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4905/2-79

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E2 - 12535

G.B.Alaverdyan, A.S.Pak, A.V.Tarasov, Ch.Tseren

DEEP INELASTIC HADRON-NUCLEUS SCATTERING AND THE PROBLEM OF "BARE" PARTICLES

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Submitted to ЯФ

Объединенный институт
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БИБЛИОТЕКА

tion of the momentum-loss spectra. When neglecting the Fermi-motion of intranuclear nucleons the main result of reference[10] can be expressed as

$$\left(\frac{d\sigma}{d\bar{q}\,dE'}\right)_{pA\to pX} = \sum_{n=1}^{\infty}\left(\frac{d\sigma}{d\bar{q}\,dE'}\right)^{(n)} N_n(\sigma,A). \qquad (1)$$

The summation in eq. (1) is taken over number of collisions the fast particle undergoes inside the nucleus. The quantity $N_n(\sigma,A)$ is the effective number of nucleons, $N_n(\sigma,A) = \frac{1}{\sigma n!}\int d\bar{b}\,[\sigma T(\vec{b})]^n \exp[-\sigma T(\vec{b})]$. All the notations correspond to those usually employed in the literature on the subject. The quantity $\left(\frac{d\sigma}{d\vec{q}\,dE'}\right)^{(n)}$ is given by the expression on type

$$\left(\frac{d\sigma}{d\bar{q}dE'}\right)^{(n)} = \int \delta(\bar{q}-\sum_{i=1}^{n}\bar{q}_i)\,\delta(E-E'-\sum_{i=1}^{n}\frac{q_i^2+M_i^{*2}-m^2}{2m}) \times$$
$$\times \prod_{i=1}^{n}\frac{d\sigma(\bar{q}_i, M_i^{*2}, E-\sum_{k=1}^{i-1}\frac{q_k^2+M_k^{*2}-m^2}{2m})}{\sigma\, d\bar{q}_i dM_i^{*2}}\, d\bar{q}_i dM_i^{*2}. \qquad (2)$$

$\bar{q}_i$ being the momentum transfer in the i-th collision, M_i^{*2} being the effective mass squared of the system produced in the i-th collisions and $\frac{d\sigma}{d\bar{q}_i dM_i^{*2}}$ is the cross section of the process $pN\to pX$. It should be noted that the performance of concrete calculations with the aim of describing experimental data is rather a difficult task requiring an account of a number of fine effects both in nuclear and in elementary process $pN\to pX$ cross sections. This can be seen from references[9-10] where the spectra of protons have been analyzed in the reaction $pA\to pX$ for small resulting losses of energy by fast particles $\Delta E \ll E$. A quite reasonable agreement has been achieved between theory and experimental data provided that in formulae of type (1) contributions of terms up to ninth-fold scattering are taken into account.

As a fast particle loses its energy during multiple scattering and formula (1) includes the quantity

$\left(\frac{d\sigma}{d\bar{q}\,dE}\right)^{(n)}$ being a convolution of nucleonic cross sections, in order to develop a correct approach for the treatment of spectra in $pA\to pX$, it is necessary to have strictly speaking, detailed information about the energy dependence of $\left(\frac{d\sigma}{d\bar{q}dM^{*2}}\right)_{pN\to pX}$. Due to the absence of such data one is forced to introduce some simplifying assumptions corresponding to certain experimental conditions under which the data considered had been obtained. So, the specific feature of the data presented in[8] is large resulting energy losses of a fast particle ($\Delta E\sim E$). If one assumes that at high energies $\left(E\frac{d^3\sigma}{d^3p}\right)_{pN\to pX}$ is a function of only the transverse momentum and a scaled variable $x=p^{c.m.}/p_0^{c.m.}$, which at $x \gg m^2/s$ (s is the c.m. system total energy squared) is equivalent to $x=p_\parallel^L/p_0^L \approx E'/E$, then considerable simplifications can be succeeded for the case of large resulting energy losses. This problem has been solved in reference[11], where the following formula is obtained for the leading particle spectra in pA collisions

$$\left(x\frac{d\sigma}{d\bar{q}\,dx}\right)_{pA\to pX} = \int d\bar{B}\,d\bar{\beta}\,d\alpha\, e^{i\bar{q}\bar{\beta}+i\alpha\ln x} \times$$
$$\times \exp(-\tilde{\sigma}\,T(\bar{B})) \times [\exp(\omega^{in}(\alpha,\bar{\beta})T(\bar{B}))-1],$$

where (3)

$$\tilde{\sigma} = \sigma_{NN}^{tot} - \omega^{el}(\bar{\beta})$$

$$\omega^{el}(\bar{\beta}) = \frac{1}{p^2}\int d\bar{q}_\perp \exp(-i\bar{q}_\perp\bar{\beta})\left(\frac{d\sigma}{d\bar{q}_\perp}\right)_{pN\to pN}$$

$$\omega^{in}(\alpha,\bar{\beta}) = \int d\bar{q}_\perp dx \exp(-i\bar{q}_\perp\bar{\beta}-i\alpha\ln x)\left(\frac{d\sigma}{d\bar{q}_\perp dx}\right)_{pN\to pX}.$$

