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The role of the pion mass on the QCD phase diagram in the $T - eB$ plane

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We investigate the effect of the pion mass on the quantum chromodynamics (QCD) phase diagram in the presence of an external magnetic field, aiming to understand it, for the first time, using Nambu\textendash Jona-Lasinio like effective models [1]. We compare results from both the local and nonlocal versions, finding that inverse magnetic catalysis (IMC) near the crossover is eliminated with increasing pion mass, while the decreasing trend of the crossover temperature with increasing magnetic field persists for pion mass values up to at least 440 MeV. Thus, the models are capable of capturing qualitatively the results found by lattice QCD (LQCD) for heavy (unphysical) pions. The key feature of these models is incorporating the reduction of the coupling constant with increasing energy. This not only reproduces the IMC effect but also describes the effects of heavier current quark masses without additional parameters. In the local NJL model, this agreement depends on parameter fitting at the physical point, whereas the nonlocal version naturally exhibits IMC effect around the crossover region, capturing the physics more naturally. We further use the nonlocal framework to determine the pion mass beyond which the IMC effect in the transition region no longer exists.

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