Nuclear Physics

Overview

The mission of the Nuclear Physics (NP) program is to explore one of the enduring mysteries of the universe, the nature of matter: its basic constituents and how they interact to form the elements and the properties we observe. Solving this mystery involves discovering, exploring, and understanding all forms of nuclear matter, not only the familiar forms of matter we see around us, but also exotic forms that existed in the first moments after the Big Bang and that may exist today inside neutron stars. The aim is to understand why matter takes on the specific forms observed in nature and how that knowledge can benefit society in the areas of energy, climate, commerce, medicine, and national security.

Understanding all forms of nuclear matter requires an enormous range of capabilities: from probing quarks and gluons inside protons, to searching for the largest nuclei that can exist. It also encompasses discovery through time and the evolution of the universe. The epoch in the cosmos when quarks and gluons first combined to form protons was millionths of a second after the Big Bang. Events in the cosmos creating heavy nuclei are still occurring today.

Theoretical approaches to further our understanding are based largely on calculations of the interactions of quarks and gluons described by the theory of Quantum Chromodynamics (QCD). An exciting vision is the prospect of Quantum Computing (QC), a revolutionary new paradigm for future computers capable of solving many-body QCD problems currently intractable with today's capabilities. Experimental approaches use large accelerators at scientific user facilities to collide particles at nearly the speed of light, producing short-lived forms of nuclear matter for investigation. Comparison of experimental observations and theoretical predictions tests the limits of our understanding of nuclear matter and suggests new directions for experimental and theoretical research. The many forms in which nuclear matter can exist requires a suite of accelerators with complementary capabilities. NP oversees operations at four accelerator facilities.

The Facility for Rare Isotope Beams (FRIB) uniquely affords access to 80 percent of all isotopes predicted to exist in nature, including over 1,000 never produced on earth. The Relativistic Heavy Ion Collider (RHIC) recreates new forms of matter and phenomena that occurred in the extremely hot, dense environment that existed in the infant universe. The Continuous Electron Beam Accelerator Facility (CEBAF) extracts information on quarks and gluons bound inside protons and neutrons that formed shortly after the universe began to cool. The Argonne Tandem Linear Accelerator System (ATLAS) "gently" accelerates nuclei to energies typical of nuclear reactions in the cosmos to further our understanding of the ongoing synthesis of heavy elements such as gold and platinum. Stewardship of these facilities is a priority role and goal of NP, as affirmed in the Nuclear Science Advisory Committee's (NSAC) 2015 Long Range Plan for Nuclear Science (LRP), *Reaching for the Horizon*.

The Electron-Ion Collider (EIC) construction project will provide unprecedented ability to x-ray the proton and discover how the mass of everyday objects is dynamically generated by the interaction of quark and gluon fields inside protons and neutrons. The EIC will maintain U.S. leadership in nuclear physics and in accelerator science and technology of colliders.

One equally exciting NP frontier does not involve accelerators, but envisions the nucleus itself as a laboratory for observing nature's fundamental symmetries. Chief among these experiments is the search, also given high priority in the 2015 NSAC Long Range Plan, for a nuclear decay predicted to happen once in 10^{28} years and only if the elusive neutrino particle turns out to be its own anti-particle. The observation of so-called neutrino-less double beta decay would result in a disruptive change in our current understanding of the elementary constituents of nuclear matter and the forces that govern them. Additional experiments include improving the precision of the current value of the neutron lifetime and expanding the limits on a possible electric dipole moment of the neutron. These studies have the potential to change our understanding of the physical world.

NP is the primary steward of the nation's fundamental nuclear physics research portfolio providing approximately 95 percent of the U.S. investment in this area. It also supports the National Nuclear Data Center which collects, evaluates, curates, and disseminates nuclear physics data for basic nuclear research and applied nuclear technologies. In collaboration with other Office of Science (SC) programs, NP continues to support development of quantum sensors and quantum control techniques, as well as efforts on artificial intelligence and machine learning which can benefit nuclear physics research and NP accelerator operations. NP also stewards accelerator research and development (R&D), pursuing next generation electron ion source developments and advancing approaches in superconducting radio frequency (SRF) technologies.

