Leading Effects in the Spectra of $\Lambda_c$ and $\bar{\Lambda}_c$ Produced in $\Sigma^- p$, $pp$ and $\pi^- p$ Interactions.

O.I.Piskounova
P.N.Lebedev Physical Institute of Russian Academy of Science,
Moscow
Russia

Abstract

The spectra of leading and nonleading charmed baryons ($\Lambda_c$ and $\bar{\Lambda}_c$) as well as the asymmetries between these spectra measured in $\Sigma^- A$, $\pi^- A$ and $pA$ collisions at $p_L = 600 GeV/c$ in the E781 experiment are simultaneously described within the framework of Quark-Gluon String Model (QGSM). It is shown that the charmed baryon spectra can be fitted by QGSM curves calculated with the parameter of diquark fragmentation, $a^{\Lambda_c}_{f}=0.006$. It was obtained in this experiment that the asymmetry between the spectra of $\Lambda_c$ 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 transferred from target proton into the kinematical region of pion projectile fragmentation.
1 Introduction

The data of E781 experiment [1] (FNAL) on spectra of charmed baryons as well as the asymmetries between Λ_c and ¯Λ_c in Σ^−A, π^−A and pA interactions at p_L = 600GeV/c have recently amplified the results of WA89 experiment [2] (CERN) at p_L = 340GeV/c and E791 experiment [3] (FNAL) at p_L = 500GeV/c. The data of these experiments on charmed meson spectra and asymmetries have been already considered in the recent 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.

The difference in x spectra (x = x_F = 2p_{II}/\sqrt{s}) of leading and nonleading particles has been explained successfully by several theoretical models as an effect of interplay between the quark contents of the projectile and of the produced hadron.

Most advanced QCD models [5, 6] have to take into account so called ”intrinsic charm” (IC) in order to describe the high value of asymmetry between the x-spectra of charmed particles and antiparticles in the fragmentation region, x →1. In QGSM [7] and other models [8] with elaborated concepts of fragmentation functions (FF), there is no necessity of such assumption, because the specifically written FF give the asymmetries rising with x. Some amount of IC can only suppress the asymmetry, as it was shown in previous calculations [4, 9].

It should be noticed that 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 proton momentum that gives an important enhancement of Λ_c spectra over the spectra of ¯Λ_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. For example, in the case of hyperon-proton interactions the Λ_c spectra will have two different ”wings”: left one at the negative x’s shows the high asymmetry towards ¯Λ_c spectra due to the leading fragmentation of target proton, the other one in the positive x region should have a bit lower asymmetry because the fragmentation of hyperon diquarks is supposed to have not that strongly leading
character [10] as proton \( ud \)-diquark fragmentation.

The asymmetry between \( \Lambda_c \) and \( \bar{\Lambda}_c \) spectra 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 \( \Lambda_c \) as with \( \bar{\Lambda}_c \), so both spectra will provide a leading character and be equal.

2 Valence Quark Distributions in QGSM.

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

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

(1)

Here, the function \( \varphi_n^H(s, x) \) is a particle distribution in the configuration of \( n \) cut cylinders and \( \sigma_n \) is the probability of this process. The cross sections \( \sigma_n \) depend on parameter of the supercritical Pomeron \( \Delta_P \), which is equal in our model to 0.12 [7].

The distribution functions of \( \Lambda_c \) in case of \( \pi^- p \) collisions are given by:

\[
\varphi_{\Lambda_c}^n(s, x) = a_{0c}^\Lambda [F_q^{(n)}(x_+)^2 F_{qq}^{(n)}(x_-) + F_{qq}^{(n)}(x_+)^2 F_q^{(n)}(x_-) + 2(n-1)F_{\text{sea}}^{(n)}(x_+)^2 F_{\text{sea}}^{(n)}(x_-)] + a_{f}^\Lambda F_{1qq}^{(n)}(x_-),
\]

(2)

where \( a_{0c}^\Lambda \) is the central (vacuum) density parameter of charmed baryon production and \( a_{f}^\Lambda \) is the fragmentation parameter of proton target diquark. In the case of \( \Lambda_c \) production in proton fragmentation the diquark fragmentation plays an important role, this diquark part of distribution should be written separately. So the distribution for \( pp \) collision will include two diquark parts, as for positive \( x \) as for negative:

\[
\varphi_{\Lambda_c}^n(s, x) = a_{f}^\Lambda F_{1qq}^{(n)}(x_+) + a_{f}^\Lambda F_{1qq}^{(n)}(x_-) + a_{0c}^\Lambda [F_q^{(n)}(x_+)^2 F_{0qq}^{(n)}(x_-) + F_{0qq}^{(n)}(x_+)^2 F_q^{(n)}(x_-) + 2(n-1)F_{\text{sea}}^{(n)}(x_+)^2 F_{\text{sea}}^{(n)}(x_-)],
\]