As an input, formula (3) includes $f(x,\bar{q}_\perp)=\left(\frac{x\,d\sigma}{d\bar{q}_\perp dx}\right)_{pN\to pX}$ and $\left(\frac{d\sigma}{d\bar{q}_\perp}\right)_{pN\to pN}$. Since in the case considered the energies are

Алавердян Г.Б. и др. **E2 - 12535**

Глубоконеупругое рассеяние адронов на ядрах
и проблема "голых" частиц

В рамках теории многократного рассеяния анализируются экспериментальные данные об импульсных спектрах протонов в реакции $p+A\to p+X$ при 19,2 ГэВ/с. Обсуждаются причины обнаружения "голых" состояний частиц другими авторами, анализировавшими эти данные. Расчеты показывают, что теория многократного рассеяния хорошо описывает экспериментальные данные о спектрах лидирующих частиц и о коэффициентах неупругости.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1979

Alaverdyan G.B. et al. **E2 - 12535**

Deep Inelastic Hadron-Nucleus Scattering
and the Problem of "Bare" Particles

The experimental data on inclusive spectra of protons in the reaction $pA\to p+X$ at 19.2 GeV/c are analysed in the framework of multipole scattering theory. The calculations schow that multipole scattering theory gives a good description of experimental data on inclusive spectra of leading particles and inelasticity coefficients in hadron-nucleus collisions. The reasons of obtaining of "bare" states of leading particles by some authers, who have analysed the same data, are discussed.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1979

One of the reasons stimulating investigation of deep inelastic hadron-nucleus scattering is the hope to obtain information about the corresponding processes on nucleons. It is considered that the utilization of nuclear targets provides one with an opportunity to study the space-time developments of stong interactions, and, in particular, to study the properties of hadrons immediately after an interaction takes place within the nucleus. There exists the notion that hadron undergoing an interaction looses its nuclear field which is then regenerated with a characteristic time τ during which it is unable to interact normally. In the literature on the subject such a state is referred to as "bare" ("young", "cut" and so on). The hypothesis in itself is of obvious interest and we shall not discuss here theoretical elaborations related; we consider a series of papers [1-8] where "the proofs" of the existence of "bare" states are given proceeding from the so-called "experimental method". Such proofs for "bare" states were claimed to be given in references [1-4] from the analyses of experimental data on proton spectra in reactions $pA\to pX$ available from [8,9] and in references [5-7] from the analyses of data on the inelasticity coefficients in hadron-nucleus collisions. The analysis of these experimental data is of independent interest and it is performed in the present paper within the framework of the Glauber-Sitenko diffractive multiple scattering theory. By the way, we clarify and discuss in detail all the mistakes the straight forward consequence of which is the conclusion about the "bareness" of leading particles claimed in references [1-7].

1. INTERPRETATION OF DATA ON SPECTRA OF PROTONS IN THE REACTION $pA\to pX$

The theoretical basis for the analysis of experimental data on proton spectra in the reaction $pA\to pX$ is provided by the Kofoed-Hansen generalization [10] of the Glauber formalizm for differential cross section of high-energy quasielastic scattering on nuclei to the case of description of the momentum-loss spectra. When neglecting the Fermi-motion of intranuclear nucleons the main result of reference /10/ can be expressed as

$$\left(\frac{d\sigma}{d\bar{q}dE'}\right)_{pA\to pX} = \sum_{n=1}^{\infty}\left(\frac{d\sigma}{d\bar{q}dE'}\right)^{(n)} N_n(\sigma, A). \qquad (1)$$

The summation in eq. (1) is taken over number of collisions the fast particle undergoes inside the nucleus. The quantity $N_n(\sigma, A)$ is the effective number of nucleons, $N_n(\sigma, A) = \frac{1}{\sigma n!}\int d\bar{b}[\sigma T(\vec{b})]^n \exp[-\sigma T(\vec{b})]$. All the notations correspond to those usually employed in the literature on the subject. The quantity $\left(\frac{d\sigma}{d\vec{q}dE'}\right)^{(n)}$ is given by the expression on type

$$\left(\frac{d\sigma}{d\bar{q}dE'}\right)^{(n)} = \int \delta(\bar{q} - \sum_{i=1}^{n}\bar{q}_i)\,\delta(E - E' - \sum_{i=1}^{n}\frac{q_i^2 + M_i^{*2} - m^2}{2m}) \times$$

$$\times \prod_{i=1}^{n} \frac{d\sigma(\bar{q}_i, M_i^{*2}, E - \sum_{k=1}^{i-1}\frac{q_k^2 + M_k^{*2} - m^2}{2m})}{\sigma\, d\bar{q}_i dM_i^{*2}}\, d\bar{q}_i dM_i^{*2}. \qquad (2)$$

$\bar{q}_i$ being the momentum transfer in the i-th collision, M_i^{*2} being the effective mass squared of the system produced in the i-th collisions and $\frac{d\sigma}{d\bar{q}_i dM_i^{*2}}$ is the cross section of the process $pN\to pX$. It should be noted that the performance of concrete calculations with the aim of describing experimental data is rather a difficult task requiring an account of a number of fine effects both in nuclear and in elementary process $pN\to pX$ cross sections. This can be seen from references /9-10/ where the spectra of protons have been analyzed in the reaction $pA\to pX$ for small resulting losses of energy by fast particles $\Delta E \ll E$. A quite reasonable agreement has been achieved between theory and experimental data provided that in formulae of type (1) contributions of terms up to ninth-fold scattering are taken into account.