Highlights of the FY 2024 Request

The FY 2024 Request for $811.4 million supports high priority efforts and capabilities in fundamental nuclear physics research; operations, maintenance, and upgrades of scientific user facilities; and projects.

Research

- *Core Research*: Primary fundamental research thrusts include:
  - The search for a Critical Point and characterization of the quark-gluon plasma at RHIC and the Large Hadron Collider (LHC)
  - Unraveling the mechanism underlying quark confinement at CEBAF and RHIC
  - Exploring the fundamental structure of nucleons at the sub-femtometer scale at CEBAF and the future EIC
  - The search for new exotic particles and anomalous violations of nature's symmetries at CEBAF
  - Probing the limits of nuclear existence; site & process for heavy element production in the cosmos at FRIB and ATLAS
  - Discovery of whether the neutrino is its own anti-particle via neutrino-less double beta decay
  - Precision measurement of the neutron's properties to search for new physics
  - Research on the strong force in many-body systems leading to precision predictions from QCD of nuclear properties and nuclear reactions via Scientific Discovery Through Advanced Computing (SciDAC)
  - Curation of reliable, accurate Nuclear Data for basic nuclear research and nuclear technologies
  - Niche capabilities and unique "hands-on" experiences in nuclear science at NP University Centers of Excellence
- *Quantum Information Science (QIS)*: Support continues for the SC National QIS Research Centers (NQISRCs) along with discovery opportunities in sensing, simulation, and computing at the intersections of nuclear physics and QIS.
- *Artificial Intelligence and Machine Learning (AI/ML)*: R&D to targeted to automate optimization of accelerator availability and performance, as well as software enabling data-analytics-driven discovery.
- *Reaching a New Energy Sciences Workforce (RENEW)*: Expanded efforts, including a RENEW graduate fellowship, to broaden participation and advance belonging, accessibility, justice, equity, diversity, and inclusion in SC research.
- *Microelectronics:* In coordination with other SC programs, support for research and development of detector materials, devices, advances in front-end electronics, and integrated sensor/processor architectures.
- *Funding for Accelerated, Inclusive Research (FAIR):* Focused investment on enhancing research at minority serving institutions (MSIs) to improve the capability of MSIs to perform and propose competitive research and will build beneficial relationships between MSIs and DOE national laboratories and facilities.
- *Accelerate Innovations in Emerging Technologies (Accelerate):* Scientific research to accelerate the transition of science advances to energy technologies. The goal is to drive scientific discovery to sustainable production of new technologies across the innovation continuum, including relevant experiences for the future workforce.
- *Established Program to Stimulate Competitive Research (EPSCoR):* Funding continues support for research in states and territories with historically lower levels of Federal academic research funding.
- Within available resources, NP will prioritize transitioning Exascale Computing Project (ECP) researchers, software, and technologies into core research efforts and DOE priorities research areas as ECP concludes.

Facility Operations

Funding supports operations of the NP scientific user facilities to enable world-class science:

- RHIC operates 2,580 hours (94 percent optimal funding) to begin the sPHENIX scientific program.
- CEBAF operates 3,350 hours (88 percent optimal funding) for the highest priority 12 GeV experiments.
- ATLAS operates 5,800 hours (91 percent optimal funding) for compelling research in nuclear structure and astrophysics.
- FRIB continues to move towards full operations, operating for 3,350 hours (94 percent optimal funding).

Projects

The Request for Construction and Major Items of Equipment (MIEs) includes:

- Continuation of research, Project Engineering and Design (PED) activities, and long-lead procurements for the Electron-Ion Collider.
- Continuation of the Ton-scale Neutrinoless Double Beta Decay (TSNLDBD) MIE to determine whether the neutrino is its own antiparticle. Funding supports the management team and coordination of the collaboration.
- Continuation of the High Rigidity Spectrometer (HRS) research project at FRIB to maximize the rate of rare neutron-rich nuclei of central importance for understanding the synthesis of heavy elements in cosmic events.