(3)

where \( F_{1qq}^{(n)}(x_+) \) is the distribution at the leading fragmentation of diquarks, while \( F_{0qq}^{(n)}(x_+) \) is the ordinary part of fragmentation written with the central density parameter \( a_{0c}^\Lambda \).
The $\Lambda_c$ distribution functions in case of $\Sigma^-p$ collisions includes also the additional diquark parts:

$$\varphi^{\Lambda_c}_n(s,x) = a^{\Lambda_c}_{f} F_{1qq}^{(n)}(x_+) + a^{\Lambda_c}_{\bar{f}} F_{1qq}^{(n)}(x_-) + (4)$$

$$a^{\Lambda_c}_{0} [F_q^{(n)}(x_+)F_{qq}^{(n)}(x_-) + F_{qq}^{(n)}(x_+)F_q^{(n)}(x_-) + 2(n-1)F_{qsea}^{(n)}(x_+)F_{\bar{q}sea}^{(n)}(x_-)],$$

where $a^{\Lambda_c}_{0}$ and $a^{\Lambda_c}_{f}$ are the same density parameters as in eqs.(2) and (3).

The particle distribution on each side of chain can be built on the account of quark contents of beam particle ($x_+ = (x + \sqrt{x^2 + x_+^2})/2$, $x_+ = 2\sqrt{m_{\Lambda_c}^2 + p_{\perp}^2}/\sqrt{s}$) and of target particle ($x_- = (x - \sqrt{x^2 + x_-^2})/2$). They are in a case of $\Sigma^-p$ collisions:

$$F_{q}^{(n)}(x_+) = \frac{1}{3} F_{s}^{(n)}(x_+) + \frac{2}{3} F_{d}^{(n)}(x_+),$$

$$F_{qq}^{(n)}(x_+) = \frac{1}{3} F_{dd}^{(n)}(x_+) + \frac{2}{3} F_{ds}^{(n)}(x_+),$$

$$F_{q}^{(n)}(x_-) = \frac{1}{3} F_{d}^{(n)}(x_-) + \frac{2}{3} F_{u}^{(n)}(x_-),$$

$$F_{qq}^{(n)}(x_-) = \frac{1}{3} F_{uu}^{(n)}(x_-) + \frac{2}{3} F_{ud}^{(n)}(x_-).$$

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

$$F_i(x_{\pm}) = \int_{x_{\pm}}^{1} f_i^{\Sigma^-}(x_1) \frac{x_{\pm}}{x_1} D_i^H \left( \frac{x_{\pm}}{x_1} \right) dx_1,$$

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 $D_i^H(z)$ 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 [11, 14, 15]. In the case of hyperon beam they depend on the parameter of the Regge trajectory of $\varphi$-mesons ($s\bar{s}$) because of s-quark contained in $\Sigma^- (\alpha_{\varphi}(0)=0).$
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 [16].

The $ud$- and $dd$-diquark fragmentation function includes the constant $a^\Lambda_c f$ which could be interpreted as "leading" parameter, but the value of $a^\Lambda_c f$ is fixed due to the baryon number sum rule and should be approximately equal to the value taken for $\Lambda_c$ spectra in our previous calculations [11]:

$$D_{dd}^\Lambda_c(z) = \frac{a^\Lambda_c f}{a_0^\Lambda_c} z^{2\alpha_R(0)-2\alpha_N(0)} (1 - z)^{-\alpha_\psi(0)+\lambda+2(1-\alpha_R(0))},$$

(7)

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 [11], 0.5, -0.5 and -2.0 correspondingly. The $\lambda$ parameter is a remnant of transverse momenta dependence, it is equal to 0.5 here (for more information see the early publications [7, 11]).

It is important here to keep in mind the possibility to create the $\Lambda_c$ baryon only on the base of string junction taken from interacting proton or $\Sigma^-$. 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):

$$D_{SJ}^\Lambda_c(z) = \frac{a^\Lambda_c f}{a_0^\Lambda_c} z^{1-\alpha_{SJ}(0)} (1 - z)^{-\alpha_\psi(0)+\lambda+2(1-\alpha_R(0))},$$

(8)

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 [12] and 1.0 [13] 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. The full list of fragmentation functions of diquarks and of string junction into charmed baryons is presented.
The main difference between the concepts of asymmetry for D-meson production \cite{4} and for \( \Lambda_c \) production is the difference between the forms of leading fragmentation functions. The parameter \( a_1 \), which was taken for the leading fragmentation of valence quark into D-mesons (see \cite{4}), is the ratio of leading D-meson density in fragmentation region, \( z \to 1 \), to the density in the central region, \( z \to 0 \). The \( a_f^{\Lambda_c} \) parameter is an absolute fraction of the energy of diquark that is brought by produced \( \Lambda_c \). But both parameters reflect actually the same idea of high density of leading hadrons near the fragmentation region \( (z \to 1) \) of those quarks (diquarks) of beam particle which can go into content of this leading hadron. This phenomenon was also named a ”beam drag” effect in some publications.

