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LEADING/NONLEADING CHARM HADROPRODUCTION IN THE QUARK-GLUON STRING MODEL

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1 Introduction

Leading effects in charm hadroproduction have been discussed [1, 2] for many years of research in this field. Measurements have been made recently in reactions like $\pi^- A \to DX$ for the momenta of incident π^-–beams from 250 GeV/c to 500 GeV/c [3, 4, 5]. An essential enchancement of leading D^-- over nonleading D^+-meson rates has been observed, especially in the region of Feynman's $x_f \to 1$. This asymmetry in the spectra of charmed mesons is defined everywhere as

$$A(x) = \frac{dN^{D^-}/dx - dN^{D^+}/dx}{dN^{D^-}/dx + dN^{D^+}/dx}. \tag{1}$$

It indicates a strong dependence on the valence quark composition of the beam particle, the so called "beam dragging" effect. Charmed mesons, $D^-(d\bar{c})$ and $D^0(\bar{u}c)$ in this case produced by a recombination of the $\bar{u}$ or d valence quarks from π^- with the $c\bar{c}$ pair from fission of a string,have harder spectra than for the other D-mesons.

The magnitudes of A(x) measured in WA82[3], E769[4] and E791 [5] experiments in the narrow range of $\sqrt{s}$=23-32 GeV have close values.

The models previously applied to describe the asymmetry dependence, were not very successful, see ref.[6], for instance. The first order QCD calculation could not produce any asymmetry because it did not take into account the quark content of the beam or target particles. The model [7] based on Lund-type string fragmentation and implemented as the Monte-Carlo programme PYTHIA usually overestimates the leading effect. There is a clear reason for such a behavior: strong asymmetry is obtained because only valence quarks can be at the ends of the strings. The fragmentation of strings gives a strong dependence between the quark contents of the produced leading and projectile particles.

S.J.Brodsky et.al.[8] was the first to have put forward the idea that 'intrinsic charm' suppresses the leading/nonleading asymmetry because the c and $\bar{c}$ quarks in the projectile particle produce both the leading and nonleading D-mesons.

The Quark Gluon String Model [9] to be discussed in this note has described well the most of experimental data on the x_f-spectra of charmed particles [11]. Intrinsic charm can be taken into account in the framework of this model as an admixture of the $c\bar{c}$ pairs in the quark sea of interacting particles. This paper considers the effects to be expected if some fraction of the charmed sea quarks is involved. It should be mentioned that the nuclear target will not be taken into account. Only pion-proton collisions will be considered.

2 Intrinsic charm in QGSM

Spectra of charmed mesons produced in pion-proton reactions are determined (in terms of QGSM) by the sum of chain distributions over all the cut n-pomeron diagrams as shown in fig.1. The D-meson distribution in each diagram consists of the contributions from the valence quark-antiquark or antiquark-diquark chains and $2(n-1)$ sea quark-antiquark chains:

$$\begin{aligned}\varphi_n^D(s,x) = a_0^D(F_q^{(n)}(x_+)F_{qq}^{(n)}(x_-) + F_{\bar{q}}^{(n)}(x_+)F_q^{(n)}(x_-)\\ +2(n-1)F_{q_{sea}}^{(n)}(x_+)F_{\bar{q}_{sea}}^{(n)}(x_-)),\end{aligned} \tag{2}$$

where a_0^D is the density of the D-meson formation in the center of the chain absolutely independent on the kind of D's.

The leading/nonleading difference is expressed mostly in the form of fragmentation functions convoluted with the structure functions of quarks at the ends of chains in formulae for $F_{q,\bar{q},q_{sea}}$, as in the following equation:

$$F_i(x_\pm) = \int_{x_\pm}^1 f_i(x_1)\frac{x_\pm}{x_1}\mathcal{D}_i^D(\frac{x_\pm}{x_1})dx_1. \tag{3}$$

The nonleading fragmentation function $\mathcal{D}(z)$ is written in the usual QGSM form :

$$\mathcal{D}_d^{D^+}(z) = \frac{1}{z}(1-z)^{-\alpha_\psi(0)+\lambda+2(1-\alpha_R(0))}, \tag{4}$$

where $\lambda=2\alpha'_{D^*}(0)p^2_{\perp D^*}$, $\alpha_\psi(0) = -2$. [11].

The leading type fragmentation function contains the factors important for asymmetry:

$$\mathcal{D}_d^{D^-}(z) = \frac{1}{z}(1-z)^{-\alpha_\psi(0)+\lambda}(1+a_1^D z^2). \tag{5}$$

The additional 2(1-$\alpha_R(0)$) in (4) means that at least one pair of ordinary quarks must be produced in addition to the valence quark at the top of the chain to obtain a nonleading D-meson ($\alpha_R(0)$=0.5 is the intercept of an ordinary quark Regge trajectory). The $a_1^D z^2$ term is introduced in [10] to provide a transition between probabilities of the D^- production at z→0 and z→1.

