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$pA \to \Lambda_c(D)X$ PROCESSES IN THE LEADING HADRON MODEL

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Վ.Մ.ԺԱՄԿՈՉՅԱՆ

$pA \rightarrow \Lambda_c(\mathcal{D})X$ ՊՐՈՑԵՍՆԵՐԸ ԱՌԱՋՆԱՅԻՆ ՀԱԴՐՈՆԻ ՄՈԴԵԼՈՒՄ

Քննված է միջուկների վրա հմայված հադրոնների ծնման ընթացքը սկզբնային պրոտոնների էներգիաների /0,4-150 ՏէՎ/ միջակայքում: Առաջնային հադրոնի բազմակի փոխազդեցությունների մոդելի շրջանակներում, բազմակի գրման տեսության օգնությամբ, կանխատեսված են արդյունարար նուկլոնային թվերի A -կախվածության պարամետրերը, որոնք համապատասխանում են $pA \rightarrow \Lambda_c(\mathcal{D})X$ պրոցեսների դիֆերենցիալ կտրվածքներին:

Երևանի Ֆիզիկայի ինստիտուտ

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Препринт ЕФИ-869(20)-86

В.М.ЖАМКОЧЯН

ПРОЦЕССЫ $PA \to \Lambda_c(\mathcal{D})X$ В МОДЕЛИ ЛИДИРУЮЩЕГО АДРОНА

Рассмотрен процесс рождения очарованных адронов на ядрах в широком диапазоне энергий начальных протонов (0,4 - 150ТэВ). В рамках модели многократных взаимодействий лидирующего адрона с использованием аппарата теории многократного рассеяния предсказаны параметры А-зависимости эффективных нуклонных чисел, соответствующих дифференциальным сечениям процессов $PA \to \Lambda_c(\mathcal{D})X$.

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$pA \to \Lambda_c(\mathcal{D})X$ PROCESSES IN THE LEADING HADRON MODEL

Charmed hadrons production on nuclei in a wide energy range of incident protons (0.4 — 150TeV) is considered. In the framework of the leading hadron multiple interactions model, using the methods of multiple scattering theory, the parameters of the A-dependence of the effective nucleon numbers are predicted which correspond to differential cross sections of $pA \to \Lambda_c(\mathcal{D})X$ processes.

Yerevan Physics Institute
Yerevan 1986

The theoretical investigation of the charmed particle production on nuclei is nowdays actual for the checking of various models [1-3] of charme formation in hadron-hadron interactions. Most of the experiments on charmed hadron production are carried out on nuclear targets and, consequently, the correct conversion of the cross sections on nuclei $hA \rightarrow h_c X$ to elementary cross sections $hp \rightarrow h_c X$ is quite an important problem.

At the investigation of the process $pA \rightarrow \Lambda_c(\mathcal{D})X$ a technique with regard to multiple interactions of the intermediate hadronic state H has been applied in this work. An analogous model has been used in Refs [4,5] for the calculation of the cross sections $h_1 A \rightarrow h_2 X$ $(h_1 = p, \pi^+, K^+ \; ; h_2 = p, \bar{p}, \pi^\pm, K^\pm)$ and allowed to describe all the experimental data on the inclusive spectra of the mentioned cross sections obtained in FNAL [6]. The principal assumptions of the model are:

a) the first act of incident h_1 hadron interaction with nucleon initiates an excited hadronic state H which undergoes multiple inelastic interactions with a cross section equal to the inelastic cross section of $h_1 N$ -interaction.

b) The H state fragmentation into final hadrons h_2 is slowed down to the Lorentz factor $E/m \gg 1$ in the laboratory reference system and takes place out of the nucleus. Due to identity of valence structures of h_1 hadron and H state the cross section $\frac{d\sigma}{dx}(HN \to h_2 X)$, corresponding to the last act of interaction in the nucleus and after fragmentation, coincides with the cross section $\frac{d\sigma}{dx}(h_1 N \to h_2 X)$ (see Refs [7,8]).

With regard to standard approximation

$$\frac{d\sigma}{dx}^{pA \to \Lambda_c(\mathcal{D})X} \Big/ \frac{d\sigma}{dx}^{pN \to \Lambda_c(\mathcal{D})X} = N_{eff}(x) \simeq \beta(x) A^{\alpha(x)} \qquad (1)$$

$$(x = E'/E)$$

the considered problem is reduced to the prediction of the values $\alpha(x)$ and $\beta(x)$, characterizing the A-dependence of the processes $pA \to \Lambda_c X$ and $pA \to \mathcal{D} X$.

