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ON THE EMISSION OF TARGET FRAGMENTS IN HADRON-NUCLEUS COLLISIONS

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1. INTRODUCTION

Hadron-nucleus collision studies have principally provided us with results on target fragmentation and particle production. It is known now that collision events are observed in which target fragmentation occurs without particle production, even at incident hadron kinetic energy much larger than the threshold for the pion production /1-3/. Characteristics of the target fragmentation process do not differ markedly in both the subclasses of hadron-nucleus collision events, when particles are produced or not /3-5/.These facts allow to conclude that particle production process, the pion production in particular, is not responsible for the target fragmentation and, therefore, the fragmentation can be analysed separately - as a process independent of the particle production one.

The subject of this work is a new view-point on the target fragment emission in hadron-nucleus collisions. It seems to be possible by this time to make some decisive contribution towards the clarification of some physical meaning of characteristics of the target fragmentation obtained experimentally.
The present paper contains six sections. After this short introduction, in the second section we formulate a terminology and give some definitions. Section three contains a short review of appropriate experimantal data.On the basis of these data we create a new picture of the target fragment emission process in section four. In section five we discuss main results obtained in our present investigations. Section six contains some short programme of further experimental testing of the point of view presented in this paper.

2. TERMINOLOGY AND DEFINITIONS

Since the work of Brown et al. /6/, tracks of the target fragments left in photoemulsions we separate usually into heavy tracks, or h-tracks. Heavy track leaving particles cause in emulsion grain density larger then 1.4 times that of primary relativistic protons; they are protons and heavier fragments from the desintegrated target nucleus.

Heavy tracks are further divided into black and grey tracks, or b- and g-tracks. Black tracks leaving particles cause grain density ~8.5 greater than that of the plateau; they are low-energy singly and multiply charged fragments - protons, deuterons, tritons with kinetic energy $E_b \leq 30$ MeV/nucleon and ^{3}He, ^{4}He nuclei with $E_b \leq 300$ MeV/nucleon; the mean kinetic energy of the b-track leaving particles is $\langle E_b \rangle \simeq 20$ MeV. The alpha/proton ratio of black track leaving particles may be smaller than 0.35 to 0.5. Grey track leaving particles cause grain density other than that of black tracks and larger than 1.4 times that of primary relativistic protons; they are also protons of kinetic energy ~30 to ~400 MeV, we call these protons "fast" later on.

We denote the multiplicity of the heavy tracks as n_h, the multiplisity of the black tracks as n_b, and the multiplicity of the grey tracks as n_g; n_h, n_g, and n_b obey the relations:

$$n_h = n_g + n_b , \quad \langle n_h \rangle = \langle n_g \rangle + \langle n_b \rangle , \tag{1}$$

where $\langle \; \rangle$ is for the mean value.

For convenience, we call later the tracks left in other detectors by the h-, g-, and b-track leaving particles simply the h-, g-, and b-tracks,correspondingly, although they may not look grey or black tracks in fact. We will use sometimes simply the terms: h-particles, g-particles, b-particles. It would not do any harm in applying the terms "fast protons", "deutrons", "tritons" and other as well.

In experiments, heavy track leaving particles are characterized by their kinetic energies E_h,emission angles θ_h, and desirably by their identity; by analogy, b- and g-track leaving particles are characterized by their E_b, E_g, θ_b, θ_g, and desirably by their identity.

The emission intensity of h-track leaving particles we determine by the multiplicity n_h of these particles, in an individual hadron-nucleus collision, or by the mean multiplicity $\langle n_h \rangle$ of these particles in a sample of hadron-nucleus collisions. By analogy, we define emission intensities of b- and g-track leaving particles as n_b, n_g, $\langle n_b \rangle$, $\langle n_g \rangle$.

An incident hadron is described by its nature and kinetic energy E.

A target nucleus is determined by its mass- and charge-numbers, A and Z; to a given target nucleus with definite A and Z corresponds definite nucleus diameter D and nucleon density distribution /7/, and definite radially independent ratio N_n/N_p between neutron N_n and proton N_p numbers in it /8/.

The thickness λ of nuclear matter layer, along the hadron path λ in an atomic nucleus, we measure in number of nucleons per some area S; it is convenient to express lengths in nuclear matter in numbers of nucleons per $S = \pi D_o^2$, where $D_o \simeq 1.8$ fm is the nucleon diameter /7/. Any target nucleus is characterized as well by its maximum thickness λ_{max} (nucleons/S) and its mean thickness $\langle \lambda \rangle$ (nucleons/S); these thicknesses can be expressed in (protons/S) too. In other words, any target nucleus can be treated /9/ as a lens-shaped slab of nuclear matter of the maximum thickness λ_{max}, the mean thickness $\langle \lambda \rangle$, and the thickness λ at any distance from the nucleus center.

