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D_s-MESONS INCLUSIVE HADROPRODUCTION IN THE QUARK-GLUON STRING MODEL

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Hadroproduction of charmed particles is now being investigated both experimentally and theoretically. On the one hand the methods, available for light hadrons such as quark models, symmetries and so on, can be applied to hadrons, containing the charmed quark. On the other hand, the presence of c- quark inside the charmed hadrons allows one to use QCD methods.

There is wide variety of theoretical models which are more or less satisfactory applied to description of charmed particle hadroproduction (see [1] and references therein).

Among these models the Quark–Gluon String model (QGSM) was successfully used for the description of many features of multiparticle production in hadron-hadron collisions both for light and charmed hadrons.

The modification of the QGSM taking into account the contributions from decays of corresponding S–wave resonances was developed in [2].

In the previous papers [2, 3] this approach was used for the calculation of charmed hadron (meson and baryon) spectra, produced by different hadron beams (π, p, Σ and Ξ) without taking into account the charmed sea contribution.

The charmed sea contribution in QGSM for the D mesons hadroproduction were considered in [4, 5] to describe the experimental data of leading/nonleading $D-$ mesons asymmetry.

The predictions for inclusive spectra of D_s- mesons produced by different hadron beams in the various modifications of QGSM without taking into account the contribution of charmed sea were calculated earlier in [2, 6]. However in these papers, due to the absence of the measurements, there was not made the comparison of the model calculations with experimental data.

In this note we analyze for the first time the recently appeared experimental data [7] - [12] on inclusive spectra and production asymmetry of the leading/nonleading charmed-strange $D_s^-(s\bar{c})$ – and $D_s^+(c\bar{s})-$ pseudoscalar mesons. The analysis has been performed in the framework of modified QGSM [2] taking
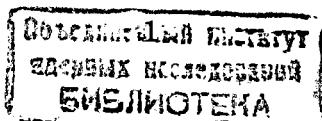
into account the contribution of vector D_s^* resonance decay into D_s through $D_s^* \to D_s \gamma$ mode [13].

The formulae for inclusive spectra of D_s^* mesons hadroproduction for different beams and the expressions for quark and diquark distribution functions in the initial hadrons were given in [2, 4].

Here we used the parametrization of charmed sea in π^- and Σ^- given in [4].

In the present paper we use the following parametrization of the quark and diquark fragmentation functions into D_s- mesons:

$$G_d^{D_s^+}(z) = (1-z)^{\lambda - \alpha_\psi(0) + 2(1-\alpha_R(0)) + 2(\alpha_R(0) - \alpha_\varphi(0))}, \quad (1)$$

$$G_d^{D_s^+}(z) = G_d^{D_s^-}(z) = G_u^{D_s^-}(z) = G_u^{D_s^-}(z) = G_{\bar{d}}^{D_s^-}(z) =$$
$$G_{\bar{d}}^{D_s^-}(z) = G_{\bar{u}}^{D_s^-}(z) = G_{\bar{u}}^{D_s^-}(z) \quad (2)$$

$$G_s^{D_s^-}(z) = (1-z)^{\lambda - \alpha_\psi(0)}(1 + a_1^D z^2) \quad (3)$$

$$G_s^{D_s^+}(z) = (1-z)^{\lambda - \alpha_\psi(0) + 2(1 - \alpha_\varphi(0))} \quad (4)$$

$$G_{c(\bar{c})}^{D_s^-(D_s^+)}(z) = \frac{b^{D_s}}{a_0^{D_s}} z^{1 - \alpha_\psi(0)} (1-z)^{\lambda - \alpha_\varphi(0)}. \quad (5)$$

$$G_{dd}^{D_s^+}(z) = (1-z)^{\lambda - \alpha_\psi(0) + 2(1 - \alpha_N(0)) + (\alpha_R(0) - \alpha_\varphi(0))} \quad (6)$$

$$G_{dd}^{D_s^-}(z) = G_{dd}^{D_s^+}(z) = G_{uu}^{D_s^-}(z) = G_{uu}^{D_s^+}(z) \quad (7)$$

$$G_{ds}^{D_s^-}(z) = (1-z)^{\lambda + \alpha_R(0) - 2\alpha_N(0) + \alpha_R(0) - \alpha_\psi} \left(\frac{1 + a_1 z^2}{2} + \frac{(1-z)^2}{2} \right) \quad (8)$$

$$G_{ds}^{D_s^+}(z) = (1-z)^{\lambda - \alpha_\psi(0) + 2(1 - \alpha_N(0)) + 2(\alpha_R(0) - \alpha_\varphi(0))} \quad (9)$$

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where $\lambda = 0.5$, $\alpha_R(0) = 0.5$, $\alpha_N(0) = -0.5$. Under these calculations we consider two values of the intercept of charmed $c\bar{c}$ trajectory $\alpha_\psi(0) = -2.18$ and $\alpha_\psi(0) = 0.$.

Now we turn to the comparison of the existing experimental data [7] - [12] for D_s mesons produced in $\pi^- p$ and $\Sigma^- p$ collisions with the QGSM calculations in the framework of the model under consideration using fragmentation functions (1) - (9). The values of free parameters were obtained by fitting to the experimental data.