In the initial energy of hundreds of GeV to several TeV one should take into account the explicit dependence of elementary cross sections of charmed particles production on the primary hadron energy E [9]. Using the technique presented in Refs [10,11] one may obtain the following expression for the inclusive cross sections of the considered processes on nucleus:

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

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

where

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

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

the indices 1 and 2 correspond to the leading hadron and Λ_c baryon (or $\mathcal{D}$ -meson), respectively;

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

$T(\vec{B})=\int\rho(\vec{B},z)dz$ is the one-particle nuclear density projection on the impact parameter plane. At $E \geqslant 5\,\mathrm{TeV}$ the obvious dependence of the cross section $\frac{d\sigma_{12}}{dx}$ on the energy E may be ignored [9], and the expression (2) obtains the form:

$$\frac{d\sigma}{dx}^{pA\to\Lambda_c(\mathcal{D})X}(x)=\frac{1}{2\pi}\int d\alpha\,\frac{e^{i\alpha\ln x}}{x}\,\omega_{12}(\alpha)\,N(\sigma_1^{in}-\omega_{11}^{in}(\alpha);\,\sigma_1^{in}),\qquad(3)$$

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

Note, that when deriving (2) and (3) and also in Ref.[4], it was assumed that the spectra $\frac{d\sigma}{dx}(pN\to HX)$ and $\frac{d\sigma}{dx}(HN\to HX)$ are identical.

The calculation of the cross sections $\frac{d\sigma}{dx}^{pA\to\Lambda_c(\mathcal{D})X}$ has been carried out by the expansion of the integrands (2) and (3) on powers of the value ω_{11}^{in} according to the equation

$$N(\sigma_1^{in}-\omega_{11}^{in};\,\sigma_1^{in})=\sum_{n=1}^{\infty}\left(\frac{\omega_{11}^{in}}{\sigma_1^{in}}\right)^{n-1}N_n(\sigma_1^{in}),\qquad(4)$$

where

$$N_n(\sigma)=\frac{1}{\sigma n!}\int(\sigma T(B))^n\,e^{-\sigma T(B)}\,d^2B,$$

whence the sought expressions of the differential cross sections come. In particular, the expression (2) transforms into

$$\frac{d\sigma}{dx}^{pA\to\Lambda_c(\mathcal{D})X}=\sum_{n=1}^{\infty}\frac{N_n(\sigma_1^{in})}{(\sigma_1^{in})^{n-1}}\,\Phi_n(x),\qquad(5)$$

where

$$\Phi_n(x)=\int_x^1 dx_1\int_{x/x_1}^1 dx_2\cdots\int_{\frac{x}{x_1\cdots x_{n-2}}}^1\frac{dx_{n-1}}{x_1\cdots x_{n-1}}\,\frac{d\sigma_{11}^{in}}{dx_1}\,\frac{d\sigma_{11}^{in}}{dx_2}\cdots\times$$

$$\times\frac{d\sigma_{11}^{in}}{dx_{n-1}}\left[\frac{d\sigma_{12}}{dx_n}(x_n;\,x_1\cdots x_{n-1}E)\right]_{x_n=\frac{x}{x_1\cdots x_{n-1}}}.$$

(Proceeding from the expressions like (5) one can choose the elementary spectra form without any preassumptions). The taking of the first five terms of the expressions into account allows to describe the process $pA \to \Lambda_c X$ and $pA \to \mathcal{D}X$ when the variable X has the values from 0.1 to 1. (The relative value of the corrections by the following terms of the expression does not exceed 1% at $X = 0.1$ and is vanishingly small at $X \to 1$).

The Fermi distribution for the one-particle nuclear density

$$\rho(r) = \rho_0 / 1 + \exp\left\{\frac{r-R}{c}\right\}$$

together with the parameters in Ref. [12] have been used in the calculations. The differential cross sections of the elementary acts of production have been chosen in the following form:

$$\frac{d\sigma}{dx}(p(H)N \to \Lambda_c X) \sim (1-x)^{0,4}; \quad \frac{d\sigma}{dx}(p(H)N \to \partial X) \sim \frac{(1-x)^3}{x} \qquad (6)$$

in accordance with the data from ISR [13,14].

