Higher order fluctuations of conserved number in a hadron resonance gas model

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Introduction

One of the major goals of high-energy heavy-ion collisions is to explore the QCD phase diagram in temperature (T) and baryon chemical potential (μ_B) plane. Lattice QCD calculations suggest that at $\mu_b \approx 0$, there is a smooth crossover from hadron phase to QGP phase, while other models predict a first-order phase transition at higher μ_B. Thus, there should be an existence of the QCD critical end point (CEP) as a termination point of the first-order phase transition line towards the cross-over region. One of the key observable for CEP is related to the event-by-event distribution of conserved numbers. The moments of the conserved numbers are related to some power of correlation length (ξ) of the system. The higher order moments have stronger dependence on the correlation length, hence, these moments are even more sensitive to the dynamical fluctuation. The ratios of moments/cumulants can be related to the susceptibilities of nth order (χ^n) obtained from the lattice QCD or the HRG model calculations. It has been found that the sixth order to the second order susceptibility ratio (χ_6/χ_2) undergo a significant sign change near the QCD phase transition [1]. This ratio is therefore a sensitive probe of the conditions at freeze-out and their relation to the critical behavior in strongly interacting matter. Present work provides a pure thermal baseline contributions to the higher moments of conserved numbers.

In the hadron resonance gas model, the partition function (Z) include all the degrees of freedom of confined and strongly interacting matter and implicitly contains all the interactions that result resonance formation [2]. In the GCE framework, the thermodynamic pressure (P) can be expressed as sum of the partial pressures of all the particle species i which can be baryon or meson at temperature T and chemical potential μ:

$$P(T, V, \mu_i) = \frac{T}{V} \ln Z_i \tag{1}$$

where $\ln Z_i$ is the partition function of individual mesons and baryons, which can be written as:

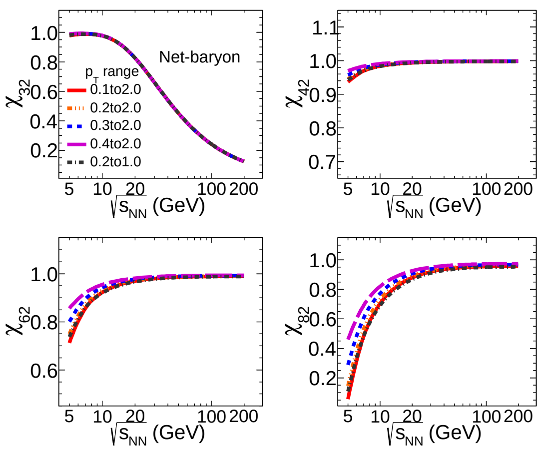

FIG. 1: Susceptibility ratios of net-baryons as a function center of mass energies for various p_T acceptances.

$$\ln Z_i(T, V, \mu_i) = \pm \frac{V g_i}{2\pi^2} \int d^3p \ln\{1 \pm e^{(\mu_i - E)/T}\}, \tag{2}$$

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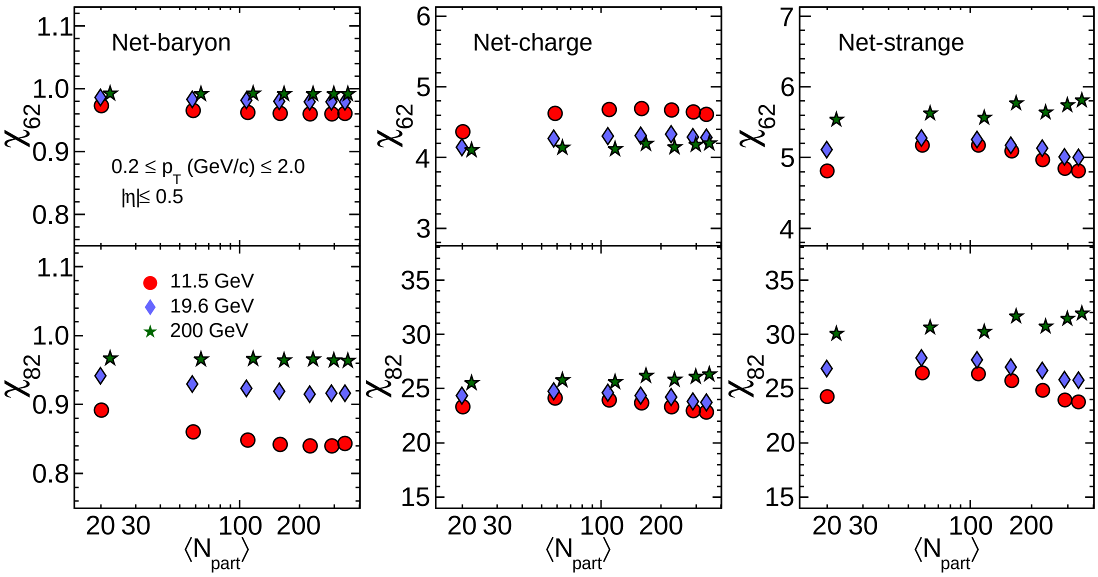

FIG. 2: Susceptibility ratios of net-baryons, net-electric charge and net-strangeness as a function of centrality ($\langle N_{part} \rangle$) for different energies.

where V is the volume of the system, g_i is the degeneracy factor and μ_i is the total chemical potential of the i-th particle, d^3p being the volume element of a particle of mass m and energy (E). The $\pm$ve signs are for baryons and mesons, respectively. In the GCE, fluctuations of conserved charges can be characterized by susceptibilities (χ_i) which are the derivatives of the partition function ln$Z$ with respect to the corresponding chemical potentials μ_B, μ_Q, or μ_S. The nth-order generalized susceptibility of i-th particle $\chi_i^{(n)}$ is written as

$$\chi_i^{(n)} = \frac{d^n[P(T,\mu)/T^4]}{d(\mu_i/T)^n}. \tag{3}$$

Results and discussion

Figure 1 shows the variation of χ_3/χ_2, χ_4/χ_2, χ_6/χ_2, and χ_8/χ_2 as a function of $\sqrt{s_{\rm NN}}$ for various p_T acceptances. It is observed that χ_{62} and χ_{82} ratios have clear p_T and $\sqrt{s_{\rm NN}}$ (particularly at lower energies). Similar study has been performed for net-charge and net-strangeness cases, which show larger energy and p_T dependence as compared to net-baryon susceptibility ratios due to the contributions from resonance decays. Figure 2 shows the centrality dependence of χ_6/χ_2 and χ_8/χ_2 ratios for net-baryon, net-electric charge and net-strangeness for different energies. It is observed that, there is small centrality dependence of net-baryon χ_8/χ_2 for lower $\sqrt{s_{\rm NN}}$. The χ_6/χ_2 values are independent of centrality for all the cases. The results presented in this paper will provide the required baseline for the corresponding measurements in the experiments to search for CEP.

References

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