3. REVIEW OF EXPERIMENTAL DATA

The emission of g- and b-track leaving particles was found experimentally to have several interesting properties.

I. Properties of the Emission of the g-Track Leaving Particles

I.1. The number $n_g = n_p$ of fast protons emitted when a hadron h traverses an atomic nucleus equals /9/ the number n_p of protons contained inside this nucleus within the cylindrical volume $\pi D_o^2 \lambda$ centered on the hadron path λ:

$$n_p = \pi D_o^2 \lambda , \tag{2}$$

where λ is measured in (protons/S); we accept, therefore, that the number n_N of fast nucleons emitted is equal to the namber n_N of nucleons contained within cylindrical volume $\pi D_o^2 \lambda$,because the ratio between the neutron number N_n and the proton number N_p inside the atomic nucleus can be treated as radially independent and equal /8/ $(A - Z)/Z$.The ralation (2) is true for $\lambda \leq D$, where D is the target nucleus diameter expressed in (nucleons/S) and λ is in (nucleons/S); collision events with $n_N > \pi D_o^2 D$ occur in no more than 10-15%, the appearance of such "large n_N events" has a simple physical explanation /10/. Of course, n_N and therefore n_p exhibits a "straggling", but we do not take it into account here, for simplicity.

I.2. The observed frequency distribution $f(n_p, A, E)$ of emitted fast protons in collisions of a hadron of kinetic energy E with an atomic nucleus of the mass number A is simply determined by the target nucleus size and nucleon density distribution in it, when $n_p \leq n_p(D)$, where $n_p(D)$is the number of protons contained within the volume $\pi D_o^2 D$ inside the target nucleus /10/. At E higher than a few GeV the frequency distribution $f(n_p, A, E)$ is energy-independent.

I.3. The mean intensity $\langle n_N \rangle$ of the nucleon emission is determined by the mean target nucleus thickness $\langle \lambda \rangle$ (nucleons/S) and by the total cross-section σ_t for hadron-nucleon collisions /11/. Observed energy-independence of the mean proton multiplicity $\langle n_p \rangle$ at energies higher than a few GeV appears due to very weak energy dependence of the total cross-section for hadron-nucleon collisions; the energy dependence of $\langle n_p \rangle$ at smaller energies reflects the energy loss of incident hadron in nuclear matter [12], and remarkable energy dependence of σ_t at this energy region [11]. Observed A-dependence of the mean intensity of nucleon emission $\langle n_N \rangle$ is determined by the A-dependence of the target nucleus size and nucleon density distribution in it [9,11].

I.4. Hadron-nucleus collision events were observed [1-3] in which fast nucleon emission occurs without particle production, without pion production in particular, even if the incident hadron energy E is much larger than the pion production threshold. At energies smaller than a few GeV incident hadron may be completely stopped and its energy deposited in the target nucleus; such a stopping occurs in association with intensive fast nucleon emission, without particle production [2].

I.5. Energy and momentum spectra, and angular distributions of fast protons emitted are the same in hadron-nucleus collisions with and without particle production, and they are independent of the energy and the identity of the impinging hadron [4,5]. The mean energy of the emitted fast nucleons is about 90 MeV, as it follows from measured mean energy of the emitted fast protons [4]. Energy and momentum spectra, and angular distributions are the same in subgroups of events with various numbers n_p of emitted fast protons.

I.6. Grey track leaving particles exhibit an anisotropic angular distribution [13,14], which stays constant as it has been proved in the energy range over about 2 GeV. Many nucleons are emitted into backward hemisphere, with emission angle up to 180 degrees; the ratio N_F/N_B between the number N_F of protons emitted into forward hemisphere and the number N_B of protons emitted into backward hemisphere is $N_F/N_B = 1.9 \pm 0.1$ and is independent of the class of hadron-nucleus collisions [4].

From these facts it follows that the fast nucleon emission process is not due to the generation in collisions of new particles, pions in particular; fast nucleon emission in some cases proceed in advance of the particle producing collision of incident hadron inside the target nucleus.

II. Properties of Emission of the b-Track Leaving Particles

II.1. Black track leaving particles exhibit an almost isotropic angular distribution [13,15].

II.2. Mean number $\langle n_b \rangle$ of the black track leaving particles is energy independent at projectile energies higher than a few GeV, at smaller energies it may be weakly energy dependent [15,16].

