# New properties of many-particle correlations in multiparticle production processes

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Data for multiple hadron generation at high energy are analyzed in terms of new correlation characteristics of length distributions of velocity intervals between velocity nonadjacent particles. Experimental distributions are found to possess (in sufficiently high multiplicity events) several maxima which are interpreted as the effect of a cluster mechanism.

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The study of two-particle correlations in multiparticle production processes at high energies has led over recent years to important conclusions concerning the mechanism of inelastic interactions. In particular, the two-step nature of these processes has been confirmed. In the first step forms called clusters are produced, which then decay into several pions (see, e.g., Refs. 1 and 2). The study of many particle correlations may be used to find the quantitative characteristics of this mechanism.

We shall show that the experimental data for multiple processes reveal an interesting structure in the velocity interval distributions between non-adjacent (in terms of velocity) particles, which provide a basis for thinking of the correlation spectroscopy of clusters and, possibly, of the nature of the quark-gluon jets in the region of small transverse momenta.

The following procedure was used to construct velocity interval distributions. In each event with $n$ charged particles, all the particles are arranged on a velocity scale in order of increasing velocity; all the possible velocity intervals ${}^{n}r_{m}$ are then measured, defined as distances on the velocity scale between those particles which are separated from one another by $m$ particles ($0 \leqslant m \leqslant n-2$).

The velocity interval distributions $P_{(m)}^{(n)}(r)$ with $m \neq 0$ were first proposed, interpreted and obtained from the photoemulsion data.[3,4] The model for the independent emission of clusters gives characteristic curves with a single maximum for such distributions.[4] Investigation of the multiperipheral cluster model predicted[5] the possible appearance of two maxima on increasing the precision of the experiment. A subsequent analysis of the data with bubble chambers relating to $p$-$p$ interactions at 70 GeV/$c$ revealed such a structure in the distributions for ${}^{10}r_3$, ${}^{10}r_4$, and ${}^{12}r_4$ ${}^{12}r_5$ (see Refs. 6 and 7).

Continuing these studies, we have now obtained velocity interval distributions for $\pi^-$-$p$ interactions at 40 GeV/$c$ and for $p$-$p$ interactions at 70 and 200 GeV/$c$. Examples of such distributions are given in Figs. 1, 2 and 3. The characteristic structure of the distributions with two or more maxima is clear. Such irregularities are obtained at all

  

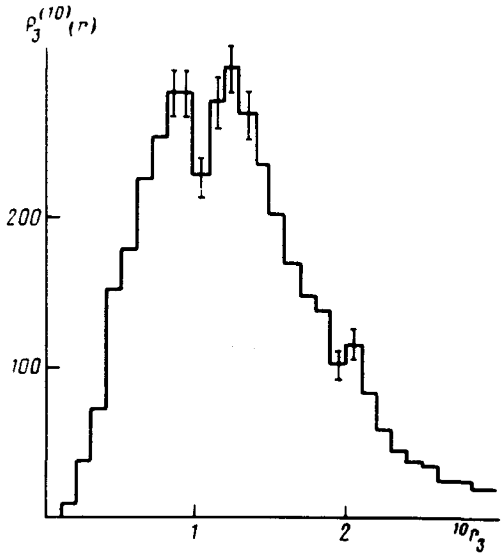


FIG. 1. Experimental distributions $P_3^{10}(r)$ for $\pi^-$-$p$ interactions at 40 GeV; errors are statistical.

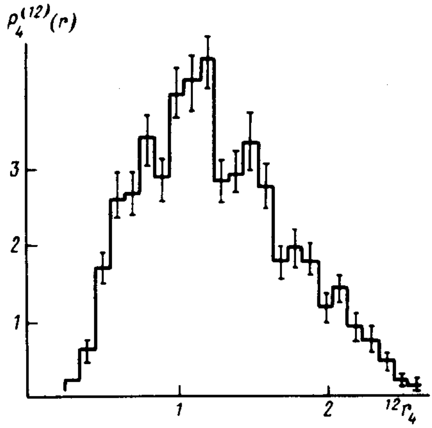


FIG. 2. Experimental distribution $P_4^{12}(r)$ for $p$-$p$ interactions at 70 GeV; normalized over the entire velocity interval.

