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Exploring the pion condensation using the Functional Renormalization Group

The full description of strongly interacting matter requires complete knowledge of the phase structure generated by a quantum field theory. In many cases, analyzing the fundamental theory that describes their interactions in a medium is quite complicated, so that it becomes interesting to use alternative theories that reproduce at least part of the physical characteristics of the fundamental theory. Effective theories provide us with a powerful mathematical and physical tool for the limit in which the application of the fundamental theory - Quantum Chromodynamics (QCD) in the case of Strong Interactions –becomes extremely complex. In the dense regime of matter, the main non-perturbative technique, lattice Monte Carlo simulations, presents an open problem called the Sign Problem due to the coupling of a specific chemical potential. However, in some situations, Monte Carlo simulations do not present such a problem, providing satisfactory results for various observable physical phenomena such as, for example, the dense isospin matter that could exist inside compact stars. Thus, the study of effective theories in environments with non-zero chemical potentials is even more relevant because it presents systems in which the Sign Problem is not present. In this work, we will investigate, using non-perturbative techniques, the phase transition of Bose-Einstein condensation in an effective theory for bosons at finite density and zero temperature. We will construct a toy model based on the Linear σ Model and implement the Functional Renormalization Group (FRG) to estimate the influence of non-perturbative effects on the critical parameters of the model.

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