Abstract

The experimental results on the behaviour of the characteristics of secondary particles depending on the disintegration degree of nuclei are used to determine the region of central collisions. It was therefore possible that:

– the correlation between the processes of total disintegration of nuclei and the central collisions of nuclei had been shown;
– the existence of the regime change points in the behaviour of the considered characteristics of secondary particles depending on the disintegration degree of nuclei had been observed in the other earlier experiments as well.

The number of all protons in \(12\)CC- interactions at the momentum of 4.2 A GeV/c obtained from the 2-m propane bubble chamber exposed at the Dubna machine is considered as a disintegration degree of nuclei.

The experimental results demonstrate that there are cases corresponding to the critical phenomena among the events with the central collisions of nuclei. For \(12\)CC-interaction the behaviour of the number of the events, depending on \(Q\) also depends on the number of fragments and has a two–steps form. This result could be explained by the existence of nuclear clusters.

Key-words: disintegration degree, central collisions, regime change points, number of all protons, \(12\)CC- interactions, 2-m propane bubble chamber, 4.2 A GeV/c, cluster

1 Introduction

The talk is dedicated to the experimental selection of the events with total disintegration of nuclei or with central collisions of ones. In paper [1] it was experimentally shown that the processes with total disintegration of nuclei correspond to the central collisions. Therefore it can generalize the results of the experiments on the total disintegration of nuclei and the central collisions. First of all it is necessary to remind that at present there are many papers in which the processes of nuclear fragmentation [2] and the processes of total disintegration of nuclei [3] are considered as a critical phenomenon. Therefore it is possible to suppose that if there are cases corresponding to the critical phenomena among the events with the total disintegration of nuclei then the points of the regime changes in the behaviour of some characteristics of secondary particles \(a_i\) depending on
the centrality degree of collisions - \( Q \) could be observed. Some experimental data obtained in nuclear-nuclear interactions at high energy demonstrate the existence of the points of the regime changes in the behaviour of the \( a_i = f(Q) \) distributions. For example in fig. 1 the average multiplicity of relativistic chaged particles depending on \( Q \) is shown for the \( ^{28}\text{Si}_{14} + E\text{m} \) reactions at the energies 3.7 and 14.6 GeV per nucleon. To determine the \( Q \) a number of charged projectile fragments \((Z_f)\) were used. The figures were obtained from paper [4]. The points of the regime change are observed in these dependences. These points were used by the authors to select the events with central collisions of nuclei.

In fig. 2 are shown the average values of pseudorapidity - \( \eta(\eta = -\ln \tan(\theta/2)) \) for \( s \)-particles\( (\text{the particles with } \beta > 0.7) \) depending on the number of \( g \)-particles\( (\text{the particles with } \beta \leq 0.7) \) for \( pE\text{m} \)-reactions at the momenta of \( p_0 = 4.5; 24.0; 50.0; 67.0 \) and 200.0 GeV/c. This figure was obtained from paper [5]. The dashed line in the figure corresponds to the cascade-evaporation model calculations. The points of the regime changes in these distributions are also seen. The cascade-evaporation model calculations cannot describe numerically these distributions.

In fig. 3 the \( Q \)-dependences of the absolute values of one-particle correlation function \( | R(pt, Y) | \) are shown for the protons in the \( ^{12}\text{CC} \)-interactions at the momentum of 4.2 A GeV/c. The data was obtained from paper [6]. Here \( Q \) is a number of protons in an event. The points of the regime changes in these figures are also seen. Thus the results clearly demonstrate that there exist the points of the regime change of the behavior of \( a_i = f(Q) \) distribution which could fix the region of the central collisions of nuclei. We believe that these points could be used to select the events with the central collisions of nuclei. So to find the points of the regime changes it is possible to investigate the \( a_i = f(Q) \) distributions' behaviour. The \( Q \) could be determinated as:

- a number of fragments\( (n_f) \);
- a number of protons in an event\( (n_p) \);
- an energy flow of particles at the emission angulars \( \theta \approx 0(\text{E}_{ZDC}) \) or \( \theta \approx 90(\text{E}_t) \) ones.