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$$\left(x\frac{d\sigma}{d\bar{q}dx}\right)_{pA\to pX} = \int d\bar{B}\, d\bar{\beta}\, d\alpha\, e^{i\bar{q}\bar{\beta} + i\alpha\ln x} \times$$

$$\times \exp(-\tilde{\sigma}\, T(\bar{B})) \times [\exp(\omega^{in}(\alpha, \bar{\beta})T(\bar{B})) - 1],$$

where (3)

$$\tilde{\sigma} = \sigma_{NN}^{tot} - \omega^{el}(\bar{\beta})$$

$$\omega^{el}(\bar{\beta}) = \frac{1}{P^2}\int d\bar{q}_\perp \exp(-i\bar{q}_\perp\bar{\beta})\left(\frac{d\sigma}{d\bar{q}_\perp}\right)_{pN\to pN}$$

$$\omega^{in}(\alpha, \bar{\beta}) = \int d\bar{q}_\perp dx \exp(-i\bar{q}_\perp\bar{\beta} - i\alpha\ln x)\left(\frac{d\sigma}{d\bar{q}_\perp dx}\right)_{pN\to pX}.$$

As an input, formula (3) includes $f(x, \bar{q}_\perp) = \left(\frac{x\,d\sigma}{d\bar{q}_\perp dx}\right)_{pN\to pX}$ and $\left(\frac{d\sigma}{d\bar{q}_\perp}\right)_{pN\to pN}$. Since in the case considered the energies are not asymptotic there may be some scaling violation. The exact form of such a violation is discussed below.

Experimental data on proton spectra in the elementary process $pN \to pX$ were fitted by the function

$$f(x,\bar{q}_\perp) = \frac{C x^{1.5}}{4\pi} B q_\perp K_1(B q_\perp) B^2 \quad , \tag{4}$$

where $B = B_0 + B_1 x$ and $K_1(Bq_\perp)$ was the Hankel function of the imaginary argument. As a result of a fit we obtained $B_0 = (1.56 \pm 0.17)\ (\mathrm{GeV/c})^{-1}$, $B_1 = (5.82 \pm 0.23)\ (\mathrm{GeV/c})^{-1}$ $C = (21.5 \pm 0.2)$ mb and $\Sigma\chi^2$/number degree of freedom =1. The function $f(x, q_\perp)$ was normalyzed to the total inelastic cross section:

$$\int_{x_{min}}^{1} f(x,\bar{q})\frac{dx}{x}\, d\bar{q}_\perp = \sigma^{in} \quad , \tag{5}$$

where $x_{min} = \frac{P_{min}}{P_0}$, P_{min} is a minimal value of leading particle momentum in the laboratory frame ($P^{c.m.}_{min} = 0$). By substituting the numerical values of $x_{min} = (m/2P_0)^{0.5}$ and C into (5), one obtains $\sigma^{in} \simeq 27$ mb, that is consistent with the values $\sigma^{tot}_{pN} = \frac{1}{2}(\sigma^{tot}_{pp} + \sigma^{tot}_{pn}) = (38.4 \pm 0.6)$ and $\sigma^{el}_{pN} = (9.64 \pm 0.73)$ mb. Bearing in mind the approximate constancy of σ^{in}_{pN} in the range (10-20) GeV/c we choose in the numerical calculations the following energy dependence (scale breaking)

$$\left(E\frac{d^3\sigma}{d^3P}\right)_{pN\to pX} = \frac{\sigma^{in} x^{1.5}(BP_\perp/2)K_1(B\cdot P_\perp)}{2\pi[1-(m/2P_0)^{0.25}]} \quad . \tag{6}$$

By substituting into eq. (3) the quantities $\omega^{el}(\vec{\beta})$ and $\omega^{in}(\alpha,\vec{\beta})$, where $\omega^{el}(\vec{\beta})$ is the amplitude of elastic pN scattering, one has

$$\frac{d\sigma}{d\theta\, dP} = \sum_{n=1}^{A}\sum_{k=0}^{A-1} \frac{\sigma^{tot} P_0 x^{1.5}}{2\pi[1-(m/2P_0)^{0.25}]}\left(\frac{\sigma^{in}}{\sigma^{tot}}\right)^n \left(\frac{\sigma^{el}}{\sigma^{tot}}\right)^k \times$$

$$\times \frac{N_{n+k}(\sigma)(n+k)!}{n!\,k!\,(n-1)!\,(2n-1)!}\, 2\, \ln^{n-1}\left\{\frac{(2P_0/m)^{0.25}-1}{(2P/m)^{0.25}-1}\right\} \times I,$$

$$I = \int dz \frac{B^2 z^{2n-1}(BP_\perp/2)^{2n-1}}{2\left(z + \frac{Bk}{2aP_\perp}\right)} \exp\left[-\frac{BP_\perp}{2}\left(z + \frac{1}{z + \frac{Bk}{2aP_\perp}}\right)\right]. \tag{7}$$

The indices n and k belong to the number of inelastic and elastic scatterings of proton with intranuclear nucleons. In numerical calculations we take into account contributions up to the seventh-fold scatterings $(n+k=7)$ and the maximal number of inelastic collisions has been taken to be $n=4$ ($k=3$).

In Table 1 we present the results of the calculations of spectra of protons in $pA \to pX$ for Al, Cu and Pb targets. The experimental data are taken from reference [8]. It is seen that, within experimental errors constituting ~15%, there is quite satisfactory agreement between the calculations and experimental data.

In Table 2, as an illustration, we have listed contributions of different fold scatterings for the lead (Pb) at two values of the momentum of scattered protons (10 and 16 GeV/c) and at two angles (12.5 and 70 mrad). It is seen that the relative contribution of multiple $(n+k \geq 2)$ scatterings grows with increasing the angle (when fixing the $x = P/P_0$ and decreasing x (when fixing the angle θ). This means that large momentum transfers and large energy losses are realized with large probability in multiple scatterings.

In papers [1-5] it has been concluded from an analysis of the experimental data [8,9] that the leading proton is unable to normally interact after the first intranuclear collision. In these article information about the cross section of the repeated interaction was obtained from the analysis of the A dependence of the quantity

$$R = \frac{1}{\sigma^{abs}_{pA}}\left(\frac{d^3\sigma}{d^3p}\right)_{pA\to pX} \Big/ \frac{1}{\sigma^{tot}_{pN}}\left(\frac{d^3\sigma}{d^3p}\right)_{pN\to pX} \tag{8}$$

Table 1

A	θ	P	Exp.	Theor.
Al	I2,5	I0	I,63E-0	I,63E-0
	20	I0	I,40E-0	I,38E-0
	30	I0	I,0IE-0	I,05E-0
	40	I0	7,9IE-I	7,86E-I
	50	I0	5,7IE-I	5,73E-I
	60	I0	4,03E-I	4,IIE-I
	70	I0	2,83E-I	2,9IE-I
	I2,5	I2	2,26E-0	2,29E-0
	20	I2	I,97E-0	I,75E-0
	30	I2	I,IIE-0	I,I7E-0
	40	I2	7,I2E-I	7,60E-I
	50	I2	4,42E-I	4,8IE-I
	60	I2	2,74E-I	2,99E-I
	70	I2	I,67E-I	I,82E-I
	I2,5	I4	2,84E-0	2,95E-0
	20	I4	I,94E-0	2,00E-0
	30	I4	I,02E-0	I,I4E-0
	40	I4	5,56E-I	6,35E-I
	50	I4	2,98E-I	3,4IE-I
	60	I4	I,60E-I	I,79E-I
	70	I4	8,I6E-2	9,26E-2

Table 1 (cont.)

A	θ	P	Exp.	Theor.
Al	I2,5	I6	3,42E-0	3,53E-0
	20	I6	I,92E-0	2,I0E-0
	30	I6	8,92E-I	I,00E-0
	40	I6	4,IIE-I	4,64E-I
	50	I6	I,86E-I	2,07E-I
	60	I6	8,09E-2	9,04E-2
	70	I6	3,26E-2	3,85E-2
Cu	I2,5	I0	2,55E-0	2,33E-0
	20	I0	2,2IE-0	I,99E-0
	30	I0	I,57E-0	I,54E-0
	40	I0	I,27E-0	I,I6E-0
	50	I0	9,30E-I	8,6IE-I
	60	I0	6,62E-I	6,25E-I
	70	I0	4,66E-I	4,48E-I
	I2,5	I2	3,49E-0	3,24E-0
	20	I2	2,67E-0	2,5E-0
	30	I2	I,72E-0	I,70E-0
	40	I2	I,IIE-0	I,I2E-0
	50	I2	6,97E-I	7,2IE-I
	60	I2	4,45E-I	4,55E-I
	70	I2	2,72E-I	2,82E-I

Table 1 (cont.)

A	θ	P	Exp.	Theor.
Cu	I2,5	I4	4,26E-0	4,I3E-0
	20	I4	2,95E-0	2,85E-0
	30	I4	I,58E-0	I,66E-0
	40	I4	8,67E-I	9,37E-I
	50	I4	4,7IE-I	5,I4E-I
	60	I4	2,59E-I	2,75E-I
	70	I4	I,36E-I	I,44E-I
	I2,5	I6	5,I4E-0	4,90E-0
	20	I6	2,89E-0	2,97E-0
	30	I6	I,36E-0	I,45E-0
	40	I6	6,40E-I	6,88E-I
	50	I6	2,95E-I	3,I5E-I
	60	I6	I,32E-I	I,40E-I
	70	I6	5,49E-2	6,I2E-2
Pb	I2,5	I0	4,02E-0	3,63E-0
	20	I0	3,52E-0	3,I2E-0
	30	I0	2,44E-0	2,42E-0
	40	I0	2,06E-0	I,83E-0
	50	I0	I,52E-0	I,36E-0
	60	I0	I,09E-0	9,95E-I
	70	I0	7,77E-I	7,I7E-I

Table 1 (cont.)

A	θ	P	Exp.	Theor.
Pb	I2,5	I2	4,95E-0	5,02E-0
	20	I2	3,8IE-0	3,89E-0
	30	I2	2,68E-0	2,65E-0
	40	I2	I,79E-0	I,75E-0
	50	I2	I,I3E-0	I,I3E-0
	60	I2	7,33E-I	7,22E-I
	70	I2	4,55E-I	4,5IE-I
	I2,5	I4	6,42E-0	6,39E-0
	20	I4	4,63E-0	4,4IE-0
	30	I4	2,47E-0	2,58E-0
	40	I4	I,38E-0	I,46E-0
	50	I4	7,54E-I	8,09E-I
	60	I4	4,20E-I	4,37E-I
	70	I4	2,30E-I	2,3IE-I
Pb	I2,5	I6	8,2IE-0	7,58E-0
	20	I6	4,43E-0	4,60E-0
	30	I6	2,I4E-0	2,26E-0
	40	I6	I,0IE-0	I,07E-0
	50	I6	4,79E-I	4,96E-I
	60	I6	2,20E-I	2,23E-I
	70	I6	9,64E-2	9,83E-2

Table 2

A	P	θ	n	k	$S_{n,k}$	$S_{n,k}$ (%)
Al	I0	I2,5	I	0	I,I6E-0	7I,I
			I	I	I,8IE-I	II,I
			I	2	3,44E-2	2,II
			I	3	6,I7E-3	0,38
			2	0	I,5IE-I	9,25
			2	I	5,54E-2	3,39
			2	2	I,47E-2	0,90
			2	3	3,09E-3	0,I9
			3	0	I,37E-2	0,84
			3	I	7,I3E-3	0,44
			3	2	2,22E-3	0,I4
			3	3	5,05E-4	0,03
			4	0	7,59E-4	0,05
			4	I	4,64E-4	0,03
	I0	70	I	0	I,44E-I	49,4
			I	I	4,89E-2	I6,8
			I	2	I,34E-2	4,6
			I	3	2,95E-3	I,0I
			2	0	3,87E-2	I3,3
			2	I	2,I5E-2	7,38
			2	2	7,I5E-3	2,45
			2	3	I,73E-3	0,59
			3	0	5,67E-3	I,95
			3	I	3,79E-3	I,30
			3	2	I,36E-3	0,47
			3	3	3,47E-3	0,I2

Table 2 (cont.)

A	P	θ	n	k	$S_{n,k}$	$S_{n,k}$ (%)
			4	0	5,0IE-4	0,I7
			4	I	3,65E-4	0,I2
	I6	I2,5	I	0	2,8IE-0	79,6
			I	I	4,67E-I	I3,2
			I	2	8,53E-2	2,4I
			I	3	I,49E-2	0,42
			2	0	I,02E-I	2,89
			2	I	3,65E-2	I,03
			2	2	9,50E-3	0,27
			2	3	I,97E-3	0,05
			3	0	2,60E-3	0,07
			3	I	I,34E-3	0,04
			3	2	4,I5E-4	0,0I
			3	3	9,39E-5	0,0030
			4	0	4,69E-5	0,00I3
			4	I	2,90E-5	0,0006
	I6	70	I	0	I,54E-2	39,9
			I	I	I,00E-2	25,9
			I	2	4,89E-3	I2,7
			I	3	I,60E-3	4,I5
			2	0	2,55E-3	6,6I
			2	I	2,23E-3	5,78
			2	2	I,06E-3	2,75
			2	3	3,27E-4	0,85

Table 2 (cont.)

A	P	θ	n	k	$S_{n,k}$	$S_{n,k}$ (%)
			3	0	I,68E-4	0,44
			3	I	I,54E-4	0,40
			3	2	7,07E-5	0,I8
			3	3	2,IIE-5	0,05
			4	0	5,60E-6	0,0I4
			4	I	5,ICE-6	0,0I3
Pb	I0	I2,5	I	0	2,36E-0	64,9
			I	I	4,27E-I	II,7
			I	2	I,03E-I	2,83
			I	3	2,66E-2	0,73
			2	0	3,57E-I	9,82
			2	I	I,66E-I	4,60
			2	2	6,53E-2	I,80
			2	3	2,I6E-2	0,60
			3	0	4,IIE-2	I,I3
			3	I	3,06E-2	0,85
			3	2	I,45E-2	0,40
			3	3	6,80E-3	0,I9
			4	0	3,20E-3	0,09
			4	I	3,30E-3	0,09
	I0	70	I	0	2,95E-I	4I,I
			I	I	I,I4E-I	I5,9
			I	2	4,02E-2	5,6I
			I	3	I,27E-2	I,77

Table 2 (cont.)

