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Nuclear Symmetry Energy in QCD degree of freedom

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Nuclear symmetry energy is an important ingredient in understanding asymmetric nuclear configuration starting from rare isotopes at nuclear matter density to the core of neutron star at extremely high density. The symmetry energy in continuous matter can be defined as
\begin{equation}
\bar{E}(\rho_N,I)=E_0(\rho_N)+E_{\textrm{sym}}(\rho_N)I^2 +
O(I^4)+\cdots,
\end{equation}
where ρ_N is the nuclear medium density and $I = (\rho_n - \rho_p)/(\rho_n + \rho_p)$ the asymmetric parameter. Our goal is to understand the iso-spin asymmetric nature of the nuclear matter using the QCD degree of freedom.

For the hadronic phase, by taking the difference between the neutron and proton self-energies calculated in the QCD sum rules, we obtained the symmetry energy in terms of local operators [1]. We find that the scalar (vector) part gives a negative (positive) contribution to the nuclear symmetry energy, which is consistent with the results from relativistic mean field theories.

For the quark phase, we used hard dense loop (HDL) resummation for the normal phase and considered BCS pairing in 2-color superconductor (2SC) phase [2]. In the normal phase, the effect of gluonic interaction to the symmetry energy, obtained from the HDL resumed free energy, was found to be small. In the 2SC phase, the BCS paring gives enhanced symmetry energy as the gapped states are forced to be in the common Fermi sea reducing iso-spin asymmetrizable states. Also, in the 2SC phase, the gluonic contribution to the symmetry energy is expected to be minimal as only the unimportant Meissner mass has iso-spin dependence. The different symmetry energy in each phase will affect the iso-spin density of the dense matter and subsequently lead to different prediction for the particle yields in HIC experiment.

[1] K.~S.~Jeong and S.~H.~Lee,
Phys. Rev. C 87, no. 1, 015204 (2013)

[2]
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arXiv:1506.01447 [nucl-th].

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