEADING EFFECTS IN THE SPECTRA OF Λ_c AND $\bar{\Lambda}_c$ PRODUCED IN $\pi^- p$ INTERACTIONS *

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The spectra of leading and nonleading charmed baryons (Λ_c and $\bar{\Lambda}_c$) as well as the asymmetries between these spectra measured in $\pi^- A$ collisions at $p_L = 600 GeV/c$ in the E781 experiment are described within the framework of Quark-Gluon String Model (QGSM). It was obtained in this experiment that the asymmetry between the spectra of Λ_c and $\bar{\Lambda}_c$ in $\pi^- A$ collisions is of nonzero value. It might be described in our model only assuming that the string junction is transfered from target proton into the fragmentation region of pion projectile. This effect should have the great impact on the baryon production asymmetry in $e - p$ interactions.

1 Introduction

The data of E781 experiment [1](FNAL) on spectra of charmed baryons as well as the asymmetries between the spectra of Λ_c and $\bar{\Lambda}_c$ in $\Sigma^- A$, $\pi^- A$ and pA interactions at $p_L = 600$ GeV/c have amplified the results of WA89 experiment [2] (CERN) at $p_L = 340$ GeV/c and E791 experiment [3](FNAL) at $p_L = 500$ GeV/c. The data of these experiments on charmed meson spectra and asymmetries have been already considered in the previous paper [4] from the point of view of Quark Gluon String Model (QGSM) in order to understand the influence of quark composition of beam particle on the shape of production spectra of heavy flavored particles. There is a large difference between leading effects in charmed meson spectra and those effects in charmed baryon spectra. Leading Λ_c baryon in proton-proton interaction might be produced by the "leading" fragmentation of proton ud-diquark bringing the large fraction of

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proton momentum that gives an important enhancement of Λ_c spectra over the spectra of $\bar{\Lambda}_c$. We are suggesting here to consider the spectra in full x region: $-1 < x < 1$, so that the left side of plots always corresponds to target proton fragmentation. The asymmetry between the spectra of Λ_c and $\bar{\Lambda}_c$ in pion-proton interaction should be equal zero in the region of pion fragmentation because pion can have the valent quark (antiquark) in common as with Λ_c as with $\bar{\Lambda}_c$, so both spectra will provide a leading character and be equal.

2 Quark-Gluon String Model

The inclusive production cross section of hadrons of type H is written as a sum over n-Pomeron cylinder diagrams:

$$f_1 = x\frac{d\sigma^H}{dx}(s,x) = \int E\frac{d^3\sigma^H}{d^3p}d^2p_\perp = \sum_{n=0}^{\infty}\sigma_n(s)\varphi_n^H(s,x). \tag{1}$$

Here, the function $\varphi_n^H(s,x)$ is a particle distribution in the configuration of n cut cylinders and σ_n is the probability of this process. The cross sections σ_n depend on parameter of the supercritical Pomeron Δ_P, which is equal in our model to 0.12 [5].

The distribution functions of Λ_c in case of π^-p collisions are given by:

$$\begin{aligned}\varphi_n^{\Lambda_c}(s,x) = a_0^{\bar{\Lambda}_c}[F_q^{(n)}(x_+)F_{qq}^{(n)}(x_-) + F_{\bar{q}}^{(n)}(x_+)F_q^{(n)}(x_-) + \\ 2(n-1)F_{q_{sea}}^{(n)}(x_+)F_{\bar{q}_{sea}}^{(n)}(x_-)] + a_f^{\Lambda_c}[F_{1qq}(x_-) + F_{SJ}(x_-)],\end{aligned} \tag{2}$$

where $a_0^{\bar{\Lambda}_c}$ is the central (vacuum) density parameter of charmed baryon production and $a_f^{\Lambda_c}$ is the fragmentation parameter of proton target diquark. In the case of Λ_c production in proton fragmentation the diquark fragmentation plays an important role, this diquark part of distribution should be written separately.

Each $F_i(x_\pm)$ $(i = s, u, d, ud, dd, ds...)$ is constructed as the convolution:

$$F_i(x_\pm) = \int_{x_\pm}^{1} f_{\Sigma^-}^i(x_1)\frac{x_\pm}{x_1}\mathcal{D}_i^H(\frac{x_\pm}{x_1})dx_1, \tag{3}$$

where $f^i(x_1)$ is a structure function of i-th quark (diquark or antiquark) which has a fraction of energy x_1 in the interacting hadron and $\mathcal{D}_i^H(z)$ is a fragmentation function of this quark into the considered type of produced hadrons H.

The structure functions of quarks in interacting proton, hyperon, or pion beams have already been described in the previous papers [7, 10, 11].

