COMPARISON OF EXPERIMENTAL AND THEORETICAL RESULTS TO DEFINE CENTRALITY OF HEAVY ION COLLISIONS

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Using the simulation data coming from the DCM, we have studied the behavior of Number of events as a function of impact parameter b and the number of charged particles N_{ch} for light and heavy nuclei at different energies. We have seen that for light nuclei, the number of charged particles N_{ch} could be used to fix the centrality. But for heavy nuclei we have got strong initial energy and mass dependences therefore the results for impact parameter b and the number of charged particles N_{ch} differ. So for heavy nuclei, a number of charged particles N_{ch} could not be use to fix the centrality.

Используя данные моделирования по Дубненской Каскадной Модели было рассмотрено поведение числа событий в зависимости от функции параметра столкновения b и числа заряженных частиц N_{ch} для легких и тяжелых ядер при различных энергиях. Видно, что для легких ядер, число заряженных частиц N_{ch} можно использовать для определения центральности. Но для тяжелых ядер, где мы имеем очень большую массу и большую начальную энергию зависимости результатов для параметра столкновения b и числа заряженных частиц N_{ch} отличаются. Таким образом, для тяжелых ядер число заряженных частиц N_{ch} не может быть использовано для определения центральности.

Yüngül və ağır ionların toqquşmalarında müxtəlif enerjilərdə Dubna Kaskad Modelindən istifadə edərək hadisələrin sayı təsir parametri b-nin və yüklü zərrəciklərin sayı N_{ch} funksiyası kimi asılılığını öyrənilib. Görünür ki, yüngül nüvələr üçün yüklü zərrəciklərin sayı N_{ch} mərkəzləşməyinin müəyyən etmək olar. Ancaq ağır nüvələr üçün biz güclü ilk enerjiyə və böyük kütləyə malik olduöumuz halda parametri b-i və yüklü zərrəciklərin sayı N_{ch} təsirlərin asılılığı fərqlənir. Beləliklə ağır nüvələr üçün yüklü zərrəciklərin sayı N_{ch} mərkəzləşməyinin təyin etmək üçün istifadə edilə bilməz.

1. INTRODUCTION

To fix the baryon density of nuclear matter, the centrality experiments are usually used. It is considered as best tool to reach the Quark Gluon Phase (QGP) [1] of nuclear matter under extreme conditions. Studying the different characteristics of events as a function of the centrality [2] in JINR (Dubna), CERN (Geneva), BNL (New-York), and SIS (Darmstadt) could give new information about the properties of nuclear matter which could appear under extreme conditions. On the other hand the centrality of collisions cannot be defined directly in the experiment. In different experiments the values of the centrality are defined [3-5] as a number of identified protons, projectiles' and targets' fragments, slow particles, all particles, as the energy flow of the particles with emission angles $\theta = 0^o$ or with $\theta = 90^o$. Apparently, it is not simple to compare quantitatively the results on centrality-dependences obtained in literature while on the other hand the definition of centrality could significantly influence the final results. May be this is a reason, why we could not get a clear signal on new phases of strongly interacting matter, though a lot of interesting information has been given in those experiments. During last several years some results of the central experiments are discussed which demonstrate the point of regime change and saturation on the behavior of some characteristics of the events as a function of the centrality [6]. It is supposed that these phenomena could be connected with fundamental properties of the strongly interacting mater and could reflect the changes of its states (phases).

2. DUBNA CASCADE MODEL

Among the host of models which are proposed to explain the general features of relativistic nucleus-nucleus collisions, Dubna Cascade Model (DCM) is the most popular model. It is an approach based on simulation (Monte-Carlo techniques) and applied to situation where multiple scattering is important. In the simplest approach it is assumed [7-12] that due to the interaction of a projectile hadron with one of the target nucleons the creation of a new particle takes place. The participating target nucleon accepts momentum and begins to move in the nucleus. All moving (cascade) particles can interact with other nuclear nucleons to produce new particles or suffer elastic rescattering. Therefore, cascade reproduction of moving particles is assumed. The interactions between cascade particles are omitted as a rule. The process continues until all moving particles either leave the nucleus or are absorbed. In the case of (A+A) collisions, it is assumed that cascade particles can interact with projectile and target nucleons. Due to analysis fast particles and correlations between slow and fast particles DCM [13] was recognized as the best model applied in the intermediate energy physics [14].

