Interacting Hadron Resonance Gas Model with Lorentz Contraction

Somenath Pal[1],* Abhijit Bhattacharyya[1], and Rajarshi Ray[2]
[1] *Department of Physics, University of Calcutta, 92, A.P.C. Road, Kolkata-700009, India and*
[2] *Center for Astroparticle Physics & Space Science, Block-EN, Sector-V, Salt Lake, Kolkata 700091, India*
&
Department of Physics, Bose Institute, 93/1, A. P. C Road, Kolkata 700009, India

Introduction

Due to the non-perturbative nature of strong interaction various effective models are used to describe the hot/dense strongly interacting matter. Such matter existed in the early universe and is expected to be present inside compact astrophysical objects. In the ultra-relativistic collisions of heavy-ions one can recreate a hot and dense strongly interacting matter. In this work we have analyzed the susceptibilities of conserved charges within Excluded Volume Hadron Resonance Gas (EVHRG) [1] model. We have considered unequal radii of different hadron species and also included the effect of Lorentz contraction for the first time.

Model description

In EVHRG model pressure is given as

$$P(T, \mu_1, \mu_2, ...) = P_{(m)}(T, \mu_1, \mu_2, ...) + P_{(b)}(T, \mu_1, \mu_2, ...) + P_{(\bar{b})}(T, \mu_1, \mu_2, ...) \quad (1)$$

where on the R.H.S., the three terms are contributions due to mesons, baryons and anti-baryons respectively.

$$P_{(m)}(T, \mu_1, \mu_2, ...) = \sum_p P^{id}_{(m)p}(T, \hat{\mu}_{(m)1}, \hat{\mu}_{(m)2}, ...) \quad (2)$$

$$\hat{\mu}_{(m)k} = \mu_k - \frac{4}{3}\pi R_k^3 P^M - 4\pi R_k^2 \sum_{n=1}^{N} R_n P_n^M \quad (3)$$

for mesons and similar equations for baryons and anti-baryons hold. Here we have assumed meson-meson, baryon-baryon and antibaryon-antibaryon repulsive interaction only. The effect of unequal radii is given by the last term of eq. (3). The effective chemical potential with Lorentz contraction becomes

$$\hat{\mu}_k^{LM} = \mu_k - \frac{4}{3}\pi R_k^3 \frac{m_0}{\sqrt{p^2 + m_0^2}} P^{LM} - 4\pi R_k^2 \frac{m_0}{\sqrt{p^2 + m_0^2}} \sum_{n=1}^{N} R_n P_n^{LM} \quad (4)$$

Results

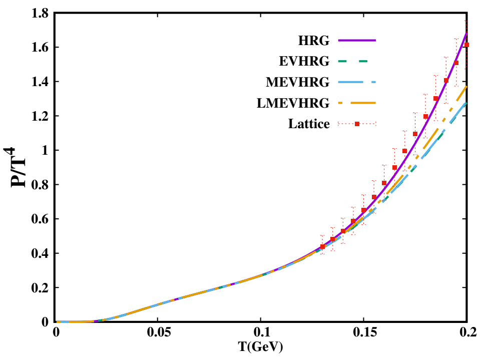

FIG. 1: Variation of scaled pressure (P/T^4) with temperature at $\mu = 0$.

In this work we have used baryon radius $R_b = 0.35 fm$, pion radius $R_\pi = 0.2 fm$ and

*Electronic address: somenathpal1@gmail.com

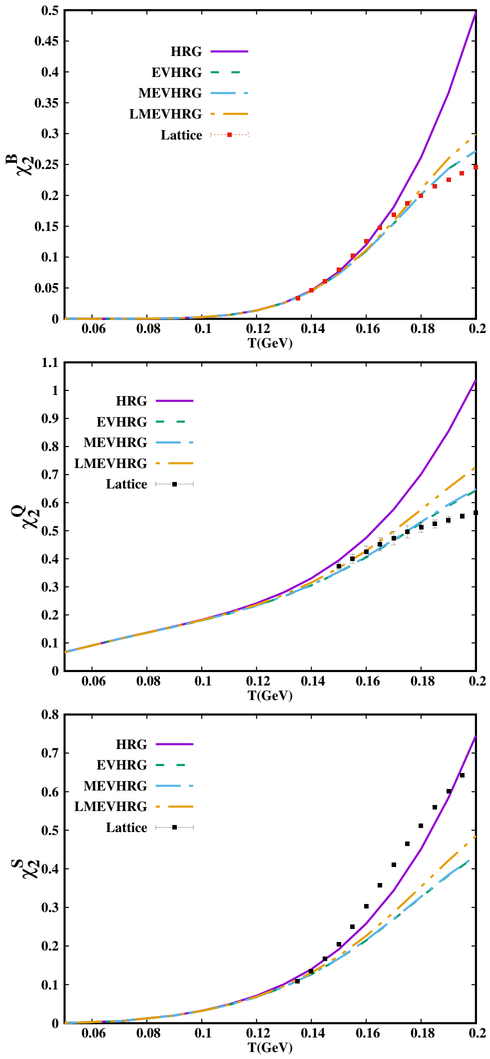

FIG. 2: Variation of second order baryon (χ_2^B), electric charge (χ_2^Q) and strangeness (χ_2^S) susceptibilities with temperature at $\mu = 0$.

radii of other mesons $R_m = 0.3fm$. We have taken into account all particles listed in particle data book up to 3 GeV mass. In the figures, 'MEVHRG' and 'LMEVHRG' denote modified EVHRG with unequal radii and Lorentz contracted MEVHRG model respectively. We have tested that difference between the values of thermodynamic quantities calculated in EVHRG and MEVHRG is larger when greater variety of hadronic radii is used. Which model, of these two, will reproduce greater values of the thermodynamic quantities will depend on the type of quantity studied and on the combination of radii chosen. If the dominating hadrons carrying a particular conserved charge are assigned larger excluded volume than that of dominated hadrons then susceptibility of that conserved charge in MEVHRG model will be lower than EVHRG case. The results of MEVHRG model are quantitatively larger than that for EVHRG model for the specific choice of hadronic radii used in this work. Although the particular choice of excluded volumes do not show significant difference between EVHRG and MEVHRG results, we have selected those values to get agreement of our results with Lattice data as much as possible, yet keeping the choice of radii simple. Strangeness susceptibility, of second order, in LQCD are higher than those in HRG. The lattice data, for fourth order, matches with pure HRG result till 0.165 GeV of temperature. However, at higher temperature, it approaches the results with Lorentz contraction. The strangeness sector gives incomplete picture about the particle spectrum and hence on thermodynamic quantities when only the hadronic states listed in Particle Data Group are considered

Acknowledgments

The work is funded by University Grants Commission (UGC) and Alexander von Humboldt (AvH) foundation and Federal Ministry of Education and Research (Germany) through Research Group Linkage programme.

References

[1] A. Bhattacharyya, S. Das, S. K. Ghosh, R. Ray and S. Samanta, Phys. Rev. **C90**, 034909(2014).

[2] V. V. Sagun, A. I. Ivanytskyi, K. A. Bugaev and I. N. Mishustin, Nucl. Phys. **A924**, 24(2014).