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Impact of rotational effects on the QCD phase diagram: chiral vortical catalysis constrained by Lattice QCD

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Vortical effects in quantum chromodynamics (QCD) have been widely explored in the past few years due to the observation of global polarization of Λ and $\bar{\Lambda}$ baryons in peripheral heavy-ion collisions by the STAR collaboration. Subsequently, the global spin-alignment pattern has been observed for K^{0*} and ϕ vector mesons by the ALICE and STAR collaborations; however, the measurements of the spin density matrix element ρ_{00} differ in both groups, indicating that the underlying physical mechanisms remain unclear. Based on some of these evidences, it is natural to believe that intricate and interesting new phenomena associated with rotations could potentially change different quantities of the QCD phase transitions.

Recent lattice QCD results indicate that the chiral and deconfinement pseudocritical temperatures increase as a function of the real angular velocity, a behavior that is not naturally reproduced in most effective approaches. This effect can be understood by separating the contributions of quarks and gluons in the action. As a result, it is observed that the pseudocritical temperatures decrease when only quarks are considered, but increase when gluons or both degrees of freedom are included simultaneously. This analysis shows that gluonic interactions are indeed fundamental pieces to describe appropriately the QCD phase diagram with rotations.

In order to explore the effects of rotations in QCD phase transitions within an effective chiral model, we consider the two-flavor Nambu–Jona-Lasinio model under the mean field approximation in a rotating rigid cylinder with constant angular velocity. To circumvent the absence of gluons in the model, we adopt a coupling fitted to describe the pseudocritical temperature of chiral phase transition obtained from lattice QCD. Considering this environment, we reproduce the previously dubbed chiral vortical catalysis effect, which is the increase in the chiral condensate as a function of the angular velocity, in contrast to what is observed in the constant coupling case. We also explore the chiral susceptibilities, effective quark masses and the phase diagram. In the last case, we observe first- and second-order phase transitions that become more pronounced as we increase the values of angular velocity, in disagreement with results obtained using constant coupling and different effective approaches.

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