In what follows, we will present four curves in all figures. They correspond to two values of α_ψ trajectory and presence or absence of the charmed sea contribution:

1) $\alpha_\psi = -2.18$ (full line) with corresponding values of parameters $a_0^D = 0.0007$, $a_1^D = 5$, $b^{D_s} = 1.6$, $\delta_c = 0.05$,

2) $\alpha_\psi = 0$ (dashed line), $a_0 = 0.0005$. $a_1 = 5$. $b^{D_s} = 1.6$. $\delta_c = 0.05$.

3) $\alpha_\psi = -2.18$ (dashed-dotted line) - the same as in 1) without charmed sea contribution $\delta_c = 0$ and

4) $\alpha_\psi = 0$ (dotted line) - the same as in 2) but $\delta_c = 0$.

The charmed sea suppression factor $\delta_c = 0.005$ was obtained earlier in [4].

All theoretical curves in the model under consideration are sums of the directly produced D_s-meson cross section and the contribution from the decay of the corresponding $D_s^* \to D\gamma$ resonance.

The experimental data on the x_F- dependence of the differential cross section of D_s^+-meson in $\pi^- p$ interaction at initial momenta $P_L = 230$ GeV [9] together with model calculations are presented in Fig.1. Note that the normalization of the experimental data on this figure is arbitrary and here we may compare only the shape of the cross section.

The model calculations for the spectra of the sum of all D_s mesons in the reaction $\pi^- p \to D_s X$ at $P_L = 350$ GeV/c are compared with the experimental data at $P_L = 350$ GeV/c [7]

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in Fig.2. It is necessary to mention that in the πp- collision the production cross sections of $D_s^-(s\bar{c})$ and $D_s^+(c\bar{s})$- mesons are equal because they do not contain the valence quarks from pion beam. The experimental measurements of the D_s^- и D_s^+- mesons total cross sections , given in [7], slightly differ each other, although they are close within the rather large experimental errors.

In Fig.3 the experimental data on the total cross section versus momentum of the initial π meson in $x_F > 0$ region are compared with the model calculations. As we can see the existing experimental data do not allow to draw a definite conclusion on momentum dependence or, as it was noted in [7], there is no indication of momentum dependence which contradicts to PYTHIA (see curve on Fig.9c in [7]) and our calculations. It is also necessary to note that the first point at $P_L = 235$ GeV/c (NA32) [9] stands for the D_s^+ meson cross section, while two others - (E769) at $P_L = 250$ GeV/c [10] and (WA92) at $P_L = 350$ GeV/c [7] were given for the sum of D_s^+ and D_s^- mesons.

The predictions of the model for the inclusive spectra of D_s^+ mesons in $\pi^- p$- collision at $P_L = 500$ GeV/c and $\Sigma^- p$ collisions at $P_L = 330$ GeV/c and 600 GeV/c are given in Figs.4 - 8.

The x_F dependence of leading/nonleading production asymmetry $A(D_s^-, D_s^+)$ for $\Sigma^- p$- collision together with experimental data of the WA89 collaboration for $P_L = 340$ GeV/c [11] is presented in Fig.9. The predictions for the same asymmetry at $P_L = 600$ ГэВ/c is shown in Fig.10.

We do not present the comparison of our calculations for asymmetry $A(D_s^-, D_s^+)$ in $\pi^- p$ collision with the experimental measurements [12] because it is equal to zero due to equality of D_s^- and D_s^+ mesons cross sections.

As we can see from the comparison with the experimental data, the model under consideration represents the shape of D_s- mesons cross section in $\pi^- p$- collision. Slightly better agreement is for the case of charmed trajectory intercept equal to $\alpha_\psi = 0$. Recent experimental measurements of leading/nonleading asym-

metry $A(D_s^-, D_s^+)$ in the $\Sigma^- p$- interaction at $P_L = 340$ ГэВ/c [7] prefer the $\alpha_\psi = -2.18$ without charmed sea contribution (curve 3 on fig.9). Unlike the π induced reactions where, as it was already noted, the asymmetry is equal to zero, in the hyperon induced reaction it should be significant due to the presence of the valence s- quark which was testified by WA89 collaboration measurements [11]. However in the description of inclusive cross section the variant 3) gives the rapidly falling cross section. Taking into account the charmed sea contribution leads to decreasing of the cross section, especially at large x_F, but leads to de decreasing of the asymmetry at the same region. Unfortunately existing experimental data due to absence of the cross sections measurements at $x_F > 0.5$ do not allow to do the unambiguous choice between considered variants.

In the model under consideration it is possible to improve the description of the experimental data [7] by slightly changing the value of the a_1 parameter in the fragmentation functions of the s- quark (3) and ds- diquark (8). However for the exact determination of the quark and diquark fragmentation functions into the D_s- mesons more precise measurements of all observations are needed: total and differential cross sections and leading/nonleading production asymmetry especially at large x_F.
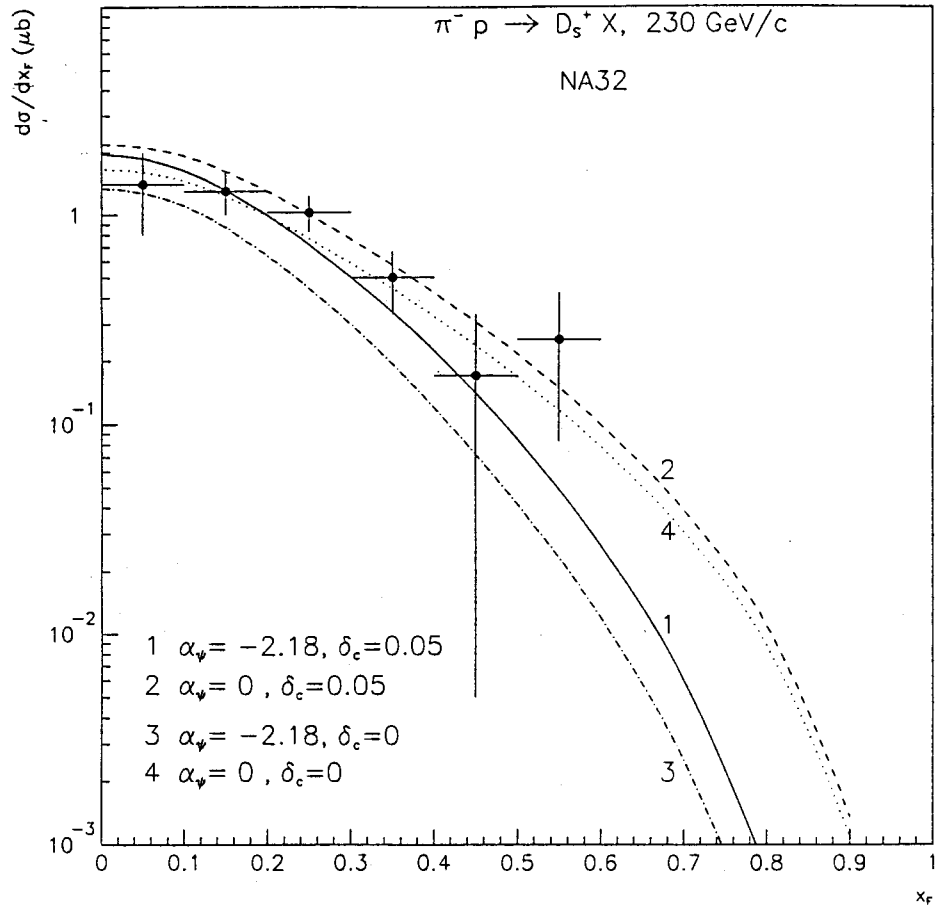
Fig.1. Comparison of the QGSM calculations with the experimental data (NA32) [9] on differential cross sections of the D_s^+-meson production in $\pi^- p-$ interaction at $P_L = 230\ GeV/c$. The theoretical curves notification: 1) full curve were calculated for $\alpha_\psi = -2.18$, 2) dashed curve stands for $\alpha_\psi = 0$ (in 1 and 2 with the contribution of the charmed sea), 3) dashed - dotted line - $\alpha_\psi = -2.18$, 4) dotted line - $\alpha_\psi = 0$ (in 3 and 4 the charmed sea contribution is absent).
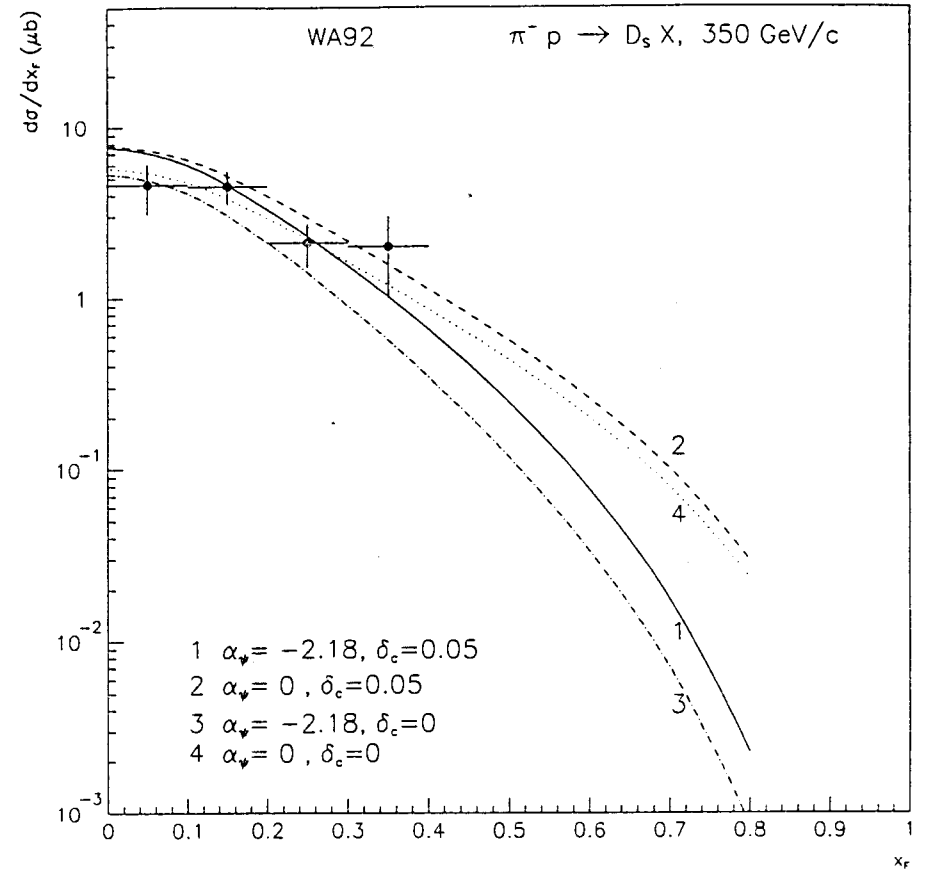
Fig.2. Comparison of the QGSM calculations with the experimental data (WA92) [7] of the summary spectra of D_s-mesons production in $\pi^- p-$ interaction at $350\ GeV/c$. The curves are the same as in Fig.1.

$\pi^- p \rightarrow D_s X \quad x_f > 0$

- NA32
- E769
- WA92

1 $\alpha_\psi = -2.18, \delta_c = 0.05$
2 $\alpha_\psi = 0, \delta_c = 0.05$
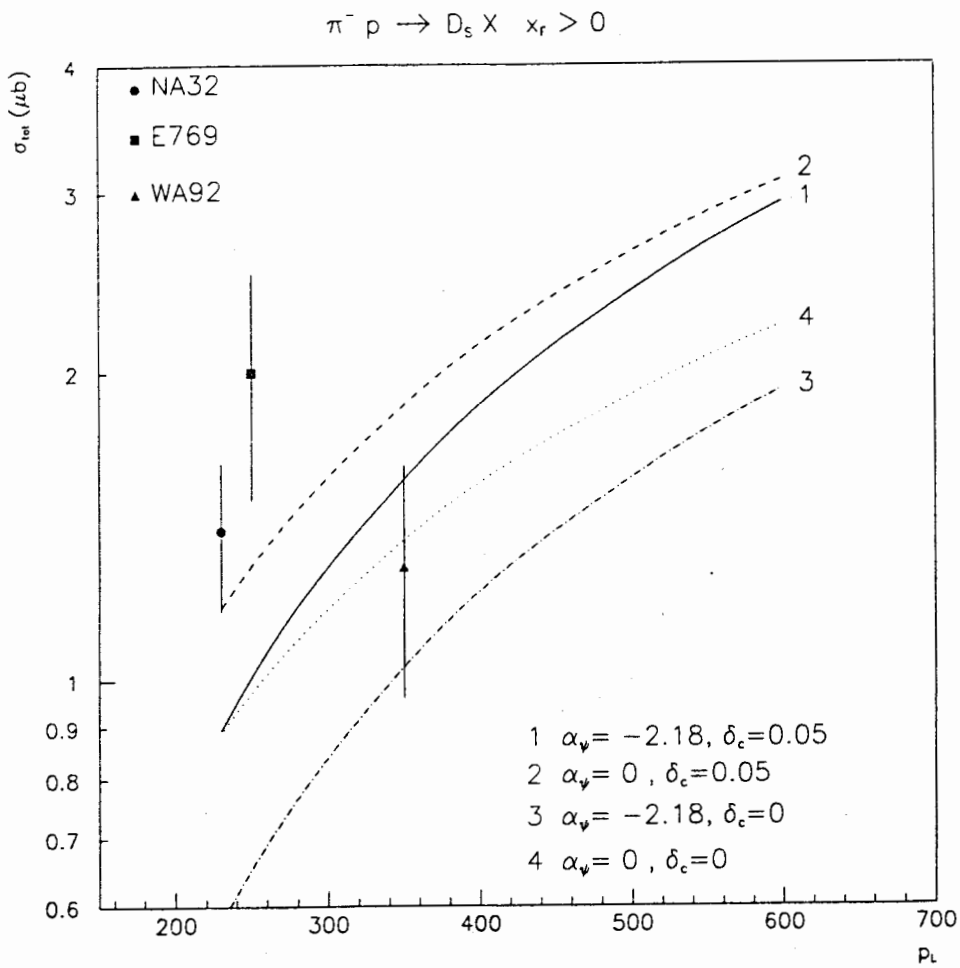3 $\alpha_\psi = -2.18, \delta_c = 0$
4 $\alpha_\psi = 0, \delta_c = 0$

Fig.3. Comparison of the QGSM calculations with the experimental data on D_s mesons total cross sections in $\pi^- p-$ interaction. The curves are the same as in Fig.1.
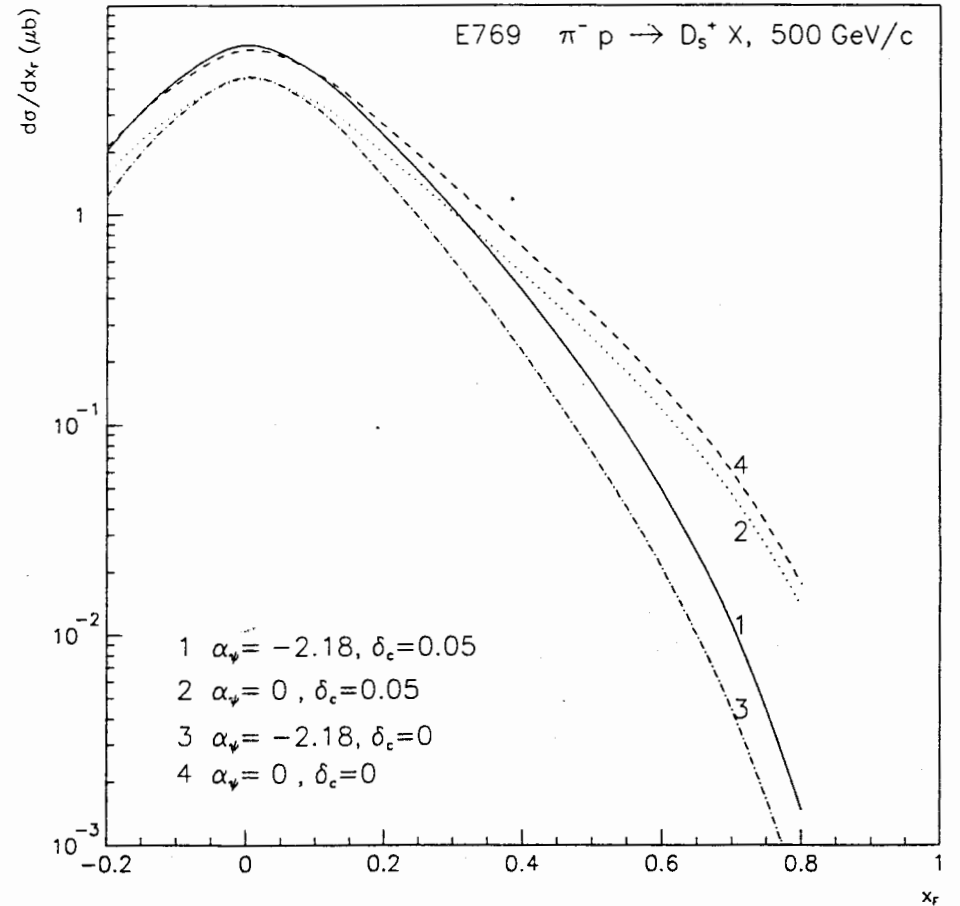
E769 $\quad \pi^- p \rightarrow D_s^+ X, \ 500 \ GeV/c$

