Isospin sensitive cluster recognition in heavy-ion collisions

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1. Introduction

During last two decades, extensive efforts have been made experimentally and theoretically to study the multifragmentation and related phenomena [1]. Rapid Progress in the production of radioactive beams has also given unique opportunity to explore isospin dynamics in the nuclear fragmentation [2]. The study on the role of isospin effects in multifragmentation is also important as it can provide vital information about the equation of state of asymmetric nuclear matter and isospin dependent nucleon-nucleon cross-section [2]. One also needs to check whether fragments of a multifragmentation reaction are stable or not. The molecular dynamics models are extensively used to study the formation of these clusters. Since primary transport theory (or model) can only give phase space of nucleons on event by event basis, therefore, secondary algorithms such as coalescence model are employed to construct fragments. A lot of effort has been made to avoid the creation of unbound, unstable, and weakly bound fragments [3]. The simplest approach for fragment identification uses spatial correlation between nucleons. This method is commonly known as *minimum spanning tree* (MST) algorithm. In this algorithm, the two nucleons with relative distance $|\mathbf{r}_i - \mathbf{r}_j| \leq R_0$ are assumed to form a cluster. The typical value of R_0 used in MST method is in the range 3-4 fm [4]. This method, however, fails to reproduce fragmentation data obtained experimentally [3, 5].
In the present paper, we aim to investigate the role of isospin via spatial constraints used in the MST algorithm. Within the framework of *isospin dependent quantum molecular dynamics* (IQMD) model, we aim to improve upon MST algorithm by including the isospin dependence in cluster identification [4]. We choose different values for R_0 spatial constraint depending upon isospin of nucleons. One set of calculations is done with $R_0^{nn} = R_0^{np} = 6fm$ and $R_0^{pp} = 4fm$. Another set of calculations uses $R_0^{nn} = R_0^{np} = 3fm$ and $R_0^{pp} = 2fm$. Finally the results obtained with isospin dependent versions (*i.e.* iso-MST) are compared with conventional MST algorithm.

2. Results and Discussion

We simulate the semi-central collisions ($b/b_{max} = 0.2$) of $^{197}Au + ^{197}Au$ at an incident energy of 600 AMeV. These collisions are simulated for 500 events using a *soft* equation of state. In the Fig. 1, we display the time evolution of persistence coefficient and gain factor for intermediate mass fragments *IMFs* ($5 \leq A \leq 65$). The model calculations using conventional MST method ($R_0 = 4fm$), are compared with two sets of iso-MST algorithm. As it is explained many times in literature [6] that the persistence coefficient tells about the stability of the fragments between two successive time steps. If a fragment does not emit any nucleon between two successive time steps, the persistence coefficient is one.

The larger values of R_0^{nn} (and R_0^{np}) as compared to R_0^{pp} have been taken keeping in mind the properties of neutron rich nuclei such as neutron skin effect. Smaller value of relative distance R_0^{pp} is also due to long range Coulomb repulsion between protons in a cluster. One can see that choice of isospin dependent spatial constraints has significant influence on the final fragment structure. The IMFs formed are more stable and bound when higher values of relative distances R_0^{nn}, R_0^{np}, R_0^{pp} are employed. Persistence coefficient obtained with lower value of spatial constraints $R_0^{nn} = R_0^{np} = 3fm$, $R_0^{pp} = 2fm$, however, exhibits lesser bound structure. Similar results

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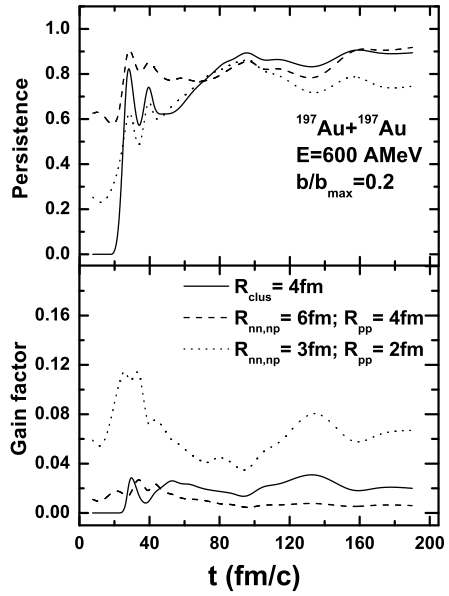

FIG. 1: The persistence coefficient (top panel) and gain factor (bottom panel) of IMFs as a function of time for the reaction of $^{197}Au +^{197} Au$ at 600 AMeV and at reduced impact parameter $b/b_{max} = 0.2$.

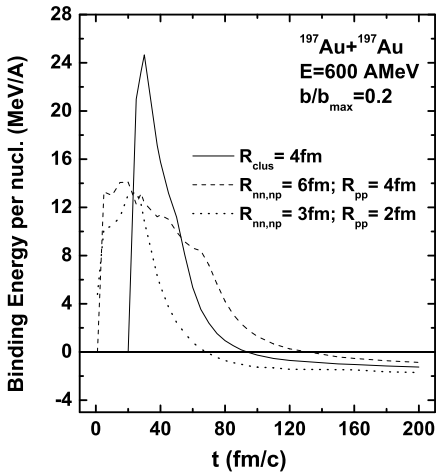

FIG. 2: Time evolution of average binding energy of IMFs for the same reaction as in Fig.1.

are found for the gain factor also. The gain factor represents the percentage of nucleons that a fragment has swallowed between two time steps. Gain factor for intermediate mass fragments approaches zero when the relative distance between the two nucleons is larger indicating that the interactions among the fragments cease at the freeze out stage. In Fig. 2, we display the time evolution of average binding energy of intermediate mass fragments for the same reaction as studied in Fig. 1. The fragments are excited in the initial stage but with the passage of time, the fragments cool down. One can also see that the IMFs formed using iso-MST algorithm are stable and bound at the end of reaction.

From the above discussion, we can infer that isospin dependence of spatial constraints can play a significant role in the identification of bound fragment structure. Our model calculations show that stable fragment configuration is obtained using iso-MST algorithm with $R_0^{nn} = R_0^{np} = 6fm$, $R_0^{pp} = 4fm$.

3. Acknowledgments

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