Such a difference between "favoured" and "unfavoured" fragmentations leads to a large asymmetry increasing with x.This asymmetry will

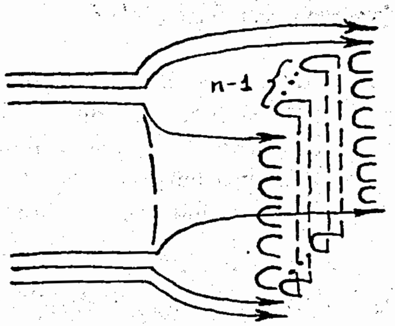
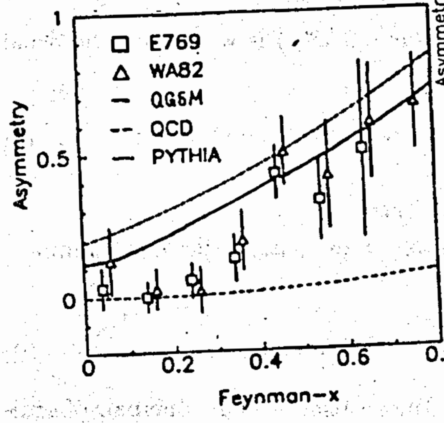


Fig.1. Diagram with an n-pomeron exchange.



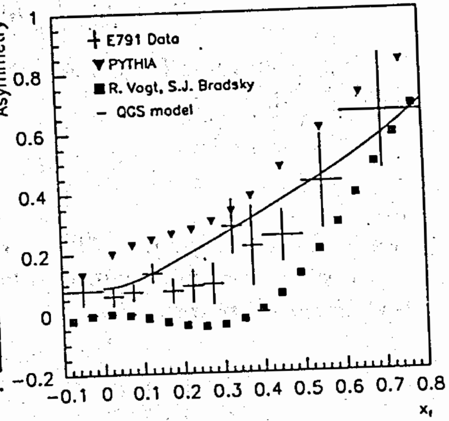


Fig.2. WA89 and E769 results.

Fig.3. E791 data.

be suppressed with the presence of the $c\bar{c}$ quark pairs in the quark sea of pion. These quarks have the following distributions:

$$f^{(n)}_{c(\bar{c})} = C^{(n)}_{c_{sea}} \delta_{c(\bar{c})} x_1^{-\alpha_\psi(0)} (1 - x_1)^{\alpha_R(0) - 2\alpha_N(0) + (\alpha_R(0) - \alpha_\psi(0)) + n - 1} \qquad (6)$$

where x_1 is the momentum fraction of the $c(\bar{c})$ quarks and $\delta_{c(\bar{c})}$ is the weight of the charmed quark pairs in the quark sea.

The fragmentation function for the chain attached to the $c(\bar{c})$ sea quark is of leading type, for example:

$$\mathcal{D}^{D^-(D^+)}_{c(\bar{c})}(z) = \frac{a^D_f}{a^D_0 z} z^3 (1 - z)^{-\alpha_R(0) + \lambda}. \qquad (7)$$

where a^D_f is of order 1.

This phenomena will cause a fall in asymmetry in the region of x where the charmed quark sea pairs are distributed.As it is evident from eq.(6),charm quarks are not spread out in narrow region of x_1,then the suppression of asymmetry will be observed more or less in the whole range of x.

3 Comparison between models and data

The asymmetry predicted in QGSM is shown as a solid line in figs.2 and 3. The value of the $c\bar{c}$ admixture is $a^D_f \delta_{c(\bar{c})}$=0.1. The behavior of each model is well illustrated according to description given above. The PYTHIA calculations give everywhere the highest asymmetry curves because the suppression caused by intrinsic charm is not taken into account. QGSM curves are of the similar form , but the agreement with data is better in the absolute values.There is a fixed fraction of intrinsic charm and specific distribution in x in the model of ref.[8].That is why the curve of the model in fig.3 is considerably lower than the experimental data in region x near 0.2. The better fits are possible as in PYTHIA and the model of ref.[8].

4 Conclusions

Thus, as it was shown in paragraph 3 a small fraction of intrinsic charm can lead to a satisfactory description of experimental results. Such fraction was included into QGSM as an additional phenomenological parameter and has been estimated from the comparison with experimental data as $\delta_{c(\bar{c})}$ =0.1. This picture can be improved if to take into account the influence of nuclear target effects. To obtain an important information on properties of hadronic wave function at high energies, it is necessary to provide a more precise evaluation of the intrinsic charm structure function.

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