3 Diquark Fragmentation Function and String Junction Transfer

The fragmentation functions of diquark and quark chains into charmed baryons or antibaryons are based on the rules written in [12]. The *ud*-diquark fragmentation function includes the constant $a_f^{\Lambda_c}$ which could be interpreted as "leading" parameter, but the value of $a_f^{\Lambda_c}$ is fixed due to the baryon number sum rule and should be approximately equal to the value taken for Λ_c spectra in our previous calculations [7]:

$$\mathcal{D}_{ud}^{\Lambda_c}(z) = \frac{a_f^{\Lambda_c}}{a_0^{\bar{\Lambda}_c} z} z^{2\alpha_R(0)-2\alpha_N(0)}(1-z)^{-\alpha_\psi(0)+\lambda+2(1-\alpha_R(0))}, \tag{4}$$

where the term $z^{2\alpha_R(0)-2\alpha_N(0)}$ means the probability for initial diquark to have z close to 0; the intercepts of Regge trajectories, $\alpha_R(0)$, $\alpha_N(0)$ and $\alpha_\psi(0)$ are taken of the same values as in [7], 0.5, -0.5 and -2.0 correspondingly. The λ parameter is an remnant of transverse momenta dependence, it is equal to 0,5 here (for more information see the early publications [5, 7]). It is important here to keep in mind the possibility to create the Λ_c baryon only on the base of string junction taken from proton of the target. The string junction brings the positive baryon number in baryons and the negative one in antibaryons. In the proton and hyperon reactions we have diquarks, so only positive baryon number should be transfered. The fragmentation function of string junction that can be transfered to region $z > 0$ is of the similar form as diquark FF written above, eq. (7) :

$$\mathcal{D}_{SJ}^{\Lambda_c}(z) = \frac{a_f^{\Lambda_c}}{a_0^{\bar{\Lambda}_c} z} z^{1-\alpha_{SJ}(0)}(1-z)^{-\alpha_\psi(0)+\lambda+2(1-\alpha_R(0))}, \tag{5}$$

where $\alpha_{SJ}(0)$ is the intercept of string junction Regge trajectory. We are not discussing here the two possible values of string junction intercept: 0,5 [8] and 1,0 [9] just taking it equal to 0,5. This choice of the intercept is a reson of the target proton string junction going easier into the region of opposite z than the diquark, as it is seen from the comparison of $z \to 0$ asymptotics in the last formulas. It will become significant when we study the baryon spectra in pion interactions.

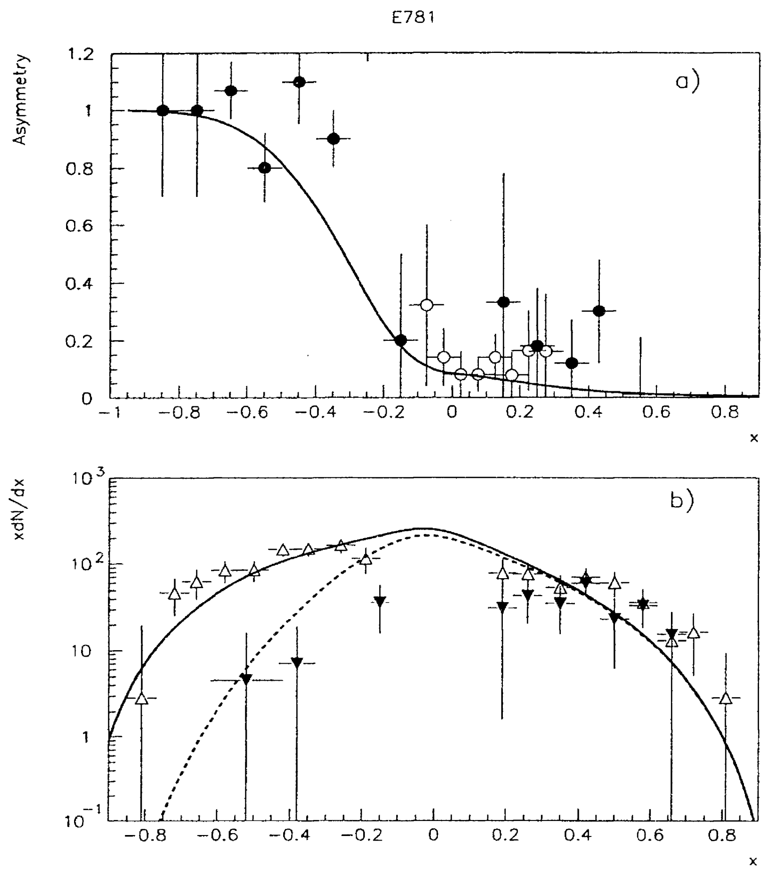

Figure 1: a) Asymmetry between Λ_c and $\bar{\Lambda}_c$ spectra obtained for $\pi - A$ $(x > 0)$ and for $p - A$ $(x < 0)$ collisions in the E781 expiment (black circles) [1] and in the E791 experiment (empty circles) [3], the QGSM calculation with the string junction transfer (solid line); b) The distributions of Λ_c (empty triangles) and $\bar{\Lambda}_c$ (black triangles) in E781 for these reactions and QGSM curves: Λ_c (solid line) and $\bar{\Lambda}_c$ (dashed line).