A	P	θ	n	k	$S_{n,k}$	$S_{n,k}$ (%)
			2	0	9,I5E-2	I2,7
			2	I	4,45E-2	6,2I
			2	2	3,08E-2	4,29
			2	3	I,2IE-2	I,69
			3	0	I,70E-2	2,37
			3	I	I,48E-2	2,06
			3	2	9,60E-3	I,34
			3	3	4,30E-3	0,60
			4	0	2,20E-3	0,3I
			4	I	2,50E-3	0,35
	I6	I2,5	I	0	5,73E-0	75,6
			I	I	I,I0E-0	I4,5
			I	2	2,56E-I	3,38
			I	3	6,44E-2	0,85
			2	0	2,40E-I	3,26
			2	I	I,09E-I	I,44
			2	2	4,I0E-2	0,54
			2	3	I,38E-2	0,I8
			3	0	7,80E-4	0,0I
			3	I	5,80E-4	0,007
			3	2	2,90E-4	0,004
			3	3	I,I0E-4	0,00I
			4	0	2,00E-5	0,0003
			4	I	2,00E-5	0,0003

Table 2 (cont.)

A	P	θ	n	k	$S_{n,k}$	$S_{n,k}$(%)
	I6	70	I	0	3,I5E-2	32,0
			I	I	2,36E-2	24,0
			I	2	I,47E-2	I4,9
			I	3	6,90E-3	7,0I
			2	0	6,00E-3	6,I0
			2	I	6,70E-3	6,8I
			2	2	4,60E-3	4,68
			2	3	2,30E-3	2,34
			3	0	5,00E-4	0,5I
			3	I	6,00E-4	0,6I
			3	2	5,00E-4	0,5I

Table 3

k_N \ n		I	2	3	4	5	6	7	8	9	I0
0,4	$R^{(n)}$	I,000	0,765	0,392	0,I59	0,053	0,0I5	0,004	0,00I	0,000	0,000
0,5	$R^{(n)}$	I,000	0,556	0,202	0,057	0,0I3	0,003	0,000	0,000	0,000	0,000
0,6	$R^{(n)}$	I,000	0,392	0,099	0,0I9	0,003	0,000	0,000	0,000	0,000	0,000

Table 4

	A	I2	27	64	I08	207
k_N = 0,4	k_A	0,4I4	0,423	0,427	0,427	0,427
k_N = 0,5	k_A	0,427	0,432	0,434	0,434	0,434
k_N = 0,6	k_A	0,436	0,439	0,439	0,439	0,439

at values of momentum and angle of secondary protons equal P =16 GeV/c and θ =12.5 mrad, respectively. The authors claim that one of the advantages of their approache is the so-called model independence,the meaning of which is that the ratio R is made to be independent of the spectrum shape on nucleons. This is achived by presenting the spectrum on nucleus $(E\frac{d^3\sigma}{d^3p})_{pA\to pX}$ in the form

$$(E\frac{d^3\sigma}{d^3P})_{pA\to pX} = (E\frac{d^3\sigma}{d^3P})_{pN\to pX} N(\sigma,\sigma'), \tag{9}$$

where

$$N(\sigma,\sigma') = \int d\bar{b}\,(e^{-\sigma T(\bar{b})} - e^{-\sigma' T(\bar{b})})/(\sigma'-\sigma) \tag{10}$$

is the effective number of nucleons introduced in ref. /12/, and σ' is the absorption cross section of a "bare" proton defining the probability of repeated interactions. Substituting eq. (9) into (8) we have

$$R = \frac{\sigma^{tot}_{pN}}{\sigma^{abs}_{pA}} N(\sigma,\sigma'). \tag{11}$$

If one takes into account that $N(\sigma,\sigma') = N_1(\sigma)$ for $\sigma'=\sigma$, then it is easy to understand that the actual meaning of eq. (11) is that the only first term from formula (1) is taken to describe the spectrum on the nucleus. One can see from Table 2 that the use of single-scattering approximation for A =207, P =16 GeV/c and θ =12.5 mrad understates the ratio R to 25%. Further, when calculating quantity (11), the authors use for nuclear density either the model of uniform density distribution /2,4/ or trapezium type distribution /3,5/. For the first case an estimate $\sigma' < \frac{1}{6}\sigma_{pN}$ is obtained /2,4/ for the second one /3,5/ $\sigma' < \frac{1}{3}\sigma_{pN}$ *.

Figure 1 shows the shape of the function under integration for the effective number $N_1(\sigma)$. It is seen that the

*It is curious that the authors in no way discuss this variation of the degree of "bareness" from the value $\frac{5}{6}\sigma_{pN}$ $\frac{2}{3}\sigma_{pN}$.

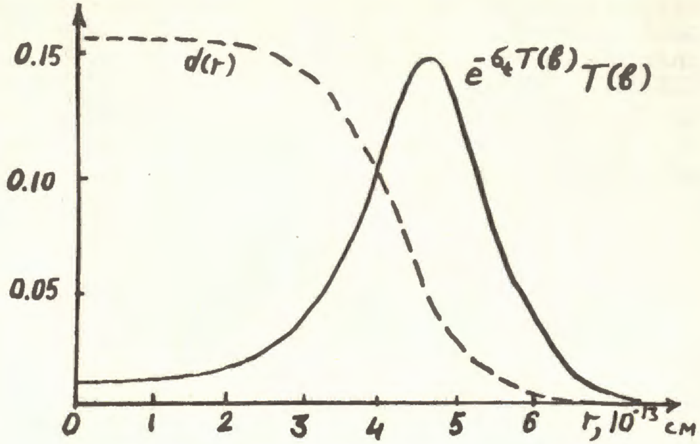

Fig.1. The shape of the function under integration for the effective number $N_1(\sigma, A) = \int T(b) e^{-\sigma T(b)} d^2b$.

main contribution to the integral comes from values of the function near the nuclear surface. It is obvious that the shape of the function under integration and consequently the numerical values of $N_1(\sigma)$ and $N(\sigma, \sigma')$ essentially depend on the model of nuclear density. In figure 2 taken from reference /18/ the A dependence of $N_1(\sigma)$ is presented calculated for the model of the uniform sphere (curve 1) and for the Fermi model (curve 2). It is seen that for heavy nuclei, the discrepancy reaches 50-60%. It should be noted that even for realistic Fermi destribution the numerical values of $N_1(\sigma)$ strongly depend on the parameter of diffuseness.

