ОБЪЕДИНЕННЫЙ
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ДУБНА

E2 - 9529

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1976

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Submitted to ЯФ

One of the great recent interest is the process of cumulative production of hadrons on nuclei [1, 2]. This name is usually used for the inclusive production of hadrons beyond the kinematical bound determined by the scattering with a single nucleon of a nucleus. Such processes are characterized by a number of peculiarities: i) the early scaling, i.e., independence of the invariant cross section of the projectile energy; ii) the power-law growth of the cross section with increasing atomic number of a nucleus, the degree of growth being 1.5-2 for the heavy produced hadrons(d, t) [1,3]; iii) the spectrum of produced hadrons decreases exponentially with energy (in the nucleus frame), the slope increasing with increasing mass of the produced particle [4] and weakly decreasing with increasing A [5]; iv) the cross section is isotropic for small momentum of produced hadrons and decreases to the backward direction for large momentum [6].

The mechanisms of the Fermi-motion or multiple scattering seem to be unable to explain this peculiarities. The most realistic hypothesis is the scattering with a coherent fluctuation of nuclear matter early used by Blokhintsev [7] for explanation of the knock-out of d, t, ^4He of a nucleus and renaisse by Baldin [8] for the cumulative effect. The aim of the paper is to show that the quark-parton modification of the idea gives the possibility of understanding the above-mentioned peculiarities.

Consider first a nucleus A as a heavy elementary particle made of n_A quarks. The amplitude of the process $B + A \to C + X$ depends on 4 invariants (*fig. 1*)

$$M^2 = p_A^2,\quad s = (p_A + p_B)^2 - M^2 \approx 2M\mathcal{E},$$

$$t = (p_C - p_A)^2 - M^2 \approx -2M\mathcal{E},$$

$$u = (p_B - p_C)^2 \approx -2E(\mathcal{E} - p\cos\theta) = -2E\mathcal{E}_\theta,$$

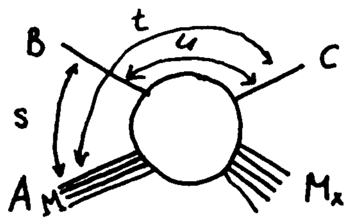

Fig. 1

where E is the total energy of projectile B, $\mathcal{E}$ and θ are the total energy and angle of production of the hadron C in the rest frame of nucleus A. The standard experimental situation, $M \approx 12$ *GeV* (^{12}C), $\mathcal{E} \approx$ 1-2 *GeV*, $E \approx 10$ *GeV*, $\theta \approx 180°$, implies the kinematical region, where $s, u, t \gg s_0$ ($\approx$ 1 *GeV*), i.e., almost *the same region as the high* $P_\perp$ *inclusive hadron production*. This analogy supported by the diagram analysis (see review /9, 10/) leads uniquely to the following mechanism of cumulative production. The projectile (*Fig. 2*)

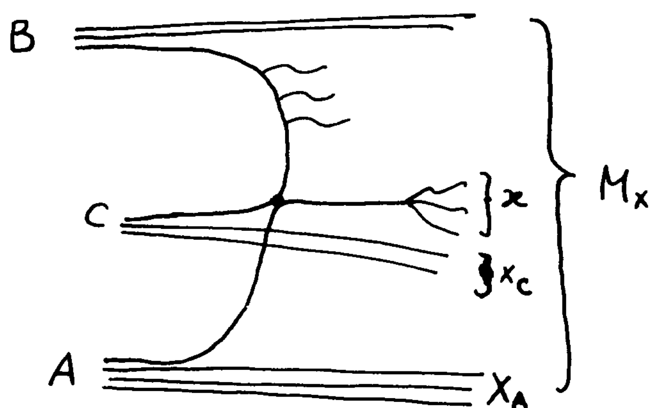

Fig. 2

scatters into the quark-partons one of which , b , (or a more complicated system of n_b quarks) collides with an a parton (or with a system of n_a partons) from nucleus and produces a parton c with large momentum transfer at backward direction. The latter scatters into hadrons one of which is registrated by an observer.