1 $\alpha_\psi = -2.18, \delta_c = 0.05$
2 $\alpha_\psi = 0, \delta_c = 0.05$
3 $\alpha_\psi = -2.18, \delta_c = 0$
4 $\alpha_\psi = 0, \delta_c = 0$

Fig.4. Predictions for the differential cross sections of the x_F- dependence of the D_s^+-meson production in $\pi^- p-$ interaction at $P_L = 500 \ GeV/c$ (E769). The curves are the same as in Fig.1.
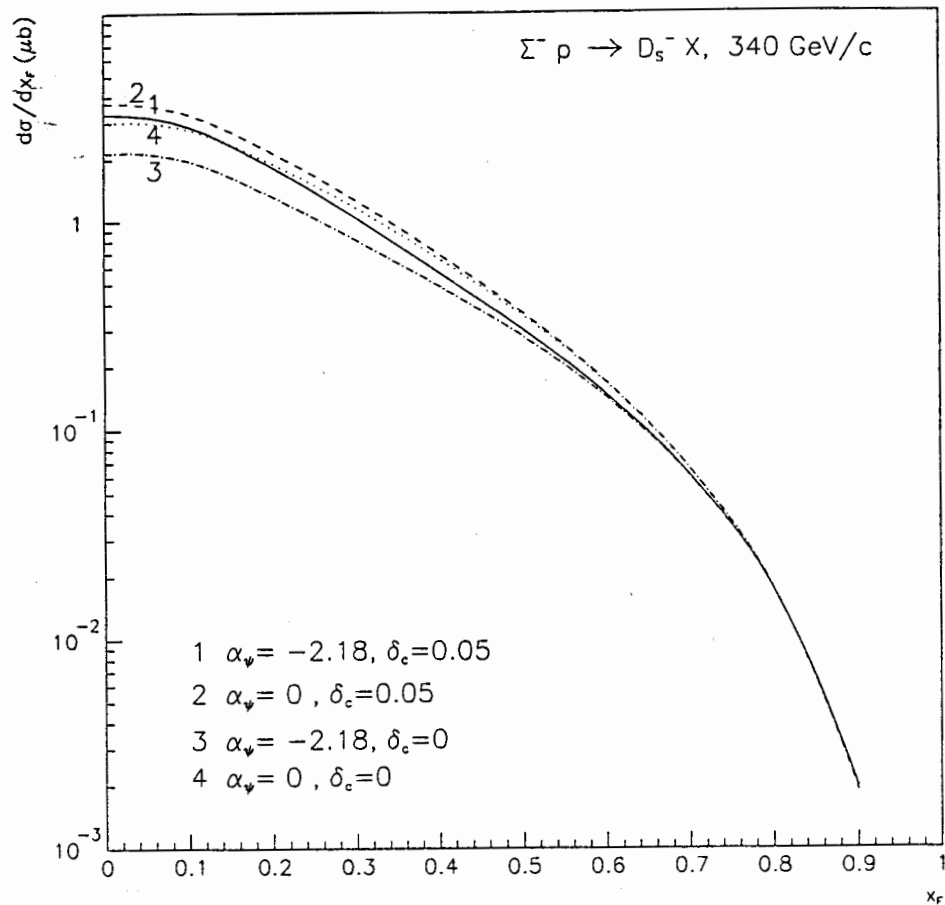
Fig.5. Model prediction for the x_F–dependence of the D_s^-–meson cross section in $\Sigma^- p$ interaction at 340 GeV/c. The curves are the same as in Fig.1.

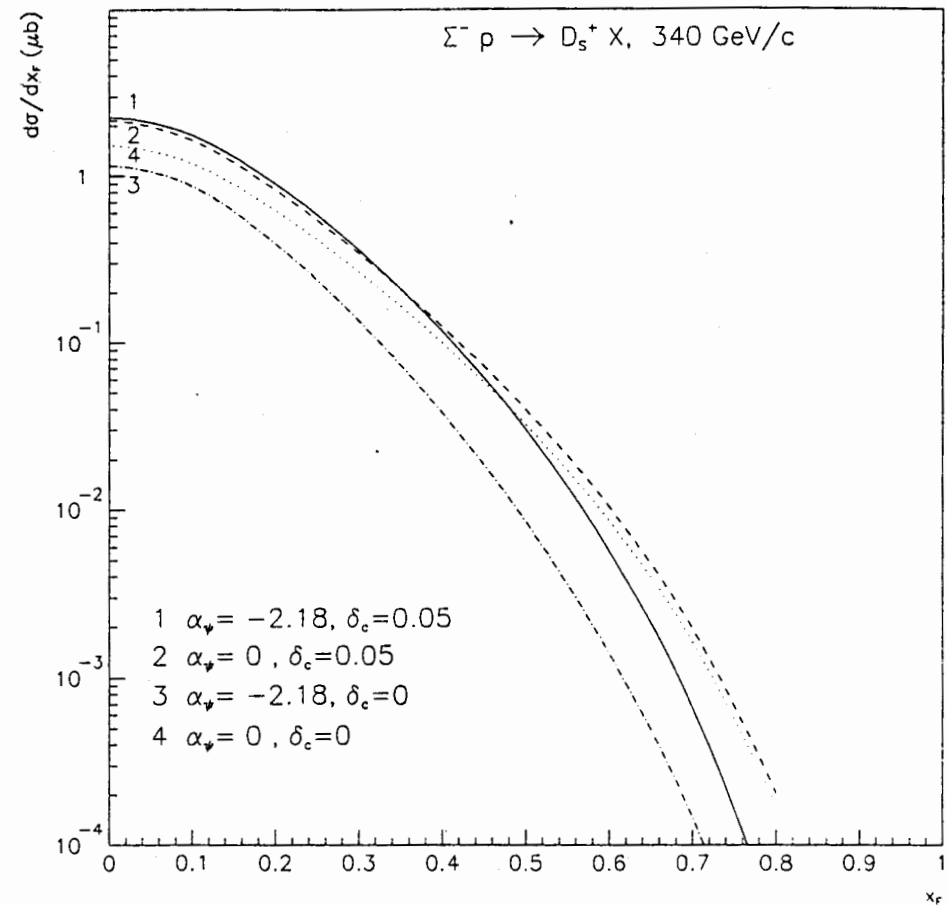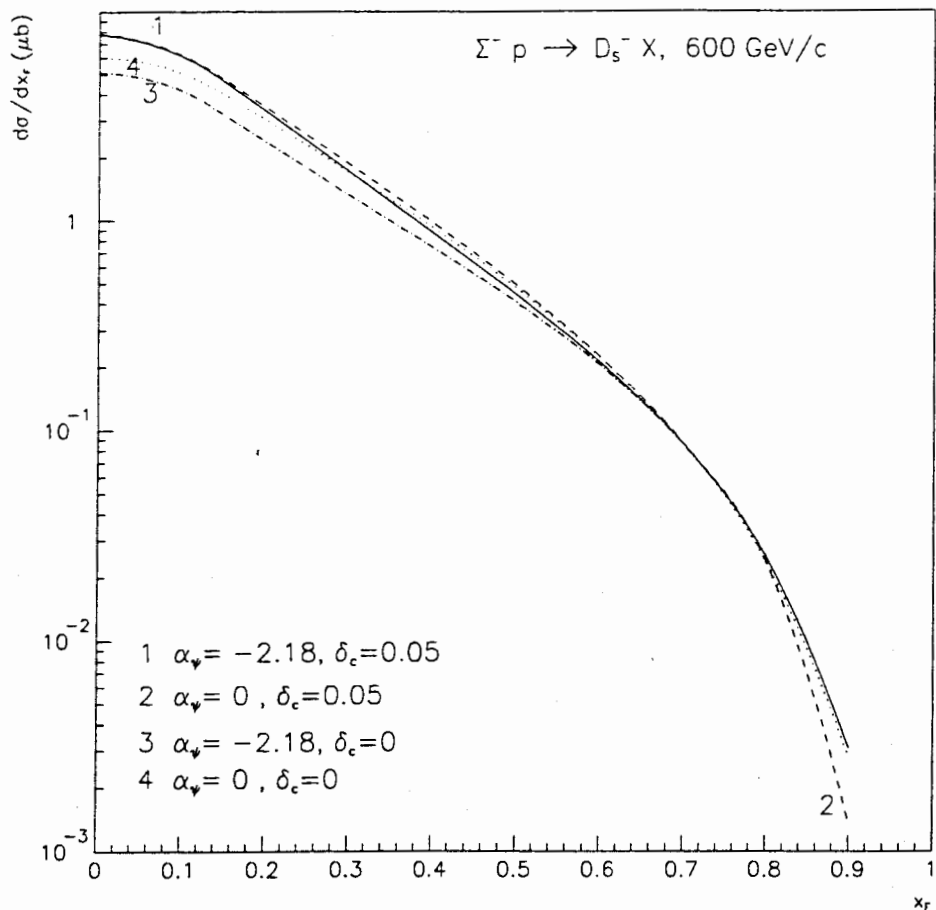Fig.6. Model prediction for the x_F dependence of the D_s^+–meson cross section in $\Sigma^- p$ interaction at 340 GeV/c. The curves are the same as in Fig.1.

Fig.7. Model prediction for the x_F-- dependence of the D_s^--- meson cross section in $\Sigma^- p$ interaction at 600 GeV/c. The curves are the same as in Fig.1.

Fig.8. Model prediction for the x_F-dependence of the D_s^+-- meson cross section in $\Sigma^- p$ interaction at 600 GeV/c. The curves are the same as in Fig.1.
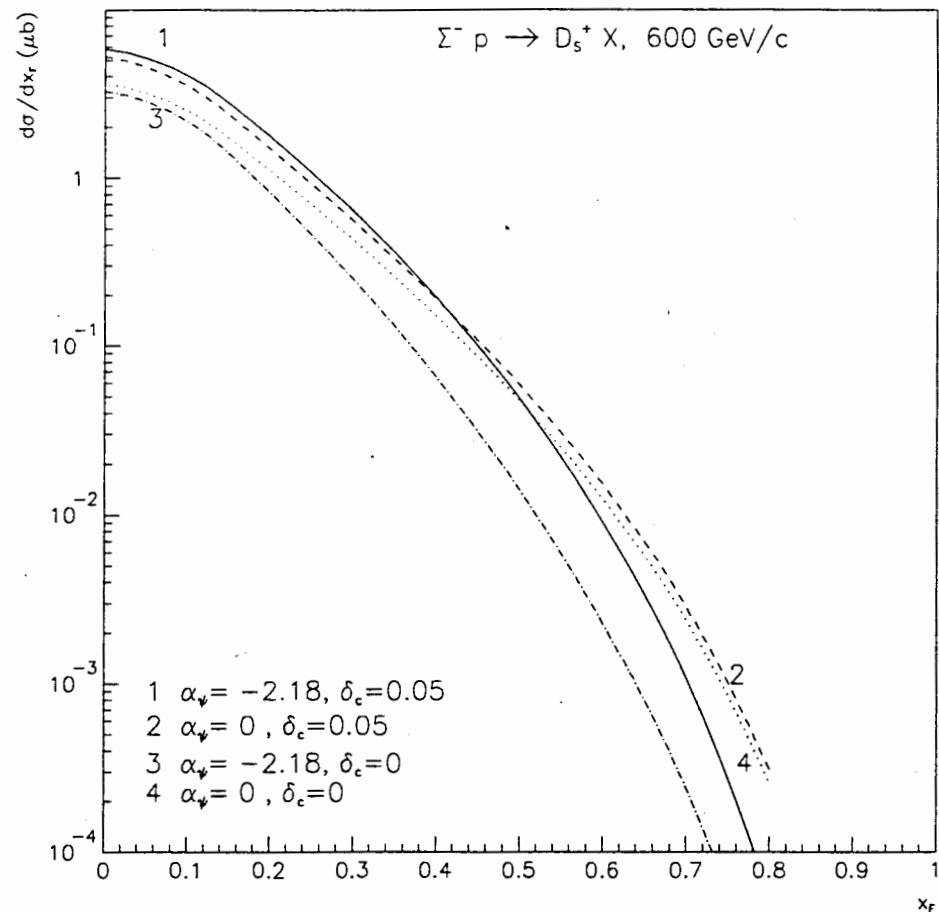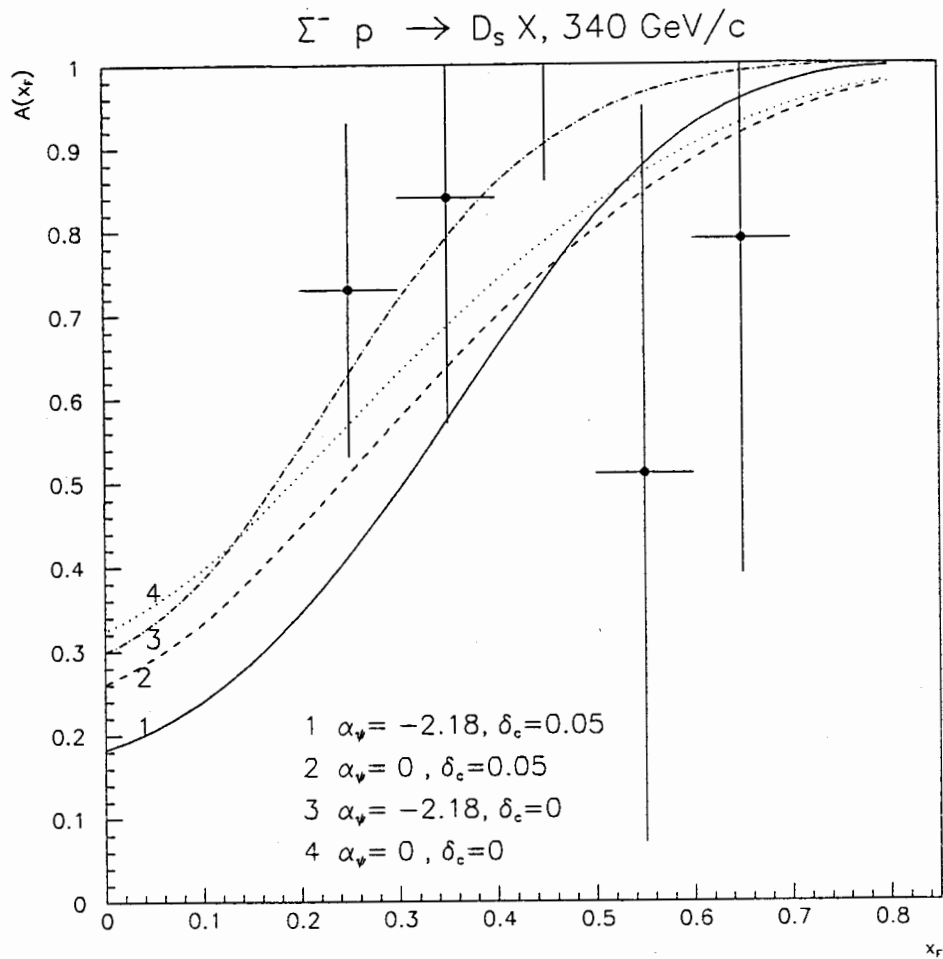
Fig.9.Comparision of the model calculations for the x_F-dependence of D_s^-/D_s^+ asymmetry for the Σ^- beam at 340 GeV/c with the experimental data [11]. The curves are the same as in Fig.1.
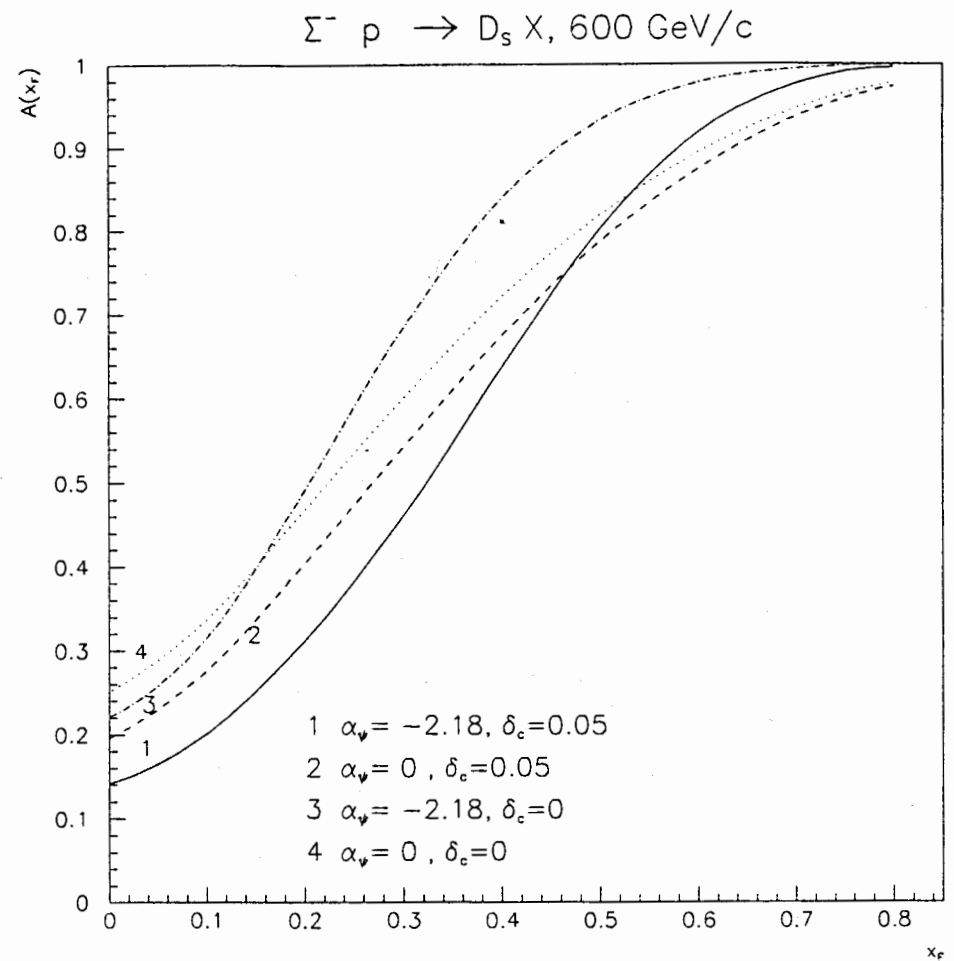
Fig.10. Predictions for the x_F-dependence of D_s^-/D_s^+ asymmetry for the Σ^- beam at 600 GeV/c. The curves are the same as in Fig.1.