II.3. Mean number $\langle n_b \rangle$ of black track leaving particles is not related to the number of generated pions [15].

II.4. Mean kinetic energy of the emitted black track leaving particles is about 20 MeV and stays constant with incident hadron energy change; it is independent as well of the identity of impinging particle [17].

II.5. The ratio N_F/N_B between the number N_F of the b-track leaving particles directed into forward hemisphere and the number N_B of the black track leaving particles directed into backward hemisphere amounts about 1.1 ± 0.1; it does not depend on n_b, and it is the same for pion-nucleus collisions [18] at 60 and 200 GeV. It is reasonable to accept that N_F/N_B is practically independent of the energy and identity of the impinging hadron.

III. Relations between Characteristics of the b-Track and g-Track Leaving Particle Emission Process

III.1. A large difference between mean energies $\langle E_g \rangle$ and $\langle E_b \rangle$ is independent of the energy and mass of the projectile and of the target mass as well [17].

III.2. A large difference between angular distributions of b- and g-track leaving particles are independent of the energy and identity of the impinging hadron, and on the target nucleus mass number as well.

III.3. The range and angular distributions of the grey track producing particles do not change with incident hadron energy change, as it has been proved at energies larger than about 2 GeV. Still less correlated with the primary energy are the black tracks, their number n_b is proportional to n_g.

III.4. The dependence of the mean number of black track $\langle n_b \rangle$ on the number n_g of grey tracks has the same behaviour through the energy range [13,14] 6.2 GeV to 400 GeV and one linear function describes it well [13]. This linear function for proton-AgBr nuclei collisions passed near the dirigin

$$\langle n_b \rangle = 1.21\, n_g + 1.49\,; \qquad (3)$$

deviation from linearity begins above $n_b > 9$, or $n_h > 16$, where one has less than 15% of all stars /13/. The $<n_b> - n_g$ correlation does not depend on the nature of the incident hadron /14/, i.e., - grey track number n_g determines only the average number $<n_b>$ of emitted b-track leaving fragments. This correlation is completely independent of the number of produced pions /14/. Even if the shower particle multiplicity increases from 2.8 to 16.8 no change is observed in the mean black- and grey-track multiplicities.

III.5. The differential frequency distributions for the stars as function of $n_h = n_g + n_b$, for proton-emulsion nuclei collisions at 6.2-3500 GeV exhibit only small irregularities and differences /13/.

III.6. The multiplicities n_g and n_h obey the relation /13/

$$<n_g/n_h> = <n_g>/<n_h> \simeq \text{const.} = 0.39, \qquad (4)$$

which indicates proportionality between n_g and n_h, and hence between n_b and n_g; this relation is energy-independent.

4. PICTURE OF THE TARGET FRAGMENT EMISSION PROCESS

The discovery of the relation (2) between the fast proton emission intensity n_p (protons/S) and the path length λ (protons/S) of the incident hadron in the target nucleus, together with the relation (3) between $n_g \equiv n_p$ and n_b, provided a starting point for a deduction of a picture of the h-track leaving particle (or target fragment) emission process in hadron-nucleus collisions; this picture should be treated as prompted by experiments.

This picture, if true, should provide qualitative and quantitative explanations of the energy independent relations (3) and (4). It is based on characteristics of the h-track leaving particles obtained in experiments, but it is reasonable to generalize these characteristics to corresponding neutral component as well.

The differnce in energy and angular distributions of g- and b-track leaving particles is indicative of a two-stage character of the h-particle emission; two different processes occur rather, although the b-particle emission process depends on the g-particle emission (relation (3)). As is known experimentally, the $<n_b> - n_g$ linear relation is for more than 85-90% of events; only for about 10-15% of events above $n_h = 16$ and $n_g = 7$ in hadron-AgBr nuclei collisions it is no longer the case. But $n_p \equiv n_g$ obeys the simple relation $n_p = n_g = \pi D_0^2 D$, where D (protons/S) is the target nucleus diameter and D_0 is the nucleon diameter, when $n_p \leq D = 7$ (protons/S) for the hadron-AgBr nuclei collisions. A physical meaning of this limitation will be explained later.

