Quark Matter 2025

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Finite-temperature expansion of the dense-matter equation of state

Intermediate to low energy heavy-ion collisions are sensitive to the finite temperature (T), high baryon number density (n_B) QCD equation of state (EoS) at a ratio between charged and total number of baryons that is fixed by the colliding species. For typical nuclei used in collisions, like gold and lead, this ratio, also known as the charge fraction ($Y_Q^{\rm QCD}$), is around 0.4. On the other hand, studies of isolated neutron stars and the dynamics of their birth and mergers require $Y_Q^{\rm QCD}$ as low as 0.01. We propose a new finite-temperature expansion of the dense-matter EoS [1] that can be used to describe neutron star mergers and core-collapse supernova explosions using as a starting point observations of isolated neutron stars and nuclear experiments. We suggest new thermodynamic quantities of interest that can be calculated from theoretical models or directly inferred by experimental data from low to intermediate energy heavy-ion collisions. With our new method, we can separately quantify the uncertainty in the $Y_Q^{\rm QCD}$ and finite T components of the EoS without making assumptions about the underlying degrees of freedom. We check the accuracy of our framework using a microscopic equation of state up to T = 100 MeV for baryon chemical potential $\mu_B \geq 1100$ MeV (~ 1 – 2 $n_{\rm sat}$) and find that the error introduced is less than 5%, with even better results for larger μ_B and/or lower T.

[1] D. Mroczek, N. Yao, et. al, 2404.01658.

Category

Theory

Collaboration (if applicable)

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