

Baryon Asymmetry in $\pi^\pm N$ Collisions

C. Merino

*Departamento de Física de Partículas
Instituto Galego de Altas Enerxías (IGAE)
Universidade de Santiago de Compostela
Galicia, Spain*

in collaboration with

G.H. Arakelyan

*Yerevan Physics Institute
Yerevan, Armenia*

and

Yu.M. Shabelski

*Petersburg Nuclear Physics Institute
Gatchina, St.Petersburg, Russia*

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Main Aim:

Analysis of the contribution of the String Junction (SJ) mechanism in meson π -baryon collisions in the frame of the Quark Gluon String Model (QGSM).

In **QCD** hadrons are composite bound state configurations built up from the quark and gluon fields.

In the **string models** the meson wave function has the form of an **open string** as it is shown in **Figure 1a**.

For the baryons two possibilities exist: **Triangle- Δ** connection (Fig. 1b), and **Star- Y** connection (Fig. 1c).

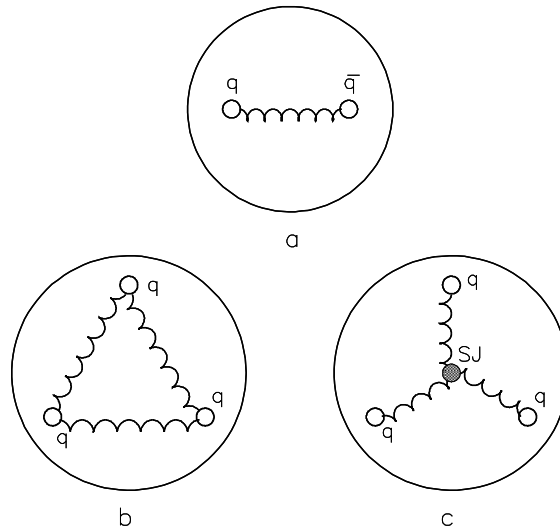


Figure 1: Composite structure of a meson (a), and a baryon (b and c), in string model.

The star- Y is considered to be the most interesting: here a baryon consists of three strings attached to three valence quarks and connected in a point x_0 called the **string junction (SJ)** (X. Artru, Nucl. Phys. B**85**, 442 (1975); G.C. Rossi, G. Veneziano, Nucl. Phys. B**123**, 507 (1977)).

In the case of inclusive reactions the baryon number transfer to large rapidity distances in hadron-nucleon reactions can be explained by **SJ** diffusion.

Inclusive spectra of secondary hadrons in πp collisions

The inclusive spectra of a secondary hadron h is determined in **QGSM** by the expression

$$\frac{x_E}{\sigma_{inel}} \frac{d\sigma}{dx_F} = \sum_{n=1}^{\infty} w_n \varphi_n^h(x_F)$$

with $x_E = E/E_{max}$, and

$$w_n = \sigma_n / \sum_{n=1}^{\infty} \sigma_n$$

the weight of the diagram with n cutted Pomerons.

The function $\varphi_n^h(x_F)$ determines the contribution of the diagram in which n Pomerons are cut. In the case of meson-baryon (πp , Kp, \dots) collisions this function has the form:

$$\begin{aligned} \varphi_n^{Mp \rightarrow h}(x_F) = & f_q^h(x_+, n) \cdot f_q^h(x_-, n) + \\ & f_q^h(x_+, n) \cdot f_{qq}^h(x_-, n) \\ & + 2(n-1)f_s^h(x_+, n) \cdot f_s^h(x_-, n) , \end{aligned}$$

with

$$x_{\pm} = \frac{1}{2} \left[\left(\frac{4m_{\perp}^2}{s} + x_F^2 \right)^{\frac{1}{2}} \pm x_F \right] ,$$

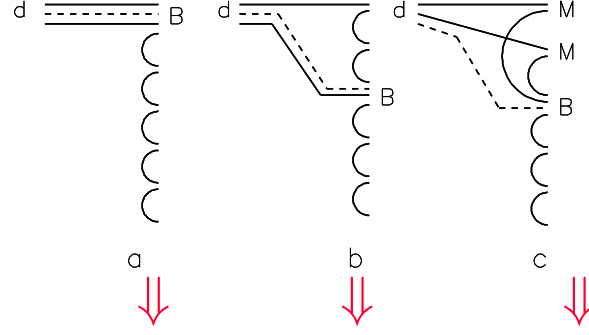
where f_{qq} , f_q , and f_s correspond to the contributions of diquarks, valence quarks, and sea quarks, respectively.