4 Sea Quark Fragmentation Functions

The main peculiarity of QGSM is the multiple pomeron exchanges \cite{7} those are taken into account at the calculations of the spectra of multipartile production, eg. (1). In this case the \( 2(n-1) \) quark-antiquark chains are connected to paired sea quark-antiquarks of the beam and target particles.

The structure functions of sea quark pairs can be written in the same way as the valence quark distributions. The structure function of \( d \)-quark in hyperon, for example, is the following:

\[
 f_{\Sigma^-}^{d}(x_1) = C_{d,d}^{(n)} x_1^{-\alpha_R(0)} (1 - x_1)^{\alpha_R(0) - 2\alpha_N(0) + (\alpha_R(0) - \alpha_v(0)) + n - 1 + 2(1 - \alpha_R(0))}.
\] (9)

Here, sea quarks and antiquarks have an additional power term \( 2(1 - \alpha_R(0)) \) corresponding to the quark distribution of two pomeron diagram that is including one sea quark pair.

The fragmentation functions of light \( u, d \) sea quark fragmentation into \( \Lambda_c \) as well as \( \bar{u}, \bar{d} \) quark into \( \bar{\Lambda}_c \) are easily built from valence quark fragmentation functions. They are also written in the Appendix.

5 Spectra and Asymmetry of \( \Lambda_c/\bar{\Lambda}_c \) in \( \pi^-p \) collisions

The asymmetry between the spectra of \( \Lambda_c \) and \( \bar{\Lambda}_c \) measured in \( \pi^-A \) collisions at \( p_L = 600 \) GeV/c \cite{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:

\[ A(x) = \frac{dN_{\Lambda_c} / dx - dN_{\bar{\Lambda}_c} / dx}{dN_{\Lambda_c} / dx + dN_{\bar{\Lambda}_c} / dx}, \]

(10)

Here \(dN_{\Lambda_c} / dx\) 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 \(xdN/dx(p \rightarrow \Lambda_c, \bar{\Lambda}_c)\) and \(xdN/dx(\pi^- \rightarrow \Lambda_c, \bar{\Lambda}_c)\) 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.

6 The Spectra and Asymmetry of \(\Lambda_c/\bar{\Lambda}_c\) in \(\Sigma^-p\) collisions

The asymmetry between the spectra of \(\Lambda_c\) and \(\bar{\Lambda}_c\) measured in \(\Sigma^-A\) collisions at \(p_L= 600\) GeV/c is shown in Fig.2 a). Asymmetry is high in both sides of graph because the diquark fragmentation takes place for the beam and the target particles.

The invariant distributions \(xdN/dx\) of charmed baryons and antibaryons obtained in hyperon interactions in E781 experiment are shown in Fig.2 b) with the QGSM curves calculated as for hyperon fragmentation (the side of positive \(x\)) as for proton fragmentation (the side of negative \(x\)). The ratio between the values of \(xdN/dx(p \rightarrow \Lambda_c, \bar{\Lambda}_c)\) and \(xdN/dx(\Sigma^- \rightarrow \Lambda_c, \bar{\Lambda}_c)\) depends on the ratio of cross sections of this two reactions. The left side of experimental plot is shifted toward the right side by the arbitrary factor for the better description as we did in the case of pion reaction.