Nuclear Physics
Funding

(dollars in thousands)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Nuclear Physics				
Medium Energy, Research	53,404	59,083	55,555	-3,528
Medium Energy, Operations	142,709	149,834	141,930	-7,904
Total, Medium Energy Physics	**196,113**	**208,917**	**197,485**	**-11,432**
Heavy Ion, Research	46,505	46,149	47,454	+1,305
Heavy Ion, Operations	183,943	182,087	176,195	-5,892
Heavy Ion, Projects	25,013	20,000	2,850	-17,150
Total, Heavy Ion Physics	**255,461**	**248,236**	**226,499**	**-21,737**
Low Energy, Research	73,935	77,651	78,409	+758
Low Energy, Operations	107,831	128,579	127,624	-955
Low Energy, Projects	17,400	23,940	9,259	-14,681
Total, Low Energy Physics	**199,166**	**230,170**	**215,292**	**-14,878**
Theory, Research	57,260	67,873	77,142	+9,269
Total, Nuclear Theory	**57,260**	**67,873**	**77,142**	**+9,269**
Subtotal, Nuclear Physics	**708,000**	**755,196**	**716,418**	**-38,778**
Construction				
20-SC-52 Electron Ion Collider (EIC), BNL	20,000	50,000	95,000	+45,000
Subtotal, Construction	**20,000**	**50,000**	**95,000**	**+45,000**
Total, Nuclear Physics	**728,000**	**805,196**	**811,418**	**+6,222**

SBIR/STTR funding:
- FY 2022 Enacted: SBIR $21,390,000 and STTR $3,006,000
- FY 2023 Enacted: SBIR $8,336,000 and STTR $1,173,000
- FY 2024 Request: SBIR $7,541,000 and STTR $1,060,000

Nuclear Physics
Explanation of Major Changes

	(dollars in thousands) FY 2024 Request vs FY 2023 Enacted
Medium Energy Physics The Request provides support for the CEBAF accelerator complex to support 3,350 operating hours (88 percent optimal funding). The Request includes support to participate in the SC initiatives for QIS, AI/ML, Microelectronics, and Accelerate.	**-11,432**
Heavy Ion Physics The Request provides funding for the RHIC accelerator complex for a 2,580 hour run (94 percent optimal funding). The Request supports the first full year of science with the super Pioneering High Energy Nuclear Interaction eXperiment (sPHENIX), which will study high rate jets of particles at RHIC. Funding supports heavy ion nuclear physics at universities and national laboratories. The Request includes support the SC initiatives for QIS and AI/ML. The Request continues other project costs (OPC) for the EIC, which will enable scientists to play a leading role in R&D and the development of scientific instrumentation and accelerator components for the EIC. The Request also supports EPSCoR State-National Laboratory Partnership awards and early career awards in EPSCoR jurisdictions.	**-21,737**
Low Energy Physics The Request provides support for operations of two low energy user facilities: the ATLAS facility, which operates for 5,800 hours (91 percent optimal funding), and FRIB, which provides beam time for 3,350 hours (94 percent of optimal funding). The Request sustains operations of the 88-Inch Cyclotron at the Lawrence Berkeley National Lab (LBNL) for a limited in-house nuclear science program and an electronics irradiation capability for Department of Defense (DOD) and National Aeronautics and Space Administration (NASA). Funding supports nuclear structure and astrophysics at universities and national laboratories. No funds are requested for the Gamma-Ray Energy Tracking Array (GRETA) and Measurement of a Lepton-Lepton Electroweak Reaction (MOLLER) MIEs, which received their final funding in FY 2023. Funding continues for the HRS to exploit the fast beam capabilities at FRIB and for the TSNLDBD experiment.	**-14,878**
Nuclear Theory Funding supports theory research efforts at laboratories and universities, the U.S. Nuclear Data Program, specialized Lattice QCD computing hardware at Thomas Jefferson National Accelerator Facility (TJNAF), and participation in the SciDAC program. The Request supports QIS, quantum computing, and AI/ML. Increased funding supports the RENEW initiative to provide undergraduate and graduate training opportunities for students and academic institutions not currently well represented in the U.S. Science and Technology Directorate (S&T) ecosystem, including a RENEW graduate fellowship. The FAIR initiative increases to provide focused investment on enhancing research at MSIs and emerging research institutions.	**+9,269**
Construction The Request provides funding for the EIC to continue Project Engineering and Design activities, and begin long-lead procurements.	**+45,000**
Total, Nuclear Physics	**+6,222**