The contributions of the incident particle and the target proton depend on the variables x_+ and x_- , respectively, and they are determined by the convolution of the diquark and quark distributions with the fragmentation functions, e.g.,

$$f_q^h(x_+, n) = \int_{x_+}^1 u_q(x_1, n) \cdot G_q^h(x_+/x_1) dx_1.$$

The diquark and quark distributions, as well as the fragmentation functions, are determined through Regge intercepts.

Figure 2: **QGSM** diagrams describing secondary baryon B production by diquark d : (a) initial **SJ** together with two valence quarks and one sea quark, (b) together with one valence quark and two sea quarks, and (c) together with three sea quarks.



$$G \sim z^\beta \cdot \left[v_{qq} \cdot (a) + v_q \cdot (b) + v_0 \cdot (c) \right]$$

$$G_{qq,SJ}^B \sim z^\beta \cdot \left[v_{qq} z^{2.5-\beta} + v_q z^{2-\beta} (1-z) + v_0 \varepsilon (1-z)^2 \right]$$

for N, Λ ,

$$G_{q,SJ}^B \sim z^\beta \cdot \left[0. + v_q z^{2-\beta} (1-z) + v_0 \varepsilon (1-z)^2 \right]$$

for Ξ ,

$$G_{SJ}^B \sim z^\beta \cdot \left[0. + 0. + v_0 \varepsilon \right]$$

for Ω, Ξ .

The fraction of the incident baryon energy carried by the secondary baryon decreases from (a) to (c), whereas the mean rapidity gap between the incident and secondary baryon increases.

The parameters v_0, v_q, v_{qq} for uu, ud diquarks have different values and they can be determined by the simplest quark statistics in terms of the relative probability to find a strange quark in the sea δ (A. Capella and C.A. Salgado, Phys. Rev. C **60**, 054906 (1999)). The exponent β is $\beta = 1 - \alpha_{SJ}$ and the factor z^β is $z^{1-\alpha_{SJ}}$.

The Regge intercept α_{SJ} and the suppression factor ε for the diagram (c) in Fig. 2 are free parameters.

The SJ mechanism for baryon production in πp and pp collisions in QGSM was analyzed by G.H. Arakelyan, A. Capella, A.B. Kaidalov, and Yu.M. Shabelski, Eur. Phys. J. C **26**, 81 (2002) with $\alpha_{SJ} = 0.5$.

A second possibility for the value of the SJ intercept, $\alpha_{SJ} = 0.9$, it was considered for the same reaction by F. Bopp and Yu.M. Shabelski, Yad. Fiz. **68**, 2155 (2005) and hep-ph/0406158 (2004).

The central production of a $B\bar{B}$ pair can be described by the following formulas:

$$\begin{aligned}
G_{uu}^p &= G_{ud}^p = G_{uu}^{\bar{p}} = G_{ud}^{\bar{p}} = a_{\bar{N}}(1-z)^{\lambda-\alpha_R+4(1-\alpha_B)}, \\
G_{uu}^\Lambda &= G_{ud}^\Lambda = G_{uu}^{\bar{\Lambda}} = G_{ud}^{\bar{\Lambda}} = a_{\bar{\Lambda}}(1-z)^{\Delta\alpha} G_{uu}^p, \\
G_{uu}^{\Xi^-} &= G_{ud}^{\Xi^-} = G_{uu}^{\bar{\Xi}} = G_{ud}^{\bar{\Xi}} = a_{\bar{\Xi}}(1-z)^{\Delta\alpha} G_{uu}^\Lambda, \\
G_{uu}^\Omega &= G_{ud}^\Omega = G_{uu}^{\bar{\Omega}} = G_{ud}^{\bar{\Omega}} = a_{\bar{\Omega}}(1-z)^{\Delta\alpha} G_{uu}^{\Xi^-},
\end{aligned}$$

with

$$\alpha_R = 0.5, \alpha_\Phi = 0., \alpha_B = -0.5,$$

$$\Delta\alpha = \alpha_R - \alpha_\Phi, \lambda = 2\alpha' \cdot \langle p_t^2 \rangle = 0.5.$$