On the basis of above reviewed results of investigations of the h-track leaving particle emission, following picture of the g-track leaving particle and b-track leaving particle emission processes can be drawn:

a) Any high energy hadron causes monotonically an appearance of fast (~ 20-400 MeV) nucleon emission when passes through an atomic nucleus; the emitted nucleons exhibit a differential energy spectrum of the form $N(E_p)\,dE_p \approx E_p^{\gamma}\,dE_p$, where $N(E_p)$ is the number of nucleons per event and per energy unit MeV, and $\gamma = 1.09 \pm 0.02$ as it is found for the emitted protons /15/; the angular distribution of these nucleons is of the form /14/ : $(1/\sigma)[d\sigma/d(\cos\theta)] \sim \exp(0.96\cos\theta)$. The energy spectrum and the angular distribution do not depend on the incident hadron identity and kinetic energy.

b) The intensity n_N of fast nucleons emitted when a hadron traverses the nucleus along a path λ (nucleons/S) equals the namber n_N of nucleons contained within the cylindrical volume $\pi D_0^2 \lambda$ centered on the hadron path: $n_N = \pi D_0^2 \lambda$; this relation is valid for $\lambda \leq D$ (nucleons/S), where D is the target nucleus diameter. The number n_p of fast protons emitted is then $n_p = \pi D_0^2 \lambda (Z/A)$; for Ag nucleus the diameter $D \approx 7$ (protons/S).

c) All the fast nucleons cannot be treated as knock-on recoils /5/; they are predominantly rether products of decays of two- of more-nucleon systems formed when a hadron traversed the target nucleus /5/; the knock-on recoils occur rarely among the fast protons emitted - in no more than about 15% of hadron-nucleus collision events.

d) The nucleon multiplicities n_N, or proton multiplicities n_p, larger than those corresponding to the number of nucleons, or protons, contained within the cylindrical volume $\pi D_0^2 D$ appear when the monotonic fast nucleon emission is disturbed; it is possible to occur when a knock-on recoil nucleon appears in hadron-nucleon collision in matter of energy large enough for causing a monotonic nucleon emission in the target nucleus as well. But, such knock-on recoils appear rarely, because the fraction of hadron-nucleus collision events with large n_p multiplicities amounts usually no more than about 15%.

e) Characteristics of fast nucleon emission do not depend on the pion production process; they are the same in hadron-nucleus collisions in which particles are produced and in the collisions without particle production /4,5/.

f) In result of emission of fast nucleons from the target nucleus a cylindrical damage appears in it. On the walls of such damages the equilibrium of forces acting on nucleons in the atomic nucleus is disturbed, and the nucleons from the walls should be evaporated first of all - just after the fast nucleon emission. The intensity of target fragments evaporated from the cylindrical walls should be determined by the surface layer of nuclear matter as thick approximately as the nucleon radius $D_o/2$ is.

g) The ratio $\langle n_g/n_h \rangle = \langle n_g \rangle / \langle n_h \rangle = \langle n_p \rangle / \langle n_h \rangle$ should be therefore: $\langle n_p \rangle / \langle n_h \rangle = \pi D_o^2 \lambda / [\pi (1.5\, D_o)^2 \lambda] = 0.44 \simeq 0.4$. This value is practically the same as it is stated experimentally /13/.

h) The ratio $\langle n_b \rangle / \langle n_g \rangle$ in any hadron-nucleus collision should be equal to the ratio between volumes $\pi [(1.5 D_o)^2 - D_o^2]\lambda$ and $\pi D_o^2 \lambda$, what gives $\langle n_b \rangle = 1.25\, n_g$. When $n_g = 0$, the incident hadron interacts still with $(A-Z)/Z$ neutrons, to which corresponds $\langle n_b \rangle = 1.25 \frac{A-Z}{Z}$ evaporated fragments. In result we have, for $n_g = 0, 1, 2, \ldots$:

$$\langle n_b \rangle = 1.25 \left(n_g + \frac{A-Z}{Z}\right), \qquad (5)$$

what is the same as the experimentally known relation (3). In fact, for AgBr nuclei it gives $\langle n_b \rangle = 1.25\, n_g + 1.60$, practically the same as the experimentally found dependence /13/(3).

i) As can be shown /11/, $\langle n_g \rangle \equiv \langle n_p \rangle \approx \langle \lambda(A,Z) \rangle$, where $\langle \lambda \rangle$ is the mean thickness of the target nucleus measured in (protons/S), the relation (5) may be rewritten in the form:

$$\langle n_b \rangle \approx 1.25 \left(\langle \lambda(A,Z) \rangle + \frac{A-Z}{Z}\right), \qquad (6)$$