Basic and Applied R&D Coordination

The NP mission supports the pursuit of unique opportunities for R&D integration and coordination with other DOE Program Offices, Federal agencies, and non-Federal entities. For example, researchers from the High Energy Physics (HEP), NP, and Advanced Scientific Computing Research (ASCR) programs coordinate and leverage forefront computing resources and/or technical expertise through the SciDAC projects and Lattice QCD research to determine the properties of as-yet unobserved exotic particles predicted by the theory of QCD, advance progress towards a model of nuclear structure with predictive capability, and dramatically improve modeling of neutrino interactions during core collapse supernovae. The U.S. Nuclear Data Program provides evaluated cross-section and decay data relevant to a broad suite of Federal missions and topics such as innovative reactor design (e.g., of interest to the NE and Fusion Energy Sciences [FES] programs), materials under extreme conditions (of interest to the BES and FES programs), and nuclear forensics (National Nuclear Administration [NNSA] and the Federal Bureau of Investigations [FBI]). NP leads an Interagency working group including NNSA, Department of Homeland Security (DHS), Nuclear Energy (NE), the Isotope R&D and Production (DOE IP) and other Federal Agencies to coordinate targeted experimental efforts on opportunistic measurements to address serious gaps and uncertainties in existing nuclear data archives, as well to meet emerging challenges such as generating new nuclear data relevant for space exploration. Capabilities and techniques developed for nuclear physics at NP accelerator facilities are used by DOD and NASA to test electronics for radiation sensitivity in furtherance of their missions. NP research develops technological advances relevant to clean energy and the development of advanced fuel cycles for next generation nuclear reactors (NE); advanced cost-effective accelerator technology and particle detection techniques for medical diagnostics and treatment (National Institutes of Health [NIH]); accelerator research and enhancing U.S.-based supply chains for critical accelerator technologies (ARDAP); and research in developing neutron, gamma, and particle beam sources with applications in cargo screening (NNSA, DHS, and the FBI).

Program Accomplishments

Advancing Knowledge of the Cosmos.

When a supernova explodes, or neutron stars collide, often extremely dense object such as black holes or neutron stars result. Knowledge of these fascinating objects remains limited. But recently, nuclear theorists at Low Alamos National Laboratory (LANL), in collaboration with an international group of researchers, have combined theory, cosmological observations, and terrestrial nuclear physics experiments to better understand the matter inside the interior of neutron stars. Their advanced theoretical modeling employed high performance supercomputers combined with neutron-star observations and results from recent terrestrial experiments. The results constrain the radius of a typical neutron star (1.4 times the mass of the sun) to be approximately 12.0 kilometers. This work demonstrates how joint analyses can shed light on the properties of neutron-rich supranuclear matter over the full density range probed in neutron stars.

Beginning a New Journey of Discovery.

FRIB at Michigan State University in East Lansing, Michigan, was completed ahead of schedule and on budget. This new Office of Science National User Facility, which took 13 years to plan, design, and construct, began operation on May 2, 2022, with a ribbon-cutting presided over by U. S. Secretary of Energy Granholm. Only weeks after the ribbon cutting ceremony, FRIB was preparing to publish “first time ever” scientific results on the structure of an isotope of magnesium with 14 “extra” neutrons beyond the number that magnesium nuclei ordinarily contain. This result signals the start of research on thousands of new neutron rich isotopes that FRIB will produce to explore the limits of nuclear existence.

Finding the Boiling Point for Quark-Gluon Soup.

