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QCD based equation of state at finite density with a critical point from an alternative expansion scheme

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Our study presents a family of Equations of State (EoS) that enable hydrodynamical simulations at unprecedentedly large baryon chemical potential (μ_B) and finite temperature (T), thus helping to constrain the critical point's location by comparing it to experimental data from the Second Beam Energy Scan.
In Ref. [1], a family of equations of state was constructed by combining Taylor expansion QCD lattice results with 3D Ising model critical behavior. However, the applicability of this family was limited to the range of $0 \leq \mu_B \leq 450$ MeV. In recent work, [2,3], a resummation scheme was proposed that extrapolates lattice QCD results to the range of chemical potentials $\frac{\mu_B}{T} = 3.5$.
In this work, we combine these approaches to obtain equations of state in the range $0 \leq \mu_B \leq 700$ MeV and 5 MeV $\leq T \leq 800$ MeV, which match lattice QCD results at low density and contain a 3D Ising model critical point. We impose stability and causality constraints and discuss the possible ranges of free parameter choices arising from the 3D Ising model to QCD mapping. We present thermodynamic observables, including baryon density, pressure, entropy, energy density, susceptibility, and speed of sound that cover a wide range in the QCD phase diagram.

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[2] S. Bors´anyi, J. N. Guenther, R. Kara, Z. Fodor, P. Parotto, A. P´asztor, C. Ratti, and K. Szab´o, "Resummed lattice qcd equation of state at finite baryon density: Strangeness neutrality and beyond,"Physical Review D, vol. 105, no. 11, p. 114504, 2022. 1

[3] S. Bors´anyi, Z. Fodor, J. Guenther, R. Kara, S. Katz, P. Parotto, A. P´asztor, C. Ratti, and K. Szab´o, "Lattice qcd equation of state at finite chemical potential from an alternative expansion scheme,"Physical review letters, vol. 126, no. 23, p. 232001, 2021. 1
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Category

Theory

Collaboration (if applicable)

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