On the evolution of heaviest fragment in peripheral Au+Au collisions using dynamical clustering model

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Introduction

The heavy-ion reactions (HI) at intermediate energies provide a unique tool to investigate the equation of state (EoS) of nuclear matter away from the saturation density. The concept of nuclear EoS, however, gets complicated by the finite character of nuclei. It would be interesting enough to study the HI reaction at low incident energies, when nucleons are still in the Fermi energy domain. The recent experiments around Fermi energy have seen the production of intermediate mass fragments (IMFs) [1]. However, the conventional method of clusterization based on the spatial correlations among nucleons *i.e. minimum spanning tree* (MST) approach is not expected to describe the fragment production at such low beam energies at least for the characteristic time of a reaction. One may have to wait long enough to detect the stable fragment configuration. In this paper, we aim to explore the application of advanced clusterization algorithm namely as *simulated annealing clusterization algorithm* (*SACA*) which is based on the minimization of fragments' total energy in low energy HI reactions. This algorithm is reported to explain the spectator matter fragmentation at relativistic bombarding energies quite accurately [2].

The Model

For the present study, we simulate Au+Au collisions at incident energy T_{lab}= 35 AMeV using the *quantum molecular dynamics* (QMD) model [3]. This approach takes into consideration the quantum features of Pauli blocking and stochastic *n*-*n* scattering. Nucleons are chosen to be Gaussian wave packets in $\mathcal{R}_3$ and $\mathcal{P}_3$ spaces which interact via mutual density dependent 2-body interactions. We shall here use the improvised version of SACA labeled as *SACA (2.1)* [4] where fragment binding energy ζ_f should be more than E_{bind} defined as:

$$E_{bind} = a_v A_f - a_s A_f^{2/3} - a_c \frac{Z_f(A_f-1)}{A_f^{1/3}} - a_{sym}\frac{(A_f-2Z_f)^2}{A_f}(\pm,0)\ a_p\frac{(1-e^{-A_f/30})}{A_f^{1/2}}, \quad (1)$$

with A_f and Z_f as mass and charge of a fragment. The last term (i.e. pairing energy term) is taken to be +ve for even-even nuclei, -ve for odd-odd nuclei and zero for odd A_f nuclei.

Results and Discussion

Turning to the results obtained with *SACA (2.1)* and MST analysis, we show in Fig.1 the time evolution of Au(35 AMeV)+Au reaction at a reduced impact parameter b/b_{max}=0.55. The average nucleon density ρ^{avg} (first panel) saturates around 100 fm/c when *SACA (2.1)* is able to detect the asymptotic size of A^{max}. The QMD+MST approach, however, detects a bigger fused system at such early times and takes longer time ($\sim$ 300 fm/c) to recognize the final A^{max}. Bottom panel displays the evolution of clusters with mass $A \geq 5$. For larger times, we can see that both approaches converge to same cluster configuration. Next, we compare the model calculations of charge of the heaviest fragment Z^{max} for unfiltered events with experimental data in Fig. 2. The filled circles represent the experimental Z^{max} obtained from peripheral events associated with the quasiprojectile (QP) decay. *SACA (2.1)* qualitatively reproduce the Z^{max} at different peripheral geometries, while MST approach fails to describe the spectator

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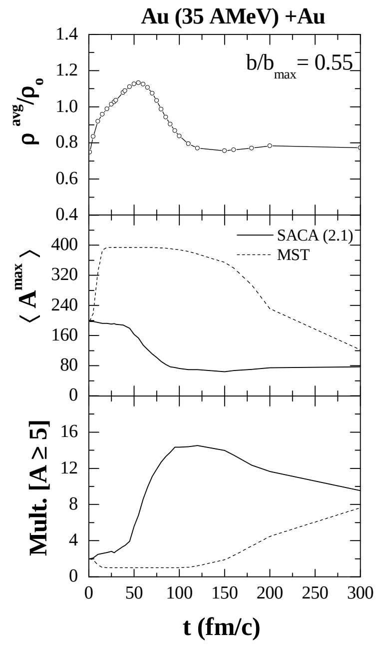

FIG. 1: The time evolution of mean nucleon density ρ^{avg}, size of heaviest fragment A^{max}, and multiplicity of heavier clusters with mass $A \geq 5$ in Au(35 AMeV)+Au collisions at reduced impact parameter b/b_{max} =0.55 (Preliminary results).

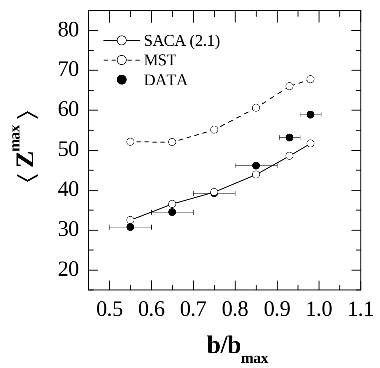

FIG. 2: The charge of heaviest fragment Z^{max} vs reduced impact parameter b/b_{max}. Model calculations using MST (dashed line) and *SACA(2.1)* (solid line) approaches for unfiltered events are compared with experimental data (filled circles) [5] (Preliminary results).

fragmentation even at 300 fm/c. This analysis suggests that *SACA (2.1)* method allows us to study the early dynamics of fragment formation when fragments are not well separated from each other in phase space.

This study shows that *SACA (2.1)* can well describe the early dynamics of reaction at low energies. This also reduces the computation time and ensures bound cluster configuration [6].

Acknowledgments

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References

[1] B. Jakobsson *et al.*, Nucl. Phys. A **509**, 195 (1990).

[2] Y. K. Vermani and R. K. Puri, Europhys. Lett. **85**, 62001 (2009).

[3] C. Hartnack *et al.*, Eur. Phys. J A **1**, 151 (1998).

[4] Y. K. Vermani *et al.*, J. Phys. G: Nucl. and Part. Phys. (2009)-in press.

[5] M. D'Agostino, private communication.

[6] Y. K. Vermani and R. K. Puri, J. Phys. G : Nucl. and Part. Phys. (2009)-submitted.