Year	Name	Institution	Brief Description
2022	Alexander Austregesilo	Thomas Jefferson National Accelerator Facility	**"Advanced Methods for Hybrid Meson Searches"** The strong nuclear force binds the fundamental quarks into composite hadrons, such as protons and neutrons, and is effectively responsible for 99% of the mass of the visible universe. Even though it is described by the theory of quantum chromodynamics (QCD) within the Standard Model of particle physics, it bears many unsolved mysteries. Confinement and the large interaction strength at low energies prevent the deduction of the hadron spectrum from first principles. Simplified models successfully describe the observed ground-state mesons and baryons as quark-antiquark or three-quark bound states, respectively, but no known mechanism in the theory forbids combinations of four or five quarks into so-called tetra- and pentaquark states. Furthermore, the carriers of the strong interaction, the gluons, can potentially contribute to the spectrum of hadrons. They can manifest themselves in the form of pure gluonic bound states, known as glueballs, or the excited gluonic field may contribute to the quantum numbers of so-called hybrid mesons. States with quantum numbers that cannot be realized by conventional quark-antiquark combinations are known as exotic mesons, which serve as unmistakable signs for hadrons beyond the simple quark models. The existence of glueballs, multi-quark states and other exotic excitations in the hadron spectrum is one of the most important predictions of the Standard Model that has not yet been confirmed experimentally. The primary objective of this research is the experimental study of these novel forms of nuclear matter within the spectrum of hadrons to further the understanding of the dynamics of the strong interaction. The Gluonic Excitation Experiment (GlueX) at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) was specifically designed to study the light-quark meson spectrum and to confirm or refute the

			contribution of hybrid mesons. To unveil the full potential of its high-precision data and ultimately to achieve its scientific mission, novel approaches must be developed and applied, using advanced analysis methods and high-performance computing. This research project will advance Jefferson Lab as a world-wide center of expertise in the field of hadron spectroscopy. The award will invest in a state-of-the-art computing infrastructure, which will be reserved to carry out this research. Advanced methods such as machine learning and artificial intelligence will be used and studied systematically. The project also includes the development and implementation of novel real-time data processing and analysis schemes for the next generation of nuclear physics experiments.
2022	Katerian Chatziioannou	California Institute of Technology	**"Studying the Properties of Supranuclear Matter With Neutron Stars"** Neutron stars are nuclear matter's last stand in the battle against total collapse under the overwhelming force of gravity. With masses comparable to that of our Sun yet smaller in size than the island of Manhattan, neutron star interiors drive matter to extreme conditions with densities exceeding those found in everyday nuclei. Under these conditions, the properties and even the composition of matter in neutron stars is uncertain. A wealth of observational and experimental data will become available in the next years. Collisions of neutron stars traveling at a fraction of the speed of light will be detected with gravitational and electromagnetic radiation; thermal emission from hot regions on the surface of isolated neutron stars will be observed with X-ray radiation; radio surveys will continue tracking neutron stars in binaries with white dwarfs and measure their masses; terrestrial experiments will constrain the properties of finite nuclei. At the same time theoretical nuclear calculations are reaching new levels of maturity. This project aims to develop the data analysis infrastructure and algorithms necessary in order to analyze and combine the incoming data. The objective is to

			determine the properties and composition of neutron star matter as well as the astronomical properties of neutron stars. Some of the key questions this research targets are how large is the pressure inside neutron stars; do deconfined quarks exist in their cores; and what is the heaviest neutron star that exists in our Universe. This project aims to use data to robustly address some of the open questions with the widest interdisciplinary interest in nuclear astrophysics: the internal structure of neutron stars, the properties of matter at the highest densities, and the astrophysical conditions of the production site of heavy elements.
2022	Yang-Ting Chien	Georgia State University	**"Probing Quark Matter and Hadronization Using Energy Flow Substructure"** A hot and dense medium created in high energy nuclear collisions, referred to as the Quark-Gluon Plasma (QGP), exhibits novel properties of a perfect fluid. Its inner working is an open question, which holds the key to a better understanding of the strong interaction. Since the QGP only lasts about 10−23 second with a size of a nucleus, jets produced during hard scattering as sprays of energetic and collinear particles can be used to probe such medium. Modifications of such energy flow substructure due to jet-medium interaction therefore encode detailed information about QGP properties. This project uses modern machine learning algorithms to search for QGP signatures in jets, which will be guided by theoretical calculations of jet substructure using Quantum Chromodynamics. Nuclear structure and hadronization, which is the transition from quarks and gluons to final state particles, can also be identified through their imprints in energy flow substructure. The project will contribute to establishing timely and firm basis for understanding the data from the Relativistic Heavy Ion Collider, the Large Hadron Collider, and the future Electron Ion Collider.
2022	John D. Despotopulos	Lawrence Livermore National Laboratory	**"Measurement of Neutron-Induced Cross Sections of Nuclides Produced at the Facility for**