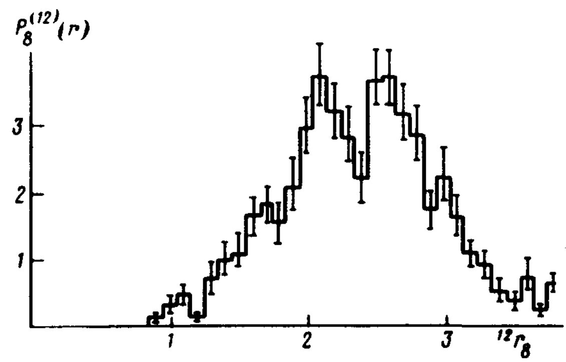


FIG. 3. Experimental distributions $P_8^{12}(r)$ for $p$-$p$ interactions at 70 GeV.

three energies. They are especially clearly evident in events with multiplicity approximately two times greater than the average, at $m = 3$, 4 and 5.

A complete analysis of the multiperipheral cluster model, which was used to predict the occurrence of maxima,[5,7] and a comparison of this model with respect to all the velocity intervals with adequate statistics, has not heretofore been carried out. However, investigations of several distributions and their substructures within the framework of this model showed that the occurrence of different maxima is related to contributions of multiperipheral block diagrams with a different number and character (soft resonances, heavy clusters, diffraction). Thus, the processes which occur with low probability (e.g., the creation of very heavy clusters or formation of two clusters together with resonances) lead to maxima were there are weak (statistically unreliable) maxima in Figs. 1–3. It is indeed this circumstance which permits us to expect with greater certainty the distinct manifestation of such a structure when the experimental statistics are improved.[1]

A semi-quantitative interpretation of multi-maxima velocity interval distributions is possible within the framework of a multi-cluster model with repulsion. In this model, it is assumed that clusters on the average are uniformly distributed along the velocity axes; however, two adjacent clusters may not have velocities differing by less than $\Delta$. The latter condition distinguishes this model[2] from the widely known model for the independent emission of clusters. It reflects the fact, known in every quantum field multipheripheral model, relating to smallness of the transmitted momenta. Maxima in this model are naturally divided into two groups.

The first group is due to $m$ particles belonging to one and the same $i$th cluster that has disintegrated into $K_i$ particles. The position of the maximum is given by the equation $r_i \approx \delta (2\pi)^{1/2}(m/K_i - 1)$, where $\delta$ is the cluster decay halfwidth along the velocity axis ($\delta \approx 0.7$–$0.9$ for an isotropic decay). The heavier the cluster, the more leftward is the distribution corresponding to its maximum (for a fixed $m$). The rightmost maximum in this group corresponds to a cluster decaying into $K_s = m + 2$ particles, and located at $r(s) \approx \delta(2\pi)^{1/2}(m/(m+1))$. (Taking the laws of conservation into account may change these values slightly). The second group of maxima arise from the intervals containing particles from two and more clusters and located to the right of $r_{(i)}$. The position of these maxima $r_\Delta$ depends on the actual diagram of cluster production and is determined by the repulsion parameter, by the values of $r_i$ for the corresponding cluster and by the laws of conservation. The boundary between these two groups lies at $r \sim 2$.

The first group is more clearly evident at relatively small $m = 3$, 4 (see Figs. 1, and 2), while the second group is more noticeable at large $m = 8$ (see Fig. 3). The model cannot give the relative height of the maxima. For the evaluation, we need to know the relative probability for the occurrence of events with a different number of clusters, and the distribution in terms of the multiplicity for an individual cluster. This may be done within the framework of a multipheripheral cluster scheme. Thus, the position and height of the maxima may be used for determining the cluster masses and the probability for their production.

In the quark-gluon picture of the process, the parameter $\Delta$ could possibly be related to the "mass" of the gluon jets, and the cluster mass to repulsion of these jets, since the gluons change to a colored quark-antiquark pair which should be distributed over different clusters in order to produce colorless particles. Then, the presence of several maxima would constitute a manifestation of a multi-jet nature of the occurrence of reactions with a high multiplicity, even in the case of small transmitted momenta where the jet overlap is large.

However, appearance of a multi-maxima structure in the velocity interval distributions is in itself an extremely interesting fact, independently of the validity of any interpretation, which indicates the fundamental properties of inelastic processes.

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1) The results given in the figures were obtained from total statistic on the order of 10,000 events. Clearly, reliable third and subsequent maxima require statistics on the order of hundreds of thousand of events.
2) A detailed account of the model will be published in the journal "Yadernaya fizika".


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