The same diagram analysis assuming finite charge renormalization and small value of the bare coupling constant ($g_0^2 \ll 1$) leads, in the „parton region" /10/

$$\left(\frac{s}{t} \gg 1,\ \frac{ut}{s} \gg s,\ M^2 \gg s \ \text{ but } \ g_0^2 \ln\frac{ut}{s s_0},\ g_0^2 \ln\frac{M^2}{s_0} \ll 1\right),$$

to the following expression for the cross section

$$\mathcal{E}\frac{d^3\sigma}{dp^3} = \frac{1}{s}\left(-\frac{s}{t}\right)^{\alpha(0)}\left(\frac{s}{tu}\right)^{\delta}\left[\frac{(6g_0)^{2n_A}(n_A!)^2}{(M^2/s_0)^{n_A-1}}\right] f\left(\frac{u}{s}, n_A\right), \qquad (1)$$

where $\alpha(0)$ is the intercept of the leading Regge singularity in $B\bar{B}$-channel (Pomeron), $\delta = n_a + n_b + n_c - 2\ (\geq 1)$ is the quark counting rule" behaviour of the subprocess $a + b \to c + x^*$. The factor in the square brackets comes from the asymptotic form of inelastic form-factor $A \to aX_A$ with respect to the large mass M^2. The function f takes into account the phase space bound when $\frac{u}{s} \approx -1$. This bound is determined by the minimal missing mass M_X and near the bound we deal in fact with inclusive process $B + A \to C + (D + F\ldots)$ with large momentum transfer. According to the quark counting rule *

$$f\left(\frac{u}{s}\right) \sim \left(1 + \frac{u}{s}\right)^F,\quad F = n_A + n_B + n_C + \min\{n_x\} - \delta - 4, \qquad (2)$$

where $\min n_x$ is the minimal quark content of X. For the large number n_A (which is assumed in the following) $F \approx 2n_A$.

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* Notice a difference with BBG-recipe /12/ which comes due to summation over all possible states x in analysis of the. Feynman diagram.

The expression (1) immediately gives the nuclear scaling when $(-s/t) \approx E/\mathcal{E} >> 1$ $(\alpha(0) \approx 1)$. However the square brackets give in contrast with experiment decrease of (1) with atomic number $A = n_A/3$ because $M = m_0 n_A$ and

$$[\quad] \sim \left(\frac{6 s_0 g_0^2}{m_0 e^2}\right)^{n_A} n_A^3 . \qquad (3)$$

Thus, the process on a nucleus as a coherent system in a whole is suppressed by this factor and more probable is the process on some coherent clusters with a smaller quark content. The expression (1) in this case gives the production cross sectuon on the cluster. The phase space behaviour (2) (the index A of n_A is omitted)

$$f\left(\frac{s}{u}\right) \sim \left(1 - \frac{\mathcal{E}_\theta}{n m_0}\right)^{2n} \qquad (4)$$

becomes now very important because it suppresses role of too light clusters.

To obtain the cross section on a nucleus it is necessary to multiply (1) by probability of formation of n-quark clusters and to sum over all possible clusters /1, 8/

$$\mathcal{E}\frac{d\sigma}{d^3p} = \sum_n C_N^n (q)^{n-1} (1-q)^{N-n} \; f \; , \qquad (5)$$

where N is the number of quarks in nucleus ($N = 3A$) and q is the probability of one quark to be in a "volume of coherence".

The coherence of quarks is stated by the emission and absorption of virtual gluon quanta moving near to the light velocity. For the projectile particle those quarks are coherent which are inside the sphere of radius $r_0 \approx 1/m_\rho$. In the nucleus rest frame this sphere is stretched along by the γ-factor and when the energy E is high enough $(\gamma > R/r_0)$ it cuts out a "tube" from the nucleus volume. So, the probability q is the ratio of the tube to the nucleus cross sections, $q \sim (r_0/R)^2 << 1$.

Substitution of (1), (3), (4) into (5) and summation by the saddle point method gives

$$\mathcal{E}\frac{d\sigma}{d^3p} = \left(\frac{E}{\mathcal{E}}\right)^{\alpha(0)-1} A^{2/3} \frac{\phi(\mathcal{E}_\theta)}{\mathcal{E}^{\delta+1}} \exp\{-\mathcal{E}_\theta B(\ln\frac{\mathcal{E}_\theta}{A^{1/3}} - C)\}, \qquad (6)$$

where ϕ and C are some power function and constant numerical parameter. The function $B(L)$ is monotonic for $L > 0$, $B(0) = 0$ and $B(L) \sim L$ when $L \to \infty$. The actual form of this function depends on the character of clusterization, i.e., on the number of quarks which can get into the coherence volume simultaneously (q-, N- or α-clusters).