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Аракелян Г.Г., Еремян Ш.С.   E2-98-236
Инклюзивное адророждение D_s-мезонов
в модели кварк-глюонных струн

В рамках модифицированной модели кварк-глюонных струн (МКГС), учитывающей вклады от распадов соответствующих S-волновых резонансов, рассматривается адророждение D_s-мезонов. Описаны существующие экспериментальные данные по инклюзивным спектрам D_s-мезонов в πp-столкновении, а также асимметрии рождения лидирующих (D_s^-) и нелидирующих (D_s^+) мезонов в $\Sigma^- p$-взаимодействии. Приведены предсказания для дифференциальных сечений и асимметрии рождения D_s-мезонов в πp- и $\Sigma^- p$-взаимодействиях при различных энергиях начальных частиц.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Arakelyan G.H., Yeremyan Sh.S.   E2-98-236
D_s-Mesons Inclusive Hadroproduction
in the Quark-Gluon String Model

The hadroproduction of D_s mesons is discussed within the framework of the modified Quark-Gluon String model (QGSM) taking into account the decays of corresponding S-wave resonances. A description of the existing experimental data on inclusive spectra of D_s-mesons production in πp-collision and asymmetry of leading (D_s^-) and nonleading (D_s^+) mesons in $\Sigma^- p$-interaction is obtained. The predictions for cross sections and leading/nonleading asymmetry in πp- and $\Sigma^- p$-collision for different initial momenta are also given.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.