INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: CFR

From QCD Lagrangian to the description of nucleon interactions in the vacuum and nuclear medium through the Functional Renormalization Group

Context :

One of the main challenges in nuclear theory is to relate the fundamental interactions described by quantum chromodynamics (QCD) to the dynamics of complex atomic nuclei. Currently, vacuum interactions are derived using chiral effective field theories (χEFT) which connects nuclear phenomena to the fundamental principles of QCD. While highly successful, these approaches are not without their limitations, mostly connected to their so-called power counting schemes. On the other hand, the description of medium-mass and heavy nuclei rely on empirical models (the energy density functional, or EDF model) involving phenomenological in-medium interaction between nucleons which are not grounded in QCD.

Research Plan :

This PhD project aims to introduce a new paradigm for deriving nucleon interactions ab initio from QCD, using the Functional Renormalization Group (FRG). The goal is to create a unified theoretical framework that describes both nucleon interactions in the vacuum (currently derived within χEFT) and in the nuclear medium, offering a non-empirical version of the interactions at the heart of nuclear EDF models.

The novelty of this project lies in extending dynamical bosonization from QCD, which has allowed for the emergence of mesons, to baryonization, generating nucleons directly from quarks.

Expected Impact :

This work aims to establish a new class of nucleonic interactions that are systematically derived from first principles. By anchoring the FRG approach in QCD, the project seeks to provide a more fundamental understanding of nuclear forces and their evolution across different energy scales. Such an interaction would serve as a crucial bridge between high-energy QCD-based descriptions and low-energy nuclear many-body theories, improving both the theoretical consistency and predictive capability of nuclear structure and reaction models. Beyond its conceptual significance, the developed interaction is expected to contribute to a more reliable description of finite nuclei and nuclear matter, with potential applications ranging from fundamental nuclear physics to astrophysical modeling.

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES