DEPENDENCE OF THE MULTIPLICITY OF SECONDARY PARTICLES IN RELATIVISTIC NUCLEUS–NUCLEUS INTERACTION ON THE COLLISION GEOMETRY*

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In most collider experiments, the multiplicity of secondary particles is used to estimate the degree of collision centrality. It is assumed that the average multiplicity increases with an increase in the participating nucleons and the collision energy. In this work, a detailed study of the dependence of the multiplicity of secondary particles on the type of target, energy, and centrality of interaction for heavy (AgBr) and light (HCNO) target nuclei present in a nuclear emulsion (Em, NIKFI BR-2) was carried out using sulfur (S-32) projectiles at 3.7 AGeV and 200 AGeV and silicon (Si-28) projectiles at 14.6 AGeV. A comparative analysis of the multiplicity for these interactions showed that in the central interactions of S at 200 AGeV with heavy nuclei of the emulsion, the energy dependence of the multiplicity differs significantly from the other considered interactions.

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1. Introduction

Quantum chromodynamics (QCD), which is used to describe strong interactions, predicts that under conditions of high temperature and high density, a new form of matter called quark–gluon plasma (QGP) can be formed [1–3].

Significant experimental studies of relativistic collisions of heavy ions are aimed at studying the phase diagram of QCD, understanding the structure of QGP, and determining the phase boundary between different phases [4–7].

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The study of fluctuations of such quantities as the multiplicity of secondary particles, average transverse momentum, multi-particle correlations in pseudorapidity distributions of secondary particles, *etc.*, makes it possible to study the region of the QCD phase diagram near the phase transition from the hadronic state to the deconfinement state [8–10]. For the analysis, different methods and approaches are used [11–13].

The analysis of experimental data plays a key role in studying the properties of QGP. The results of the analysis depend not only on parameters controlled at the stage of experiment preparation, such as the energy, type, and size of colliding nuclei, but also on parameters that vary randomly from event to event and are related to the collision geometry. One of these parameters is the collision centrality. It determines the size of the overlapping region of colliding nuclei, which undoubtedly affects the properties of the resulting substance. In this case, it is assumed that nucleons from the overlap region form secondary particles registered in the detectors, and, therefore, the more interacting nucleons, the greater should be the multiplicity of secondary particles. Fragments of colliding nuclei consist of nucleons outside the overlap region. Therefore, fragments of interacting nuclei can be used to estimate the centrality of the interaction. The larger the size of the fragments, the lower the degree of centrality of the collision [14–16].

In the colliding beam experiments, information on the fragmentations is usually not available. Therefore, the experimentally measured quantity, which indirectly characterizes centrality, in most experiments uses the multiplicity of produced particles [17]. However, the multiplicity of secondary particles can change not only depending on the degree of centrality of the collision (the number of participating nucleons), but also on the interaction dynamics. In experiments with a fixed target, fragmentation analysis can be additionally used. Therefore, to evaluate the geometry of the collision, the accelerator experiment with the fixed target has more advantages [18]. Moreover, the fixed target mode allows for the intensive study of rare processes, the measurements of the parameters needed to analyze the data of cosmic rays [19–22].

In this work, a detailed study of the dependence of the multiplicity of secondary particles on the energy and centrality of interaction has been carried out. Centrality was estimated from the fragmentation of interacting nuclei.

2. Experimental details

The present analysis has been carried out with the data obtained from the nuclear emulsion track detector (NIKFI BR-2). For the analysis, we used the experimental data on inelastic interactions of sulphur (S-32) projectiles at 3.7 AGeV and 200 AGeV and silicon (Si-28) projectiles at 14.6 AGeV

[23, 24]. In the measured interactions, all charged secondary particles were classified according to the generally accepted terminology of the emulsion experiment.

3. Assessing the centrality

One of the most accurate methods for evaluating collision geometry is analyzing fragments of colliding nuclei. Figure 1 (left) shows a schematic representation of the interaction of the sulfur nucleus with the heavy nucleus of the nuclear emulsion.

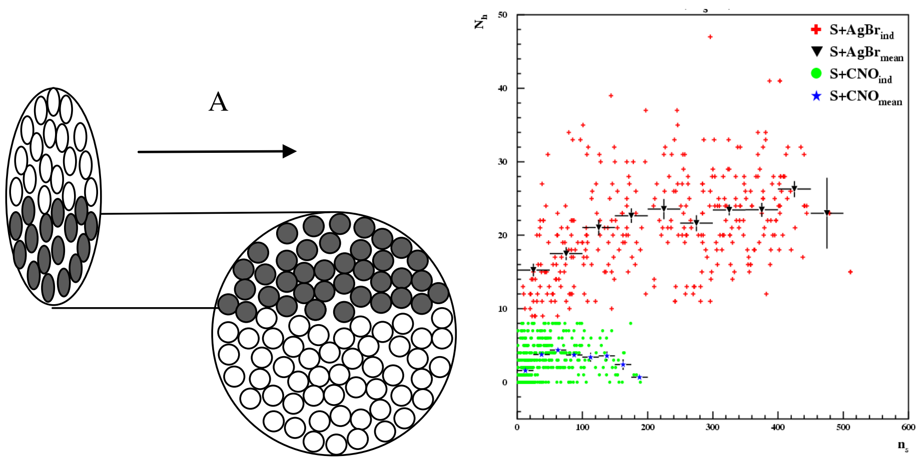

Fig. 1. Assessing the centrality. Left: Schematic representation of the interaction of the sulfur nucleus with the heavy nucleus of the nuclear emulsion; Right: Dependence of the number of fragments of the target nucleus N_h and the multiplicity of shower particles n_{s} for interactions S+Em 200 AGeV.

