**Title: From Quarks to Stars; A Quantum Computing Approach to the Nuclear Many-Body Problem**

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To understand why visible matter is stable, and thereby shed light on the limits of nuclear stability, is one of the overarching aims and intellectual challenges of basic research in nuclear physics, with broad connections and implications to many other fields in Science, from the synthesis of the elements to our basic knowledge and insights of nuclei and nuclear matter in general. Central to these scientific endeavors is our basic understanding, from experiment and theory, of the complicated nuclear quantum-mechanical many-body problem. This involves relating the stability of matter to the underlying fundamental forces and particles of nature as manifested in nuclear matter. It represents one of the overarching research aims at present and planned rare isotope facilities like FRIB at Michigan State University.

In nuclear theory, many important and profound advances that address these fundamental research themes have been made in recent years, with some of the most creative and impactful developments led by investigators on this proposal.  The nuclear many-body problem is perhaps one of the most difficult quantum-mechanical problems and due to the many degrees of freedom involved, there are significant limitations to what can be done even with the most powerful supercomputers in this soon-to-be era of exascale computing. During the last two decades however, quantum computing has emerged as a new computational paradigm that offers the hope of evading many of the above challenges encountered when solving fundamental problems on classical computers. In order to research several of these challenges, we propose a series of new projects that bridge the gap between quantum computing as it exists today and the targeted territory of unsolved nuclear physics problems.

To achieve our scientific goals we aim at developing new algorithms for optimizing quantum wave functions with the goal to circumvent many of the high-dimensionality problems encountered on classical computers. We also explore new applications of error stabilization techniques, machine learning, and quantum compiling to make efficient short-depth quantum circuits. Other proposed projects focus on real-time evolution, the calculation of observables using new algorithms, and creative adaptations of quantum simulators to many-body problems in nuclear physics.

We are confident that the scientific output of this collaboration will have a significant and lasting impact on the landscape of quantum computing applied to nuclear physics, and that the new algorithms and methods we develop will have an equally important impact on quantum computing and quantum information science, as well as a broad range of applicabilities to quantum-mechanical many-body problems in other fields.