3. RESULTS FROM CENTRAL EXPERIMENTS

In paper [15] the results from BNL experiment E910 on pion production and stopping in proton-Be, Cu, and Au collisions as a function of centrality at a beam momentum of 18 GeV/c are presented. The centrality of the collisions is characterized using the measured number of «grey» tracks, N_{grey}, and a derived quantity ν, the number of inelastic nucleon-nucleon scatterings suffered by the projectile during the collision. In Fig. 1, the values of average multiplicity for π^{-} -mesons (<π^{-} multiplicity>) as a function of N_{grey} and ν is plotted for the three different targets. One can observe that < π^{-} multiplicity> increases approximately proportionally to N_{grey} and ν for all three targets at small values of N_{grey} or ν

and saturates with increasing N_{grey} and ν in the region of more high values of N_{grey} and ν. Fig. 2 is a plot of multiplicity of grey particles - N_g–dependences verses $< N_b >$ average multiplicity of b-particles for different reactions taken from [16]. One can see that the values of $< N_b >$ increase with N_g in the region of the values of $N_g < 8$. Than the values of the $< N_b >$ saturate in the region $N_g \geq 8$ as well as in Ref.[17].

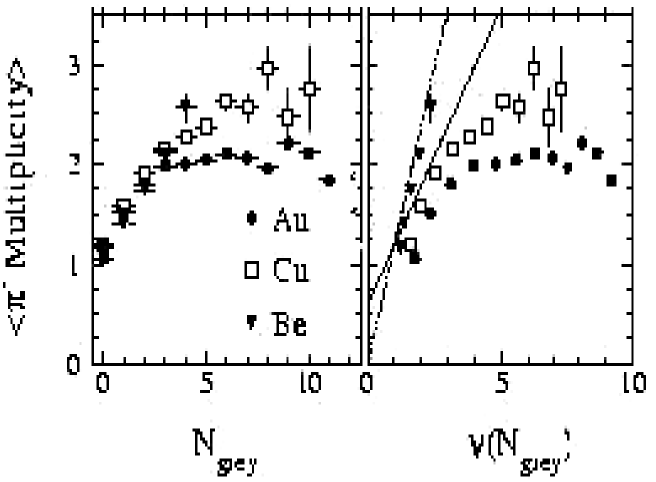

Fig.1. The average multiplicity of the π^- -mesons produced in proton-Be, Cu, and Au collisions as a function of centrality at a beam momentum of 18 GeV/c. Solid line demonstrates the results coming from the WN-model [15].

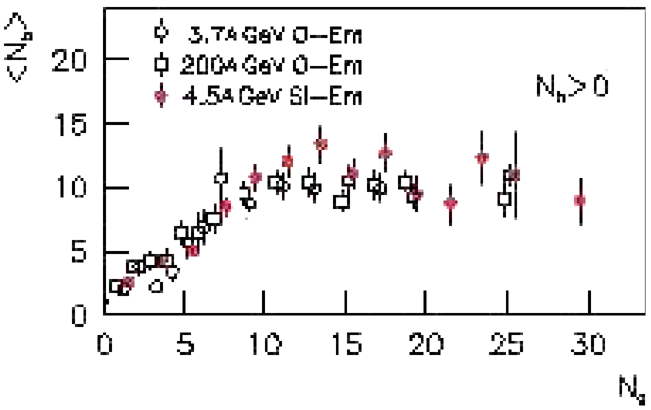

Fig.2. N_g –dependences of $< N_b >$ for different reactions [16]

The main results of these central experiments are: The regime change has been observed: at some values of centrality (as critical phenomena); for hadrons-nucleus, nucleus-nucleus and even in ultra relativistic heavy ion collisions; in the energy ranges from SIS energy up to RHIC; almost for all particles; after the point of regime change, saturation is observed; the existing simple models cannot explain the effect. If the regime change takes place unambiguously two times, this would surely be the most direct experimental evidence seen to observe the QCD critical point and phase transition. But the central experiments could not confirm it. One of its reasons may be the incorrect definition of the centrality. So it is very important to study the connections between the different methods for fixing the centrality and looking for the new possibilities to fix the centrality especially in heavy ion collisions where the formation of QGP is expected. The main goal of our paper is to study the connections between different methods offered to fix the centrality and search for new methods to fix the centrality.

4. METHOD

To reach our goal, we use the simulation data coming from the DCM. DCM is usually used for a chosen variable to fix centrality. It is supposed that its values have to increase linearly with a number of colliding nucleons or baryon density of the nuclear matter. The simplest mechanism that could give this dependence is the cascade approach. So, we have used DCM to simulate events at different energies and mass colliding hadrons and nuclei. This code [18] is written by F.G. Geregy and J.J. Musulmanbekov and was modified by S.Yu. Shmakov and V.V. Uzhinskii in 1993. The DCM is used for calculation of nucleus-nucleus inelastic interactions at energies up to 20 A GeV.We considered the following reactions: He+He; C+C; Au+Au at the energies; 1; 6; 12; 18 A GeV/c for 200 events. Two variables were used to fix the centrality: a) impact factor *b,* which could not be define experimentally; b) charged particles N_{ch} , which could be defined experimentally.

5. DUBNA CASCADE MODEL RESULTS

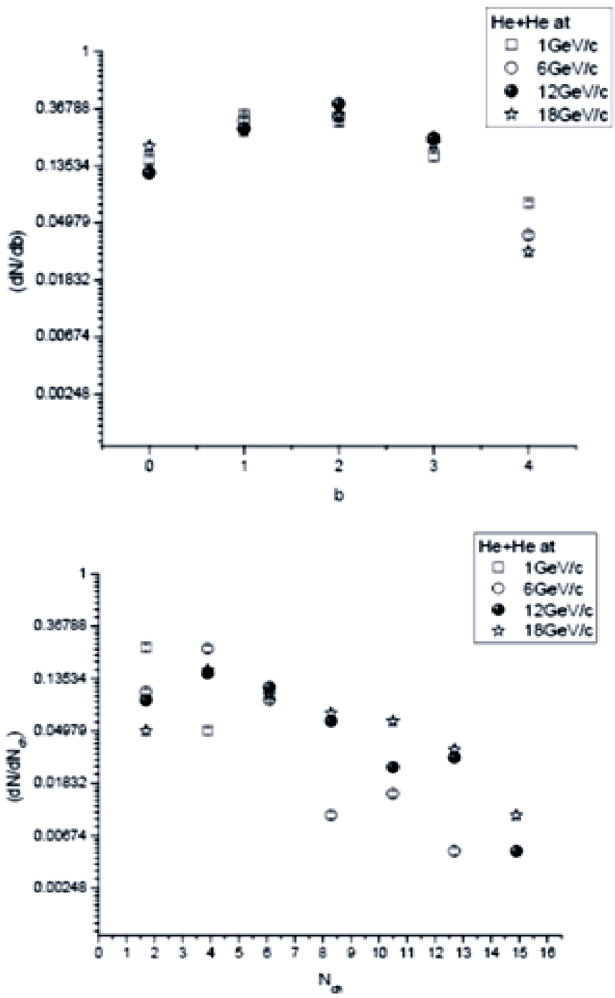

Fig.3. The *b* and N_{ch} dependences of normalized event numbers for *He+He* interactions coming from DCM

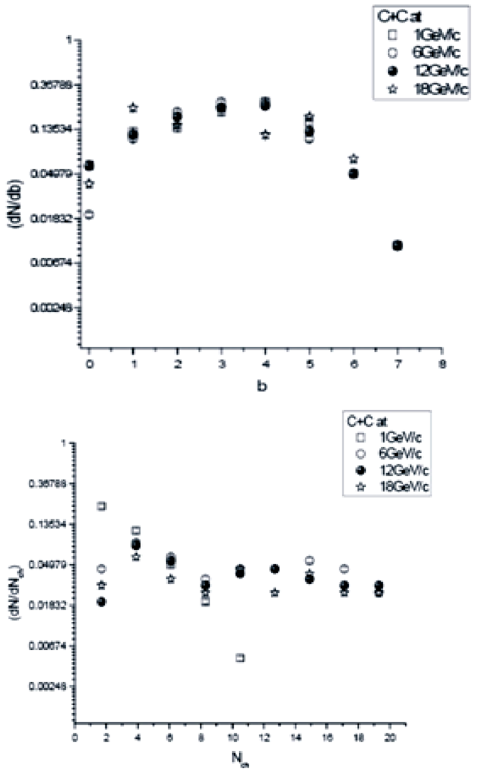

Fig.4. The *b* and N_{ch} dependences of normalized event numbers for *C+C* interactions coming from DCM