COMPARISON WITH EXPERIMENTAL DATA

Λ and $\bar{\Lambda}$ production in $\pi^\pm p$ collisions

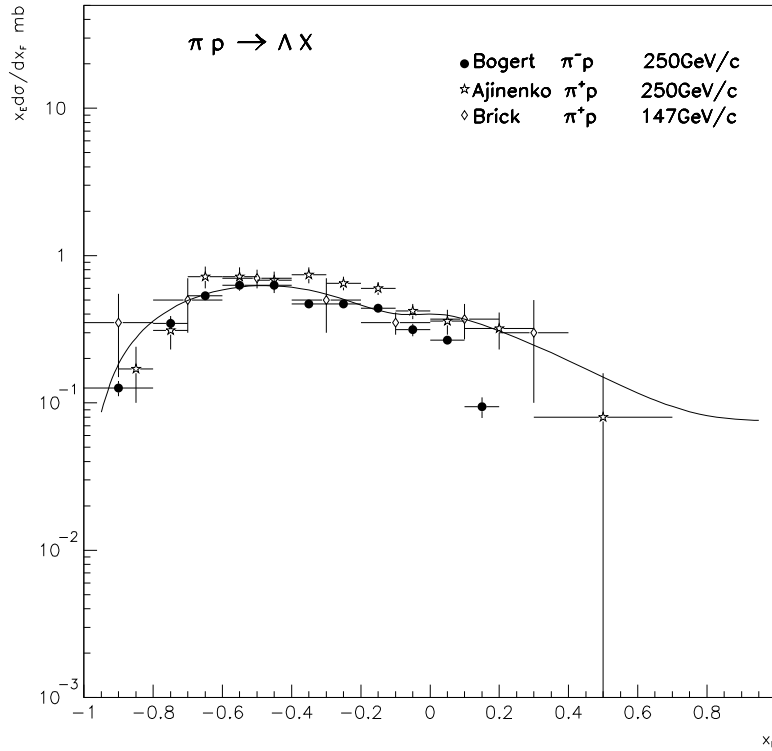


Figure 3: The experimental data on x_F spectra of Λ in $\pi^\pm p$ collisions at 147GeV/c and 250GeV/c, together with QGSM description. The curve corresponds to the calculation with $\alpha_{SJ} = 0.9$.

