Fluctuations And Correlations As Signatures Of Phase Transition In Strongly Interacting Systems

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In various astrophysical objects like Neutron stars, Supernovae or in early stages of the Universe, hot and/or dense relativistic plasma might exist. Properties of such strongly interacting systems are therefore pretty important to study. It is therefore necessary to have adequate theoretical frameworks. The lattice formulation of QCD provides a first principle approach. A parallel approach of QCD-inspired non-perturbative models is often as well adopted in this regard. One such widely used model is the Polyakov–Nambu–Jona-Lasinio (PNJL) model. This thesis is devoted to analysis of strongly interacting systems in terms of its thermodynamic properties and fluctuations and correlations of conserved charges present in it under the framework of 2+1 flavor PNJL model.

Fluctuations and correlations of conserved charges present in a system provide useful measures regarding the notion of phase transitions. At the same time, it is to be kept in mind that the systems under concern produced in experiments might have finite sizes. Emphasizing on the importance of finite size consideration, we simulated the scenario [1] for different finite volumes at finite temperatures as well as chemical potentials. To include the effect of finite volumes, a non-zero lower momentum cutoff $p_{min} = \pi/R = \lambda(say)$ is introduced where R is the lateral size of the system. On studying the fluctuations of various conserved charges at different orders as functions of temperature, we see that there is quantitative dependence on the system size. The behavior of ratios of fourth to second order fluctuations for different conserved charges as a function of temperature shows that the scaling holds good only away from the crossover region. The volume dependence of the correlations is similar to those of the fluctuations. Study of the ratios of fluctuations of different charges respectively for the 2^{nd} and 4^{th} orders show very small scaling violation analogous to the that of ratios of same order correlation to fluctuation coefficients. Moving to the finite chemical potential domain, we observe a very interesting result taking different order ratio. The ratio c_1^q/c_2^q is displayed in Fig.(1) for a few representative values of temperature. Incidentally the windows of μ_q, where maximum scaling violation occurs, correspond to those close to the phase boundary. For $T < 100$ MeV there is even a discontinuity indicating the existence of the first order line in the phase diagram for the corresponding system size.

Over the years, different thermodynamical studies carried out in the PNJL framework showed quite a good match with lattice results. However, recently lattice results have been obtained in the continuum limit which imposed the necessity to reparametrize the model [2]. The corresponding consequence was not perfect still. Quite a disagreement was observed in the low temperature sector which could however be anticipated due to lack of hadronic degrees of freedom in that regime. To correct this, instead of including a switching function connecting the hadronic

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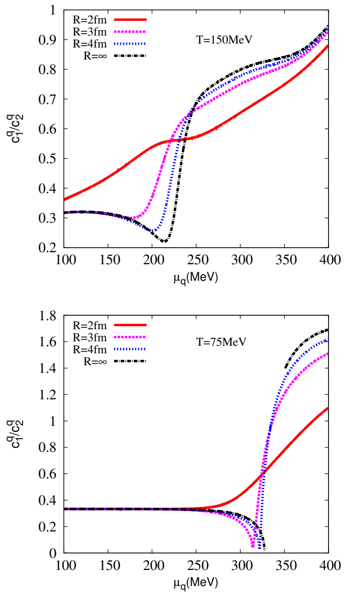

FIG. 1: Ratios of net quark number density to the quark number fluctuations as functions of quark chemical potential at different temperatures.

and partonic sectors, which could be one possible way, here we [3] have considered mesonic fluctuations over the mean field results to describe the lattice QCD equation of state suitably. Using the Random Phase Approximation to evaluate the temperature dependence of the mesonic masses, we obtain remaining thermodynamics in usual manner.

Pressure, when computed as a function of temperature, as seen in Fig.(2), shows a nonzero value at low temperatures giving excellent match with lattice continuum results. This is in stark contrast to the previous PNJL results, which giving a close to zero value at low temperatures, directly indicated absence of proper hadronic contributions. On a similar note, all other thermodynamical variables computed from pressure match our expectation quite beautifully. Spurious issue like absence of minima in c_s^2 is also resolved.

Fluctuations of conserved charges can be obtained from pressure by reading off the Taylor coefficients. Here we have shown only the

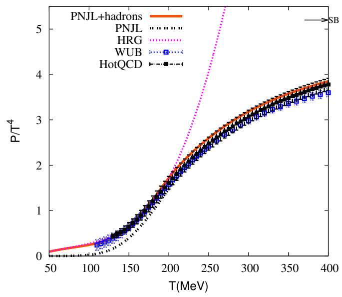

FIG. 2: Pressure plotted as a function of temperature

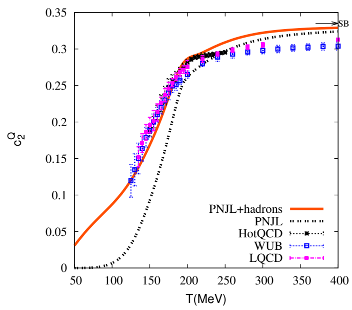

FIG. 3: (color online) Charge fluctuation plotted as a function of temperature.

electric charge fluctuation in Fig. (3), which shows that the large discrepancy between PNJL and lattice results below crossover temperature T_c, is now removed on proper inclusion of hadronic states.

1. Acknowledgment

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