When water is boiled, it undergoes a phase transition from a liquid to a gas (steam). Knowing the temperature where water turns to steam tells us about the forces between water molecules and their degrees of freedom. Similarly, inside nuclei, quarks, and gluons (the building blocks of protons and neutrons) are normally trapped. But adding energy can cause a phase transition where quarks and gluons enter a liquid-like state called the quark-gluon plasma, or QGP. Knowing the precise temperature where a transition to the QGP occurs can provides invaluable insight on forces binding quarks and gluons. To do this requires advanced particle detectors like the Solenoidal Tracker at RHIC (STAR) detector at Brookhaven National Laboratory (BNL). Recent measurements at STAR have allowed scientists to significantly narrow the window on the temperature and pressure where the phase transition to a QGP occurs. This research will significantly advance our understanding of quarks and gluons, and by extension, protons, neutrons, and the nuclei they form as well.

Filling in the gaps.
The analysis of nuclear fuel cycle is one of the most important topics for applied nuclear physics. New experiments performed with the Oak Ridge National Laboratory's Modular Total Absorption Spectrometer (MTAS) carried out at the ATLAS at the Argonne National Laboratory (ANL) have now corrected outdated data on energy release patterns (decay heat) dating from decades ago. The new decay heat data not only allow for improved reactor designs but also elucidate the properties of anti-neutrino emission in nuclear reactions and contribute to non-proliferation studies as well.

Predicting the Neutron Skin Thickness of Heavy Nuclei.
Using high performance computers and experimental data from the Lead Radius Experiment (PREX) experiment at Thomas Jefferson National Accelerator Facility, heavy-ion experiments at the Gesellschaft für Schwerionenforschung (GSI) Helmholtz Centre for Heavy Ion Research in Germany, and research data from Brookhaven National Laboratory and Lawrence Berkeley National Laboratory, theorists in the NUCLEI SciDAC collaboration performed state-of-the art theoretical computations which predicted the neutron skin thickness for Lead 208 would be about one third of a femtometer, in excellent agreement with experimental results. The same study provided stringent new constraints on the possible radii of neutron stars.

Discovering the Origin of Meteoritic Stardust Grains.
Small inclusions in meteorites (called stardust) have an isotopic composition that can only be explained by assuming that they originated from stellar explosions. Using the Laboratory for Experimental Nuclear Astrophysics (LENA), newly acquired data allow an accurate prediction of the silicon isotopic ratios in different types of stellar explosions to determine if an observed meteoritic grain originated from a supernova or a nova that occurred sometime before the solar system was born. LENA is part of the Triangle Universities Nuclear Laboratory (TUNL), run by a consortium of Duke University, North Carolina Central University, North Carolina State University, and the University of North Carolina at Chapel Hill.

Nuclear Physics
Medium Energy Physics

Description

The Medium Energy Physics subprogram focuses primarily on experimental tests of the theory of the strong interaction, known as Quantum Chromodynamics (QCD). According to QCD, all observed nuclear particles, collectively known as hadrons, arise from the strong interaction of quarks, antiquarks, and gluons. The protons and neutrons inside nuclei are the best-known examples of hadrons. QCD, although difficult to solve computationally, predicts what hadrons exist in nature, and how they interact and decay. Specific questions addressed within this subprogram include:

- What is the internal landscape of the protons and neutrons (collectively known as nucleons)?
- What does QCD predict for the properties of strongly interacting matter?
- What is the role of gluons and gluon self-interactions in nucleons and nuclei?

Scientists use various experimental approaches to determine the distribution of up, down, and strange quarks, their antiquarks, and gluons within protons and neutrons, as well as clarifying the role of gluons in confining the quarks and antiquarks within hadrons. Experiments that scatter electrons off protons, neutrons and nuclei are used to clarify the effects of the quark and gluon spins within nucleons, and the effect of the nuclear medium on the quarks and gluons. The subprogram also supports experimental searches for higher-mass "excited states" and exotic hadrons predicted by QCD, as well as studies of their various production mechanisms and decay properties.

The Medium Energy subprogram supports research at and operation of the subprogram's primary research facility, the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF). In addition, the subprogram provides support for spin physics research at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL), which is the only collider in the world that can provide polarized proton beams.

