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CUMULATIVE HADRON PRODUCTION IN QUARK MODELS OF FLUCTON FRAGMENTATION

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1. Introduction

Prediction and experimental discovery of cumulative processes /1/ and their further wide experimental and theoretical investigation caused numerous models for explanation of this interesting phenomenon. Common property of all the models is participation of massive (heavier than a nucleon) internucleus object in the process, on which the production of cumulative particle occurs. Depending on the manner of creation of this object in the rest system of a nucleus, all the models can be divided into "hot" and "cold" ones /2/, i.e. the models, in which the massive object is created by an incident hadron /3/ (due to the multiple rescattering or the "colour charge-exchange" or the fireball formation, etc.) and the models assuming its existence are an inherent property of the nuclear structure. These objects are fluctuations of the nuclear matter density - "Blokhintsev's fluctons" /4/ originally proposed for the explanation of intensive nuclear-fragment knock out and production of high momentum backward protons /5/ and regarded now either as multiquark configurations /6,7/ or as few-nucleon correlations /8/.

As a main experiment allowing one to distinquish between these two big classes of models one may choose a deep inelastic scattering of leptons on nuclei in the region of Bjorken variable values $X > 1$. Since the Bjorken variable can be interpreted as a minimal target mass in nucleon mass units and lepton practically is unable to compress nuclear matter or rescatter, the lepton "sees" structures existing only in a nucleus.

Up to now, in the $X > 1$ region there have been two experimental observations in favour of the "cold" models: the SLAC experiment on a deuterium /9/ $eD \to e'X$ in the $X \lesssim 1.7$ region ($Q^2 \lesssim 8$ GeV^2) and the preliminary data of the NA-4 collaboration /10/ $\mu C \to \mu' X$ in the $X \lesssim 1.5$ region ($Q^2 \simeq 200 \div 300$ GeV^2). However, the first process cannot be regarded as completely deep inelastic one because $W_X \simeq 1.5 \div 2.5$ GeV. The second process is needed to confirm the correctness of the event selection method; thus, one has either to wait for the final NA-4 result or to test it by another collaboration (e.g. NA-37 /11/).

Meanwhile, even now one seems to have an oportunity to obtain quite definite indications of the type of the model. The matter is that in all "cold" models the cumulative particle distribution is proportional to the nuclear structure function which is expressed through the nucleon structure function /12/ ; hence, the relation between different cumulative processes can be obtained. It is done in Section 2. In Section 3 we parametrize the spectrum of cumulative stripping nucleons of a deuterium and check this parametrization for deep inelastic processes on a deuterium; the above-mentioned relation for cumulative pions and K^+-mesons is checked in Section 4. The productions of cumulative mesons on heavier nuclei are also discussed here. In Section 5 we discuss the obtained results and the role of productions of cumulative K^--mesons and antinucleons for investigating quark nuclear structure.

2. Mutual connection of cumulative processes

Common property of the proposed "cold" -type models is that the invariant cross section of the $AB \to hX$ process for the particle in the fragmentation region of the A nucleus at small transverse momentum has the following form:

$$\rho_{A\to h}(x, y, p_\perp) \equiv \frac{\varepsilon d\sigma}{A\, d^3p} = \int\limits_x^A f_h^B\left(\frac{x}{\alpha}, y, p_\perp\right) F_A(\alpha) \frac{d\alpha}{\alpha}, \tag{1}$$

where F_A are the structure functions of a nucleus (divided by the baryon number A), f_h^B is a function whose choice depends on the production mechanism of a particular h-particle rather than of a nucleus, i.e. the same as in the $NB \to hX$ process on a nucleon; x,y - variables will be defined bellow.

