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ЦЕНТРАЛЬНЫЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ
ИНФОРМАЦИИ И ТЕХНИКО-ЭКОНОМИЧЕСКИХ ИССЛЕДОВАНИЙ
ПО АТОМНОЙ НАУКЕ И ТЕХНИКЕ

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PRODUCTION OF CHARMED HADRONS
IN PROTON-NUCLEUS COLLISIONS AT HIGH ENERGIES

ЕРЕВАН-1984

At present there exist a number of theoretical approaches [1-3] that predict characteristics of production processes of the particles containing charmed quarks in hadron-hadron collisions. For the analysis of such predictions of certain importance is the correct conversion of appropriate cross sections on the nucleus $pA \rightarrow hch\bar{c}^{+...}$ to elementary cross sections $pp \rightarrow hch\bar{c}^{+...}$, since most experiments on charmed particle production are performed on nuclear targets ($hch\bar{c}$ is the brief notation of a pair of charmed hadrons, in the main $hch\bar{c} = \Lambda_c \bar{D} \otimes D \bar{D}$). In this connection it should be noted that the existing viewpoints [4,5] on the dependence of cross sections of the processes $pA \rightarrow hch\bar{c}^{+...}$ on the atomic number of nucleus A , as a rule, are intuitive and are reduced to the fact that cross section of the process $pp \rightarrow hch\bar{c}^{+...}$ should be multiplied by a factor A^α (appropriate values for α are chosen equal to 1 or 2/3).

It is easy to note, however, that such assumptions are groundless, since if the above approximation is used

$$\frac{d\sigma}{d^3p}^{pA \rightarrow hch\bar{c}^{+...}} = N_{eff} \frac{d\sigma}{d^3p}^{pp \rightarrow hch\bar{c}^{+...}}, N_{eff} = \beta \cdot A^\alpha \quad (1)$$

then, by analogy with processes of production of ordinary hadrons on nuclei [6], the degree α should be the function of the Feynman variable $x \approx \frac{E'}{E}$ (E' is the energy of the detected hadron, E is the energy of the incident particle) and q_{\perp} , which is the transverse component of the momentum transfer. Besides, to describe the process, certain information on factors β is required, since in general $\beta(E, E', q_{\perp}) \neq 1$

The aim of the present paper is the prediction of the quantities α and β for cross sections of the processes $pA \rightarrow \Lambda_c X$ and $pA \rightarrow D X$ in the framework of the multiple scattering theory (MST) [7]. One should also take into account that in the considered range of initial energies (from hundreds GeV to several TeV) the cross sections of charmed particle production on nucleon have an apparent dependence on the incident proton energy [4], which considerably complicates the scheme of appropriate calculations in the framework of MST.

Using the method presented in [8,9], one may obtain the following expressions for inclusive cross sections of the considered processes on a nucleus:

$$\frac{d\sigma}{dx} \quad pA \rightarrow \Lambda_c(\bar{D})X \quad (x, E) = \frac{1}{(2\pi)^2} \int_{-\infty}^{\infty} d\alpha \int_{-\infty}^{\infty} d\alpha' \Omega_{12}(\alpha, \alpha', E) \frac{e^{i\alpha \ln x}}{x} \times \quad (2)$$

$$\times N(\sigma_1^{in} - \omega_{11}^{in}(\alpha, \alpha'); \sigma_2^{in} - \omega_{22}^{in}(\alpha)),$$

where indices 1 and 2 correspond to the incident proton and baryon (or D-meson), respectively,

$$\Omega_{12}(\alpha, \alpha', E) = \int \frac{1}{x'} \frac{d\sigma_{12}(x, x', E)}{dx} e^{-i\alpha \ln x + i\alpha' \ln x'} dx dx'$$

$$\omega_{11}(\alpha, \alpha') = \int \frac{d\sigma_{11}(x)}{dx} e^{-i(\alpha + \alpha') \ln x} dx,$$

$$\omega_{22}(\alpha) = \int \frac{d\sigma_{22}(x)}{dx} e^{-i\alpha \ln x} dx;$$

$\frac{d\sigma_{ij}}{dx}$ are the cross sections of elementary inclusive processes $i + N \rightarrow j + X$ normalized according to $\int \frac{d\sigma_{ij}}{dx} dx = \sigma_{ij}$ ($x = \frac{E'}{E}$)

$$N(\sigma_1, \sigma_2) = \int d^2B \frac{e^{-\sigma_1 T(\vec{B})} - e^{-\sigma_2 T(\vec{B})}}{\sigma_2 - \sigma_1},$$

$T(\vec{B}) = \int \rho(\vec{B}, z) dz$ is the projection of the one-particle nuclear density $\rho(\vec{r})$ on the plane of the impact parameter.

The cross sections $\frac{d\sigma}{dx} \quad pA \rightarrow \Lambda_c(\bar{D})X$ have been calculated by the expansion of the integrand (2) by powers of the values ω_{ij}^{in} ($i=1,2$). The consideration of the first five terms of expansion has allowed description of the process $pA \rightarrow \Lambda_c X$ at values of the variable x from 0.2 to 1, and for the process $pA \rightarrow DX$ at $0.1 < x < 1$. (The relative value of the correction due to subsequent terms of expansion does not exceed 2% on the lower boundary of the variable x and is negligible at $x \rightarrow 1$).

