Chiral phase transition properties at finite spin density

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We consider the effect of finite spin density on the QCD phase diagram using the Linear Sigma model coupled to quarks (LSM_q) [1]. We introduce the spin density via a quark spin potential (μ_Σ) in the canonical formulation of the spin operator. The spin potential enters non-trivially in the zero-point, temperature-independent part of the fermion loop leading to an ambiguity in the vacuum renormalization term to the free energy. Eliminating the regularization freedom through comparison with recent low-μ_Σ lattice data [2], we extend the phase diagram of QCD at finite spin density to regions inaccessible to lattice simulations. We show that, as the spin potential increases, the temperature of the chiral crossover transition diminishes and the chiral crossover turns into a first-order transition at a second-order critical end-point.

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[2] V. V. Braguta, M. N. Chernodub, and A. A. Roenko, "Chiral and deconfinement thermal transitions at finite quark spin polarization in lattice QCD simulations," Phys. Rev. D **111**, 114508 (2025), arXiv:2503.18636 [hep-lat].