"Length" of the correlation between the produced particles in multiple production

S. A. Azimov, K. G. Gulamov, V. I. Petrov, N. S. Skripnik, T. P. Trofimova, L. P. Chernova, and G. M. Chernov

Physicotechnical Institute, Uzbek Academy of Sciences
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An investigation of associative multiplicities in inelastic hadron collisions with nucleons and nuclei in the energy region 20–200 GeV points to a long-range character of the correlations between the produced particles.

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The universally known interest in correlation phenomena in multiple generation, has been aroused by the low sensitivity of single particle spectra to the choice between various models of the process, which are frequently antagonistic in their axiomatics. The most frequently discussed have been the so-called "short-range" correlations in rapidity (y), but the overwhelming majority of data on these correlations are based on investigations with the aid of the formalism of inclusive correlation functions, within the framework of which

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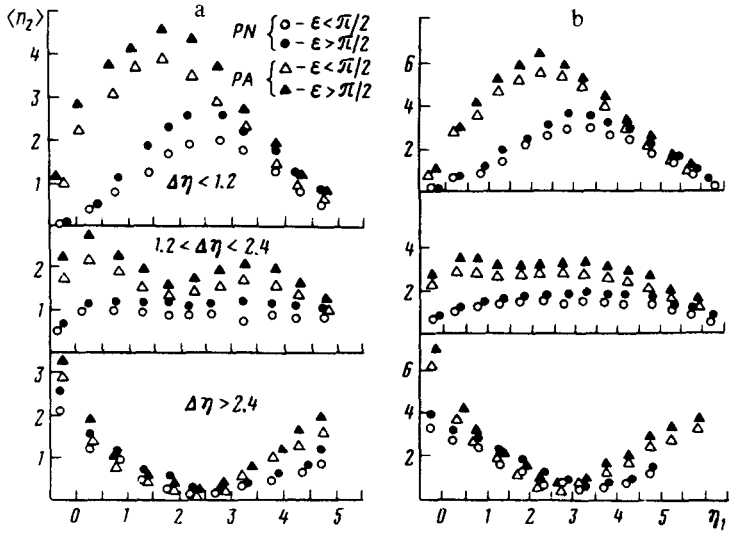

FIG. 1. Dependence of the associative multiplicites n_2 at different ϵ_{12} and $\Delta\eta$ on η_1 for the reactions (1) and (2) at 50(a) and 200(b) GeV/c.

there arise strong pseudocorrelations (of "short-range" character!) due to the shape of the n-distribution in the dependence of $d\sigma/dy$ on the multiplicity n of the produced particles.[1,2]

In the present paper, investigating the associative multiplicites[3] of charged particles accompanying the production of an inclusive particle in hadron-nucleon (hN) and hadron-nuclear[1)] (hA) collisions, we shall show the following:

a) The correlations in multiple production have a long-range character (with a possible "admixture" of a short-range component in the central region).

b) The correlations in hN and hA collisions are quite similar in character and "length."

c) The pure resonant (e.g., [4]) or "light-cluster" interpretations of correlation phenomena are not very likely.

The analyzed experimental material consisted of pN and pA collisions at 21, 24, 50, 67, and 200 GeV/c and $\pi^- N$ and $\pi^- A$ at 50 GeV/c, registered in nuclear emulsions. The numbers of the events are listed in the table; part of the material[2)] was obtained by the collaborations cited in[5] and by the Cracow group[6]; no coherent reactions with nuclei were considered, and events on the free hydrogen of the emulsion were excluded (statistically) also from the hA cases.

We have considered the multiplicites n_2 in the inclusive reactions:

$$p + N \to 1 + 2 + X, \tag{1}$$

$$p + A \to 1 + 2 + X \tag{2}$$

TABLE I.

P_0 GeV/c	First particle	Number of hN events	Number of hA events	Note
21	p	729	252	Emulsion in strong magnetic field
24	p	–	1373	
50	p	1021	1391	
50	π^-	242	536	Emulsion in strong magnetic field
67	p	1119	1633	
200	p	2093	2743	

(1, 2—charged particles, $X \equiv$ everything else) at $\epsilon_{12} \gtrless \pi/2$ ($\epsilon_{12} = \cos^{-1}(\mathbf{r}_1\mathbf{r}_2/r_1r_2)$ is the pair azimuthal angle ($\mathbf{r}$ is the transverse momentum) and at different relative distances $\Delta\eta = |\eta_1 - \eta_2|$ along the longitudinal collision axis ($\eta = -\ln\tan(\theta/2) \approx y$, and θ is the emission angle in the l. s.) as functions of the quasirapidity η_1 of the inclusive particle 1. These relations yield obviously direct information on the "length" of the correlations, which must follow from the conservation of the transverse momentum (information on the mechanism of the compensation of $\mathbf{r}_1$).