Thus, the neglect of contribution of multiple scattering and incorrect calculation of contribution of single fold scatterings lead to the result that the quantity defined by eq. (8) appears to be underestimated to 75-90%.In order to coordinate their calculations with experimental data the authors of references /1-5/ decrease the value of σ, which defines an absorption and the particle becomes "bare" in one case to 5/6 and in the second one to 2/3. As they describe not the spectra, but only one point for each nucleus, they are able to come to an agreement with the experimental data. If they had tried to describe the quantity R at other values of the secondary particle

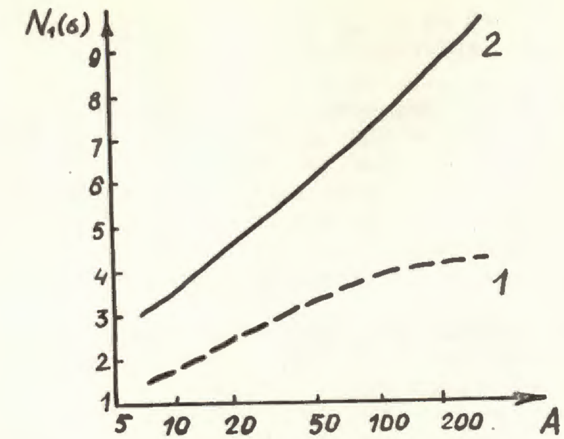

Fig.2. The A-dependence of $N_1(\sigma,A)$ is presented calculated for the model of the uniform sphere (curve 1) and for the Fermi model (curve 2).

angle or momentum, using the same value of σ' (even with account of many-fold scatterings) as they obtained, they would have been forced to vary again the value of σ', i.e., the degree of "bareness" of the leading particle would depend on x and θ. Of course, as is shown above, all these complications are entirely unnecessary, if the calculations are perfromed correctly.

A few words about models of hadron-nucleus interactions, in which the leading particle becomes "entirely bare" and $\sigma'=0$ after the first collision /14/ *. It is quite obvious from the above discussion that in such models ratio (8) is equal to $R = (\frac{d^3\sigma}{d^3p})_{pA\to pX} / (\frac{d^3\sigma}{d^3p})_{pN\to pX} = N(0,\sigma)$ and does not depend either on x nor on θ.Of course, this positively contradicts the experimental data.

* The authors of paper /14/ consider this as a proven fact on the basis of papers of type /1-7/.

2. ANALYSIS OF DATA ON INELASTICITY COEFFICIENTS

It is considered that one of the most convincing arguments supporting the existence of "bare" states is the weak A-dependence (or even, at some conditions, independence) of inelasticity coefficients established in hadron-nucleus interactions. It should be noted, of course, that the data on inelasticity coefficients are scarce and not always the results of different groups agree with each other.

Let us discuss the data, presented in reference [5]

$$k_A \simeq A^{\alpha}, \qquad \alpha = 0.06 \pm 0.03 \qquad (12)$$

$$k_A = \mathrm{const}(A) = 0.44 \pm 0.01\,. \qquad (13)$$

There, on the basis of (12) and (13) the unsubstantiated claim is made about the weakness of repeated interactions with internuclear nucleons. Actially, the results (12) and (13) are quite interpretable in the multiple scattering theory with normal cross section of repeated interactions.

Let $x = E'/E$ is an amount of energy carried away by fast particle, and, consequently, $(1-x)$ is an amount of lossed energy. Then, by definition we have

$$k_A = \int (1-x)\left(\frac{d\sigma}{dx}\right)_{pA\to pX} dx \Big/ \int \left(\frac{d\sigma}{dx}\right)_{pA\to pX} dx, \qquad (14)$$

where $\left(\frac{d\sigma}{dx}\right)_{pA\to pX}$ is given by formula (3).

In ref. [11] on the basis of eq. (14) the formula has been obtained relating the inelasticity coefficients in $pA(k_A)$ and $pN(k_N)$ collisions

$$k_A = k_N \frac{N(0,\sigma k_N)}{N(0,\sigma)}, \qquad (15)$$

where

$$N(0,\sigma) = \frac{1}{\sigma}\int d\bar{b}\,[1-\exp(-\sigma T(\bar{b}))].$$

Formula, analogous to (15) has been used already in ref. [15], where it is shown that the variation of the quantity k_N in reasonable limits allows one to describe all the totality of experimental data on k_A. It is easy to obtain by using formula (15) that

$$\alpha = 0.12 \quad \text{at} \quad k_N = 0.4,$$
$$\alpha = 0.09 \quad \text{at} \quad k_N = 0.5 \qquad (16)$$
$$\alpha = 0.06 \quad \text{at} \quad k_N = 0.6\,.$$

Thus, result (12) cannot be considered as an evidence of weakness of the repeated interaction. As regards result (13), it has been obtained by averaging of experimental distribution on amount of energy x, carried away by fast particle. Since this distribution is strongly affected at the ends $(x\sim 0,\ x\sim 1)$, experimentally an averaging was performed over the interval $0.3<x<0.9$. Let us discuss the result (13) with the account of this circumstance.