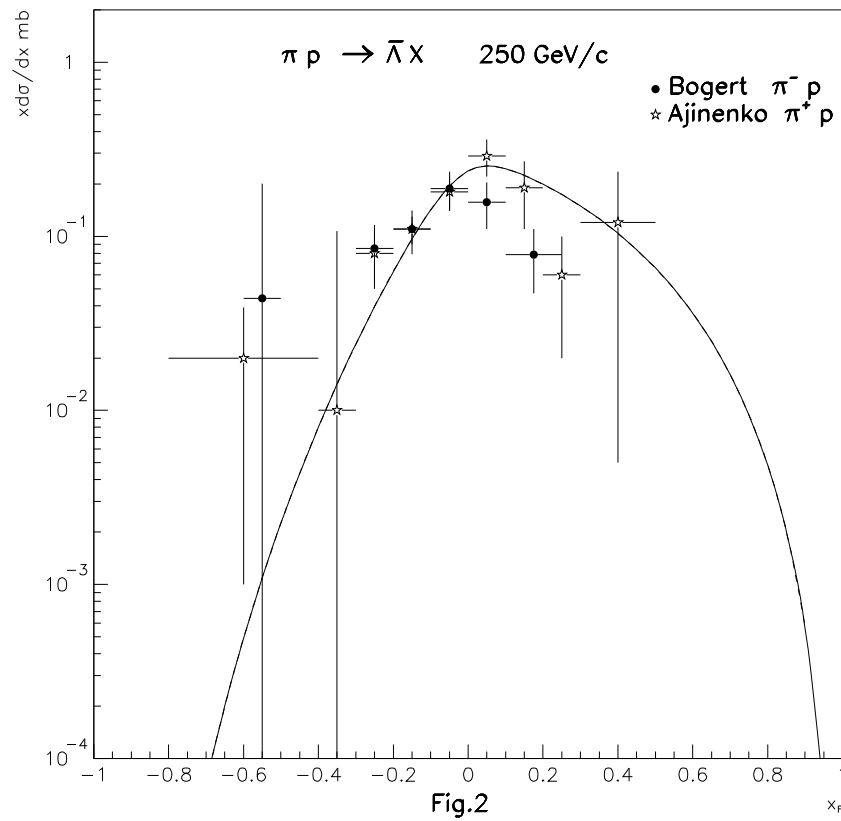


Figure 4: The x_F spectra of $\bar{\Lambda}$ in πp collisions. Experimental data at 250 GeV/c and the corresponding QGSM description.

The present report is devoted to the calculation of the asymmetry in baryon and proton production in the case of π beams

We analyse the existing data on asymmetry of Λ and $\bar{\Lambda}$ production on π beams, and we compare the experimental data with the theoretical prediction for a value of the SJ intercept, $\alpha_{SJ}=0.9$

The $\Lambda/\bar{\Lambda}$ asymmetry is defined as

$$A^{\Lambda/\bar{\Lambda}} = \frac{N_{\Lambda} - N_{\bar{\Lambda}}}{N_{\Lambda} + N_{\bar{\Lambda}}}$$

for each x_F bin.

From the theoretical point of view, since $\pi^+ = u\bar{d}$ and $\pi^- = \bar{u}d$, and $p = uud$ and $\Lambda = uds$, the difference in the asymmetry computed for π^+p and for π^-p in the proton case is not present in the Λ case:

