Thermodynamics of strongly interacting system from reparametrized Polyakov−Nambu−Jona-Lasinio model

Abhijit Bhattacharyya[1], Sanjay K. Ghosh[2], Soumitra Maity[2],* Sibaji Raha[2], Rajarshi Ray[2], Kinkar Saha[2,3], and Sudipa Upadhaya[2]
[1]*Department of Physics, University of Calcutta, 92, A.P.C Road, Kolkata-700009, INDIA*
[2]*Department of Physics, CAPSS, Bose Institute, Block-EN, Sector-V, Salt Lake, Kolkata-700091, INDIA and*
[3]*Department of Physics, Visva Bharati, Santiniketan 731235, INDIA*

The Polyakov−Nambu−Jona-Lasinio model [1] has been quite successful in describing various qualitative features of observables for strongly interacting matter, that are measurable in heavy-ion collision experiments. The question still remains on the quantitative uncertainties in the model results. Such an estimation is possible only by contrasting these results with those obtained from first principles using the lattice QCD framework. Recently a variety of lattice QCD data were reported in the realistic continuum limit [3, 4]. Here we make a first attempt at reparametrizing the model so as to reproduce these lattice data.

Methodology

The effective Polyakov loop potential is chosen to be of the form,

$$\frac{\mathcal{U}(\Phi,\bar{\Phi},T)}{T^4} = -\frac{b_2(T)}{2}\bar{\Phi}\Phi - \frac{b_3}{6}(\Phi^3+\bar{\Phi}^3) + \frac{b_4}{4}(\bar{\Phi}\Phi)^2 \quad (1)$$

The coefficient $b_2(T)$ is chosen to have a temperature dependence of the form [2],

$$b_2(T) = a_0 + a_1 exp(-a_2\frac{T}{T_0})\frac{T_0}{T}, \quad (2)$$

and b_3 and b_4 are chosen to be constants.

The Polyakov loop fields are expected to approach unity for large temperatures. Therfore for an effective model of pure glue theory the minimization of the potential would be obtained for $lim_{T\to\infty}\Phi = 1$. Also the pressure should be that of the massless free gluon gas. Using these two conditions one may obtain b_3 and b_4 in terms of $b_2(T \to \infty) = a_0$. The parameters a_1, a_2 and T_0 and κ may thereafter be fixed phenomenologically by requiring that the crossover temperature comes around $T_c \sim 160$MeV, along with the pressure to agree with the lattice QCD results for various temperatures.

We first fixed the parameter values of a_0, T_0 and κ. Then $b_3(= 0.805)$ and $b_4(= 7.555)$ were obtained in terms of a_0. Thereafter a_1 and a_2 were adjusted to get the best combination for the crossover temperature T_c and the pressure to agree with lattice QCD continuum results. The set of parameters thus obtained is given in Table I,

Interaction	T_0 (MeV)	a_0	a_1	a_2	κ
6-quark	175	6.75	-9.0	0.25	0.1
8-quark	175	6.75	-9.8	0.26	0.1

TABLE I: Parameters for the Polyakov loop potential.

Results

An important observation in the continuum extrapolated lattice results is that the pressure of strongly interacting matter is sig-

*Electronic address: soumitra.maity1984@gmail.com

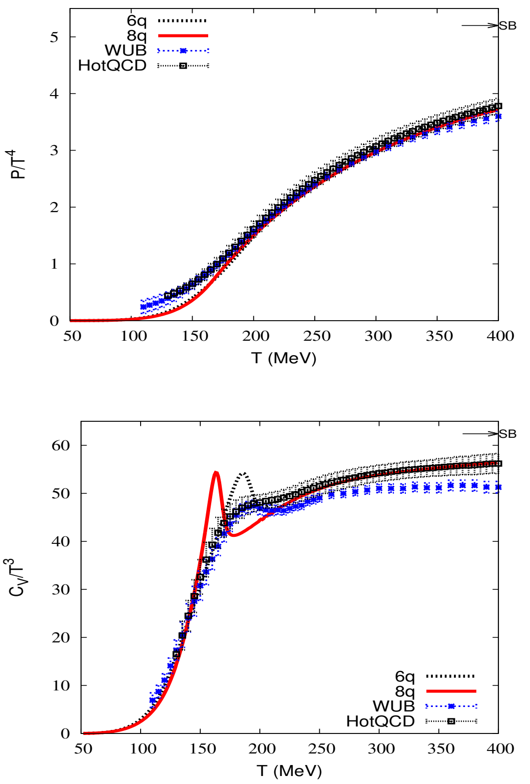
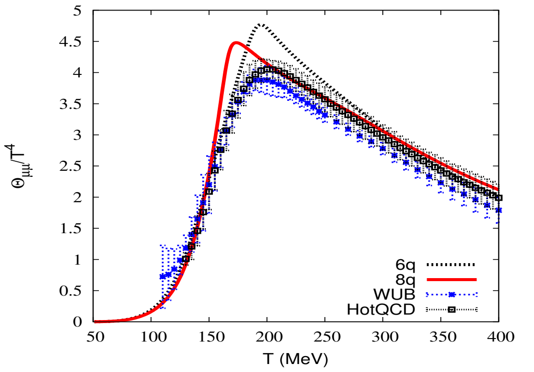


FIG. 1: The scaled pressure and scaled specific heat as functions of temperature. The continuum extrapolated dataset of HotQCD and Wuppertal-Budapest (WUB) collaborations are taken respectively from [3] and [4].

nificantly below that of ideal gas of quarks and gluons even at reasonably large temperatures. This implies that the gluon mediated interactions must be strong even though the degrees of freedom may have changed from hadronic to partonic ones. So we chose to reparametrize the Polyakov loop self interactions in the PNJL model which is supposed to mimic the gluonic effects. The NJL model parameters were set from hadronic properties at zero temperature and chemical potentials.

We found excellent agreement of the equation of state in the PNJL model with that of lattice QCD data in a wide range of temperature. The specific heat has a small peak near the crossover in the model. Though not a promi-



nent peak but a hump is surely present in the lattice QCD data.

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