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Medium Separation Scheme and the Cold-Magnetized Superconducting Quark Matter

In this study, we investigate the interplay between chiral and diquark order parameters in cold and dense quark matter under the influence of an external magnetic field. To this end, we use an SU(2) version of the Nambu-Jona-Lasinio model, including both scalar and diquark interactions. A key aspect of our analysis is the role played by different regularization schemes, particularly the Magnetic Field Independent Regularization (MFIR) and the Medium Separation Scheme (MSS). We compare the results obtained using these schemes with those derived from the most commonly adopted approaches, which rely on smooth functions and step functions to handle divergences. Within this framework, we systematically explore how the variations in the external magnetic field at finite baryon density impact the behavior of the diquark condensate and the dynamically generated quark mass. Additionally, we examine the thermodynamic properties of the system and construct the corresponding phase diagram in the $\mu \times eB$ plane when medium contributions are completely separated from divergent integrals. Our findings highlight the importance of the proper separation of medium effects from vacuum contributions, preventing the arise of artificial oscillatory behavior in the physical quantities that have been frequently –and incorrectly –associated as manifestations of the van Alphen–de Haas (vA-dH) effect in the literature, as well as the decrease of the diquark condensate with the increase of the density.

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