$$A_{\pi^+p}^{\Lambda/\bar{\Lambda}} = A_{\pi^-p}^{\Lambda/\bar{\Lambda}}.$$

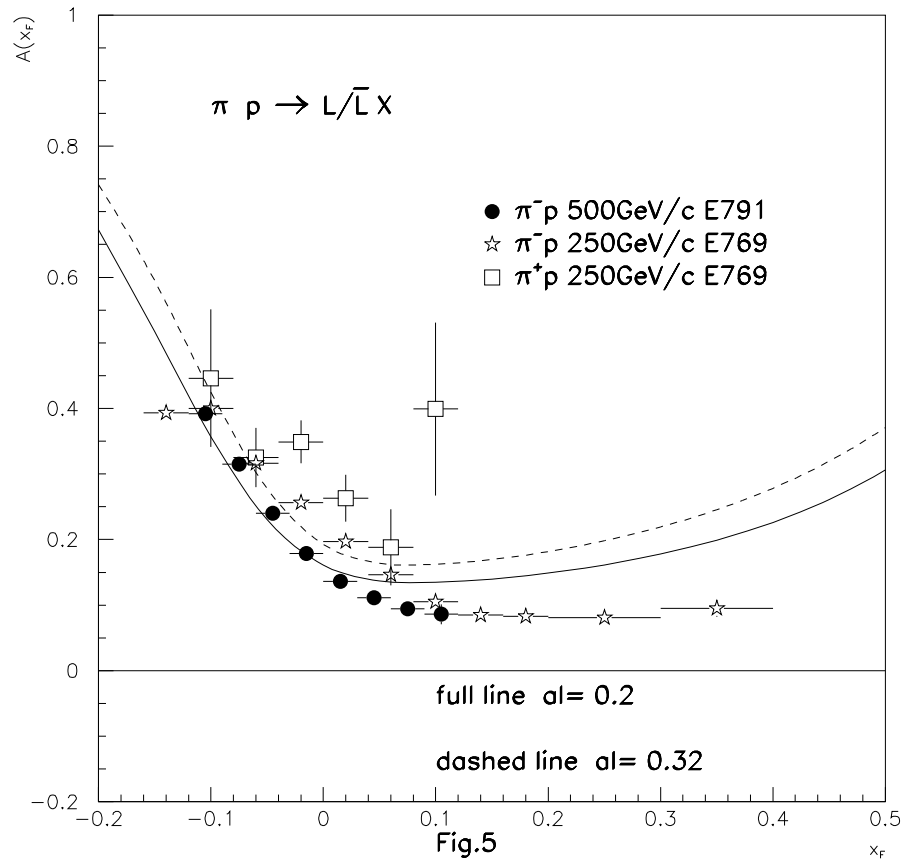


Figure 5: The **QGSJ** description of the asymmetry $\Lambda/\bar{\Lambda}$ in $\pi^\pm p$ collisions. The theoretical curves correspond to **SJ** with $\alpha_{SJ} = 0.9$, and the values $\delta = 0.2$ and $\delta = 0.32$ should be considered as lower and upper bounds for the strangeness suppression factor, $\delta = S/L$.

In this figure one can see how the **QGSJ** description of the asymmetry $\Lambda/\bar{\Lambda}$ in $\pi^\pm p$ collisions gives a reasonable agreement with most of the experimental points.

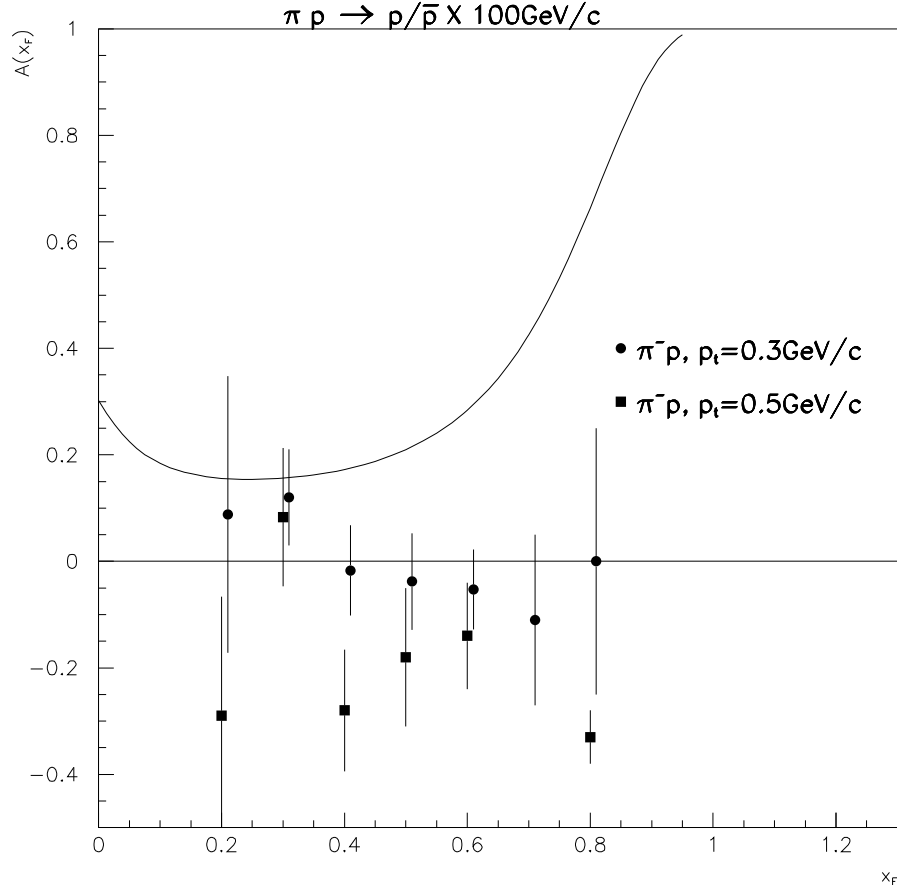


Figure 6: The QGSM description of the asymmetry p/\bar{p} in $\pi^- p$ collisions at 100GeV/c. The solid curve corresponds to SJ with $\alpha_{SJ} = 0.9$, and the dashed line corresponds to the calculation without SJ .