By assuming that the leading particle disctribution on the amount of energy taken away has the form

$$\frac{1}{\sigma}\frac{d\sigma}{dx} = x^{\delta}(1+\delta), \quad \text{where} \quad \delta = \frac{(1-2k_N)}{k_N} \qquad (17)$$

it is easy to obtain that after n-fold interaction of the leading particle inside the nucleus, the corresponding distribution takes the form

$$\frac{1}{\sigma}\frac{d\sigma^{(n)}}{dx} = \frac{1}{\Gamma(n)}\, x^{\delta}\ln^{(n-1)}\left(\frac{1}{x}\right)(1+\delta)^n, \quad \frac{1}{\sigma}\int_0^1 \frac{1}{x}\frac{d\sigma^{(n)}}{dx}dx = 1\,. \qquad (18)$$

It is seen from (18) that particles undergoing many scatterings are concentrated at small values of x, $x\sim 0$. Therefore, the neglect of events with $0<x<0.3$ is equivalent to depression of the mechanism of multiple scatterings. The degree of depression of n-fold scattering in comparison with single-fold ones can be studied through the ratio

$$R^{(n)} = \int_{x_{min}}^{x_{max}} \frac{d\sigma^{(n)}}{dx}dx \Big/ \int_{x_{min}}^{x_{max}} \frac{d\sigma^{(1)}}{dx}dx\,. \qquad (19)$$

Table 3 presents the values of $R^{(n)}$ calculated for different values of k_N and at x_{min} =0.3 and x_{max} =0.9. One can see that effects of many-fold scatterings leading to the A-dependence of inelasticity coefficients k_A are simply depressed by an inefficiency of the experimental set-up.

Results of a calculation of k_A following the formula

$$k_A = \sum_{n=1}^{\infty} W_n \int_{x_{min}}^{x_{max}} (1-x) \frac{d\sigma^{(n)}}{dx} dx \Big/ \sum_{n=1}^{\infty} W_n \int_{x_{min}}^{x_{max}} \frac{d\sigma^{(n)}}{dx} dx, \qquad (20)$$

where $W_n = \frac{N_n(\sigma)}{N(0,\sigma)}$ are presented in Table 4. It is seen that independently of the input value of k_N, the inelasticity coefficient in pA collisions appears to be practically independent on A and is equal k_A =0.44. So, the result (13) also does not contradict the model of multiple scatterings with normal cross section of the repeated interaction.

Finally, it is necessary to mention the measurement of inelasticity coefficients in πEm interactions at P_π=50-60 GeV/c performed recently and the intepretation of these data by authors of refs. /6,7/. Values $k(\pi N)$ =0.63 ± 0.03 and $K(\pi Em)$ =0.81 ± 0.03, defined in these papers are in agreement with each other in the framework of multiple scattering model with normal cross sections. This can easily be established using formula (15). But the authors make an original attempt to estimate the value of repeated interaction cross section in accordance with the following scheme

$$(1-k_A) = (1-k_N)^{\tilde{\nu}} \qquad (21)$$

and later

$$\sigma' = \frac{(\tilde{\nu}-1)\sigma}{\bar{\nu}-1}. \qquad (22)$$

Here $\tilde{\nu}$ is the average number of interactions the fast particle undergoes inside the nucleus, "experimentally defined" from eq. (21), and $\bar{\nu} = \Sigma \nu W_\nu = \frac{A\sigma_{\pi N}}{\sigma_{\pi A}}$ in the average number of interactions calculated in accordance with the multiple scattering model with normal cross section. The incorrect character of the procedure of obtaining of the value of $\tilde{\nu}$ from eq. (21) becomes obvious, if one takes into account that

$$1-k_A = \sum_{n=1}^{\infty} W_n (1-k_N)^n \qquad (23)$$

and not

$$1-k_A = (1-k_N)^{\sum_{\nu=1}^{\infty} \nu W_\nu} = (1-k_N)^{\bar{\nu}}. \qquad (24)$$

Equation (23) coincides with (24) only if W_n is a δ-function. Thus, the estimate of σ' in accordance with eq. (21) and (22) cannot be taken seriously.

3. CONCLUSIONS

The multiple scattering theory successfully describes experimental data on the leading particle spectra and on inelasticity coefficients with the cross section of repeated collisions which is equal to the cross section of the incident hadron.

Conclusions about the existence of bare particles drawn in refs. /1-7/ are, as is shown in the present paper, the consequences of a series of mistakes. The subjective wishes of the authors of refs. /1-7/ to observe "bare" particles have played here not the last part.

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Received by Publishing Department
on June 11 1979.