For further confirmation of the results on the existence the regime change points and for clarification of the reasons of these points appearance we studied the influence of nuclear fragmentation process on the behaviour of the events number depending on \( Q \). Supposing these points beeing connected with the appearence of a critical phenomenon the fragment number change could also have a critical character with the \( Q \) increase. Because the intermediate nuclear formations \( (\text{for example nuclear cluster}) \) could be a source of the nuclear fragmentation.

## 2 Experiment

We used 20407 events of \( ^{12}\text{CC} \)- reactions at the momentum of 4.2 A GeV/c obtained from the 2-m propane bubble chamber of LHE, JINR\( (\text{the methodical details are described in papers [7]} \). To determine the values of the \( Q \) two variants were considered. In the first variant the values of the \( Q \) were determined as

\[
Q = n_+ + N_p - n_-, \quad (1)
\]

here \( n_+ \), \( n_- \) and \( N_p \) are the numbers of identified \( \pi^+ \), \( \pi^- \)-mesons and protons respectively.

In that determination the \( Q \) is a number of all the protons in an event without taking
into account a remainder of nuclei. In the second variant the $Q$ values were determined as

$$Q = N_+ - n_-,$$

(2)

here $N_+$ are charges of all the positively charged particles in an event including the nuclear fragments. In that determination the $Q$ is a summary charge of an event.

3 Results

The distributions of the events number depending on the $Q$ are shown in fig.4a,b. In fig.4a the empty starlets correspond to the first variant and the full starlets - to the second variant. From fig. 4a it is seen that the fragments number to determine the $Q$ being included the form of distributions sharply changes and has a two-steps structure.

In fig.4b are shown the $Q$-dependences of the events number for the calculation data obtained from the quark-gluon string model (QGSM) without the nuclear fragments. The empty starlets correspond to the cases in which the stripping protons were not taken into account and the full starlets correspond to the cases in which the stripping protons were included. It is seen that the form of the distribution strongly differs from the experimental one in fig.4a. There is no two-steps structure in this figure. Therefore we can assert that this difference is connected with the existence of fragments in experimental events.

Thus, the results demonstrate that the influence of nuclear fragmentation process in the behaviour of the events number depending on the $Q$ has a critical character. To explain this result we suppose that it could be connect with the existence of nuclear clusters. It is possible to think that with the increasing of centrality degree the probability of cluster formation grows but further increasing the $Q$ (in the region of high $Q$) leads to the big clusters decay on nuclear fragments and then on free nucleons (see fig.5). It could be a reason for observation of two-step structure in the distributions. The first step connected with the formation of a cluster and second one with its decay.

4 Conclusion

1. The experimental results obtained in the nuclear-nuclear collisions at high energy clearly demonstrate the points of the regime change of the behaviour of some characteristics of secondary particles depending on the centrality degree of collisions. It could mean that there are cases corresponding to the critical phenomena among the events with the central collisions of nuclei.

2. For $^{12}CC$-interaction the behaviour of the number of events, depending on $Q$ also depends on the number of fragments and has a two-steps form which is not reproduced by the calculated data in the framework of the QGS model without nuclear fragments. This result could be explained by the existence of nuclear clusters.
Captions of figures

1. Q-dependences of multiplicity of relativistic charged particles in Si+Em reactions at the energies of a) 3.7 GeV per nucleon; b) 14.6 GeV per nucleon.
2. $n_g$-dependences of the average values of $\eta = -\ln \tan(\theta/2)$ for $n_s$-particles.
3. Q-dependences of the absolute values of one particle correlation function for the protons in $^{12}CC$-interaction.
4. Q-dependences of the event number of $^{12}CC$-interactions: a) experiment; b) quark-gluon string model.
5. Fig.5

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Fig. 1 a,b
Fig. 2.
Figure 4a,b.
Region of Peripheral Collisions

Region of Central Collisions
(or total disintegration of nuclei)

Fig. 5