Finite Size Effect on QCD Phase Transitions via a Non-perturbative QCD Approach

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QCD phase transitions have been explored for more than forty years and some significant progresses have been made. Now not only theories but also experiments, *e.g.*, the Beam Energy Scan (BES) program at RHIC, the FAIR at GSI and the NICA at DUBNA, all take the search for the critical end-point (CEP), which separates the first order phase transition region from the crossover region of the system with physical quark mass, as their investigation focus. It is well known that the observable system in laboratory experiment is in finite size. Moreover, what one can measure in experiment are the states after the chemical freeze-out but not at the phase transition line. Then the finite size effect on the QCD phase transitions and the chemical freeze-out conditions is studied in recent years. However, quite unfortunately, different methods give contradictory results. It is then imperative to investigate the phase transitions and the chemical freeze-out conditions via sophisticated QCD approaches including the finite size effect.

It has been known that the Dyson-Schwinger equations (DSEs), a non-perturbative continuum approach of QCD, can successfully describe the QCD phase transitions and hadron properties (for recent reviews, see *e.g.*, A. Bashir *et al.*, Commun. Theor. Phys. 58: 79 (2012); I. C. Cloet and C. D. Roberts, Prog. Part. Nucl. Phys. 77: 1 (2014)). We then take the DSE method including the finite size effect to do the work. We calculate the chiral and baryon number susceptibilities and other properties in terms of not only temperature but also chemical potential of the light-flavor quark system. With the chiral susceptibility and other criteria, we fix the phase diagram. By comparing the baryon number fluctuation ratios χ_1^B/χ_2^B and χ_3^B/χ_1^B with the experimental data, we determine the freeze-out conditions. We observe that shortening the size scale of the system reduces the (pseudo)critical and the freeze-out temperatures and enlarges the chemical potential of the CEP, and retards the increase of the freeze-out chemical potential. Meanwhile, the calculated $\sqrt{S_{\rm NN}}$ dependence of the kurtosis χ_4^B/χ_2^B ($\kappa\sigma^2$) agrees with experimental data in $\sqrt{S_{\rm NN}} \geq 19.6\,\text{GeV}$ region more excellently and exhibits a non-monotonic behavior in lower $\sqrt{S_{\rm NN}}$ region.

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