Year	Name	Institution	Brief Description
2018	Raul Briceno	Old Dominion University	**"Multi-Hadron Systems via Lattice Quantum Chromodynamics"** The vast majority of the states of Quantum Chromodynamics (QCD) are composed of more than one hadron. These manifest themselves as very short lived resonances or as stable bound states (light nuclei). The goal of this research is to use lattice QCD to develop and implement a universal framework for studying these systems directly from QCD. This framework will open up new classes of physical observables, presently out of reach of theoretical studies but crucial to guiding, confirming, and complementing experimental efforts to understand the QCD spectrum at the Jefferson National Accelerator Laboratory and beyond. Two major milestones are expected to be reached by this research. The first includes developing and implementing techniques for a first study of three-hadron states, allowing for the determination of three-nucleon forces and QCD excitations that couple to multi-hadron states as in the so-called Roper resonance. The second milestone entails studies of the structural composition of resonant and non-resonant few-hadron systems. Combined, these two goals will give access to unexplored sectors of QCD states and allow for construction of an image of their intrinsic character.
2018	Cesar da Silva	Los Alamos National Laboratory	**"Gluon Saturation Search in the Deep Small Bjorken-x Region using the Large Hadron Collider Beauty Experiment (LHCb)"** High-energy collisions, such as the ones produced at Relativistic Heavy Ion Collider (RHIC) in Brookhaven/NY and at the Large Hadron Collider (LHC) at CERN/Switzerland, can produce matter with high gluon densities. Gluons are the particle mediators responsible for the strong nuclear interactions. At high density gluons can start to fuse and form condensates, similar to cold atom experiments where discoveries have been awarded four Nobel prizes in the last 20 years. These condensates show particles with interesting collective behavior. This research aims for the unambiguous observation of gluon condensates in collisions produced at the LHC using the LHC Beauty

			experiment (LHCb), which has a unique detector coverage to observe saturated gluons. This study will include development of improved techniques to select events with isolated photons, improve tracking of particles and analysis directed at demonstrating the existence of the predicted gluon condensate. The results of this work will have implications in the current understanding of particle production in proton and nucleus collisions and the quantum behavior of the strong forces.
2018	Luiz De Viveiros Souza Filho	Pennsylvania State University	**“Project 8 at Penn State: Developing the Ultimate Neutrino Mass Experiment”** The neutrino mass is one of the most important unknown quantities in physics. The most sensitive direct searches for the neutrino mass rely on the beta decay method: nuclei undergoing beta decay emit an electron and a neutrino. Thanks to energy conservation, one can determine the mass of the neutrino from the shape of the electron spectrum near its endpoint, that is, the maximum energy of the emitted electrons. The Project 8 experiment has developed a novel technique called Cyclotron Radiation Emission Spectroscopy (CRES) to precisely measure the beta decay spectrum in tritium, and thus obtain a neutrino mass measurement with sensitivity surpassing that of existing experiments. An electron trapped in a uniform magnetic field will emit cyclotron radiation with frequency that depends on its kinetic energy, so that a measurement of the radiation provides a nondestructive electron energy measurement. The Project 8 collaboration has already demonstrated the viability of this technique using a small-scale (~10 cm3) prototype. However, an attempt at measuring the neutrino mass will require a vast increase in the number of tritium decays, which can be accomplished through an increase in detector volume to 10-100 m3. One crucial feature of such a detector is the ability to identify single electrons in a large cavity instrumented with a multi-channel antenna array, which will present unique challenges for the acquisition and reconstruction of signals. This project will develop the signal reconstruction techniques and electronics needed to take CRES to the next level, such as the use of digital beam-forming for single electron detection and tracking in large volumes. This research project will include the simulation of the expected electron signal in software and hardware; building of test chambers

			instrumented with multiple prototype antennas and electronics; development of signal reconstruction algorithms; and the construction and operation of the Project 8 detector, with a focus on signal acquisition, electronics, and data analysis. The successful completion of this project will extend the functionality of the CRES technique to large scales, providing essential tools and support that will allow Project 8 to move into the next phases of its experimental program, and lead to the ultimate neutrino mass experiment.
2018	Stefano Gandolfi	Los Alamos National Laboratory	**“Weak Interactions in Nuclei and Nuclear Matter”** The goal of this project is to develop a comprehensive understanding of the structure and electroweak processes in nuclei and nucleonic matter that are critical to present and future experiments at rare isotope facilities, high-energy accelerators, and to astrophysical observations. Neutrino interactions with nuclei and dense matter, in particular the theory support to future double beta-decay experiments, have been identified as one of the most important scientific questions in nuclear physics in the most recent Nuclear Science Advisory Committee long-range plan. These properties are critical to an understanding of finite nuclei, how they interact with high-energy electrons and neutrinos produced at accelerators, and also to astrophysical environments like neutron stars and supernovae. In order to solve for these problems, sophisticated computational techniques are required. In this project we use numerical methods based on Monte Carlo integrations. These methods can efficiently exploit the largest available supercomputers, and our codes are developed to efficiently use the largest available high-performance machines. The main input for these calculations are i) the interactions describing how nucleons interact within nuclei, and ii) the interactions of nucleons with external probes like electrons and neutrinos. We use numerical methods to calculate nuclear properties with the goal of validating our models for i) and ii) by comparing our calculations with available precise data on beta decays and electron scattering in nuclei, and then make predictions for neutrino scattering, neutrino propagation in neutron stars and supernovae, and relevant matrix elements for double beta-decay experiments.
2018	Benjamin Jones	University of Texas	