The complete calculations carried out with the fragmentation function written for \(\Lambda_c\) and \(\bar{\Lambda}_c\) production give the good description of data with the value of parameter \(a^\Lambda_{cf}=0,006\).
7 Conclusions

In this paper we have examined the data on charm baryon production in proton, pion and hyperon beam interactions with the fixed target at $p_L = 600\text{GeV/c}$ in the E781 experiment. The following new ideas about $\Lambda_c$ and $\bar{\Lambda}_c$ spectra and asymmetries are to be mentioned here as the outcome of the QGSM study:

a) the features of baryon charge transfer by the string junction of the target proton are disclosed in the nonzero baryon/antibaryon asymmetry in the pion beam fragmentation region although we did not intend here to distinguish between two values of $\alpha_{SJ}(0)$;

b) $\Lambda_c$ and $\bar{\Lambda}_c$ spectra in the proton and hyperon beam interactions can be described with the same leading fragmentation parameter, $a_f^{\Lambda_c} = 0.006$;

c) the asymmetry is not a proper quantity to study the behavior of baryon spectra in the region of $x$ close to 1; though the baryon/antibaryon asymmetry for $\pi^- p$ reaction shows the good agreement with QGSM curves, the spectra of charmed baryons require more detailed description in pion fragmentation region;

d) there is 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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8 Appendix

The concept of quark chain fragmentation function has been manifested in [7, 14]. The production of $\Lambda_c$ as well as $\bar{\Lambda}_c$ ($D_{0ud}^{\Lambda_c}(z)$ etc.) takes place in the central region ($z=0$) of quark-antiquark chain with the constant density parameter $a_0^{\Lambda_c} = 4.010^{-4}$. The fragmentation functions of projectile diquarks into $\Lambda_c$ ($D_{1ud}^{\Lambda_c}(z)$ and the similar) require the specific parameter $a_f^{\Lambda_c} = 0.006$. Departing from these statements the full set of FF that is necessary for the calculation of spectra of $\Lambda_c$ and $\bar{\Lambda}_c$ is written as following:

$$D_{u}^{\Lambda_c}(z) = D_{d}^{\Lambda_c}(z) = \frac{a_0^{\Lambda_c}}{z}(1 - z)^{\alpha_R(0) - 2\alpha_N(0) + \lambda \alpha_R(0) - \alpha_\psi(0)}.$$
\[ D_{a}^{\Lambda_{c}}(z) = D_{u}^{\Lambda_{c}}(z) = \frac{d_{0}^{\Lambda_{c}}}{z}(1 - z)^{\alpha_{R}(0) - 2\alpha_{N}(0) + \lambda + \alpha_{R}(0) - \alpha_{\psi}(0) + 2(1 - \alpha_{R}(0))}, \]

\[ D_{s}^{\Lambda_{c}}(z) = \frac{d_{0}^{\Lambda_{c}}}{z}(1 - z)^{\alpha_{R}(0) - 2\alpha_{N}(0) + \lambda + \alpha_{R}(0) - \alpha_{\psi}(0) + 2(1 - \alpha_{R}(0)) + \alpha_{R}(0) - \alpha_{\varphi}(0)}, \]

\[ D_{1ud}^{\Lambda_{c}}(z) = \frac{d_{f}^{\Lambda_{c}}}{d_{0}^{\Lambda_{c}} z} z^{1 + \alpha_{R}(0) - 2\alpha_{N}(0)}(1 - z)^{-\alpha_{\psi}(0) + \lambda}, \]

\[ D_{1dd}^{\Lambda_{c}}(z) = \frac{d_{f}^{\Lambda_{c}}}{d_{0}^{\Lambda_{c}} z} z^{2\alpha_{R}(0) - 2\alpha_{N}(0)}(1 - z)^{-\alpha_{\psi}(0) + \lambda + 2(1 - \alpha_{R}(0))}, \]

\[ D_{1ds}^{\Lambda_{c}}(z) = \frac{d_{f}^{\Lambda_{c}}}{2d_{0}^{\Lambda_{c}} z} z^{-\alpha_{N}(0) + 3\alpha_{R}(0) - \alpha_{\psi}(0)}(1 - z)^{-\alpha_{\psi}(0) + \lambda + 2(1 - \alpha_{R}(0))}, \]

\[ D_{1sJ}^{\Lambda_{c}}(z) = \frac{d_{f}^{\Lambda_{c}}}{d_{0}^{\Lambda_{c}} z} z^{1 - \alpha_{sJ}(0)}(1 - z)^{-\alpha_{\psi}(0) + \lambda + 2(1 - \alpha_{R}(0))}, \]

\[ D_{0udd}^{\Lambda_{c}}(z) = D_{0dd}^{\Lambda_{c}}(z) = \frac{d_{0}^{\Lambda_{c}}}{z}(1 - z)^{-\alpha_{\psi}(0) + \lambda + 4(1 - \alpha_{N}(0))}, \]

\[ D_{0ds}^{\Lambda_{c}}(z) = \frac{d_{0}^{\Lambda_{c}}}{z}(1 - z)^{-\alpha_{\psi}(0) + \lambda + 4(1 - \alpha_{N}(0)) - \alpha_{R}(0) - \alpha_{\varphi}(0)}. \]

