# Fluctuations and correlations in strongly interacting system using PNJL-HRG hybrid model

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It is highly interesting to investigate different properties of strongly interacting matter in terms of fluctuations and correlations of conserved charges present in it. Over the years, study of different observables in the Polyakov loop enhanced Nambu−Jona-Lasinio (PNJL) model [1] showed good match with lattice findings. However recent continuum lattice data [2–4] called for a model reparametrization [5], subsequent comparison of which with lattice data showed disagreement in low temperature sector. This is expected due to lack of hadronic degrees of freedom in this model. In an attempt to have a model which describes both low and high temperature regimes, we here discuss a framework [6] in which hadronic matter described using the HRG model [7] is smoothly *switched* to PNJL one describing partonic matter. A reliable way to understand phase transition dynamics is through study of correlations and fluctuations of conserved charges. At finite temperatures and chemical potentials, fluctuations of conserved charges are sensitive indicators of transition from hadronic to partonic matter. The existence of the CEP can be signalled by singularities in fluctuations.

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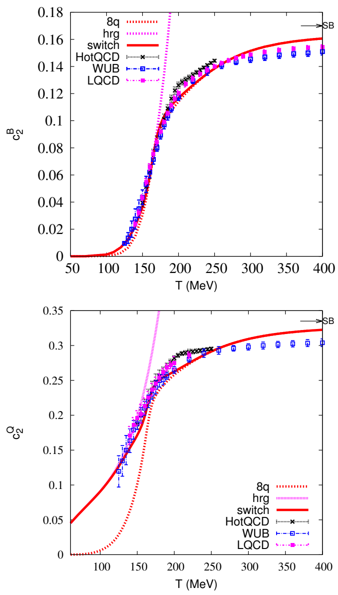


FIG. 1: Baryon number and charge fluctuations as functions of temperature. The continuum lattice data are from Ref. [2] (HotQCD), Ref. [3] (WUB) and Ref. [4] (LQCD).

### Methodology and results

The susceptibilities are obtained as a Taylor series expansion of pressure in terms of corresponding chemical potentials. The diagonal Taylor coefficients $c_n^X(T)$ $(X = B, Q, S)$ of $n^{th}$ order for the scaled pressure $P(T, \mu_B, \mu_Q, \mu_S)/T^4$ may be written in terms of the fluctuations $\chi_n^X(T)$ of the corresponding order as,

$$c_n^X(T) = \frac{1}{n!}\frac{\partial^n(P/T^4)}{\partial(\frac{\mu_X}{T})^n} = \frac{T^{n-4}}{n!}\chi_n^X(T) \quad (1)$$

where the expansion is carried out around $\mu_B = \mu_Q = \mu_S = 0$. Similarly, off-diagonal coefficients $c_{n,m}^{X,Y}(T)$ $(X, Y = B, Q, S;\ X \neq Y)$ of the $(m+n)^{th}$ order are related to correlations between conserved charges $\chi_{n,m}^{X,Y}(T)$ as,

$$c_{m,n}^{X,Y} = \frac{1}{m!n!}\frac{\partial^{m+n}(P/T^4)}{(\partial(\frac{\mu_X}{T})^m)(\partial(\frac{\mu_Y}{T})^n)} = \frac{T^{m+n-4}}{m!n!}\chi_{n,m}^{X,Y}(T) \quad (2)$$

Once the fluctuations and correlations are obtained in both the models, they are combined into the PNJL-HRG model using the same switching function $S(T)$ identified in [8]. They are given by,

$$c_n^X = S(T){c_n^X}_P + (1 - S(T)){c_n^X}_H \quad (3)$$
$$c_{m,n}^{X,Y} = S(T){c_{m,n}^{X,Y}}_P + (1 - S(T)){c_{m,n}^{X,Y}}_H \quad (4)$$

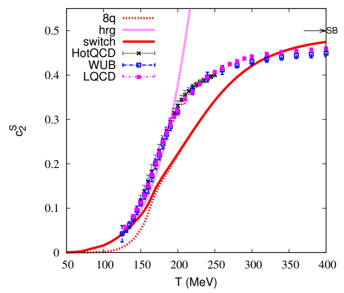


FIG. 2: Strangeness fluctuation as function of temperature. The continuum lattice data are from Ref. [2] (HotQCD), Ref. [3] (WUB) and Ref. [4] (LQCD).

We found that the fluctuations of baryon number and electric charge computed in the PNJL-HRG model are in good quantitative agreement with the lattice QCD data. However the strangeness fluctuation in the PNJL model is somewhat different from the lattice QCD data around the crossover region.

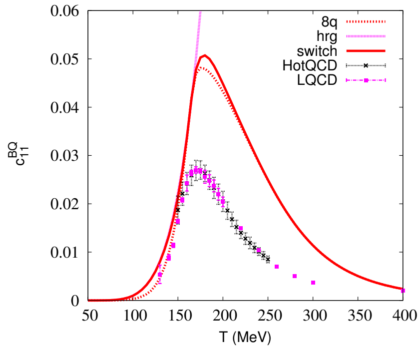


FIG. 3: Baryon-electric charge correlation as function of temperature. The continuum lattice data are from Ref. [2] (HotQCD) and Ref. [4] (LQCD).

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**References**

[1] S. K. Ghosh *et.al.* Phys. Rev. D **73**, 114007 (2006).
[2] A. Bazavov *et al.* (HotQCD Collaboration), Phys. Rev. D **86**, 034509 (2012)
[3] S. Borsanyi *et.al.* J. High Energy Phys. **1201**, 138 (2012).
[4] R. Bellwied *et.al.* Phys. Rev. D **92**, 114505 (2015).
[5] A. Bhattacharyya *et.al.* Phys. Rev. D **95**, 054005 (2017).
[6] M. Albright *et.al.* Phys. Rev. C **90**, 024915 (2014).
[7] P. Braun-Munzinger *et.al.* in *Quark Gluon Plasma 3*, edited by R.C. Hwa and X.N. Wang, (World Scientific Publishing, 2004).
[8] A. Bhattacharyya *et.al.* arXiv:1708.04549 [hep-ph].