The exact form of the cross section $\frac{d\sigma}{dx}(p(H)N \to HX)$ can be experimentally determined by measuring the total longitudinal momentum distribution of all particles produced in the pionization and target fragmentation regions. As there are no such data at present, we have used here a simple approximation:

$$\frac{d\sigma}{dx}(p(H)N \to HX) = \sigma^{in}_{PN} - \sigma_{diff} + 10\sigma_{diff}\,\theta(x-0,9). \qquad (7)$$

σ_{diff} - is the cross section of diffraction dissociation of proton (or of the state H), while

$$\int_0^1 \frac{d\sigma}{dx}(p(H)N \to HX)\,dx = \sigma^{in}_{PN}.$$

The values σ^{in}_{PN} and σ_{diff} are determined according to Ref. [15]

at different values of initial energy. As to the dependence of the cross sections $pN \to \Lambda_c(D)X$ on the incident proton energy, the results from Ref.[3] have been used here which are in satisfactory agreement with the experimental data from Ref.[9]. The simplified parametrization of the theoretical curve [3] may be presented as:

$$\sigma(pN \to \Lambda_c(D)X) \sim 1 - 3.71 \ln E + 0.728 \ln^2 E \qquad (122.5\,\mathrm{GeV} < E \leq 5\,\mathrm{TeV}). \tag{8}$$

This parametrization suggests a factorized dependence [3] of the cross sections $pN \to \Lambda_c(D)X$ on the variable X and the incident proton energy.

The calculation of the effective nucleon numbers (1) has been carried out for ^{12}C, ^{27}Al, ^{64}Cu, ^{108}Ag, ^{207}Pb nuclei. In Fig.1(a,b) curves are presented, found after approximation, that show the change of the index α in the A-dependence (1) as a function of the variable X for the processes $pA \to \Lambda_c X$ and $pA \to DX$ at initial proton energies of 400GeV, 2TeV, 30TeV and 150TeV. The corresponding functions $\beta(X)$ are presented in Fig.2(a,b).

As the presented curves show, the values of the effective nucleon numbers are in quite delicate dependence on the variable X. So, e.g., for the process $pA \to \Lambda_c X$ at $E = 2\mathrm{TeV}$ the values of α change from $\alpha \simeq 0.36$ at $X \to 1$ to $\alpha = 0.54$ at $X = 0.1$*.

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*Analogous calculations in the framework of standard approach of the multiple scattering theory bring to considerably different results [16]. So, in the considered case ($pA \to \Lambda_c X$, $E = 2\mathrm{TeV}$) the variation range of α would be 0.42 - 0.87.

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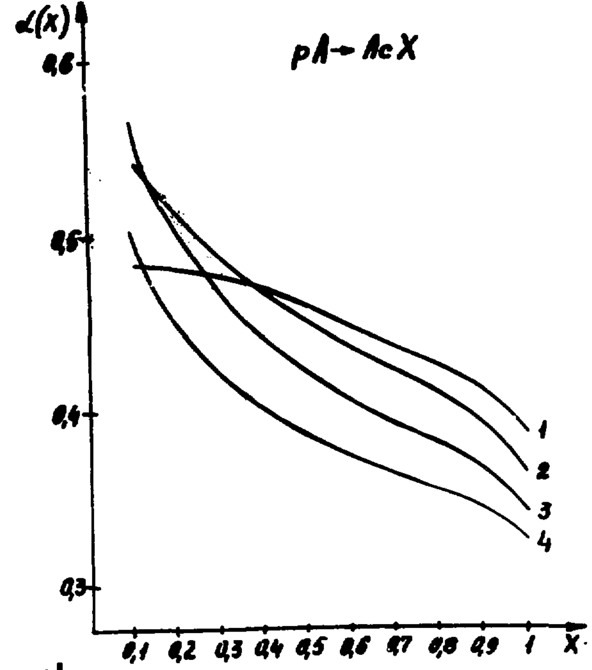

