Fluctuations of conserved charges in a hadronic system in presence of repulsive interaction

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Introduction

Strongly interacting matter at extreme conditions can be recreated in relativistic heavy-ion collision experiments. Such experiments have become an active tool to study the phase transition between Quark-gluon plasma phase and hadronic matter. In this work we investigate the effects of repulsive interaction among hadrons on the fluctuation of conserved charges within the ambit of Hadron Resonance Gas (HRG) model with short range repulsive interaction through a mean-field approach (HRGMF model) [1].

Model description

Repulsive interactions among hadrons can be treated in mean field approach where the single particle energies ϵ_a get shifted by the mean field repulsive interaction as

$$\varepsilon_a = \sqrt{p^2 + m_a^2} + U(n) = E_a + U(n) \quad (1)$$

$$U(n) = Kn \quad (2)$$

Here 'n' is the total hadron density and 'K' is a phenomenological parameter. The pressure for baryons (B) and antibaryons ($\bar{B}$) is

$$P_{B\{\bar{B}\}}(T,\mu) = T \sum_{a \in B\{\bar{B}\}} \int d\Gamma_a \ln\left[1 + e^{-(\frac{E_a - \mu_{\rm eff}\{\bar{\mu}_{\rm eff}\}}{T})}\right] + \frac{1}{2} K_b n^2_{B\{\bar{B}\}} \quad (3)$$

and similarly for mesons.

Results

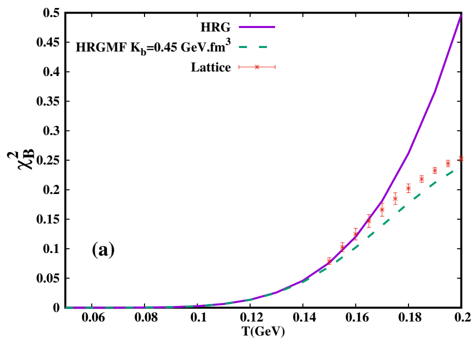

FIG. 1: Baryon number susceptibility of second order at μ=0.

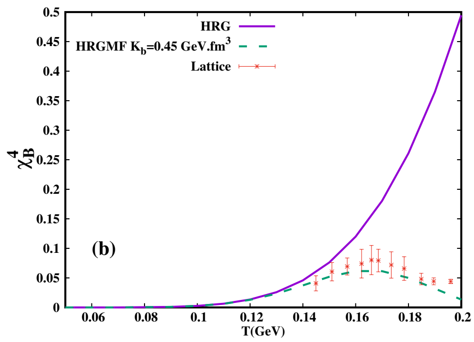

FIG. 2: Baryon number susceptibility of fourth order at μ=0.

We have chosen repulsive mean-field interaction among meson pairs, baryon pairs and

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anti-baryon pairs while replulsive interaction among two different hadronic classes is considered to be absent. We have taken three different representative values for meson mean field parameter, *viz.*, $K_m = 0, 0.1$ and 0.15 GeV·fm^3, while we have fixed baryon mean-field parameter $K_b = 0.45$ GeV·fm^3.

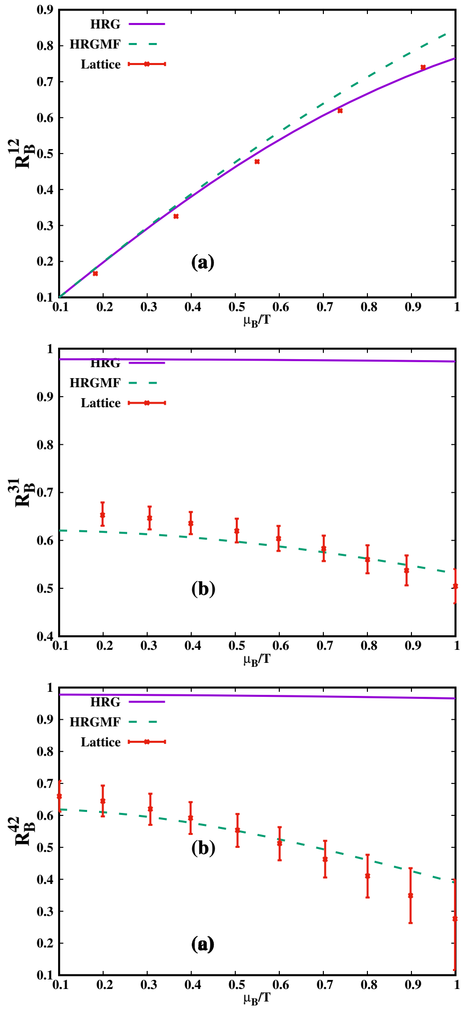

FIG. 3: R_B^{12}, R_B^{31} and R_B^{42} (defined in the text) as functions of μ_B/T.

From Fig. (1) and (2) we can see that when the interaction among the baryons is switched on through K_b, the baryon number susceptibilities (especially χ_B^4) show non-monotonic behaviour. We see that HRG model without repulsive interaction reproduces the LQCD results for baryon number susceptibilities up to a temperature of $T = 160$ MeV after which it shows significant deviation. On the other hand, results obtained using HRGMF model provides a very good qualitative and quantitative agreement with LQCD data. Since mesons do not contribute to baryon number susceptibilities χ_B^n (note that we have considered repulsive interaction among baryon pairs and meson pairs only) hence the results are indepedent of K_m.

As shown in Ref. [2], in general, the susceptibilities of conserved charges at non-zero chemical potential can be expanded in powers of μ_i/T $(i = B, Q, S)$ with coefficients in the expansion being generalised susceptibilities that can be evaluated at vanishing chemical potentials with T=158 MeV. As in Ref. [2], we have considered the case of strangeness neutral system i.e. $n_S = 0$ and a fixed ratio of the net number of electrically charged hadrons to baryons i.e. $n_Q/n_B = 0.4$ which are representative conditions realized in heavy ion collision experiments with gold or uranium nuclei.

On the top panel of Fig. (3) we have plotted the ratio of mean to variance of net baryon number i.e $R_B^{12} = \chi_B^1(T, \mu_B)/\chi_B^2(T, \mu_B)$ as a function of μ_B/T. On the middle panel, we have shown the skewness ratio $R_B^{31}(T, \mu_B) = \frac{\chi_B^3(T,\mu_B)}{\chi_B^1(T,\mu_B)}$. Finally, in the bottom panel, we have shown the kurtosis ratio i.e. $R_B^{42} = \frac{\chi_B^4(T,\mu_B)}{\chi_B^2(T,\mu_B)}$ as a function of μ_B/T.

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