			“Single Molecule Fluorescence Imaging for a Background-Free Neutrinoless Double Beta Decay Search” The nature of the neutrino and its mass are fundamental unknowns in nuclear and particle physics, with consequences for cosmological mysteries including the matter / antimatter asymmetry of the Universe, and the existence of new physics at very high energy scales. The only known way to establish experimentally that the neutrino is a Majorana particle (meaning that it is its own anti-particle) is through observation of the ultra-rare and still unobserved process of neutrinoless double beta decay. All experiments that have searched for this process to date have been plagued by backgrounds from ambient radioactivity in detector materials. To meet the target sensitivity of next-generation searches, ultra-low background techniques leading to contamination of less than 0.1 counts per ton per year in the signal region of interest are required. No such technology has yet been demonstrated to achieve this goal. This work involves R&D toward a novel method of achieving a background free search for neutrinoless double beta decay in xenon-136: barium tagging using single molecule fluorescent imaging, coupled to high pressure xenon gas time projection chambers. This mixes advances from biochemistry, microscopy, nuclear and particle physics to yield a technology that may be paradigm shifting for the field, enabling a new class of highly sensitive, background-free neutrinoless double beta decay searches.
2018	Zach Meisel	Ohio University	**“Constraining Neutron Star Structure with Indirect Nuclear Reaction Studies”** How matter behaves at the highest densities achieved by nature is an open question. Studies of neutron stars, ultradense remnants from stellar explosions, provide unique windows into the behavior of matter existing at densities beyond that of an atomic nucleus and at temperatures low enough for quantum phenomena to emerge at macroscopic scales. Such studies often rely on comparisons between astrophysics model calculations and astronomical observations. However, these model calculation results sensitively depend on largely uncertain nuclear physics input. Of particular interest are the nuclear reactions

			responsible for energy generation and element creation in Type I X-ray bursts, thermonuclear explosions on the surface of a neutron star accreting material from a companion star. The objective of this project is to remove or reduce the most significant nuclear physics uncertainties for these bursts using indirect nuclear reaction measurements at the Edwards Accelerator Laboratory at Ohio University and the National Superconducting Cyclotron Laboratory at Michigan State University. To assess their impact, measurement results will be included in state-of-the-art astrophysics model calculations of observable phenomena from accreting neutron stars. The overall outcome of this work will be substantial improvement in our understanding of the outer structure of accreting neutron stars and, thereby, of high-density low-temperature matter.
2018	Jacquelyn Noronha-Hostler	Rutgers University	**“Dynamical Aspects of the Quark Gluon Plasma”** Shortly after the Big Bang the entire universe was filled with a nearly perfect fluid, known as the Quark Gluon Plasma. Relativistic heavy ion collisions can now reproduce this fluid in the laboratory. The Quark Gluon Plasma exhibits a rapid, but smooth cross-over phase transition into hadrons at vanishing net-baryon densities. Recent experiments plan to explore finite baryon densities, where a critical point is expected. If found, this would mark the first discovery of a critical point in a relativistic system described by a fundamental theory of nature, which would have far-reaching consequences for high-energy nuclear physics and nuclear astrophysics (such as in neutron star mergers). Characteristic temperatures of equilibrium (e.g., the inflection point of the entropy density) and transport coefficients (e.g., the minimum of the shear viscosity over entropy density) vary widely at a cross-over phase transition, but converge at a critical point. Extracting the behavior of these characteristic temperatures is a major focal point of this research. Specifically, the interplay between strange and light hadrons is exploited to study the flavor hierarchy in the cross-over region. To investigate this, a viscous relativistic hydrodynamics framework with two conserved charges is being developed into a new open-source code, along with initial conditions that contain baryon number and strangeness. Flow observables sensitive to the equation of state and transport coefficients are calculated across beam energies. New techniques are

