Investigation of an angular distribution of protons in peripheral and central nucleus-nucleus collisions at the momentum of 4.2 A GeV/c.

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Abstract
The experimental results on the relation between the number of events, the angular distributions of protons and full number of protons are presented for $^{12}$CC-interactions at the momentum of 4.2 A GeV/c. The influence of nuclear fragmentation process on the results is also considered. The obtained results confirm the assumption that there exist the critical phenomena among the central collisions and it is necessary to use a percolation approach for the full description of the central collisions.

1. Introduction
At present there are many papers in which the processes of nuclear fragmentation [1] and the processes of a total disintegration of nuclei [2] (or central collisions) are considered as the critical phenomena and for their description a percolation approach was proposed.

Some experimental results obtained in the region of high energy [3]-[5] clearly demonstrate the existence of the regime change points in the behaviour of different characteristics of secondary particles and the events depending on centrality degree of collisions (in different papers the number of all protons [4], the number of multicharged fragments [3] and other parameters were considered for the latter).

We believe that if the observed regime change points are connected with the appearance and the decay of percolation cluster then with the increase of the centrality degree of collisions the behaviour of the secondary particles and the events characteristics depending on centrality degree of collisions must also depend on the number of fragments in the event, as the percolation cluster could be a source of nuclear fragments.

The purpose of our investigation is to test this idea experimentally.

2. Experiment
The experimental data have been obtained from the 2-m propane bubble chamber of LHE, JINR. We used 20407 $^{12}$CC- interactions at the momentum of 4.2 A GeV/c (for methodical details see [5]).

To reach the purpose we investigated a number of the events depending on the variable $Q$. To determine the values of $Q$ two variants were considered. In the first variant the values of $Q$ were determined as $Q = n_{\pi^+} + N_p - n_{\pi^-}$. Here $n_{\pi^+}, n_{\pi^-}$ and $N_p$ are the...
number of identified $\pi^+$, $\pi^-$ mesons and protons respectively (in figures these points are denoted as the empty starlets). In that determination $Q$ is a number of all the protons in an event without taking into account a remainder of nuclei. In the second variant the values of $Q$ were determined as $Q = N_+ - n_{\pi^-}$. Here $N_+$ are charges of all the positively charged particles in an event including nuclear fragments (in figures these points are denoted as the full starlets). In that determination $Q$ is a summary charge of an event.

3. Experimental results.

3.1. Q-dependence of the events number.

The distributions of the events depending on $Q$ are shown in fig.1a,b. It is seen that with the exclusion of fragments number to determine $Q$ the form of distributions sharply changes and has a two-steps structure(fig.1a, full starlets).

In fig.1b are shown the Q-dependences of the events for the calculation data obtained from the quark-gluon string model [7] (QGSM) without nuclear fragments. The empty starlets correspond to the cases when the stripping protons were not taken into account and the full starlets correspond to the cases when the stripping protons were included. It is seen that the form of the distribution strongly differs from the experimental one in fig.1a. There is no the two-steps structure in this figure. Therefore we can assert that this difference is connected with the existence of fragments in $^{12}$CC - interactions.

Thus, the results demonstrate that the influence of nuclear fragmentation process in the behaviour of different characteristics of the events depending on $Q$ has a critical character. We suppose this result to be connected with percolation clusters.

3.2. Q-dependence of the protons angular distributions.

To confirm the existence of percolation cluster we analysed the angular spectrums of identified protons depending on $Q$ and the number of fragments. We have obtained $N_i = \frac{N_i'}{\sum_{i=1}^{J} N_i'} = f(\cos \theta_i)$ (here $N_i'$ are a number of the protons at an emission angle of $\theta_i$ and $J$ is a total number of the protons in an event) for the following groups of events depending on $Q$: $Q \leq 5$(this is peripheral collisions-$N_1$); $Q = 6 - 7(N_2); 8 - 9(N_3); \geq 10$(this is central collisions-$N_4$).

To investigate $Q$-dependences of $N_i$-functions we used the following quantities: $f_1 = \frac{N_4 - N_3}{N_4 + N_3}; f_2 = \frac{N_4 - N_2}{N_4 + N_2}; f_3 = \frac{N_4 - N_1}{N_4 + N_1}$. To investigate the values of $f_i$ depending on the number of fragments we also used(as in (3.1)) two variants to determine the variable $Q$.

Fig.2 shows the $Q$-dependences of $f_1, f_2$ and $f_3$ as a function of $\cos \theta_i$. As well as in fig.1 the empty starlets corresponds to the cases when the nuclear fragments were not taken into account and the full starlets – the cases when the nuclear fragments were included. It is seen that these distributions differ for the two different variants of $Q$-determination. We see the increase of $f_3$ with the increase of $\cos \theta_i$ i.e. an additional production of protons in this interval. We suppose the percolation cluster to be a source of additional protons in this interval.

4. Summary

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. This form is not reproduced
by the calculated data in the framework of the QGS model which does not take into
account nuclear fragments. This result as well as the results obtained from the anal-
isys of angular distributions of protons in peripheral and central collisions could be a
confirmation of the existence of percolation clasters.

Finally we want to say that at GSI, AGS and Nuclotron energies this result can signal
about the existence of the transition of nuclear matter from nucleon states to its mixed
ones. At RHIC or LHC energies , a similar result could help to detect "critical" signals
of phasetransition nuclear matter.

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**Figure captions**

Fig.1. Q-dependence of the number of events.
Fig.2. Q-dependence of the angular distribution of protons.
$^{12}\text{CC proton}$

(a) $f_1$ vs. $\cos \theta_p$

(b) $f_2$ vs. $\cos \theta_p$

(c) $f_3$ vs. $\cos \theta_p$