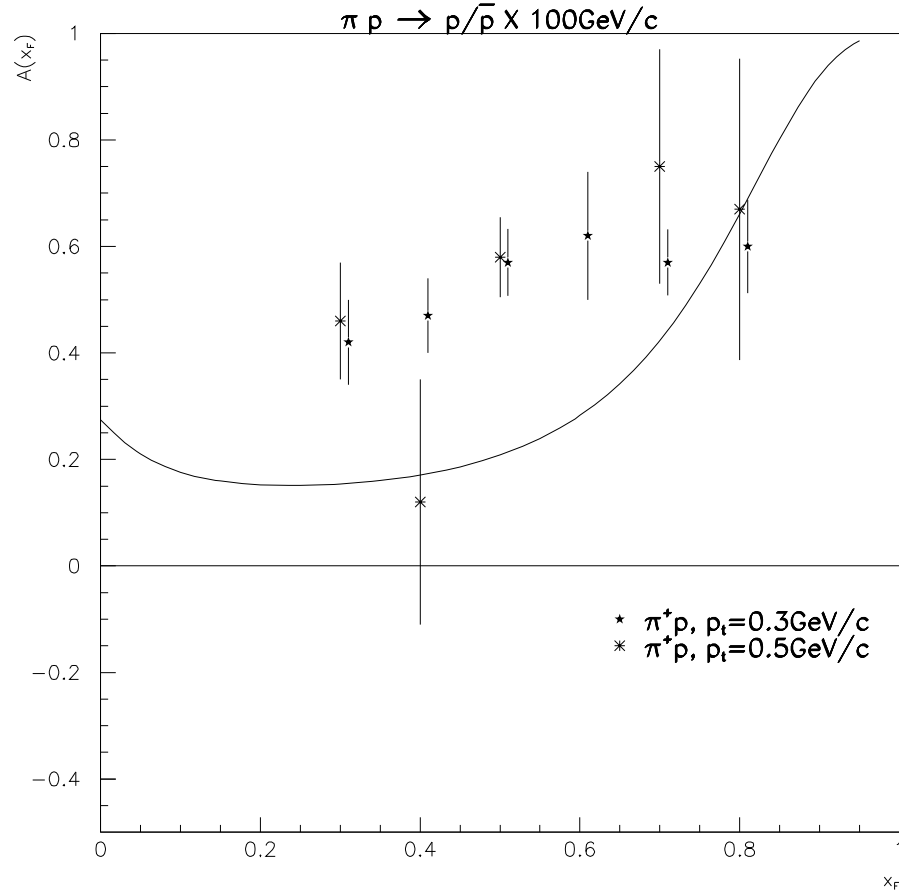


Figure 7: The QGSM description of the asymmetry p/\bar{p} in π^+p collisions at 100GeV/c. The solid curve corresponds to SJ with $\alpha_{SJ} = 0.9$, and the dashed line corresponds to the calculation without SJ .