It is easy to see that the expression (6) gives the qualitative description of the cumulative production features i)-iv). The cross section increases with Z as $A^{2/3 + (\mathcal{E}_\theta/3) < B/L >}$. With increasing mass of the produced particles and with decreasing $\ln \mathcal{E}_\theta / A^{1/3}$ and consequently the slope B increases. The cross section is isotropic for $p/\mathcal{E} << 1$ and decreases to the backward direction when $p/\mathcal{E} \approx 1$. The quantitative description depends on the model of clusterization. ***Figure 3*** represents the function for 1) independent quark clusters, 2) nucleon clusters and 3) α-particle clusters and the attempt to determine B from experiments /5/ on π^- backward production on C, Al, Cu and Pb target with energies T_{kin}=199, 225, 423, 676 and 1072 ***MeV***. In spite of the change of c and ϕ the whole set of experimental points can move over the field of picture; it seems that the best agreement can be reached in the α-particle model of clusterization.

A more detailed description and fits including other experimental data will be published elsewhere.

To complete the paper we note that the most interesting prediction of the proposed mechanism is great correlations of two cumulative particles (π-mesons for instance) because it comes from one parton.

It is clearly also that the same mechanism of clusterization is responsible also for the A-dependence of large $P_\perp$ inclusive production on nuclei /13/.

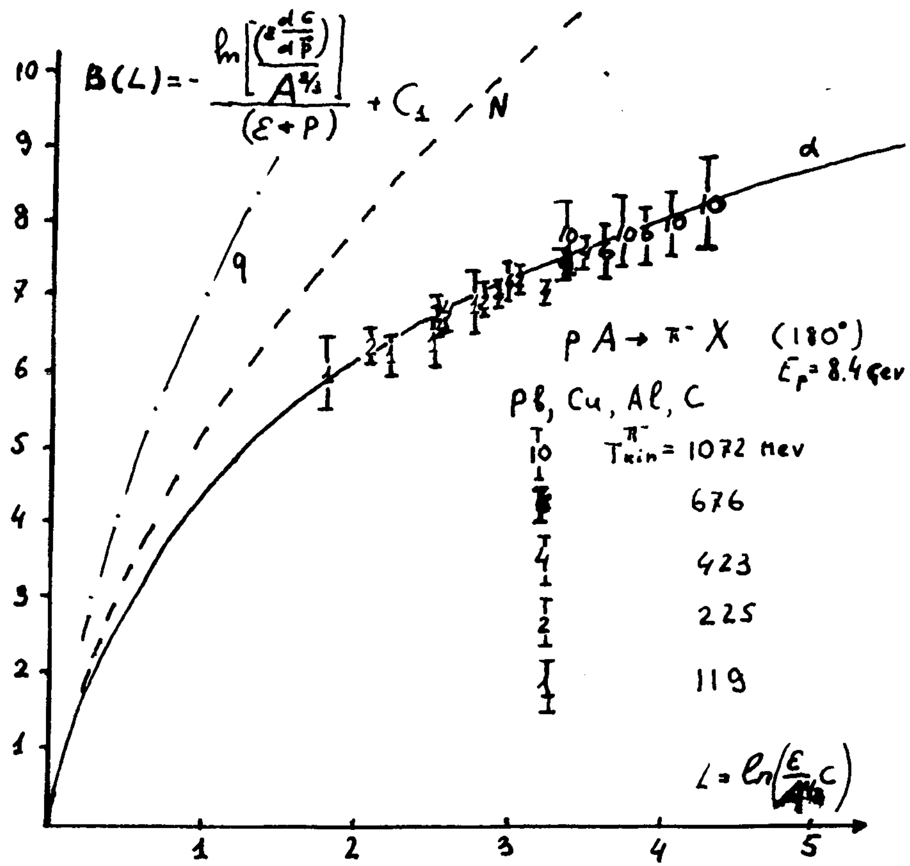

Fig. 3

It is a pleasure for me to express the gratitude to A.M.Baldin, D.I.Blokhintsev, S.B.Gerasimov, I.F.Ginzburg, N.B.Kalinkin and A.V.Radjushkin for useful discussion.

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Receibed by Publishing Department on February 10, 1976.