Really, the cross section for the limiting fragmentation mechanism /1/ is simply proportional to F_A , i.e. $f_h^B\left(\frac{x}{\alpha}\right) \sim \delta\left(\frac{x}{\alpha} - 1\right)$. The fusion model /13/ is characterized by the same property. For the hard scattering model /6/ , one can easily derive

$$f_h^B\left(\frac{x}{\alpha}, y, p_\perp\right) \sim \int\limits_{y/(1-x/\alpha)}^{1} d\beta\, F_B(\beta)\, \mathcal{D}_h\left(\frac{x}{\alpha} + \frac{y}{\beta}\right) \frac{d\sigma}{dt}\left(\frac{x}{\alpha}, \frac{y}{\beta}, p_\perp\right),$$

where F_B , $\mathcal{D}_h$ and $\frac{d\sigma}{dt}$ are the strcuture function of an incident hadron, the fragmentation function of a scattered parton into h -hadron and the cross section of a parton subprocess, respectively, and $x = -u/s$, $y = -t/s$. Finally, for the dual string model /14/

$$f_h^B\left(\frac{x}{\alpha}\right) \sim \mathcal{D}_h\left(\frac{x}{\alpha}\right).$$

Now, let us consider the nuclear structure function. In the classical potential picture of a nucleus, any structure function is expressed by the nucleon distribution (defined by the one-nucleon wave function) in A nucleus and by the nucleon structure function $F_N(x)$

$$F_A(x, Q^2) = \int\limits_x^A T_A(\alpha)\, F_N\left(\frac{x}{\alpha}, Q^2\right) d\alpha, \tag{2}$$

noting that the T_A distribution must be normalized to conserve the baryon number (when the valence quark distribution F_{3A} is taken for F_A), $\int_0^A T_A(\alpha)\, d\alpha = 1$, and the energy-momentum (when the summary distribution $F_{2A} + G_A$ of all quarks, antiquarks and gluons is taken for F_A), $\int_0^A \alpha T_A(\alpha)\, d\alpha = M_A/A\cdot m \simeq 1$. Substituiton of (2) into (1) immediatelly gives a simple connection between the cross section of the process on a nucleus and that on a nucleon appropriate for the $x > 1$ cumulative region

$$\rho_{A\to h}(x, p_\perp) = \int\limits_x^A T_A(\alpha)\, \rho_{N\to h}\left(\frac{x}{\alpha}, p_\perp\right) \tag{3}$$

Additionally, one can say that the multiquark fluctuation (or the few-nucleon correlations) make contribution to the high-momentum part ($\alpha > 1$) of the T_A -function because, as it is known, the conventional Fermi motion hardly describes this part of the cumulative particle spectrum /15,7/.

However, the investigation of deep inelastic scattering off nuclei shows that the nuclear structure function in general cannot be reduced to that of a nucleon, i.e. there is such a connection like (2) with only one indivisible function T_A for any distribution of quarks and gluons.

This is most brightly revealed in the so-called "EMC-effect" for the ratio of structure functions of the nucleus A and deuteron /16-18/.

The independence of QCD evolution equations of the target type allows one to conclude /19/ that for the nucleus A and nucleon in general there are connections like (2) with three independent distributions: one for the nonsinglet channel (for valence quarks , F_3), T_A^{NS}, normalized on the baryon number conservation

$$F_{3A}(x,Q^2) = \int_x^A T_A^{NS}(\alpha)\, F_{3N}\left(\frac{x}{\alpha}, Q^2\right)\frac{d\alpha}{\alpha}, \quad \int_0^A T_A^{NS}(\alpha)d\alpha = 1 \tag{4}$$

and two for the singlet channel $T_A^{\pm}$ (for the sum of the distribution of all quarks and antiquarks F_2 and gluons G). The analysis of the EMC-effect, however, shows /12/ that, one can obtain a good quantitative description of the ratio R of the structure functions within the whole experimentally known x region, assuming firstly, that $T_A^+ = T_A^- = T_A^S$ normalized on the energy-momentum conservation

$$F_{2A}(x,Q^2) = \int_x^A T_A^S(\alpha)\, F_{2N}\left(\frac{x}{\alpha}, Q^2\right) d\alpha, \quad \int_0^A \alpha\, T_A^S(\alpha) d\alpha = \frac{M_A}{A\cdot m} \simeq 1, \tag{5}$$

and secondly, that T_A^S and T_A^{NS} integrally differ from each other in $4 \div 6\ \%$ (for medium and heavy nuclei):

$$\int_0^A (T_A^S - T_A^{NS})\, d\alpha = \Delta_A \simeq 0.04 \div 0.06, \tag{6}$$

namely the number of particles in a nucleus is larger than A. Here such delicate details of the R ratio as the independence of the $x \simeq 0.27$ point (where R=1) of A are also naturally reproduced.

Further experiments of the BCDMS and EMC collaborations for Fe/D and Cu/D ratios /20,21/ also confirmed the small (~ 5%) deviation of R from the unity in the $x \approx 0$ region.

To provide the same EMC-effect value for valence quarks in the $x > 0.4$ region that follows from the experimental fact of the approximate equality of $x\cdot F_{3A}$ and F_{2A} in this region, it is also necessary that

$$\int_0^A (1-\alpha)\, T_A^{NS}(\alpha)\, d\alpha = \int_0^A \alpha \left[T_A^S(\alpha) - T_A^{NS}(\alpha)\right] d\alpha \simeq \Delta_A, \tag{6'}$$

i.e. that total momentum of "valence" nucleons is smaller than that of a nucleus.

The difference (6, 6') inevitably leads to the nucleus consisting not only of quark-antiquark and gluon seas contained in "valence" nucleons but of, though not big $(\sim \Delta_A)$, yet as hard as the valence quark distribution, the "collective" sea of quark-antiquark pairs

$$O_A(x,Q^2) \equiv F_{2A} - x\cdot F_{3A} = \int_x^A T_A^{NS}(\alpha)\, O_N\left(\frac{x}{\alpha},Q^2\right)d\alpha + \int_x^A \left[T_A^S(\alpha) - T_A^{NS}(\alpha)\right] F_{2N}\left(\frac{x}{\alpha},Q^2\right)d\alpha. \tag{7}$$

The last statement comes from the equality

$$\langle\alpha_{0'}\rangle = \int_0^A \alpha\left[T_A^S - T_A^{NS}\right]d\alpha \Big/ \int_0^A \left[T_A^S - T_A^{NS}\right]d\alpha \simeq 1.$$

This particularly does not allow one to pack the collective sea in real pions for which $\langle\alpha_{0'}\rangle \simeq m_\pi/m \simeq 1/7$. It is the collective sea that defines the antiquark spectrum in hard region.

Thus, we see that for secondary particles containing nuclear valence quarks, one can consider with accuracy of a few percent that $T_A \simeq T_A^{NS} \simeq T_A^S$ and use expression (2) and hence (3) with the normalization

$$\int_0^A \alpha\, T_A(\alpha)\, d\alpha = 1 - \Delta_A, \qquad \int_0^A T_A(\alpha)\, d\alpha = 1. \tag{8}$$

The inclusion of the collective sea in (7) has a paramount importance for particles not containing nuclear valence quarks (e.g. K^- and $\bar{p}$).

As for the T_A distribution of nucleons, one certainly can consider the connection (2) as the definition. The main question is how well it corresponds to the nucleon distribution observed in the processes like $eA \to e'p(A-1)$, in stripping of light nuclei or in cumulative production of nucleons where the main mechanism seems to be the nuclear dissociation /8/:

$$\frac{1}{A}\,\frac{\varepsilon\, d\sigma}{d^3p}\Big|_{A\to N} \sim \alpha\, T_A(\alpha). \tag{9}$$

Just this fact must be examined firstly by comparing with experiment the deuteron structure function in the deep inelastic electron scattering (especially in the $x > 1$ cumulative region) calculated in accordance with the formula like (2) by using the $T_D(\alpha)$ distribution obtained from the deuteron stripping. To the point, one-nucleon wave function obtained from the $eD \to e'pn$ and that from deuteron stripping agrees rather well with each other /22/, and this permits one to expect a good agreement between (2) and the deep inelastic scattering data.

Then using the same $T_D(\alpha)$ we check the relation (3) that, as it has been mentioned above, depends neither on the details of the fragmentation, nor on the details of the nuclear structure, and is defined only by the structure function of a nucleus.

It is necessary to note that such a studying was carried out by L.L.Frankfurt and M.I.Strikman in late seventieth (see reviews /8/) using the deuteron wave function including short-range correlations of nucleons (for a review of other theoretical approaches see the paper by V.A.Karmanov and I.S.Shapiro /23/). However, firstly, after the EMC-effect was discovered it became clear that the standard wave function normalized to energy and particle number contradicts experiment. Secondly, since then the new data on the deuteron stripping as well as on cumulative nucleons knocked out from a deuteron were obtained. Finally, according to the data /24,25/ on cumulative protons for medium and heavy nuclei in a wide energy region up to 400 GeV, a more correct scaling variable of the $AB \to CX$ process seems to be the "minimal target mass" (so-called Stavinsky's $- X_s$)

$$X_s = A \frac{p_c p_B - m_c m_B}{(p_A p_B - m_A m_B) - (p_A p_c - m_A m_c)} , \tag{10}$$

where $p_{A,B,C}$ and $m_{A,B,C}$ are 4-momenta and masses of the nucleus A and particles B and C. Next important advantage of this variable with respect to the light-front one is that its limit value $X_s = A$ is reached at the process kinematic boundary, i.e. the very view of formulas (1) and (3) demands that $X = X_s$. For the deep inelastic lepton scattering (10) coinsides with the Bjorken X.

3. Definition of the T_D -function

Let us consider parametrization of the $T_D(\alpha)$ – distribution of nucleons in a deuteron and its determination from experimental data. Its form depends, certainly, on a nuclear model. As it has been mentioned above, the standard models of the Fermi motion fail to explain the comparatively large cross sections of the cumulative particle production and need hypothesis either of the multiquark fluctons or of the short-range few-nucleon correlations (FNC) in nuclei. The $T_A(\alpha)$ -distribution in these cases can be represented as follows:

$$T_A(\alpha) = \sum_{k=1}^{A} P_k^A \cdot T_k(\alpha) , \tag{11}$$

where P_k^A is the probability of the $3k$ -quark configuration (or of the K -nucleon correlation) and $T_k(\alpha)$ is the effective distribution of nucleons in such a formation. The difference between these approaches is that for multiquark fluctons

$$\int_0^A \alpha T_k(\alpha)\, d\alpha < \int_0^1 \alpha\, T_1(\alpha)\, d\alpha , \tag{12}$$

i.e. the total momentum of the valence quarks of the flucton correlation is smaller than the sum of momenta of its constituent nucleons, while for the FNC the valence "nucleons" must carry the whole correlation momentum.

Let us use expression (6) with the $T_1(\alpha)$-distribution defined by the Paris wave function and the effective nucleon distribution $T_k(\alpha)$ in the $3k$ -quark flucton chosen in the following form:

$$T_k(\alpha) = C_k \alpha^{A_k} (k - \alpha)^{B_k} . \tag{13}$$

The B_k value is defined from the comparison of the expression for the structure function (2) with the valence quark distribution in the $3k$ -quark colourless system which gives the model of the quark-gluon dual strings /26/:

$$q_k(x) \sim x_k^{-\alpha_R(0)} \cdot (1 - x_k)^{2[1-\bar{\alpha}_B(0)](k-1) + \alpha_R(0) - 2\bar{\alpha}_B(0)} ,$$

where $x_k = x/k$, $\alpha_R(0)$ and $\bar{\alpha}_B(0) \simeq -0.5 \div 0.0$ are the intercept of the boson (ρ, f, A_2, ω) and average baryon (N, Δ) Regge trajectories. Here, the expression $\alpha_R(0) - 2\bar{\alpha}_B(0) \simeq 3/2$ in power index corresponds to the valence quark distribution in a nucleon /14,15/, and the additional factor $(1 - x_k)^{2[1-\bar{\alpha}_B(0)](k-1)}$ is due to the delay probability of $(k-1)$ "nucleons" (quarks and diquarks) /14,16,27/. This gives only $B_k = 2[1 - \bar{\alpha}_B(0)](k-1) - 1$ and automatically reproduces the Regge behaviour of the inclusive spectra at $x_k \to 1$. The value of the power index A_k and the coefficient C_k of the nucleon effective distribution are defined by normalization conditions of the T_k -function

$$\int_0^A T_k(\alpha)\,d\alpha = 1 \quad , \quad \int_0^A \alpha\, T_k(\alpha)\,d\alpha = 1 - \Delta_k \quad , \tag{14}$$

where Δ_k defines the value of average momentum of the collective sea of flucton s. Since Δ_A =0.04 $\div$ 0.06 ., and due to the fact that for the $T_1(\alpha)$ -distribution defined by the Paris potential $\Delta_1 = 0$, for the six-quark flucton (neglecting other multiquark states)

$$P_2^A \cdot \Delta_2 \simeq \Delta_A$$

and for the probability of multiquark states $P_2^A \simeq 10 \div 20\%$ the value of Δ_2 is about 0.25 $\div$ 0.50.

In this paper the values $\bar{\alpha}_B(0)$, Δ_2 and P_2^D are considered as free parameters. The data on the deuteron stripping with energies 2.1 /26/ and 5.75 /27/ Gev/N , and those on the cumulative proton production off deuteron at 8.9 GeV/N momentum /23/ were fitted. The variable (10) was used as the scaling one and

$$T_1(\alpha) = \int d^3k \,\left|\Psi_{Paris}(k^2)\right|^2 \delta\left(\alpha - \frac{\sqrt{k^2+m^2} - k_z}{\sqrt{k^2+m^2}}\right). \tag{15}$$

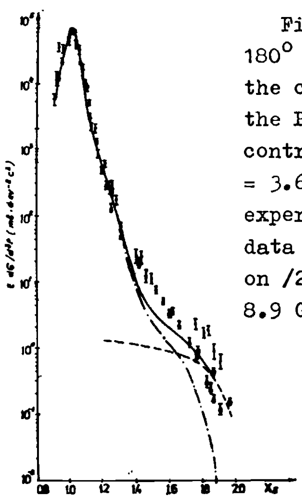

Fig. 1. The spectrum of protons produced at 180° in the pD $\to$ pX reaction; the dash-dot line - the contribution of the spectator mechanism with the Paris w.f. of deuteron; the dashed line - the contribution of the fluction component, P_2^D = = 3.6%; the solid line - the summary spectrum; the experimental data (the relative normalization of data is given in the text): ● - 2.1 GeV/nucleon /28/; ▲ - 5.57 GeV/nucleon /22/; ■ - 8.9 GeV/nucleon /29/.

Since the distribution $T_D(\alpha) = (1 - P_2^D)\cdot T_1(\alpha) + P_2^D \cdot T_2(\alpha)$ defines only the form of the proton momentum spectrum, each group of the data has been fitted by means of formula (9) with its own normalizing coefficient. These experimental data (corrected by the

correspondent coefficients) and curve obtained by the fit are shown in Fig.1, the fitting of the parameters gives

$$\bar{\alpha}_B(0) = -0.05; \qquad \Delta_2 = 0.34; \qquad P_2^D = 3.6\%.$$

We have to note that in accordance with its definition the six-quark flucton in the $\alpha \simeq 1.5$ region may not also include the correction due to the final state interaction /30/. One has to stress that the expression for $T_D(\alpha)$ has to be treated no more than the parametrizations of experiment, since the value of a multiquark admixture in deuteron depends either on choosing one-nucleon part or the form of $T_2(\alpha)$.

Now, using the obtained effective nucleon distribution, one can examine the relationship (2). This will permit one to answer the question to what extent the function $T_A(\alpha)$ entering in (2) reflects the real nucleon distribution.

We will use the SLAC data /9/ in the $X > 1$ region at $Q^2 = 2 \div 8$ Gev^2 . The results of this comparison[1)] are shown in Fig. 2, where the dashed-dotted curve corresponds to the standard Fermi motion (the Paris w.f.) with P_2^D=0. It is seen that in the $X > 1$ region the agreement is rather good and this allows one to conclude that the T_D -function is close to the effective nucleon distribution.

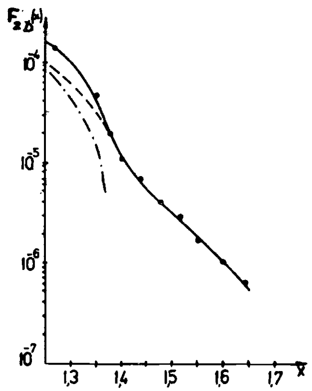

Fig. 2. The deuteron structure function $F_{2D}(x)$. The dash-dot line - the calculation with the Paris w.f. and P_2^D = 0; the dashed line - contribution of the flucton with P_2^D= 3.6%; solid line - the summary contribution; O - the SLAC data /9/.

Note also that the distribution T_D obtained here practically coincides with that used in /33/ for the description on large-$P_\perp$ meson production in proton-nucleus collisions /34/. For the explanation of the cross section of $pD \to \pi X$ process /34/ (with account of double rescattering), one needed the contribution of a flucton component in a deuteron to be about 2$\div$3%.

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1) Here, for $F_{2N}(X)$ at $Q^2 < 4$ Gev^2 the parametrization /31/ and at $Q^2 > 4$ Gev^2 the parametrization /32/ were used.

4. Cumulative meson spectrum

Now we will examine the relationship (3) for the cumulative production of π^- and K^+ – mesons on a deuteron. For $\rho_{N\to\pi,K^+}(x) \equiv \frac{\mathcal{E}\, d\sigma}{d^3p}(x)$ the approximation of the experimental data from the paper /35/ was used. In Fig. 3 the comparison of the calculations by formula (3) with the experimental data /36/ is shown by the solid line. The dashed-dotted line corresponds to $P_z^D = 0$. Good agreement of the theoretical curve with experiment shows that the mechanism of the cumulative pion fragmentation on a deuteron is the same as that on a free nucleon within the experimental accuracy.

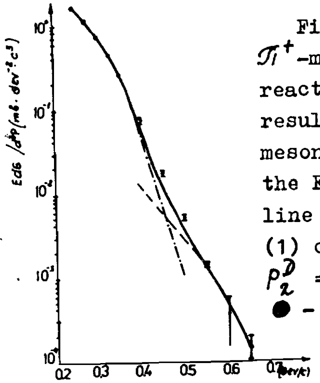

Fig. 3. The invariant cross section of π^+-mesons emitted backward in the $pD \to \pi^+ X$ reaction; the dash-dot line – the calculation result for the semi-sum of the spectrum of π^+-mesons in pn and pp – collisions according to the Fermi motion (the Paris w.f.); the dashed line – the calculation according to the formula (1) only with account of 6q-state in deuteron, P_{2}^{D} = 3.6%; the solid line – the summary; ● – the experimental data at p_0 = 8.9 GeV/c/36/.

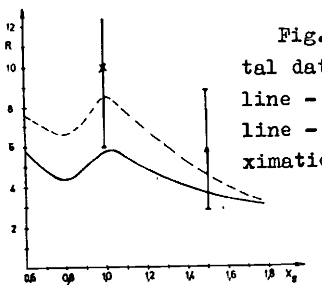

Fig. 4. R = π^+/K^+ versus x_s ; the experimental data –x ϑ = 90°, ▲ ϑ = 150° /37/; the solid line – the calculation for ϑ =180°; the dashed line – the calculation correspondent to the approximation (16).

It is a pity that there are no good enoguh data on deuteron at angles close to 180° for cumulative K^+-mesons. In Fig. 4 the prediction for the π^+/K^+ – ratio for an angle 180° and the available data /37/ at 90° and 150° are shown. Here we also plotted (by the dashed line) the results of calculation (see e.g. /38/ using the approximation (instead of the convolution (4))

$$\frac{\mathcal{E}\, d\sigma^A}{d^3p}(x) = \sum_{k=1}^{A} P_k^A \cdot \frac{\mathcal{E}\, d\sigma^N}{d^3p}\left(\frac{x}{k}\right) \cdot \int_x^k T_k(\alpha)\, d\alpha \quad . \qquad (16)$$

One can see that, firstly, the results do not differ strongly from each other, and secondly, the weak angle dependence of the ratio π^+/K^+ may be expected. The π^- and K^+- meson production on heavier nuclei needs special consideration because of the different A-dependence of their cross section in the cumulative region /36/. This difference seems to be hardly explained by expressions (3) probably due to kaon secondary interactions with nuclear matter because of the kaon shorter formation length. So, assuming for the rough estimation to zero formation length for K^+-mesons (for cumulative pions it is assumed to be greater than the nuclear size) and taking into account the K^+-meson rescattering (see Appendix), one can obtain the A-dependence shown in Fig. 5 ($d\sigma_{A\to K^+} \sim A^{\alpha}$). It is seen that the formation length difference can give the observed effect.

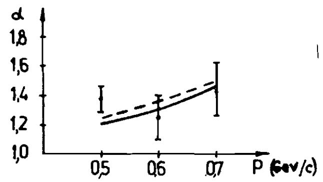

Fig.5. $\alpha = \ln(\rho_{A_1}/\rho_{A_2})/\ln(A_1/A_2)$ versus the momentum p of K^+-mesons, where $\rho_A = \mathcal{E}\frac{d\sigma}{d^3p}$ – the inclusive spectrum of K^+-mesons produced in the pA-collision at an angle of ϑ = 180°. The dashed is given for A_1 = ^{207}Pb, A_2 = ^{27}Al; the solid line – for A_1 = ^{207}Pb, A_2 = ^{12}C; ● – the experimental data at p_0 = 8.9 GeV/c /36/.

Secondary nuclear effects are certainly essential in the non-cumulative region $x < 1$ as it is indicated by much stronger deviation of the ratio of cross sections $\rho_{A\to\pi}/\rho_{D\to\pi}$ from unity /39/, than that in deep inelastic scattering /16-18/.

5. Discussion

So, we show that at last for the deuterium nucleus, for which the secondary nuclear effects seem to be small, the spectrum of cumulative particles with common with nucleus valence quarks with an accuracy up to several percent is determined by the effective distribution of nucleons in a nucleus, which clearly speaks in favour of the "cold" models. Concerning heavier nuclei the comparison of data with Exp. (3) allows one to estimate what part of the cross section is due to the secondary nuclear processes.

The above mentioned accuracy is defined by the difference between the T_A^S and T_A^{NS} distributions in the hard part of spectrum $x > 1$. However, it does not mean that in all cases the quark distribution in a nucleus is reduced to the nucleon one with this accuracy. The difference between T_A^S and T_A^{NS} leads, as it has been stressed in the Introduction, to a completely new element of the nuclear structure - the additional collective nuclear quark-antiquark and gluon sea, which though characterized by a small parameter Δ_A (or Δ_2 for the multiquark fluctuations), however has the same hardness of the distribution spectrum as the valence quarks have. This circumstance plays the main role for the spectrum of those cumulative particles which do not contain nuclear valence quarks such as K^--mesons and antinucleons. One naturally expects their spectrum in the $x > 1$ region to be fully determined by this additional sea because of much faster decrease of the nucleon sea. By this reason the study of such cumulative particles gives an interesting apportunity for a better understanding of a true nature of the difference between the nuclear structure function and that of a free nucleon.

So, if this difference occurs due to the redistribution of valence and sea quarks in the multiquark fluctons /32,40/, as it has been assumed in Section 3, in the region $x \simeq 1$, where the multiquark component contribution to the valence quark distribution is yet not big, and the contribution of collective sea antiquarks becomes dominant, one has to expect that the production ratio $K^+/K^- \simeq u_A(x)/\bar{u}_A(x)$ will depend weakly on x and will be of the order of $2/P_2^A \cdot \Delta_2 \simeq 2/\Delta_A \simeq 30 \div 40$ (for medium and heavy nuclei). In the $x \simeq 2$ region, where the multiquark fluctons become dominating also in the valence part, this ratio must fall down up to $\simeq 2/\Delta_2 \simeq 4 \div 6$. In contrast with this such a falling down must not occur if the redistribution of valence and sea quarks takes place over the whole nucleus (either due to a redistribution in each nucleon /8/ or due to repumping of a part of nucleon momentum[2] to a meson /42,43/ or a nucleon-antinucleon component /12/).

The same information may be obtained also from the cumulative antiproton research. Moreover, this investigation given an information about possible packing of the collective sea. If this sea is packed in nucleon-antinucleon pairs (the interpretation of the paper /12/,

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[2] Non-nucleon degrees of freedom in nuclei are also given in /41/.

the main mechanism of the antinucleon production will be antidiquark fragmentation; one has to expect rather a big value of the ratio $\bar{p}/p \sim \Delta_A/2$. Such a big value seems to contradict the experiment /36/ where this ratio at the same x (though at 90°) is less than 10^{-3}. If there is no such a packing to antinucleons, the mechanism of the fragmentation of the nuclear sea antiquark to the antiproton becomes dominant, which leads to an additional suppression of the antiproton production.

Thus, the processes of the production of cumulative K^--mesons and antinucleons are an interesting manifestation of the specific properties the quark structure of a nucleus and deserve special investigation. They will be considered in one of the next papers.

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Appendix

The A-dependence of cumulative K^+-mesons was estimated in the following way. This meson was assumed to be produced by the interaction of an incident proton with a flucton and further rescattered on quasifree nucleons of a nucleus. For comulative K^+-mesons with $x < 2$ one can choose as a flucton only $6q$-clusters and elastic KN-scattering because of small energy of K^+-mesons. Then, in the quasiclassical approximation the spectrum of K^+-mesons produced in pA-interaction can be represented as follows:

$$\rho_{pA\to K^+X}(x,p_\perp) = P_2^A \cdot \sum_\nu N_\nu \cdot \int f(p', \cos\vartheta') \frac{p'E'}{pE} \frac{d\sigma^{(\nu)}}{d\Omega'} d\Omega' ,$$

$$\frac{d\sigma^{(\nu)}}{d\Omega} = \frac{1}{\sigma_{KN}} \int \frac{d\sigma^{(\nu-1)}}{d\Omega} \cdot \frac{d\sigma_{KN}}{d\Omega'} d\Omega' , \qquad (A.1)$$

where P_2^A is the probability of the $6q$-component in a nucleus /2,7/;

$$N_\nu = \frac{1}{\nu!} \int \left(\sigma_{KN} T_+(b,z)\right)^\nu e^{-\sigma_{KN} T_+(b,z)} \rho(b,z)\, d^2b\, dz$$

is the effective number of the ν-multiple interactions of cumulative K^+-meson; $\rho(b,z)$ is the nuclear density; $T_+(b,z)=\int_z^\infty \rho(b,z')\,dz'$; σ_{KN} is the total cross section of the K^+N-interaction; $f(p,\cos\vartheta)$ is the spectrum of K^+ – mesons from the interaction of protons with the $6q$-fluction depending on the momentum and the scattering angle ϑ; $d\sigma_{KN}/d\Omega$ is differential cross section of the elastic K^+N-scattering; p, E are the momentum and the energy of final K^+-meson. Integration limits in (A.1) are considered in detail in /30/. Here, we have neglected soft rescatterings of an incident proton.

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Ефремов А.В. и др. E2-87-355
Образование кумулятивных адронов
в кварковых моделях фрагментации флуктонов

Анализируются кварковые модели образования кумулятивных частиц и ЕМС-эффект. Показано, что все они характеризуются универсальной связью спектра кумулятивных нуклонов и сечения кумулятивных частиц, содержащих валентные кварки ядра. Проводится проверка этой связи для дейтрона и обсуждается роль вторичных ядерных процессов для тяжелых ядер. Отмечена особая роль "морских" кумулятивных частиц ($K^-,\bar{p}$) в понимании природы различия структурных функций ядра и свободного нуклона.

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Cumulative Hadron Production in Quark Models
of Fluction Fragmentation

Quark models of cumulative particle production and the EMC-effect are analyzed. It is shown that all these models are characterised by universal relation of the cumulative nucleon spectrum with the production cross section of cumulative particles containing nuclear valence quarks. Testing of this relation for a deuteron is carried out and the role of secondary nuclear processes for heavy nuclei is discussed. Special role of "sea" cumulative particles ($K^-,\bar{p}$) for understanding the nature of the EMC-effect is discussed as well.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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