Contribution ID: **518** Type: **Talk**

An effective field theory of thermal QCD with higher dimensional gradient term

Wednesday 14 December 2022 12:00 (15 minutes)

Effective field theories (EFTs) provide us a powerful way of organising low-energy physics of interest in quantum field theories. The Physics of QCD at very low temperature and at very high temperature are well described by; respectively, theory of pions, and an effective weak coupling expansion. These EFTs usually depend on hierarchy of scales, and usually become ineffective when temperature is around cross over temperature (around a few hundred MeV).

To inspect the physics of QCD around cross over temperature T_{co}, we build an effective field theory of thermal QCD around T_{co}. Employing the global symmetries of the QCD as our guiding principle, we organize the effective field theory. In particular we use the vector and axial symmetries of QCD for the case of two flavors of quarks to arrange theory. We write down all possible axial preserving and breaking terms upto dimension six operators to build the model. The dimension-6 interaction terms consist of broadly two classes of interaction terms, current-current interactions Ref. [1] and 6-dimensional higher derivative term (will be refereed to as gradient-cubed term hereafter). We find the gradient-cubed term to modify the current term, giving rise to PCAC relation with this new current.

We proceed to treat this EFT in mean field theory (MFT). All the current-current interactions give rise to an effective mass term, with all the coupling coefficients reduced to an effective coupling Ref. [2] . The original EFT was organized in powers of temperature/T_0, where T_0 is a cut-off scale, and at chiral limit in this theory, the gradient-cubed term is one of the terms which stays unaffected after MFT treatment. We proceed to obtain the free energy for this MFT. At chiral limit we find two solutions for the critical temperature T_c . After discarding the unphysical solution we manage to get bounds on the coupling of gradient-cubed term. At chiral limit the phase transition is found to be of second order with the gradient-cubed term modifying the value of T_c . The QCD phase diagram at chiral limit also gets modified due to the contribution of gradient-cubed term, when compared to only current-current interaction terms. The curvature of the critical line at chiral limit also depend on the gradient-cubed term.

We proceed to inspect the pionic fluctuations around the mean field theory. The properties of pionic theory at 1-loop is found to be dependent on the gradient-cubed terms. The physical parameters of the pionic theory, namely, m_π, f_π, u_π, get contributions from the gradient-cubed term. We find the Gell-Mann-Okaes-Renner (GMOR) relation to be valid in this theory also. The curvature coefficients κ_2 and κ_4 are found to be modified and depend on the coupling of gradient-cubed term.

Keywords : QCD at finite temperature, Cross-over temperature, Critical Temperature, Pionic theory, Phase Diagram QCD.

References

[1] S. Gupta and R. Sharma, "Effective field theory for warm QCD," Phys. Rev. D **97** (2018) no.3, 036025, [arXiv:1710.05345 [hep-ph]].

[2] S. Gupta and R. Sharma, "Real time warm pions from the lattice using an effective theory," Int. J. Mod. Phys. A **35** (2020) no.33, 2030021, [arXiv:2006.16626 [hep-ph]].

Session

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Session Classification: WG5-Heavy Ions and QCD