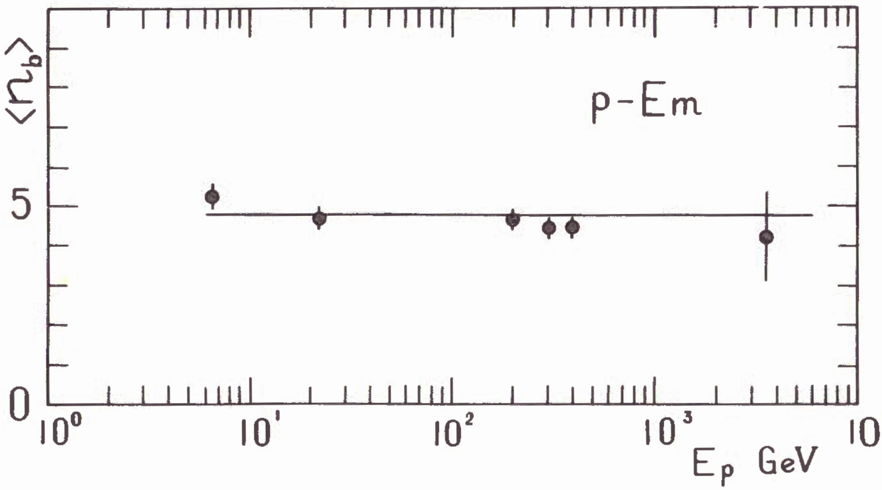

Fig. 1. Experimental testing of formula (6) in proton-emulsion nuclei collisions at 6-3500 GeV.—— predictions given by formula (6), ● experimental data /13,15,19/.

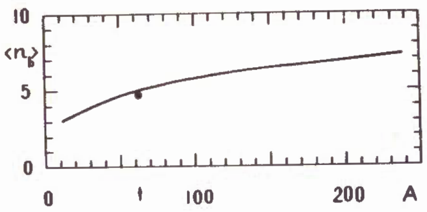

Fig. 2. A-dependence of the emission intensity n_b of the b-track leaving particles. ● experimental point obtained in proton-emulsion nuclei collision studies /13,15,19/ at 6-3500 GeV. The arrow indicates the mean $\langle A \rangle$ for a standard emulsion.

where $\langle n_b' \rangle$ is the mean multiplisity of the b-track leaving particles corresponding to the mean fast proton multiplicity $\langle n_p \rangle$. Formula (6) can be tested directly in experiments, for example - for the proton-AgBr nuclei collisions $\langle \lambda(A,Z) \rangle = 2.78$ (protons/S) and $\langle A \rangle = 94$, $\langle Z \rangle = 41$, formula (6) gives $\langle n_b \rangle = 5.09$ what is the same as the experimentally known value /13/ $\langle n_b \rangle = 5.22 \pm 0.29$ at 22.5 GeV energy of the incident protons. In fig. 1 the calculated $\langle n_b \rangle$ values for proton-emulsion nuclei collisions at various energies are confronted to the experimentally known /13,15/ values at 6-3500 GeV. In fig. 2 A-dependence of $\langle n_b \rangle$ is shown, as predicted by formula (6).

5. DISCUSSION AND SUMMARY

In the picture presented in the preceding section, the g-track leaving particles are emitted from definite cylindrical volume $\pi D_o^2 \lambda$ and the b-track leaving particles are emitted from the $0.5 D_o$ thick wall of definite coaxial pipe $\pi [(1.5 D_o^2)^2 - D_o^2]\lambda$ centered on the incident hadron course along λ in nuclear matter. The ratio between both the volumes v_1 and v_2 is independent of the collision impact parameter $d = (D^2/4 - \lambda^2/4)^{1/2}$, where D is the diameter of the target nucleus, and of the energy E and identity of the incident hadron. Because the number of the grey track leaving particles emitted in a hadron-nucleus collision is determined by the volume v_1 and that of the black leaving particles by v_2, it is clear why an "astonishing" /13/ insensivity to primary energy and identity of the correlation between black and grey tracks occurs.

But, the nuclear matter layer thickness λ involved to the incident hadron interaction in nuclear matter is independent of the hadron energy E when E is larger than a definite energy value ϵ_h for a given nucleus; ϵ_h amounts a few GeV for the heaviest nuclei /12/. When $E < \epsilon_h$, the length λ of the incident hadron in nuclear matter is energy-dependent, because of the energy loss of the hadron, and increases from $\lambda \simeq 1$ (nucleon/S) up to $\lambda = D$ (nucleons/S) with E increase from the pion production threshold $E = E_t$ up to $E = \epsilon_h$. The ratio between v_1 and v_2 is energy-independent but the number n_N of nucleons emitted from the volume v_1 and the number n_f of fragments evaporated from the volume v_2 are energy-dependent, because of the energy-dependence of the length λ; the ratio $<n_N>/<n_f>$ is energy-independent as well. The energy dependences of both the intensities n_N and n_f can be simply determined, as it has been done for the intensity of the fast nucleon emission /11/.