			Rare Isotope Beams (FRIB) using the National Ignition Facility (NIF)" This research leverages unique capabilities at two of the nation's premier research facilities, the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory and the Facility for Rare Isotope Beams (FRIB) at Michigan State University. FRIB is the only accelerator in the world capable of generating many of the nuclear isotopes that are created inside stars, whereas NIF is the world's only facility capable of recreating the conditions inside stars, which it achieves by aiming 192 laser beams onto a tiny capsule to induce nuclear fusion. When nuclear fusion occurs, material added into the target will undergo neutron-induced reactions, and nuclear cross sections can be determined by collecting samples for analysis. This project will harvest radioactive isotopes from FRIB, radiochemically purify those isotopes and add them to the inside of a NIF target capsule in order to study these same isotopes in a neutron-rich environment similar to that in stellar interiors. The measured cross sections will improve our understanding of stellar nucleosynthesis and benefit national security, both key goals of the Office of Nuclear Physics. These measurements will be among the first ever made in a true high energy density plasma and for radioactive species with short half-lives.
2022	Anders Knospe	Lehigh University	"Heavy Flavor at RHIC" In the first few microseconds after the Big Bang, the universe consisted of a hot and dense state of matter called the quark-gluon plasma (QGP). This state of matter is essentially a "soup" of quarks and gluons, the subatomic particles which make up protons and neutrons, which in turn are the building blocks of atomic nuclei. Scientists at modern collider facilities accelerate nuclei to very high energies and smash them into each other, which "melts" them into their constituent quarks and gluons and recreates the QGP. The plasma expands and cools during its short lifetime (~10-23 seconds) before making the transition back to regular matter. Physicists use a wide variety of probes to characterize the properties of the QGP in detail. This work will use heavy quarkonia,

			which are bound charm-anticharm or bottom-antibottom mesons, as probes of the quark-gluon plasma. The presence of a QGP will inhibit the formation of heavy quarkonia in a way that depends on both the temperature of the plasma and how tightly bound the quarkonium state is. Measurements of the abundances of different types of quarkonia in heavy-ion collisions, compared to a proton-proton collision baseline, will allow us to probe the properties of the QGP, including its temperature evolution. In this work, we will measure the yields of charm-anticharm and bottom-antibottom quarkonia in small (proton-proton) and large (heavy-ion) collision systems to shed light on how the suppression of these bound states evolves with system size. Furthermore, the quark-gluon plasma has been observed to behave as a liquid with a very low viscosity. We will conduct measurements of the flow parameters of bottom-antibottom quarkonia to characterize the extent to which bottom quarks participate in the collective motion of the system. This work will make use of the excellent particle identification and tracking capabilities of the STAR detector and the newly upgraded sPHENIX detector, both at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. Our use of heavy, rare particles to probe the quark-gluon plasma will shed light on the behavior of this unique state of matter and help us better understand the strong nuclear force, one of the fundamental forces of nature.
2022	Christopher Monahan	William & Mary	**"The Three Dimensional Structure of the Proton"** Protons and neutrons are the basic building blocks of almost all visible matter, and account for 95% of the mass of the visible universe. Protons and neutrons are composed of smaller particles, quarks, bound together by the strong nuclear force, which is carried by gluons and is responsible for all nuclear matter, from hydrogen ions to neutron stars. The exact arrangement of quarks and gluons inside protons and neutrons is not well known. This project helps understand the three-dimensional arrangement of quarks and gluons within protons and neutrons, using large-scale supercomputing facilities to calculate the

			properties of protons and neutrons directly from the strong nuclear force. These calculations complement data on proton and neutron structure obtained from experiments performed at Thomas Jefferson National Accelerator Facility and the planned electron-ion collider at Brookhaven National Laboratory and provide a basis for combining experimental and theoretical data in a consistent framework.
2022	Guido Pagano	Rice University	**"Trapped-Ion Quantum Simulation for Nuclear Physics"** Quantum Field Theories play a central role in our understanding of nature providing a framework for understanding the interactions between elementary particles and for studying the real-time dynamics of matter after the Big Bang. However, despite significant progress in classical computational techniques, there are a number of roadblocks that prevent us from simulating these theories at large scale and in their real-time dynamics using conventional approaches. A fundamental challenge is related to the computational cost that grows exponentially with the number of particles, making large-scale simulations classically intractable. One promising approach to overcome these challenges is the use of quantum processors for directly simulating field theories. Recent advances in quantum-computing hardware have allowed access to regimes on the verge of surpassing classical computers. The overarching goal of this project is to use one of the most promising quantum platforms, trapped atomic ions, to directly map and simulate field theories and nuclear physics models. However, these theories are not readily mappable in existing quantum platforms. Therefore, the focus of this project is to study and experimentally realize new analog and hybrid analog-digital quantum simulation protocols that can directly realize quantum field theories in trapped-ion systems. The new experimental tools developed in this project will provide a foundation for the simulation of quantum matter in the Standard Model, approaching a regime that cannot be efficiently accessed with conventional computing techniques.
2022	Zhaowen Tang	Los Alamos National Laboratory	**"Understanding the 10 Seconds Neutron Lifetime Discrepancy"**

			The Standard Model of particle physics describes the way that all known elementary particles behave under three of the four known forces of the universe, the electromagnetic, weak, and strong interactions. Under this theory, the free neutron decays 100% of the time into a proton, electron, and antineutrino, with a lifetime of about 15 minutes. In combination with other experiments, the neutron lifetime can provide constraints on many extensions of the Standard Model. Also, knowledge of the neutron lifetime at the 1 second level is necessary to improve predictions of the elements generated from the Big Bang. There are primarily two different methods to measure the neutron lifetime: experiments based on cold neutron beams and experiments using ultracold neutron bottles. The results of these two methods differ by 9.6 seconds, which corresponds to a chance of 1 in 3.5 million that the two results are compatible with each other. There are two possible explanations for this large discrepancy: unaccounted effects in the interpretation of data (systematic error) in one or both of the methods, or a new mode of decay of the neutron that produces thus far unknown and undetected particles. This research plans to measure the neutron lifetime to the 1 second level using an alternative method with completely different systematic errors compared to previous measurements. A result that agrees with the bottle experiments will suggest that there are unaccounted systematic errors in the beam measurements, and a result that agrees with the beam experiments can be interpreted as a discovery of a new hidden decay mode of the neutron.