INTERNSHIP PROPOSAL

(One page maximum)

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Transfer Learning Approaches Leveraging Nuclear *Ab Initio* Reaction Models

The predictive accuracy of nuclear models hinges on developing a systematically improvable theoretical framework with precise approximations and Uncertainty Quantification (UQ). Effective Field Theories (EFTs), with their ability to bridge vast scales in nuclear many-body problems, are widely regarded as the most promising path to achieve this. However, the reach of ab initio methods remains limited for nuclear structure—understanding how nucleons organize within the nucleus—and for predicting nuclear reactions—an area crucial for advancing our understanding of astrophysical phenomena. Currently, the unreliability or scarcity of nuclear data weakens our ability to estimate astrophysical processes accurately.

To predict nuclear reactions, one must follow the following path:

- Reduce the A-body problem to a few-body problem: Nuclear collisions involve highly correlated, many-body quantum phenomena, exhibiting complex behaviors from chaos to superfluidity. Modeling nuclear collisions starts with the proton and neutron degrees of freedom, reordering them into a coordinate system suited to the specific reaction. Only then can irrelevant degrees of freedom be traced out, leading to an effective collective Hamiltonian that accurately describes the collision. However, achieving this rigorously is possible only with ab initio methods and limited to a low number of proton and neutron constituents.
- Solve the few-body problem: The derived channel and channel-coupling Hamiltonian is then used in few-body solvers to compute reaction cross-sections and compare them with experimental data.

Despite major advances in recent decades, ab initio calculations across the nuclear chart remain a distant goal. Realistically, modeling complex nuclear collisions over wide energy ranges will remain out of reach for decades, if not centuries, even with quantum computing, due to the dantean complexity of the problem. Addressing this requires a novel approach, enabled by recent advances in data-driven statistical methods using Artificial Neural Networks (ANNs).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

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