Figure 1 shows by way of example plots of $\langle n_2 \rangle$ against η_1 for pN and pA collisions at 50 and 200 GeV/c (the picture is similar for all other p_0). It is seen that: a) the compensation of $\mathbf{r}_1$ of particle 1 is by both "close" (small $\Delta\eta$) and "far" (large $\Delta\eta$) partner particles ($\langle n_2(\epsilon > \pi/2)\rangle - \langle n_2(\epsilon < \pi/2)\rangle) > 0$ everywhere). If particle 1 is in the central region, it is genetically connected in the main with the near particles (possible existence of "short-range" correlations), and if particle 1 is in the fragmentation regions of the projectile or of the target, then $\mathbf{r}_1$ is compensated principally by the far partners. We note, however, that the difference $\langle n_2(\epsilon > \pi/2)\rangle - \langle n_2(\epsilon < \pi/2)\rangle$ is larger the greater the total number of partners with given $\Delta\eta$, so that the "specific" average multiplicity of the compensating particles depends very weakly on $\Delta\eta$. Thus, the cor-

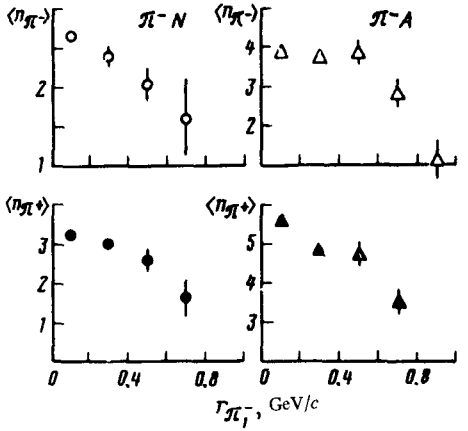

FIG. 2. Plots of $\langle n^-_{\pi_2}\rangle$ and $\langle n^+_{\pi_2}\rangle$ against $|\mathbf{r}^-_{\pi_1}|$ in the reactions π^-N, $\pi^-A \to \pi^-_1 + \pi^\pm_2 + X$ at 50 GeV/c.

relations between the particles in multiple production is in the main of long-range character; the data of the type shown in Fig. 1 are apparently difficult to explain within the framework of popular (but naive) models with *independent*, isotropically decaying clusters. b) The character of the functions $\langle n_2(\eta_1)\rangle$ for hN and hA collisions is qualitatively the same for all η_1. This means that the conservation laws (and the possible dynamic couplings) control the particle production in hA collisions to the same degree as in the elementary act. In the target-nucleus fragmentation region this fact is far from trivial and is in particular difficult to understand from the point of view of the cascade concepts or, again, in models with independent clusters.

Important additional information concerning the character of the connection between the produced particles can be obtained from experiments in which the charges (as well as the momenta) of the secondary particles are measured. We have considered, in particular, the dependences of $\langle n_{\pi_2}^{\pm}\rangle$ on $y_{\pi_1}^{\pm}$ and $r\pi_1^{\pm}$ at different Δy and ϵ_{12} in the inclusive reactions

$$\pi^- N, \pi^- A \to \begin{cases} \pi_1^- + \pi_2^- + X, \\ \pi_1^- + \pi_2^+ + X, \\ \pi_1^+ + \pi_2^- + X, \\ \pi_1^+ + \pi_2^+ + X \end{cases} \tag{3}$$

at 50 GeV/c and did not observe a noticeable dependence of the noted effects on the signs of the charges of the partner particles (an example is shown in Fig. 2). Thus, the compensation of $\mathbf{r}_1$ is ensured to an approximately equal degree by all the partners regardless of their charges, and this, in our opinion, is difficult to reconcile with the pure "resonant" treatment[4] of correlation phenomena in multiple production.

The properties of the produced particles noted in the present communication are probably explainable in models in which an essential role is played by the statistical (thermodynamic, hydrodynamic?) mechanism of creation or formation of "heavy" intermediate formations (clusters). Of course, any conclusions concerning the correctness or, conversely, the incorrectness of various approaches to the problem of multiple production acquires the force of proof only if the experimental data can be quantitatively compared with calculations within the framework of the corresponding approaches. We hope to consider this question, as well as to attempt to separate the kinematic and dynamic contributions to the considered connections between the secondary particles, in a subsequent paper.

[1)]The study of the correlations in hA events is only in the initial stage.[2]

[2)]The authors are indebted to the colleagues participating in the collaborations[5] for joint work on the choice of the material, and to Dr. J. Babecki for supplying the data of[6].

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