4 Spectra and Asymmetry of $\Lambda_c/\bar{\Lambda}_c$ in $\pi^- p$ collisions

The asymmetry between the spectra of Λ_c and $\bar{\Lambda}_c$ measured in $\pi^- A$ collisions at p_L= 600 GeV/c [1] is shown in Fig.1 a). The nonzero asymmetry in the region of pion fragmentation is described on the base of baryon string junction transfer from the proton fragmentation region (see section 3). The asymmetry is defined as:

$$A(x) = \frac{dN^{\Lambda_c}/dx - dN^{\bar{\Lambda}_c}/dx}{dN^{\Lambda_c}/dx + dN^{\bar{\Lambda}_c}/dx}, \tag{6}$$

Here dN^{Λ_c}/dx and $dN^{\bar{\Lambda}_c}/dx$ are the event distributions measured in the experiment [1]. The invariant distributions xdN/dx of charmed baryons and antibaryons obtained in pion interactions in E781 experiment are shown in Fig.1 b) with the QGSM curves calculated for pion fragmentation (the side of positive x) and for proton fragmentation (the side of negative x). The ratio between the values of $xdN/dx(p \longrightarrow \Lambda_c, \bar{\Lambda}_c)$ and $xdN/dx(\pi^- \longrightarrow \Lambda_c, \bar{\Lambda}_c)$depends on the ratio of cross sections of these two reactions. The absolute values of cross sections are not measured in the present experiment, so the left side of experimental plot in Fig.1 b) can be shifted towards the right side by the arbitrary factor, and we did it here in order to make a better description.

5 Conclusions

In this paper we have examined the data on charm baryon production in pion beam interactions with the fixed target at $p_L = 600GeV/c$ in the E781 experiment. The few conclusions about Λ_c and $\bar{\Lambda}_c$ spectra and asymmetries are to be mentioned here as the outcome of the QGSM study. The features of baryon charge transfer by the string junction of the target proton are disclosed in the nonzero baryon/antibaryon asymmetry in the kinematical region of pion beam fragmentation. We could not distinguish between two values of string junction trajectory intercept, $\alpha_{SJ}(0)$. The more pecise study with pion, muon and photon beams should allow to determine this value as well as the parameters of structure function of proton string junction. We have got fixed the leading fragmentation parameter of Λ_c production, $a_f^{\Lambda_c}$=0.006, that will help us to predict the charm baryon production in the higher energy reactions with different beam particles. In the same time, the spectra of charmed baryons require more detailed description in the pion fragmentation region. So, the analysis of only asymmetry is not a proper instrument to study the bechavior of baryon spectra in the region of x close to 1. It should be noticed that there was no necessity to involve the intrinsic charm into the calculations of charmed baryon spectra at the up-to-date level of experimental data.

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References

[1] SELEX Collab., F. Garcia Fermilab-Pub-01/258-E, Phys. Lett. B **528** (2002) 49;
J. Russ *et al.*, in *Proceed. of ICHEP2000*, Osaka, 2000; Fermilab-Conf-00/252; hep-ex/0010011.

[2] WA89 Collaboration, M.I. Adamovich *et al.*, Europian Phys. J. C **8** (1999) 593.

[3] E791 Collaboration, E.M. Aitala *et al.*, Phys. Lett. B **411** (1997) 230; Nucl. Phys. B **478** (1996) 311.

[4] O. Piskounova, Phys. of At. Nucl. **64**, 98 (2001).

[5] *Quark-Gluon String Model*, A. Kaidalov and K.A. Ter-Martirosyan, Sov. J. Nucl. Phys. **39**, 1545 (1984); **40**, 211 (1984);
A.B. Kaidalov , Phys.Lett. B **116**, 459 (1982).

[6] O. Piskounova Nucl. Phys. B (Proceed Suppl.) **93** (2001) 144; hep-ph/0010263; Phys. At. Nucl. **66** (2003) 332; hep-ph/0202005.

[7] A. Kaidalov and O. Piskounova, Sov. J. Nucl. Phys. **43**,1545(1986);
O. Piskounova , Phys. of At. Nucl. **56**, 1094 (1993).

[8] G.C. Rossi and G. Veneziano, Nucl. Phys. B **123**, 507 (1977);
G.H. Arakelyan, A. Capella, A. Kaidalov and Yu.M. Shabelski. Eur. Phys. J. C **26**, 81–90, 2002.

[9] B. Kopeliovich and B. Zakharov, Phys. Lett. B **211**, 221 (1998).

[10] O. Piskounova, preprint FIAN-140, 1987.

[11] O. Piskounova, Nucl. Phys. B **50**, 508 (1996); Phys. of At. Nucl. **60**, 439 (1997); hep-ph/9904208 (1999).

[12] A. Kaidalov, Sov. J. Nucl. Phys. **45**, 1450 (1987).