\[ D_{\tilde{u}}^{\Lambda_{c}}(z) = D_{u}^{\Lambda_{c}}(z) = \frac{d_{0}^{\Lambda_{c}}}{z}(1 - z)^{\alpha_{R}(0) - 2\alpha_{N}(0) + \alpha_{R}(0) - \alpha_{\psi}(0) + \lambda + 2(1 - \alpha_{N}(0))}, \]

\[ D_{\tilde{u}}^{\Lambda_{c}}(z) = D_{\tilde{u}}^{\Lambda_{c}}(z), \]

\[ D_{\tilde{s}}^{\Lambda_{c}}(z) = D_{s}^{\Lambda_{c}}(z), \]

\[ D_{0udd}^{\Lambda_{c}}(z) = D_{0udd}^{\Lambda_{c}}(z) = \frac{d_{0}^{\Lambda_{c}}}{z}(1 - z)^{\alpha_{R}(0) - 2\alpha_{N}(0) + \lambda + 2(1 - \alpha_{N}(0)) + \alpha_{R}(0) - \alpha_{\psi}(0)}, \]

\[ D_{0ds}^{\Lambda_{c}}(z) = \frac{d_{0}^{\Lambda_{c}}}{z}(1 - z)^{\alpha_{R}(0) - 2\alpha_{N}(0) + \lambda + 2(1 - \alpha_{N}(0)) + \alpha_{R}(0) - \alpha_{\psi}(0) + \alpha_{R}(0) - \alpha_{\varphi}(0)}. \]

References

[1] SELEX Collaboration, F.Garcia Fermilab-Pub-01/258-E, Phys.Lett.B528,49(2002); J.Russ, in Proceedings of ICHEP2000Osaka,2000, Fermilab-Conf-00/252, hep-ex/0010011.
[2] WA89 Collaboration, M.I.Adamovich et.al., European Phys.J.C8,593(1999).

[3] E791 Collaboration, E.M.Aitala et.al., Phys.Lett.B411,230(1997), Nucl.Phys.B478,311(1996).

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

[5] Intrinsic Charm Model, S.Brodsky and R.Vogt, Nucl.Phys.B 438,261(1995).

[6] Recombination 2 Component Model, G.Herrera and J.Magnin Eur.Phys.J.C2,477(1998).

[7] Quark-Gluon String Model, A.B.Kaidalov and K.A.Ter-Martirosyan, Sov.J.Nucl.Phys.39,1545(1984), 40,211(1984); A.B.Kaidalov, Phys.Lett.B116,459(1982).

[8] A.K.Likhoded and S.R.Slabospitsky, Phys.of At. Nucl.60,981(1997).

[9] G.H.Arakelyan ,Phys.Atom.Nucl.61,1570(1998).

[10] O.I.Piskounova in Proceedings of BEACH2000,Valencia,2000; hep-ph/0010263.

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

[12] G.C.Rossi and G.Veneziano, Nucl.Phys.B 123,507(1977); A.Capella et. all,hep-ph/0103337.

[13] B.Z.Kopeliovich and B.G.Zakharov, Phys.Lett.B211,221(1998).

[14] O.I.Piskounova, preprint FIAN-140,1987.

[15] O.I.Piskounova, Nucl.Phys.B50,508(1996), Phys.of At.Nucl.60,439(1997), hep-ph/9904208 (1999).

[16] A.B.Kaidalov, Sov.J.Nucl.Phys.45,1450(1987).
Figure 1:  a) Asymmetry between $\Lambda_c$ and $\bar{\Lambda}_c$ spectra obtained for $\pi - A$ ($x > 0$) and for $p - A$ ($x < 0$) collisions in the E781 experiment (black circles) \cite{1} and in the E791 experiment (empty circles) \cite{3}, the QGSM calculation with the string junction transfer (solid line); b) The distributions of $\Lambda_c$ (empty triangles) and $\bar{\Lambda}_c$ (black triangles) in E781 for these reactions and QGSM curves: $\Lambda_c$ (solid line) and $\bar{\Lambda}_c$ (dashed line).
Figure 2: a) Asymmetry between $\Lambda_c$ and $\bar{\Lambda}_c$ spectra obtained for $\Sigma^- - A$ ($x > 0$) and for $p - A$ ($x < 0$) collisions in the E781 experiment (black circles) and in the WA89 experiment (empty circles); the QGSM calculations (solid line); b) The spectra of $\Lambda_c$ (empty triangles) and $\bar{\Lambda}_c$ (black triangles) in E781 for these interactions and the corresponding QGSM curves: $\Lambda_c$ (solid line) and $\bar{\Lambda}_c$ (dashed line).