			developed to study this flavor hierarchy from first principles and to extract the characteristic temperatures from experimental data. Through the new dynamical framework, this project provides essential guidance to the Beam Energy Scan II runs at the Relativistic Heavy-Ion Collider and the future Facility for Antiproton and Ion Research in Germany in the search for the Quantum Chromodynamics critical point and subsequent investigation of the baryon-rich Quark Gluon Plasma.
2018	Jaideep Taggart Singh	Michigan State University	**"Towards a Next Generation Search for Time-Reversal Violation Using Optically Addressable Nuclei in Cryogenic Solids"** Certain rare pear-shaped nuclei have unmatched sensitivity to new kinds of forces between subatomic particles that are not the same when the arrow of time is reversed. Such forces are believed to be responsible for the near absence of antimatter in the observable Universe. These rare isotopes, some for the first time, will be produced in large numbers at the Facility for Rare Isotope Beams currently under construction at Michigan State University providing an unprecedented opportunity to probe for new physics. In anticipation, we will use abundant isotopes to develop new techniques to manipulate nuclei embedded inside an optically transparent solid at cryogenic temperatures. Implantation into a solid, such as neon and argon, is potentially an effective way to both efficiently capture and repeatedly probe the small number of rare nuclei, such as radium and protactinium. An optically transparent host medium at cryogenic temperatures would allow for the laser manipulation of the nuclei in a thermally quiet and stable environment for a wide variety of guest species such as polar molecules. In such systems, the nuclei are exposed to extraordinarily large electric fields and magnetic field gradients, which significantly amplifies the measurability of certain time-reversal violating effects. The potential sensitivity of this new approach could be at least a few hundred times greater than the current leading experiment which uses mercury atoms.
2018	Anne-Marie Valente-Feliciano	Thomas Jefferson National Accelerator Facility	

			“Next Generation Superconducting Radio Frequency (SRF) Cavities with Optimized RF Performance via Energetic Condensation Thin Film Technology” A key to future generations of particle accelerators is to sustain the highest possible acceleration kick with minimum construction and operation costs. Bulk niobium (Nb) is currently the standard material used in superconducting radio-frequency (SRF) accelerating cavities. Current techniques are approaching the fundamental limit of this material. The greatest potential for new performance capabilities and cost reduction lies with methods and materials that directly engineer the sub-micron-thick critical surface layer of superconducting material inside cavities. Recent strides in the development of novel deposition techniques (energetic ion vacuum deposition) open the door to the production of engineered SRF surfaces either as a single layer superconductor, such as niobium on copper (Nb/Cu), or multilayered superconductor-insulator-superconductor structures. This innovation promises to extend the performance of SRF Nb cavities beyond the current material limits. While conventional deposition techniques rely on thermally induced growth processes, which limit the deposition quality of refractory materials such as Nb and its compounds on low temperature substrates (Cu) , energetic ion deposition techniques allow film growth processes to be manipulated, to produce high quality crystalline materials with excellent adhesion to the substrate and sharp, clean transitions between layers. The increased flexibility and control of the deposition processes lead to films with improved characteristics. This research focuses on the development of SRF cavities coated with (1) vanguard-quality Nb films and (2) nanometric Nb3Sn-based multilayered structures. Ultimately, both thin film technologies will be integrated to produce fully engineered SRF surfaces useful at different frequencies, and at possibly higher temperatures. These highly performing thin film SRF cavities will also simplify the accelerating system, dramatically changing the cost framework of SRF accelerators. The final integrated concept will provide significantly improved RF performance, higher efficiency and quality control for accelerating structures relevant to next generation research accelerators for science and other societal and commercial applications.
2018	Anselm Vossen	Duke University	

			“Novel Experimental Probes of Quantum Chromodynamics in Semi-Inclusive Deep-Inelastic Scattering and e+e Annihilaiton” The mass of most visible matter in the universe is due to the dynamics of the interaction of quarks and gluon inside nucleons. While the theory of quantum chromodynamics (QCD) provides an accurate description of the fundamental laws governing strong interactions, a comprehensive description of the dynamics that give rise to the observed properties of the nucleon still eludes us. We aim to develop experimental and analysis techniques that make full use of the unprecedented statistical power provided by the datasets to be collected at the upgraded electron scattering facility at the Jefferson National Accelerator Laboratory (JLab). In particular, we plan to utilize correlations in the angular distributions of particles produced from quarks when nucleons are broken up in hard scattering events and their polarizations. These methods will have broad applications in the exploration of QCD. With the first datasets collected at the upgraded JLab we can for example gain insight into the force that the gluon fields inside the nucleon exert on the quarks as they move through the field as well as elucidate the role of spin in the formation of bound quark states. Combining these results with an independent measurement in e+-e- annihilation, using data from the new SuperKEKB facility in Japan, will allow us to disentangle the effects of interactions of the quark inside the nucleon from those the quark underwent after the breakup of the nucleon.