To estimate the collision geometry, the nucleons of interacting nuclei are conditionally divided into two groups. The first group includes interacting nucleons–participants, which produce high-energy shower secondary particles n_{s}.

The second group is nucleons that do not participate directly in the interaction. They form spectator fragments of the projectile-nucleus, N_{f}, and fragments of the target-nucleus, N_h.

Based on geometric concepts, it follows that in peripheral events one multi-charged fragment of the projectile-nucleus should be detected. Moreover, the higher is its charge, the greater the degree of collision peripherality. In strongly central interactions, events of complete destruction (when there are no multi-charged fragments) of the projectile-nucleus can be observed.

Figure 1 (right) shows the relationship between the multiplicity of shower particles and the number of fragments of the target nucleus for the interactions of sulfur nuclei with emulsion nuclei at an energy of 200 *A*GeV. Separation of events with different targets was carried out according to the following criterion. The heaviest of the light nuclei of the nuclear emulsion is oxygen. Its charge is 8. Therefore, all events with $N_h > 8$ are interactions with heavy nuclei (AgBr).

The mean curve for S+AgBr is characterized by a steady increase in the region up to $n_s \sim 200$. The level separates peripheral and central interactions. The increase in the number of h-particles is associated with the fragmentation of multi-charged fragments of the target-nucleus. At a level approximately corresponding to $n_s \sim 200$, the target-nucleus is completely destroyed.

4. Dependence of the multiplicity on the centrality

To study the features of the dependence of multiplicity on energy, the degree of centrality of the collision, and the degree of asymmetry of the interacting nuclei, all events were divided into 4 parts depending on the number of fragments of the target-nucleus and multi-charged fragments of the projectile-nucleus. The results are presented in figure 2.

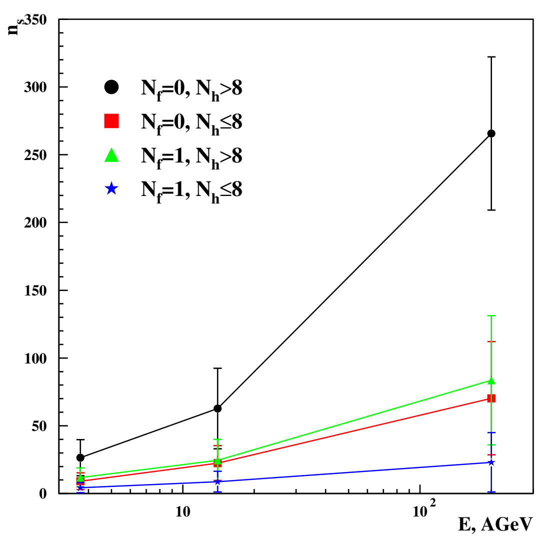

Fig. 2. Dependence of the average multiplicity of n_s in the S+Em 3.7 *A*GeV, Si+Em 14.6 *A*GeV, and S+Em 200 *A*GeV interactions on the interaction energy for events with different numbers of fragments of the target-nucleus N_h and multi-charged fragments of projectile-nucleus N_f.

From the analysis of figure 2, it follows that the average multiplicity increases with the energy. A comparative analysis of the multiplicity for these interactions showed that in the central interactions of sulfur 200 AGeV with heavy nuclei of the emulsion, the energy dependence of the multiplicity differs significantly from the other considered interactions.

At an energy of 14.6 AGeV, the multiplicity of shower particles is approximately two times higher than at an energy of 3.7 AGeV. For peripheral and central interactions, the coefficient of multiplicity increase approximately coincides. For an energy of 200 AGeV, the magnification factor also approximately coincides with all the considered sets, except for the central interactions of sulfur nuclei with heavy emulsion nuclei.

This "anomalous" behavior indicates that the multiplicity of secondary particles in an event is determined not only by the energy, centrality, type of interacting nuclei, but also by other factors. Probably, the dynamics of the interaction of sulfur nuclei with the heavy nuclei of the nuclear emulsion differs from the dynamics of other considered interactions.

5. Conclusion

The detailed study of the dependence of the multiplicity of secondary particles on the type of target, energy, and centrality of interaction for heavy (AgBr) and light (HCNO) target nuclei present in a nuclear emulsion was carried out using sulfur (S-32) projectiles at 3.7 AGeV and 200 AGeV and silicon (Si-28) projectiles at 14.6 AGeV. A comparative analysis of the multiplicity for these interactions showed that in the central interactions of S at 200 AGeV with heavy nuclei of the emulsion, the energy dependence of the multiplicity differs significantly from the other considered interactions. This "anomalous" behavior indicates that the multiplicity of secondary particles in an event is determined not only by the energy, centrality, and type of interacting nuclei, but also by other factors. Probably, the dynamics of the interaction of sulfur nuclei with the heavy nuclei of the nuclear emulsion differs from the dynamics of other considered interactions.

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