Sensitivity study of experimental measures for nuclear liquid gas phase transition in statistical multifragmentation model (SMM)

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The experimental measures of the multiplicity derivatives, the moment parameters, the bimodal parameter, the fluctuation of maximum fragment charge number (NVZ), the Fisher exponent (τ) and Z_{ipf}'s law parameter (ξ) [1], are examined to search for the liquid gas phase transition in nuclear multifragmention processes within the framework of the statistical multifragmentation model (SMM).

Y.G. Ma *et al.* in Ref. [1] were examined most of these measures except the multiplicity derivatives, as a function of the excitation energy, using rather light reaction systems of ^{40}Ar+^{27}Al, ^{48}Ti and ^{58}Ni at 47 MeV/nucleon, and showed that all of them show a critical behavior around E/A = 5.6 MeV. However since all values of the measures are plotted as a function of the excitation energy, the signature appears as a broad peak around E/A = 5.6 MeV. Recently the multiplicity derivatives is proposed by S. Mallik et al. [2] for a sensitive probe for the first order phase transition.

SMM calculations are performed with the source mass number As = 100, charge number Zs = 45, the fragmenting volume V = $6V_0$. The default symmetry energy coefficient = 25 MeV is used. The input source excitation energy (E_x) varies from 1 to 15 MeV/nucleon with the energy step of 0.25 MeV/nucleon.

The specific heat capacity has long been considered to be a measure that should provide important information on the postulated nuclear liquid gas phase transition. As one can see from Fig. 1 (a) that a significant plateauing of the caloric curve is found at Ex ~ 4 MeV for the SMM calculations, which reflects a sharp increasing of the C_v as shown in Fig. 1 (b). The sharp maximum of the C_v strongly

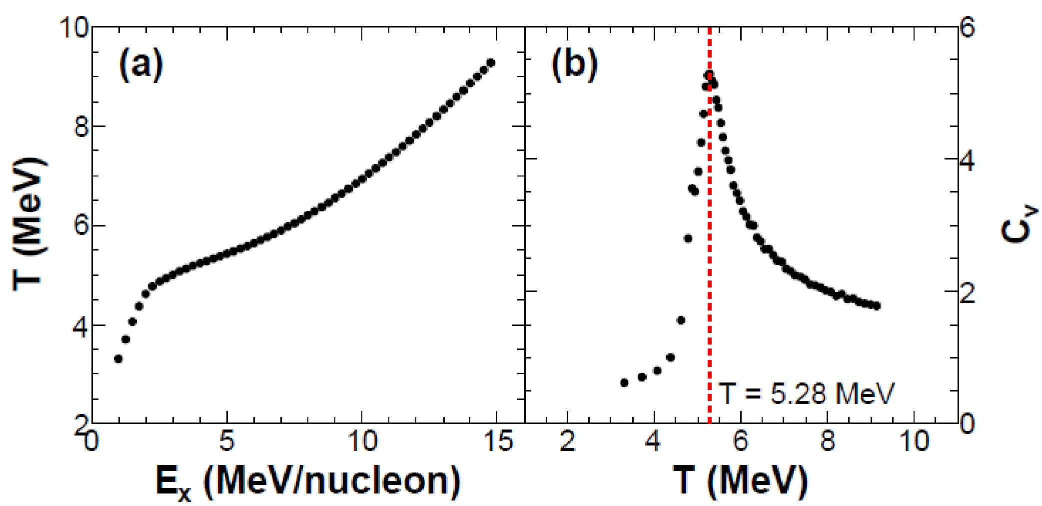

FIG. 1. (Color online) (a) Caloric curve of fragmenting source with As = 100, Zs = 45 of SMM calculations. (b) Specific heat capacity C_v derived from caloric curve as a function of source temperature. The vertical line shows the critical point at T = 5.3 MeV.

suggests the liquid gas phase transition occurs in SMM. The critical point at temperature T = 5.3 MeV is obtained. The other measures are also examined and results are shown below. All measures examined above show a critical behavior around T=5.3 MeV.

The sensitivity of these measures are further studied within 5% uncertainties around the peak in each measure. Fig. 2 shows the sensitivities of all these measures except for the bimodal parameter, in which the inflection point is used to obtain the critical point and the sensitivity is unable to be defined.

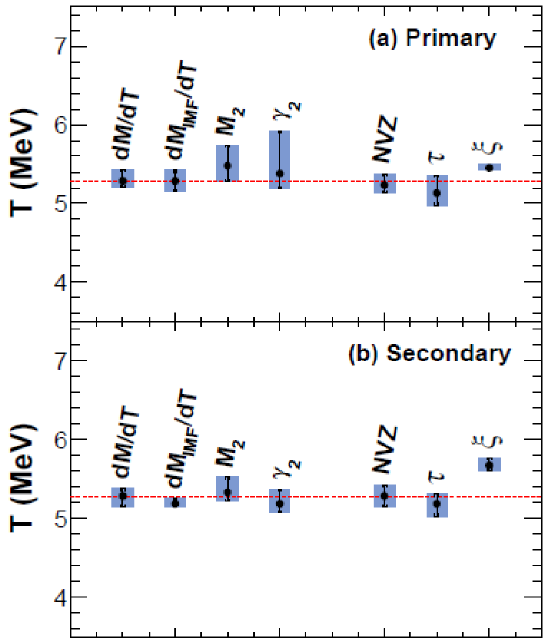

FIG. 2. (Color online) (a) The sensitivities in the critical temperature of primary fragments for all the measures except for bimodal parameter. (b) The same as that in (a) but of secondary fragments. The horizontal lines indicate the critical point at T = 5.3 MeV from Fig. 1 (b). Solid circles correspond to the critical temperature extracted by each measures. The errors indicate the sensitivities in the critical temperature when the critical measures have 5% uncertainties.

From the Fig. 2, we conclude that all measures examined here are sensitive to the first order phase transition, but the total multiplicity derivative and NVZ provide the most accurate measures both for the primary and secondary fragments

[1] Y.G. Ma *et al.*, Phys. Rev. C **71**, 054606 (2005).
[2] S. Mallik *et al*., Phys. Rev. C **95**, 061601(R) (2017).