Black track leaving particles exhibit an almost isotropic angular distribution /15/. This is discovered for a sample of any-type hadron-nucleus collision events. But, according the picture drawn above, some anisotropy in angular distribution of the black track leaving particles may be found in a sample of events in which incident hadron is deflected only in its passage through the target nucleus and h-track leaving particles are emitted without particle production (in particular without pion production); the anisotropy should be relative to the plane containing the incident hadron course and perpendicular to the deflection plane. Simular anisotropy in angular distribution of the g-track leaving particles intensity was found and discussed in details in one of my works /20/.

According to our picture the emission of $n_p = 1, 2, 3...$ fast protons involves in average nuclear layer thicknesses $\lambda_1, \lambda_2, \lambda_3, ...$ correspondingly, at definite impact parameters $d_1, d_2, d_3, ...$ The cylindrical volumes $v = v_1 + v_2 = \pi(1.5D_0)^2\lambda$, where $\lambda = \lambda_1 = 1$ (proton/S), $\lambda = \lambda_2 = 2$ (protons/S), $\lambda = \lambda_3 = 3$ (protons/S),... are centered on the hadron courses $\lambda_1, \lambda_2, \lambda_3, ...$ at distances $d_1, d_2, d_3, ...$ from the target nucleus center. In fig.3 it is shown how large part of the target nucleus ejects the h-track leaving particles, in any of the cases under consideration, in proton-Ag collisions.

It will be useful to sketch once again briefly how the emission process of the h-track leaving particles proceeds. From fig.3 it is clear that in any hadron-nucleus collision only an active part of the target nucleus is destroyed, this part is in average as large as the volume $\pi(1.5D_0)^2\lambda$. For various nuclei with the mass numbers of about 100, as for the Ag nucleus, in nearly 90% of collision events the active part is situated in such a way that only the cylindrical part of the residual nucleus, near its surface, is destroyed. The nucleons on the damaged part of the target nucleus surface are not in the equilibrium state as the nucleons on the rest of the nucleus surface and, therefore, evaporate simply. After the emission of the fast nucleons and the evaporation of the target fragments, the residual target nucleus may be in an instable state and then it must decay into stable nuclear fragments. The decay process should proceed in expense of the inner nuclear energy of the residual instable nucleus.

