Extraction of critical exponents within dynamical model calculations

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Introduction

In the last few decades heavy-ion collisions in the intermediate energy domain have been analyzed extensively to search for liquid-gas phase transition signatures. It is only with great accuracy and difficulty that number of such signature parameters have been constructed and/or proposed. Mostly, the phase transition is inferred from the power-law dependence of charge of intermediate mass fragments ($5 \leq A_f \leq A_{Total}/3$) distribution near critical point. Others use critical exponents based on moments (or normalized moments) of charge distribution, fluctuation of size of largest fragment, second largest fragments, multiplicity derivative of fragments, observation of scaling laws etc. [1–5]. One of the goals of these studies is to map the phase coexistence region in multifragmentation.

Recently, Lin *et al.,* [5] studied various critical exponents in the light of statistical multifragmentation model (SMM). Their calculations reflects that the simultaneous study of all these parameters can better help to pin down the critical point of phase-transition. But studies with other models are also needed to pin down critical point in a model independent way. In the present study, we attempted to examine the phase-transition signals within quantum molecular dynamics (QMD) model [6]. We use two different fragment recognition algorithms. In first one fragments are identified on the basis of spatial proximity of nucleons and is dubbed as minimum spanning tree (MST) method. In second one metropolis technique is used for fragment identification and is termed as simulated annealing clusterization algorithm (SACA) [6–8]. We will look for two main aspects: 1) the observation of few of the possible phase-transition signals in dynamical model calculations and/or 2) to see if they are influenced by the different fragment identification techniques.

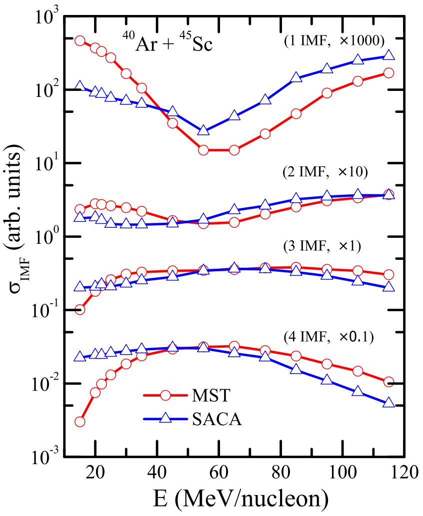

FIG. 1: The cross-section of IMF production at different incident energies for the central reactions of ^{40}Ar+^{45}Sc using MST and SACA fragment identifiers.

Results and discussion

In Fig. 1, we plotted the cross-section to obtain events with one, two, three and four intermediate mass fragments (IMFs) for the central reactions of ^{40}Ar+^{45}Sc in the incident energy range of 15-115 MeV/nucleon. The circles (triangles) represent the results obtained using MST (SACA) method as fragment identifier. Lines are drawn to guide the eyes. Ma *et al.,* [3] proposed that σ_{IMF}=1 events show minima and σ_{IMF}=2 events show maxima at critical point. We also observe this minima for σ_{IMF}=1 at ∼ 55 MeV/nucleon for both frag-

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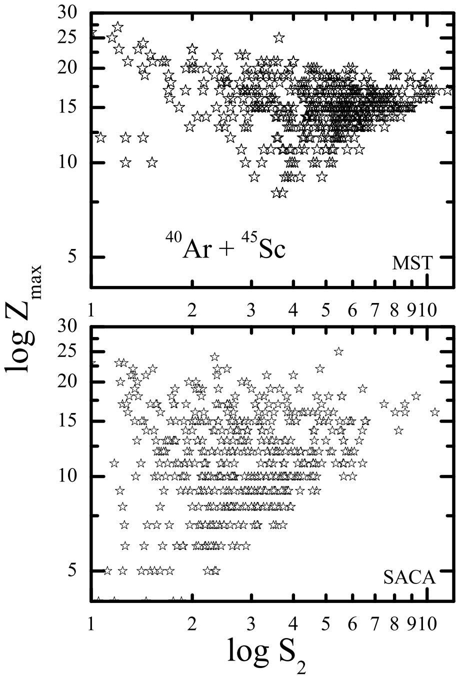

FIG. 2: Campi plot for fragments identified using MST (upper panel) and SACA (lower panel) methods for the central reactions of ^{40}Ar+^{45}Sc at their respective critical points.

ment identification techniques. The minima is broader (55-65 MeV/nucleon) for the case of MST identified fragments and sharper for SACA identified fragments. But for the same system experimental studies have observed the critical point of phase transition at 23.9 ± 0.7 MeV/nucleon [2]. Therefore, even though we do not exclude the possibility of observation of such minima as a phase-transition signal away from critical point but our results show that it can not contribute much to pin down the exact critical point. On the other hand, σ_{IMF}=2 events do not show maxima or any characteristic signal as proposed in Ref. [3]. Higher multiplicity events also do not contribute for any particular behavior at critical point.

Next, we fit the charge distribution of IMFs and found critical point to exist at $\sim$ 18 and $\sim$ 23 MeV/nucleon for MST and SACA identified fragments, respectively. Campi plots are also used to describe the critical point of phase-transition [1, 3]. In Fig. 2, we plotted (Campi plot) the values of the charge of the largest fragment (Z_{max}) and normalized second moment (S_2) obtained on event-by-event basis [1]. These results are shown at incident energies where critical point is observed with MST and SACA identified fragments. We see that the Campi plots differ significantly for both the fragment identification methods. It was shown in previous studies that scattering in Campi plots enhance near and/or at critical point [1, 3]. We see such signals are better preserved by SACA identified fragments. The MST identified fragments also show characteristic signal but show more dominance in liquid-phase side in fragmentation. This may be due to the incapability of MST method to disentangle the overlapping fragments which is well tackled in SACA method. Therefore, our study shows that the critical parameters should be analyzed in the light of various clusterization algorithms to pin it down within dynamical calculations.

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