Fluctuations of the density of particles produced in the interactions of fast hadrons with nuclei

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Assuming that the interaction of fast hadrons with hadrons is described by pomeron exchange, it is shown that the fluctuations of the density of the particles produced in collisions between hadrons and nuclei are allowed for rapidities that are close to the fragmentation region of the nucleus.

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The suppression of intranuclear cascade and the ensuing complicated dependence of the inclusive cross section on the mass number A of the nucleus are most important features of the interaction of a fast hadron with a nucleus. As shown by Kancheli[1] (see also[2]) in the Regge scheme these characteristic features of the collisions of fast hadrons with nuclei are strict consequences of the rules governing cuts in reggeons,[3] which leads to nontrivial mutual cancellations of the absorptive parts of the pomeron amplitudes. The inclusive cross section $d^3\sigma_A/dydp_T^2$ is determined in this case by the sum of the contributions of the diagrams of Fig. 1, and its ratio to the inclusive cross section for a particle production in hadron-nucleon collisions

$$\left(\frac{d^3\sigma_A}{dy\,dp_T^2}\right)\Big/\left(\frac{d^3\sigma_N}{dy\,dp_T^2}\right)=\left(\frac{\sigma_A^{in}}{\sigma_N^{tot}}\right)\Phi\,(A, y, Y) \tag{1}$$

(y is the rapidity of the observed particle and Y is the rapidity of the incident hadron in the rest system of the nucleus) decreases with increasing rapidity y

$$\begin{aligned}\Phi(A, y, Y) &\sim A^{1/3} \quad &\text{if } y\sim 1\\ \Phi(A, y, Y) &\to 1 \quad &\text{if } y >> 1\end{aligned}. \tag{2}$$

Exactly the same behavior is exhibited by the ratio of the densities of the produced particles

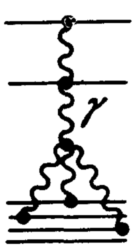

FIG. 1.

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$$\nu_A(y)/\nu_N(y) = \Phi(A, y, Y), \tag{3}$$

where

$$\nu_A(y) = (\sigma_A^{in})^{-1} \int d^2p_T \frac{d^3\sigma_A}{dy\,dP_T^2}; \qquad \nu_N(y) = (\sigma_N^{tot})^{-1} \int d^2p_T \frac{d^3\sigma_N}{dy\,dp_T^2}. \tag{4}$$

As shown in[3], long fluctuations connected with pomeron branch cuts are determined by diagrams containing pomeron closed loops inserted in the "cut" pomeron lines: the inclusive cross section $f_1(y,\lambda)$ for the production of a "hole" in the rapidity spectrum from y to $y+\lambda$ is determined by the insert $\Sigma_1(y,\lambda)$ in Fig. 2(a), while that of the "column," $f_2(y,\lambda)$, is determined by the insert $\Sigma_2(y,\lambda)$ in Fig. 2(b).

From the point of view of the cancellation of the corresponding absorption parts, the insert Σ_i in the reggeon diagram does not differ in any way from the insert γ corresponding to the usual inclusive cross section. Therefore the corresponding inclusive cross sections for the production of holes and columns are determined by the same diagrams of Fig. 1, with γ replaced by Σ_i.

In contrast to γ, the inserts Σ_i are nonlocal quantities that depend both on y and on λ. This, however, does not introduce any additional difficulties: disregarding the fine structure of the columns and other higher-order effects, we have in the lowest approximation, assuming the reggeons in Σ_i to be "bare",

$$\Sigma_i(y, \lambda) = \phi_i(y)\eta(\lambda). \tag{5}$$

It is now easily seen that

$$f_i^A(y, \lambda)/f_i^N(y, \lambda) \sim \Phi(A, y, Y). \tag{6}$$

Thus, fluctuations of the density distribution of the particles produced in hadron-nuclear collisions depend on the rapidities of the produced particles; at fixed λ they increase as y approaches the fragmentation region of the nucleus. In other words, even though the density of the particles is large at $y \sim 1$, the density of fluctuations are also large.

A similar situation arises also in collisions of fast nuclei with nuclei. In this case we have

$$f_{A_1A_2}(y)/f_N(y) \sim \Phi(A_1, A_2, y, Y) \tag{7}$$

and, since

$$\Phi(A_1, A_2, y, Y) = \Phi(A_1, Y - y + \lambda, Y)\Phi(A_2, y, Y), \tag{8}$$

where $\Phi(A,y,Y)$ is the same function as in (1) of[1]. In this case we have two rapidity regions in which the density of the produced particles and its fluctua-

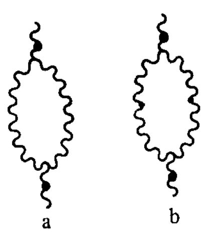

FIG. 2. The cross on line denotes a cut pomeron.

tions are large: $y \sim 1$ near the region of the fragmentation of the nucleus A_2, and $Y - y + \lambda \sim 1$ near the region of fragmentation of the nucleus A.

We note that these conclusions depend neither on the assumed concrete model of the pomeron interaction nor on the approximation assumed for Σ_i. Inclusion of any interactions between the pomerons and the summation of higher-order diagrams must be reconciled with the initial rules for cutting the pomerons[3] and must therefore lead to the same diagrams of Fig. 1, with the initial pomeron (both cut and uncut) replaced by an effective pomeron, but the relations (1), (3), and (6) remain unchanged. The function $\Phi(A, y, Y)$ depends on the model and its study is of interest for the purpose of verifying these models.

In conclusion, let us dwell on the phenomena expected in individual many-particle events. At large Y in individual events at $y \lesssim \ln Rm$ (R is the radius of the nucleus and m is the mass of the nucleus) a "hole" or "column" with dimensions $\lambda \sim 2$ will appear with weight ~ 1. This behavior of $\nu_A(y)$ recalls the singularity, discussed in[4], of the individual events: an anomalously large number of produced particles was observed in the rapidity interval $\lambda \sim 2$—3 in the region $y \sim 1$. This seemed to contradict the absorptive models. The analysis presented above shows that the observed inhomogeneities of $\nu(y)$ can be possibly explained on the basis of the existing Regge model.

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