In calculations we have made use of the Fermi distribution for the one-particle nuclear density [10]

$$\rho(z) = \rho_0 / (1 + \exp\{\frac{z-R}{c}\}) \quad (3)$$

differential cross sections of elementary acts are chosen as follows:

$$\frac{d\sigma}{dx} (pN \rightarrow \Lambda_c X) \sim (1-x)^{0.4}; \quad \frac{d\sigma}{dx} (pN \rightarrow DX) \sim \frac{(1-x)^3}{x} \quad (4)$$

in accord with ISR data [11,12]; $\frac{d\sigma}{dx} (pN \rightarrow pX) = \sigma_p^{in}$ (with account of the possibility of the proton-neutron transition, since $\sigma(pN \rightarrow hc\bar{h}\bar{c} + \dots) \approx \sigma(nN \rightarrow hc\bar{h}\bar{c} + \dots)$). As for the dependence of cross sections $pN \rightarrow \Lambda_c(\bar{D})X$ on the incident proton energy, here we have used results of [3] that are consistent with experimental data [4]. The simplified parametrization of the theoretical curve [3] may be written as

$$\sigma(pN \rightarrow \Lambda_c(\bar{D})X) \sim 1 - 3.71 \ln E + 0.728 \ln^2 E = F(E) \quad (5)$$

(E > 122.5 GeV).

Note that we have proceeded from the factorized dependence (see [3]) of inclusive cross sections of the processes $pN \rightarrow \Lambda_c(\Xi)X$ on the variable x and energy of the incident proton.

In choosing parametrizations for inclusive cross sections of the processes $\Lambda_c N \rightarrow \Lambda_c X$ and $\Xi N \rightarrow \Xi X$, we have made use of the condition of smallness of the c-quark-nucleon interaction cross section. In this approximation elasticity coefficients in such processes should be equal to the mean portion of the - quark momentum in a charmed hadron [13] ($\langle x \rangle_{\Lambda_c} = 0.71$; $\langle x \rangle_{\Xi} = 0.83$ at $M_c = 1.5$ GeV). Parametrizing inclusive cross sections in the simplest form $\frac{d\sigma}{dx} \sim x^a(1-x)$ we will obtain that $\alpha_{\Lambda_c} = 2.5$; $\alpha_{\Xi} = 5$ correspond to the given values of $\langle x \rangle$. Proportional constants are fixed from the conditions:

$$\sigma_{tot}(\Lambda_c N) = \frac{2}{3} \sigma_{tot} + (pN) \approx \sigma_{tot}(\mathcal{N}N)$$

$$\sigma_{tot}(\Xi N) = \frac{1}{2} \sigma_{tot}(\mathcal{N}N)$$

that are valid in the model of constituent quarks and noninteracting c-quark.

The final form of the chosen cross sections is:

$$\frac{d\sigma}{dx}(\Lambda_c N \rightarrow \Lambda_c X) = 15.75 \sigma_{\mathcal{N}N}^{in} x^{2.5}(1-x); \quad \frac{d\sigma}{dx}(\Xi N \rightarrow \Xi X) = 216 \sigma_{\mathcal{N}N}^{in} x^5(1-x) \quad (6)$$

In fig.1a the obtained curves are presented that describe the variation of the degree α in A-dependence (1) as a function of the variable x for the processes $pA \rightarrow \Lambda_c X$ and $pA \rightarrow \Xi X$ at two values of the initial energy of protons - 400 GeV and 2 TeV. Appropriate functions $\beta(x)$ are presented in fig.2a,b.

As it follows from the presented diagrams, values of ef-

fective nucleon numbers (1) depend essentially on x . For example, for the process $pA \rightarrow \Lambda_c X$ at E = 400 GeV the value of the degree α varies from $\alpha \approx 0.44$ at $x \rightarrow 1$ to $\alpha \approx 0.77$ at $x = 0.2$.

Note that in deriving of (2) we have ignored the variation of total inelastic cross sections caused by the energy loss of hadrons at inelastic interactions in nucleus. At considered initial energies their variation is negligible and cannot cause any essential revision of results presented in figs.1,2.

Consider now total cross sections of charmed hadron production on nuclei. Integrating the expression (2) over the variable x , we obtain

$$\sigma^{pA \rightarrow \Lambda_c(\Xi)X}(E) = \frac{1}{2\pi} (dd' \Omega_{12}(0, \alpha', E) N(\sigma_2^{in} - \omega_H^{in}(0, \alpha'); 0)) \quad (7)$$

whence, allowing for (4) and (5), we have

$$N_{eff}^{tot}(E) = \frac{\sigma^{pA \rightarrow \Lambda_c(\Xi)X}}{\sigma^{pN \rightarrow \Lambda_c(\Xi)X}} = \frac{1}{2\pi} \int dd' dx' \frac{e^{i\alpha \ln x'}}{x'} \frac{F(x'E)}{F(E)} N(\sigma_2^{in} - \omega_H^{in}(0, \alpha'); 0) \quad (8)$$

(We have ignored here the contribution from recoil nucleons due to the presence of the effective threshold over initial energy for the process $pN \rightarrow h_c h_c^+ + \dots$).