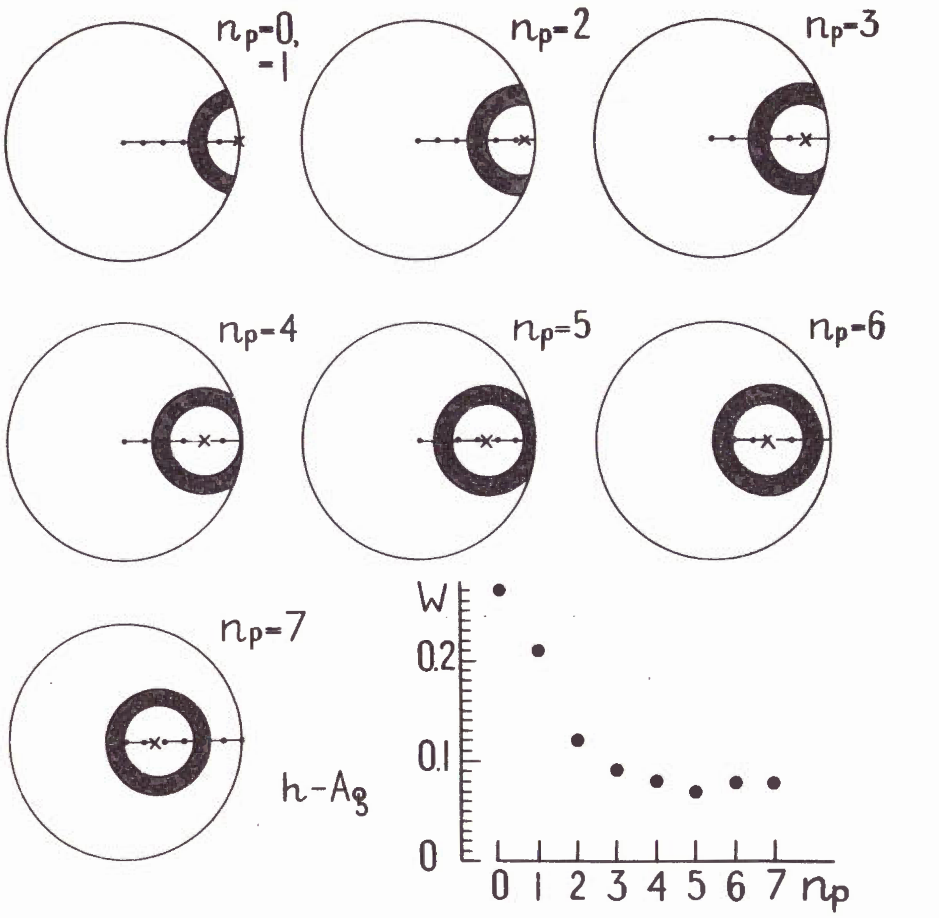

Fig.3. Schematic representation of the parts of the target nucleus involved in the h-track leaving particle emission when the incident hadron hits the Ag nucleus at the impact parameters $d_0, d_1, d_2, d_3, ...$ and causes the emission of $n_p = n_g = 0, 1, 2, 3, ...$ fast protons. The black rings are normal projections of the thicknesses of the walls of the cylinders $\pi[(1.5D_0)^2 - D_0^2]\lambda$ centered on the hadron path λ in nuclear matter; the hadron path is perpendicular to the picture plane at the point x; b - track leaving particles are emitted from the part of the volume $\pi[(1.5D_0)^2 - D_0^2]\lambda$; the g-track leaving particles are emitted from the volume $\pi D_0^2\lambda$, inside the pipe $\pi[(1.5D_0)^2 - D_0^2]\lambda$. The probability of occurrence of proton-Ag collision at impact parameters $d_0, d_1, d_2, d_3, ...$ is denoted by W. It is seen that in almost all collisions the emission of h-track leaving particles goes from the outer part of the target nucleus.

In collisions of hadrons with lighter nuclei, $A \leq 100$, in almost all cases the evaporation of the b-track leaving particles goes from the surface of the residual targer nuclei. When A increases, being $A \geq 100$, the percentage of the surface evaporation descreases slightly, but in almost all events the evaporation is practically from the surface of the destroyed part of the nucleus.

The point of view presented in this paper can be applied for nucleus-nucleus collisions as well. In fact, it is known /17/ that the number of n_g and n_b particles is redistributed so that the ratio $\langle n_g \rangle / \langle n_b \rangle$ increases nearly by a factor of four when proton-Ag collision at 10 GeV is changed for ^{12}C-Ag one. Within the frames of our picture of the n_b-particle emission process, it may be written $\langle n_g \rangle / \langle n_b \rangle = (\pi D_o^2 \lambda) / \{\pi[(1.5 D_o)^2 - D_o^2]\lambda\} = 0.8$, for proton-Ag collisions, and $\langle n_g \rangle / \langle n_b \rangle = (\pi R_c^2 \lambda) / \{\pi[(R_c + 0.5 D_o)^2 - R_c^2]\lambda\} = 3$, for ^{12}C-Ag collisions. Therefore, the relation between the outcomes in proton-Ag and ^{12}C-Ag collisions amounts 3.8, what is near to the value 4 for this relation obtained in the experiment /17/.

6. PREDICTIONS FOR EXPERIMENTAL TESTING

It may be useful to sketch briefly a programme for future experimental testing of the point of view presented in this paper. It is of great importance: a) to find the predicted asymmetry in b-track leaving particle emission relative to the plane containing incident hadron course and perpendicular to the hadron deflection plane, in events with deflected projectile without particle production; b) to test experimentally the $\langle n_b \rangle = f(A)$ relation presented in fig.2; c) to test the relation $\langle n_b \rangle = f(A, n_p)$ presented in fig.4; d) to test the exact formula (6´) for the target fragment mean multiplicity n_b written below; it contains energy-dependence of $\langle n_b \rangle$ as well.

Exact formula for n_b can be obtained without difficulties - one should only put the exact relation between $\langle n_p \rangle$ and $\langle \lambda(A,Z) \rangle$ to formula (5) instead of the quantity n_p ; the relation is /11/

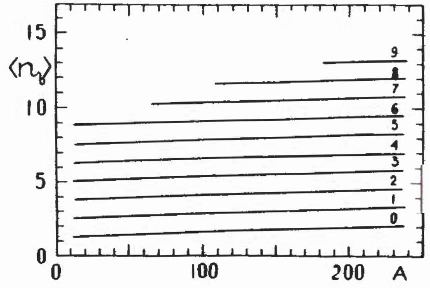

Fig.4. The dependence $\langle n_b \rangle = f(A, n_g)$ predicted by formula (5) for various target nuclei A. Numbers 0,1, 2,3,... on the curves are the multiplicities n_g of emitted fast protons.

