On the stability of fragment structures within clusterization based on thermal binding energies

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Introduction

Dynamical models preserve the correlations and fluctuations among the nucleons; therefore, are extensively used to study the formation of clusters in heavy-ion reactions. One of the problems with the molecular dynamics model is that it follows the time evolution of the nucleons only and therefore, one has to construct the fragments. To explain multifragmentation, it is very necessary to have an algorithm which can give stable and realistic fragments. Between various available clusterization algorithms, the widely used one is based on spatial constraint among nucleons, namely minimum spanning tree (MST) method. This method, by definition, may detect the unbound excited fragments. We modify this method by putting additional binding energy checks, *i.e.,* cold binding energy cut (labelled as MST-B) and temperature-dependent binding energy [1] cut (labelled as MST-BT), on fragments formed by the MST method. The reader is referred to Ref. [2] for the details of the model (Quantum Molecular Dynamics model) used in the present study and to Ref. [3] for the details of the modifications of the MST method. We will then compare the stability of the fragments obtained using above mentioned procedures. This analysis will shed light on the role of thermal effects in fragmentation which have been incorporated via clusterization algorithm.

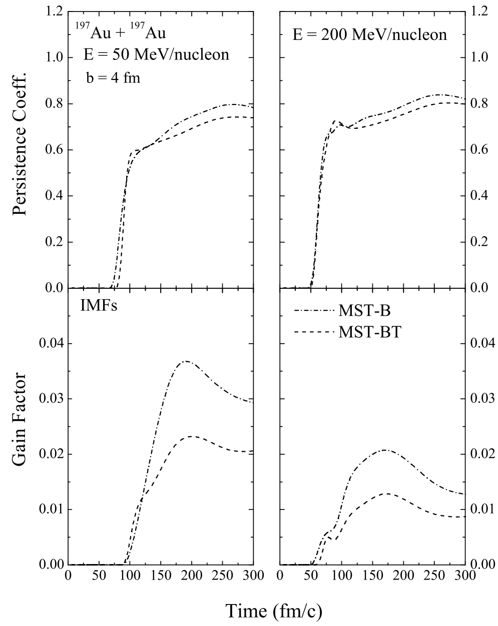

FIG. 1: The persistence coefficient and gain factor of IMFs as a function of time for the reactions of ^{197}Au+^{197}Au at an incident energy of 50 MeV/nucleon (left panels) and 200 MeV/nucleon (right). (preliminary results)

Results and discussion

The *persistence coefficient* and the *gain factor* [4, 5] are generally used to study the stability of fragments. The persistence coefficient and gain factor tell about the stability of the fragments between two successive time steps. If the fragment does not emit any nucleon between two subsequent time steps, the persistence coefficient is unity. On the other hand, if fragment gets disintegrated between two consecutive time steps, persistence coefficient is zero. On the other hand, gain factor provides the information that whether a fragment has swallowed some nucleons or not between two consecutive time steps. Thus, it will tell that

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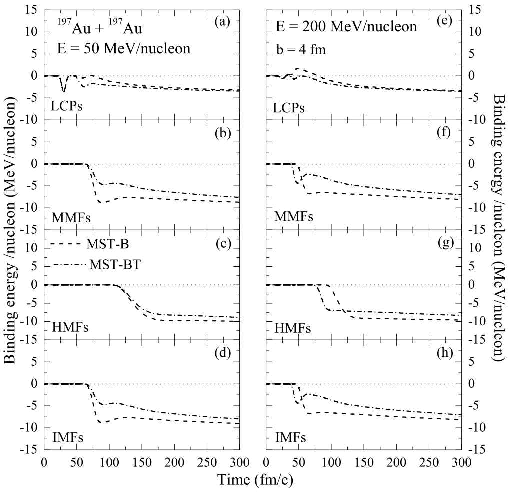

FIG. 2: The time evolution of the binding energy per nucleon of different fragments for the reactions of ^{197}Au+^{197}Au at an incident energies of 50 (left panels) 200 MeV/nucleon (right) at an impact parameter of 4 fm.

whether the interactions among the fragments have ceased or not. For detailed description of the two, reader is referred to Refs. [4, 5]

To study the stability of the fragments formed using MST-B and MST-BT methods, we display in Fig. 1, persistence coefficient and gain factors for the reactions of ^{197}Au+^{197}Au at incident energies of 50 and 200 MeV/nucleon at an impact parameter of 4 fm using a soft equation of state and energy-dependent nucleon-nucleon cross section. From the figure, we observe that persistence coefficient is close to unity at the freeze out time, thus indicating towards the formation of stable fragments. Higher values of persistence coefficients with MST-BT compard to that of MST-B clearly points that MST-BT gives us more bound structures as compared to MST-B. Similar results are found for the gain factor also. Gain factor of the fragments approaches zero, thus representing that the interactions among the fragments cease at the freeze out stage.

In Fig. 2, we display the average binding energies of various fragments (light charged particles (LCPs) [$2 \leq A \leq 4$], medium mass fragments (MMFs) [$5 \leq A \leq 20$], heavy mass fragments (HMFs) [$21 \leq A \leq 65$] and intermediate mass fragments (IMFs) [$5 \leq A \leq 65$]) for the reactions of ^{197}Au+^{197}Au at incident energies of 50 and 200 MeV/nucleon. From the figure, we find that the fragments are excited in the initial stage but as the time progresses the fragments cool down. Although MST-B gives tightly bound structures, but it will omit the fragments which are mildly excited and will yield stable structure at the freeze out stage. These mildly excited fragments will fulfill the thermal binding energy criteria (MST-BT) and remain as fragments. By observing these results of persistence coefficient, gain term and binding energy/nucleon, we find that fragments formed by the MST-B and MST-BT are bound and stable. Also, between MST-B and MST-BT, the latter will not only give us the fragments which are more realistic and stable, but also can detect the stable fragment structure earlier in time. Comparison of the available experimental data for whole mass range and different energies is under progress.

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