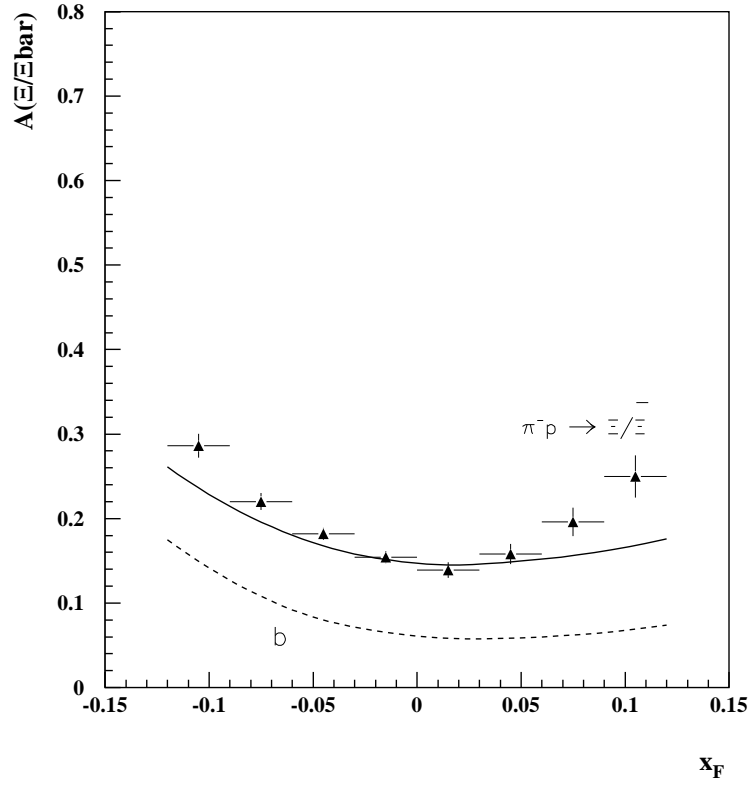


Figure 8: The **QGSM** description of the asymmetry $\Xi/\bar{\Xi}$ in π^-p collisions at 500GeV/c. The solid curve corresponds to **SJ** with $\alpha_{SJ} = 0.9$, and the dashed line corresponds to the calculation without **SJ** .

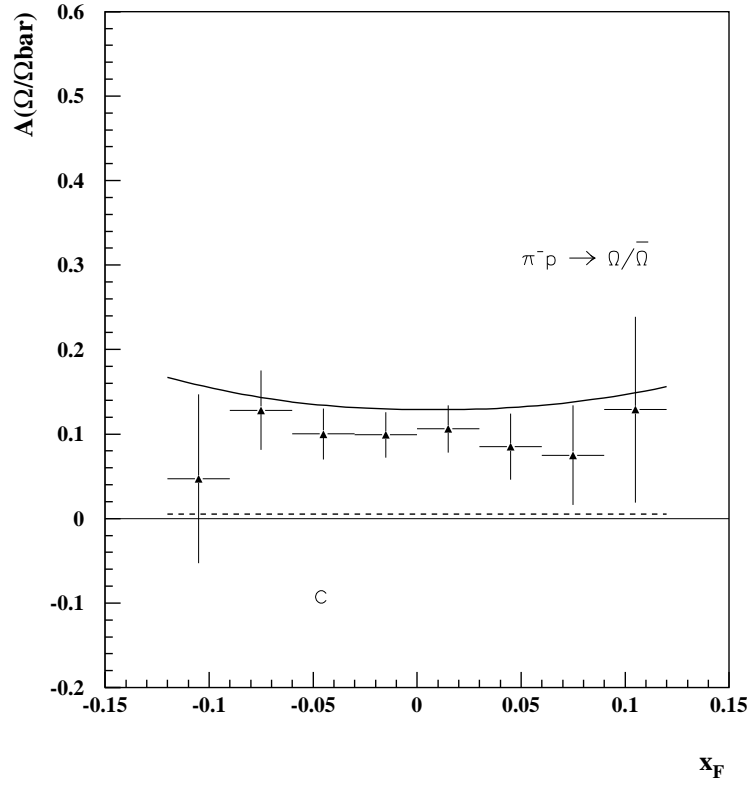


Figure 9: The **QGSJ** description of the asymmetry $\Omega/\bar{\Omega}$ in $\pi^- p$ collisions at 500 GeV/c. The solid curve corresponds to **SJ** with $\alpha_{SJ} = 0.9$, and the dashed line corresponds to the calculation without **SJ**.

It is important to note that, since that Ω ($\bar{\Omega}$) is a purely s -quark (\bar{s} -antiquark) system, without the **SJ** contribution the asymmetry $A(\Omega/\bar{\Omega})$ is exactly equal to zero.

CONCLUSIONS

We have shown that experimental data on high-energy Λ production support the possibility of baryon charge transfer over large rapidity distances. The $\Lambda/\bar{\Lambda}$ asymmetry is provided by SJ diffusion through baryon charge transfer.

The presence of baryon asymmetry in the projectile hemisphere for πp collisions provides good evidence for such a mechanism.

As for the values of the parameters α_{SJ} and ε which govern the baryon charge transfer, we have seen that the data on strange baryon production at comparatively low energies equally favor the values $\alpha_{SJ} = 0.5$ and $\alpha_{SJ} = 0.9$.

To get a good understanding of the dynamics of the baryon charge transfer over large rapidity distances new experimental data in meson collisions with nucleons and nucleus in the meson fragmentation region are needed.