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Critical fluctuations of the higher moments of order parameter and energy from 3D-Ising, O(2) and O(4) models

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Higher moments of net-baryon are suggested to be sensitive probe of QCD critical end point [1] in relativistic heavy ion collisions. Their critical fluctuations are highly interesting and instructive for the exploration of QCD phase diagram from both theoretical and experimental sides.

According to the universality of critical behavior, the QCD critical end point, and the chiral phase transition in two-flavor QCD are argued to be the same universality class of 3 dimensional Ising model [2], and O(2), or O(4) model[3], respectively. The generic structures of net-baryon fluctuations at QCD critical end point and chiral phase transition in the chiral limit with vanishing baryon chemical potential can be discussed by the order-parameter fluctuations in Ising model and the energy fluctuations in O(2), or O(4) model [4,5]. So in the present work, the higher moments of order parameter and energy from 3D-Ising, O(2) and O(4) models near the critical temperature at finite size are systematically studied, and compared with those obtained from effective models, and Lattice QCD calculations.

It is found that the generic structures of order-parameter fluctuations in 3D-Ising, O(2) and O(4) models are similar. So do energy fluctuations. On the other hand, the singular structures of order parameter fluctuations appear at lower moments, e.g., the oscillation structures of 4th moment of order parameter, which may reflect the generic structure of 4th order moment of baryon number in the vicinity of critical end point, are similar to the 3rd moments of energy, which corresponding to the 6th moment of net-baryon number at chiral phase transition in the chiral limit with vanishing baryon chemical potential. This means that even higher moments, such as 6th moments of net-baryon number, are necessary in probing the chiral phase transition temperature, the same as what suggested in ref. [5].

The generic singular structures of order-parameter fluctuations in 3D-Ising and energy fluctuations in O(2), or O(4) models are qualitatively consistent with corresponding estimations of Nambu-Jona-Lasinio [6], Linear Sigma model [7], Polyakov-Nambu-Jona-Lasinio [8], Polyakov Quark Meson models [9], and current lattice QCD calculations [10].

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