Thus, the form of effective nucleon numbers $N_{eff}^{tot}(E)$ appears to be the same for the processes $pA \rightarrow \Lambda_c X$ and $pA \rightarrow \Xi X$ which is physically clear due to the choice of dependence (5) common for both processes.

In fig.3 values of $N_{eff}^{tot}(pA \rightarrow \Lambda_c(\Xi)X)$ obtained for various nuclei at two values of the initial energy of protons (400 GeV and 2 TeV) are presented as diagrams. Calculation of values has been performed in accord with (8) using the distribution (3) for the one-nucleon nuclear density. Note that if we judge of the proportional rise with the increase in the atomic number,

appropriate values of the degrees α for the given curves make $\alpha \approx 0.78$ at $E = 400$ GeV and $\alpha \approx 0.81$ at $E = 2$ TeV and differ from traditional values $2/3$ and 1 .

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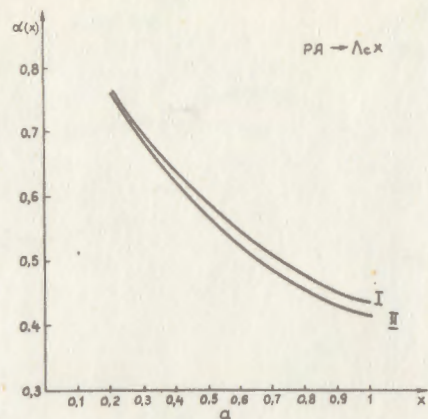


Рис. 1а

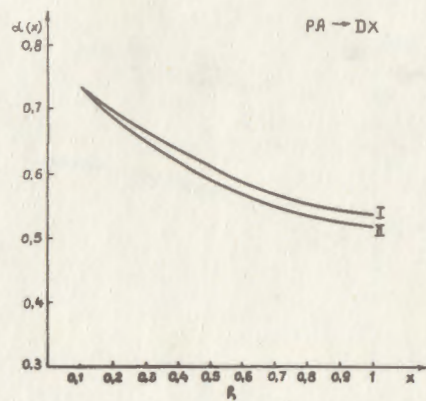


Рис. 1б

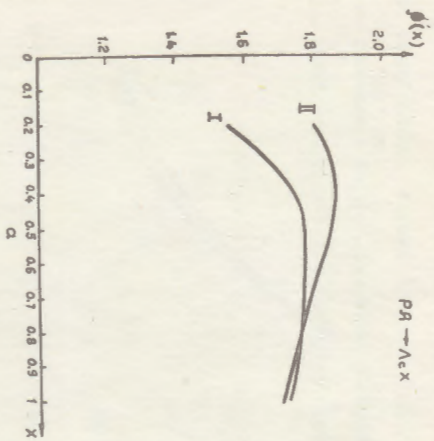


FIG. 2.8

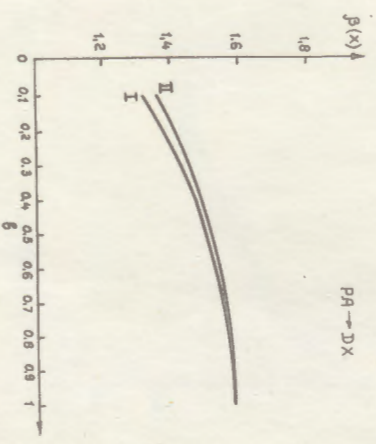


FIG. 2.6

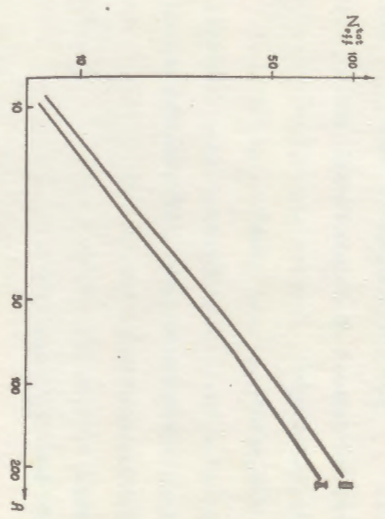


FIG. 3

Figure Captions

Fig.1. Degrees α in the A-dependence of inclusive cross sections of the processes $pA \rightarrow \Lambda_c X$ and $pA \rightarrow \Xi X$ at various values of the variable x .

I - E = 400 GeV.

II - E = 2 TeV.

Fig.2. Factors β for the processes $pA \rightarrow \Lambda_c X$ and $pA \rightarrow \Xi X$ at various values of the variable x .

I - E = 400 GeV.

II - E = 2 TeV.

Fig.3. Values of effective nucleon numbers for total cross sections of the processes $pA \rightarrow \Lambda_c(\Xi)X$ as a function of atomic numbers of nuclei A.

I - E = 400 GeV.

II - E = 2 TeV.

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