$\langle \lambda(A,Z) \rangle (1 - e^{-\langle \lambda(A,Z) \rangle / \langle \lambda_t \rangle})$, where $\langle \lambda_t \rangle$ in (protons/S) is the mean free path for any hadron-nucleon collision inside the target nucleus, related to the total cross-section σ_t for hadron-nucleon collision /11/. It gives:

$$\langle n_b \rangle = 1.25 [\langle \lambda(A,Z) \rangle (1 - e^{-\langle \lambda(A,Z) \rangle / \langle \lambda_t \rangle}) + \frac{A - Z}{Z}]. \qquad (6')$$

The energy-dependence of $\langle n_b \rangle$ is contained in the energy-dependent quantity $\langle \lambda_t \rangle$.

REFERENCES

1. Strugalski Z., Pluta J. Sov.Journ.of Nucl.Phys., 1974, 27, p. 504.
2. Strugalski Z. et al. JINR, E1-11975, Dubna, 1978.
3. Sumbera M., Vokal S. Acta Phys.Slov., 1982, 32, p.265.
4. Strugalski Z. JINR, E1-83-155, Dubna, 1983.
5. Strugalski Z. JINR, E1-83.344, Dubna, 1983.
6. Brown H. et al. Phil.Mag., 1949, 40, p.862.
7. Elton L.R.B. Nuclear Sizes, Oxford Univ.Press, 1961.
8. Strugalski Z. Nucl.Phys., 1966, 87, p.280.
9. Strugalski Z., Pawlak T. JINR, E1-81-378, Dubna, 1981.
10. Strugalski Z. JINR, E1-82-401, Dubna, 1982.
11. Strugalski Z. JINR, E1-83-851, Dubna, 1983.
12. Strugalski Z. JINR, E1-83-850, Dubna, 1983.
13. Winzeler H. Nucl.Phys., 1965, 69, p.661.
14. Otterlund I. et al. Nucl.Phys., 1978, B142, p.445.
15. Tsai-Chü C.O. et al. Nuovo Cim.Lett., 1977, 20, p.257.
16. Bannik B.R. et al. JINR, P-13055, Dubna, 1980.
17. Tolstov K.D. Z.Phys.A - Atoms and Nuclei, 1981, 301, p.339.
18. Babecki J., Nowak G. Inst.of Nucl.Phys., Krakow, Poland, March, 1979.
19. Meyer H. et al. Nuovo Cim., 1963, 28, p.1399.
20. Strugalski Z. JINR, E1-82-802, Dubna, 1982.

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Стругальский З. E1-84-195
Об испускании ядерных фрагментов в столкновениях адрон-ядро

Описывается картина испускания быстрых /~ 20-400 МэВ/ протонов и испарения ядерных фрагментов, следующая из результатов экспериментальных исследований столкновения адрон-ядро. Согласно этой картине: 1/ испускание нуклонов и испарение ядерных фрагментов протекает независимо от процесса рождения частиц; 2/ только некоторая активная часть ядра-мишени, вблизи его внешней области, подвергается разрушению в процессе столкновения в большинстве случаев; 3/ средняя кратность $<n_b>$ испаренных фрагментов подчиняется простому соотношению $<n_b> = 1{,}25(<\lambda(A,Z)> + \frac{A-Z}{Z})$, где $<\lambda(A,Z)>$ есть средняя толщина ядра-мишени, выраженная в числе протонов на некоторую поверхность $S(fm^2)$.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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Strugalski Z. E1-84-195
On the Emission of Target Fragments in Hadron-Nucleus Collisions

A picture of the fast /~ 20-400 MeV/ nucleon emission and target nucleus fragment evaporation in hadron-nucleus collisions is described, as prompted by experimental data. According to it: 1/ The nucleon emission and fragment evaporation proceed independently of the particle production process; 2/ In collisions only an active part of the nucleus, on its outer part, is destroyed predominantly; 3/ The mean multiplicity $<n_b>$ of the evaporated fragments obeys simple relation $<n_b> = 1.25(<\lambda(A,Z)> + \frac{A-Z}{Z})$, where $<\lambda(A,Z>$ is the mean thickness of the target nucleus in protons per some area $S\ fm^2$.

The investigation has been performed at the Laboratory of High Energies, JINR.

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