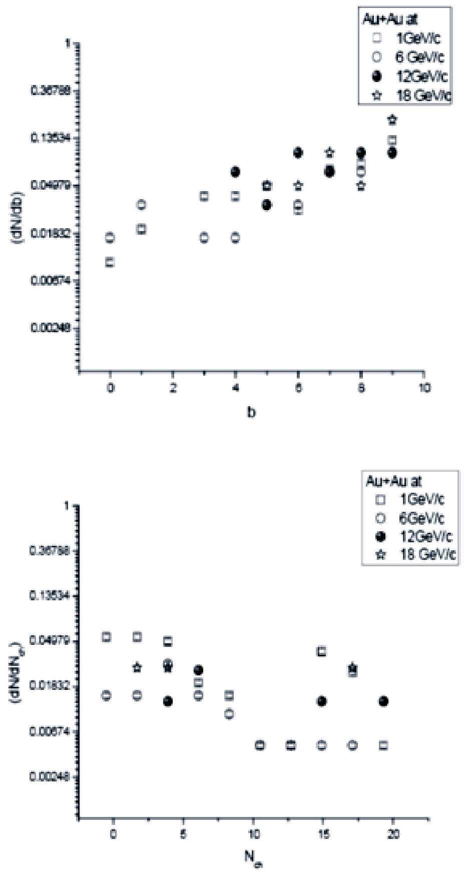

Fig.5. The *b* and N_{ch} dependences of normalized event numbers for *Au+Au*- interactions coming from DCM.

6. DISCUSSION

The behavior of the normalized event number dN/db as a function of *b* and the dN/dN_{ch} as a function of N_{ch} for *He+He* reactions at different initial energies are shown in fig.3. One can see that the behavior of the impact parameter distributions don't depend on the energy of the colliding nuclei for most central (*b=0*), central and semi central collisions ($0 < b < 3$). We can see some mass dependence for the peripheral collisions ($b>3$). We can also say that there are 2 regions on the behavior of the dN/db as a function of the *b*. In first region $b < 3$, the values of dN/db greater than in region with $b > 3$.The behavior of the event number as a function of N_{ch} has the stronger energy dependences. We can say that at energies equal and great than 6 GeV we can find some analogies between the behavior of the distribution of the events as a function of the *b* and N_{ch}. It means in these cases the N_{ch} could be use to fix the centrality instead of *b* .In fig. 4 ,the behavior of the normalized event number as a function of *b* and N_{ch} for *CC* reactions at different energies is shown. There is some energy dependence for the behavior of dN/db as a function of the *b* in the region of momentum great that 12 AGeV/c. For these reactions there are 3 regions on the behavior of the N as a function of the *b*: *b=0* most central collisions; $0< b <5$ central and semi central collisions and $b>5$ peripheral collisions. So one can say that with increasing the mass of the colliding particles, DCM give some energy dependence for the behavior event number as a function of *b.* Again we can say that the behavior of the event number as a function of N_{ch} has the stronger energy dependences. The fluctuation in the behavior of the event number as a function of N_{ch} increase and it is very difficult to find some analogies between the behavior of the distribution of the events as a function of the b and N_{ch}. So it means that it will be very difficult to use the last to fix the centrality instead of *b*. The same result we can get for the heavy ion collisions. For *Au+Au* reactions at different energies the *b* and N_{ch} dependences of normalized event number dN/db and dN$_{ch}$ are shown in the Fig.5. We can see the strong dependence for the behavior of event numbers as a function of the impact parameter b. This picture also indicates different regions for the behavior of event numbers as a function of the
b but N_{ch} has strong energy dependence. We cannot find any analogy for the behavior of the distributions with b and N_{ch} . It means that for heavy nuclear interactions N_{ch} *is* not good variable to fix the centrality.

7. CONCLUSION

The behavior of the normalized event number as a function of impact parameter b and charged particles N_{ch} for *He+He, C+C and Au+Au* reactions at different initial energies coming from DCM are point that for the light nuclei charged particles N_{ch} could be used to fix the centrality. For heavy nuclei we have got strong initial energy and mass dependences and the results for impact factor b and charged particles N_{ch} differ. So in this case charged particles N_{ch} could not be use to fix the centrality.

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