Fig.1a

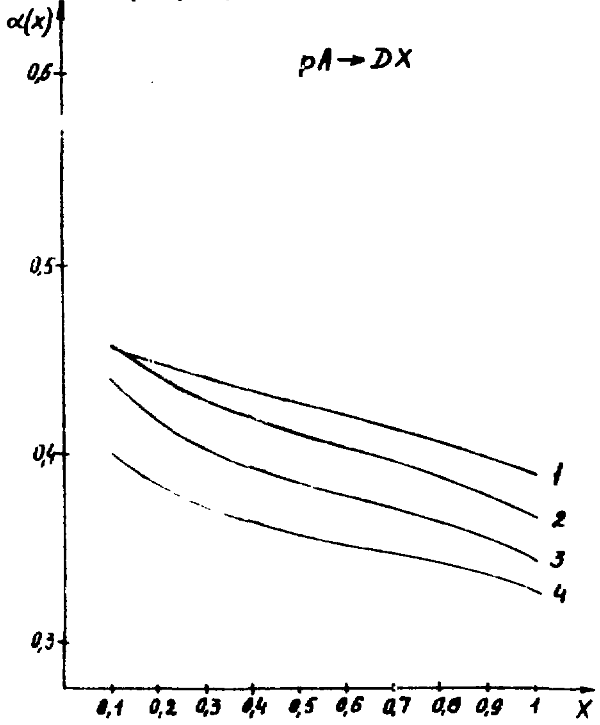

Fig.1b

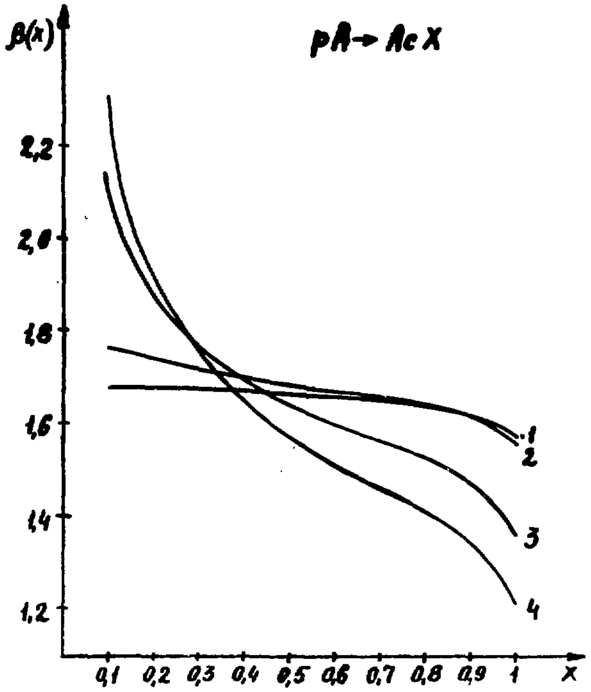
pA→ AcX
β(x)
2,2
2,0
1,8
1,6
1,4
1,2
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
X
1
2
3
4

Fig.2a

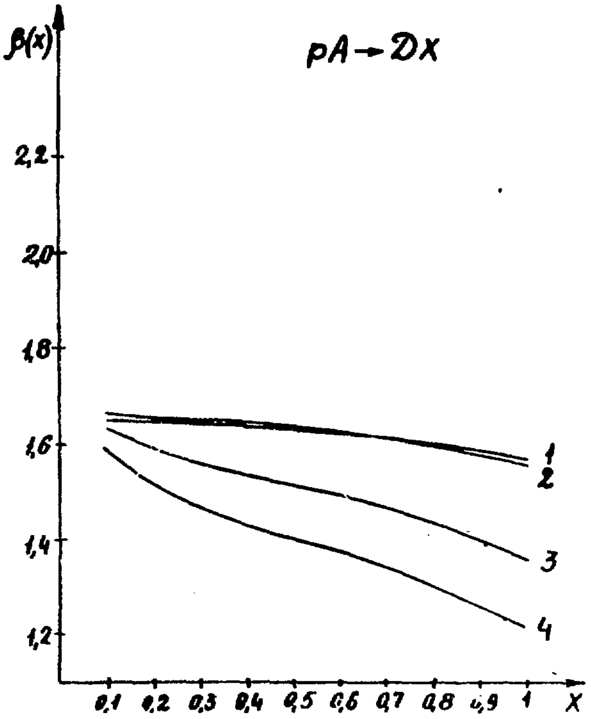
pA→DX
β(x)
2,2
2,0
1,8
1,6
1,4
1,2
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
X
1
2
3
4

Fig.2b

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(на английском языке, перевод Папяна Г.А.)

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