Correlations in a doubly inclusive nuclear reaction

M. G. Gornov, A. K. Ponosov, V. P. Protasov, and F. M. Sergeev

Moscow Engineering-Physics Institute
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It is proposed to separate the mechanisms of multiple generation in elementary collisions by studying the correlations in the doubly inclusive nuclear reactions $a+A\to b+c+$ (anything). Using as an example the reaction $\pi^-+A\to\Lambda+K^0+$ (anything), it is shown that the method is sensitive to the manner in which the secondary particles are produced.

It has been pointed out recently that multiple production on nuclei can turn out to be a very sensitive test by which models of multiple processes in elementary collisions can be distinguished.[1] The gist of the matter is that the development of a cascade in condensed nuclear matter leads to a change in the kinematic characteristics of the secondary particles. This change depends on the concrete variant of the first interaction with the intranuclear nucleon, so that the difference between the variants can in principle be observed experimentally. As a check, it is proposed to study certain properties of nuclear reactions that are inclusive with respect to one particle, namely, the distributions with respect to the rapidities and the dependence of the average multiplicity of the selected particle on the atomic number A of the target nucleus and on the primary energy.[1]

We wish to note in this connection that it is possible to use for this purpose the doubly-inclusive nuclear processes $a+A\to b+c+$ (anything).

The multiple production mechanisms in an elementary collision manifest themselves in the form of correlations between selected particles.[2] The secondary interactions in the nucleus should enhance the difference in the degree of correlation, depending on the model of the primary reaction. Thus, for single-step models, when the entire aggregate of particles is produced directly at the instant of the first impact (say, multiperipheral), the subsequent development of the nuclear cascade leads to a weakening of any correlations that might have existed. For models in which the secondary particles are products of the decay of an initially produced excited center ("nova," fireball), the nucleus does not affect the correlations at all, since the excited system interacts inside the nucleus as a whole. Thus, the method may turn out to be more sensitive than the singly-inclusive characteristics. For "classical" energies in the region of resonance production, double inclusive reactions on the nucleus are a useful means of separating resonances whose production cross sections are small. On the other hand, using resonance production as an example, it is possible to verify whether a method works.

We present below the result of an analysis of the reaction

$$\pi^-+A\to\Lambda+K^0+\text{(anything)}. \qquad (1)$$

The material was obtained with the aid of the 105 cm freon chamber of our Institute at a primary momentum 3.9 GeV/c. Multiple reactions with simultaneous observation of Λ and K^0 are classified as "experimentally difficult." Their cross sections are small, so that the summary number of events observed in hydrogen bubble chambers does not exceed several hundred. Separation of the resonant states of the ΛK^0 system is also difficult, since the resonance region is located at the maximum of the nonresonant background.

We have analyzed 600 reactions (1). We investigated

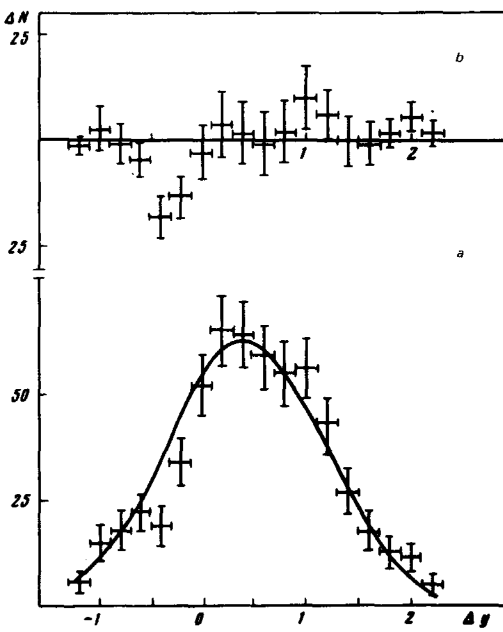

FIG. 1. (a) Distribution of reaction (1) with respect to the rapidity difference Δy of the inclusive particles. Solid curve $(1/\sigma_T)(d\sigma/dy_1)(d\sigma/dy_2)$. (b) The correlation function g.

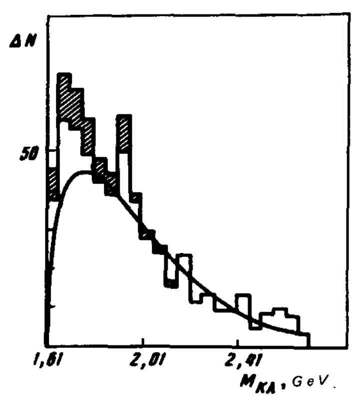

FIG. 2. Mass spectrum of the ΛK^0 combination. The shaded events are those with $-0.6<\Delta y<-0.1$. The smooth curve shows the phase volume.

the correlation function

$$g(y_1, y_2) = \frac{d^2\sigma}{dy_1\, dy_2} - \frac{1}{\sigma_T}\frac{d\sigma}{dy_1}\frac{d\sigma}{dy_2},$$

where y_1 and y_2 are the rapidities of the selected particles, $y=(1/2)\ln[(E+P_{\parallel})/(E-P_{\parallel})]$, while E and $P_{\parallel}$ are the energy and longitudinal momentum and σ_T is the total cross section of reaction (1).

Following[3] (where reference to the original source can be found), we have taken the value

$$\frac{d\sigma}{dy_{1(2)}} = \int dy_{2(1)} \frac{d^2\sigma}{dy_1 dy_2}.$$

To preserve the statistics, the function g and its components are presented as functions of the rapidity difference $\Delta y = y_1 - y_2$ (Fig. 1). We see that there are no correlations whatever for positive values of Δy. Negative correlations begin to appear in the region $\Delta y < 0$ and reach a maximum at $\Delta y \approx -0.4$. It is of interest to compare the correlation function g with the mass spectrum of the combination ΛK^0. Figure 2 shows the $M_{K\Lambda}$ spectrum for the entire sampling and that part of the spectrum which corresponds to the region $-0.6 < \Delta y < -0.1$, where a correlation of the rapidities is observed. There is a correspondence between the separated values of Δy and of that section of the spectrum $M_{K\Lambda}$ in which the resonances are registered, namely 1.6 GeV $\lesssim M_{K\Lambda} \lesssim$ 2.0 GeV (see, e.g., [4]).

Thus, one can indeed speak of the sensitivity of the method to definite mechanisms of particle generation.

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