CEBAF provides high quality beams of polarized electrons that allow scientists to extract information on the quark and gluon structure of protons and neutrons from measurements of how the electrons scatter when they collide with nuclei. CEBAF also uses highly-polarized electrons to make very challenging precision measurements to search for processes that violate a fundamental symmetry of nature, called parity, in order to search for physics beyond what is currently described by the Standard Model of particle physics. These capabilities are unique in the world. The increase in beam energy provided by the 12 GeV CEBAF Upgrade continues to open up exciting new scientific opportunities and secures continued U.S. world leadership in this area of physics. Research at RHIC using colliding beams of spin-polarized protons, is providing information on the spin of the proton in a kinematic range complementary to that at CEBAF to extend present knowledge beyond the kinematic boundaries accessible at CEBAF alone. Research support for CEBAF and RHIC includes laboratory and university scientific and technical staff needed to conduct high priority data analysis to extract scientific results. Complementary, focused experiments that require different capabilities can be conducted at the High Intensity Gamma-Ray Source (HIGS) at the Triangle Universities Nuclear Laboratory (TUNL), a University Center of Excellence; Fermi National Accelerator Laboratory (FNAL); European laboratories; and elsewhere. The Research and Engineering Center (REC) of the Massachusetts Institute of Technology has specialized infrastructure used to develop and fabricate advanced instrumentation and accelerator equipment for the nuclear physics community.

A high scientific priority for this community is addressing an outstanding grand challenge question of modern physics: how the fundamental properties of the proton such as its mass and spin are dynamically generated by the extraordinarily strong color fields resulting from dense systems of gluons in nucleons and nuclei. The EIC, to be located at BNL, plans to address this science. Scientists and accelerator physicists from the Medium Energy subprogram are strongly engaged and play significant leadership roles in the development of the scientific agenda and implementation of the EIC.

Transformative accelerator R&D efforts advanced approaches in SRF technology and accelerator science aimed at improving the operations of existing facilities and developing next-generation facilities for nuclear physics. Nuclear physicists participate in activities related to quantum information science (QIS) and quantum computing (QC), in coordination with other SC research programs. NP-specific efforts include R&D on quantum sensors to enable precision NP measurements, development of quantum sensors based on atomic-nuclear interactions, and development of quantum computing algorithms applied to quantum mechanical systems and NP topical problems. Scientists develop cutting-edge techniques based on artificial intelligence and machine learning (AI/ML) of relevance to nuclear science research and accelerator facility operations. NP continues support for applications of artificial neural networks in the analysis of nuclear physics data. Additionally, NP is supporting technical development at the intersections between real-time ML and control and the optimization of accelerator systems operations and detector design using AI/ML models. Scientists participate in the SC initiative on Microelectronics research and development, emphasizing unique microelectronics that survive in cryogenic and high radiation environments.

The Request also continues support for honoraria for awards, including the Enrico Fermi Awards and the Ernest Orlando Lawrence Awards.

Research

The Research activity supports high priority research at universities, TJNAF, BNL, ANL, LANL, and LBNL and carries out high priority experiments at CEBAF, RHIC, and elsewhere. Scientists conduct research to advance knowledge and to identify and develop the science opportunities and goals for next generation instrumentation and facilities, primarily for CEBAF and the EIC. Scientists participate in the development and implementation of targeted advanced instrumentation, including state-of-the-art detectors for experiments that may also have application in areas such as medical imaging instrumentation in coordination with NIH and homeland security. Scientists are engaged in experimental QIS research. TJNAF staff focus on the 12 GeV experimental program, including implementation of select experiments, acquisition of data, and data analysis at CEBAF's four experimental halls. Staff also participate in the RHIC spin program and play critical roles in instrumentation development for the EIC. Researchers participate in the development of scientific and experimental plans for the EIC. The subprogram also supports a visiting scientist program at TJNAF and bridge positions with regional universities as a cost-effective approach to augmenting scientific expertise at the laboratory and boosting research experience opportunities.

TJNAF scientists and university groups play leadership roles in new experiments in the 12 GeV scientific program, and are engaged in commissioning experiments, instrumentation development, and data taking. Scientists at several national laboratories are engaged in planning for the construction of the EIC and its scientific instrumentation. ANL researchers continue precise measurements of the electric dipole moments of laser-trapped atoms as part of an intensive world-wide effort to set limits on QCD parameters and contribute to the search for possible explanations of the excess of matter over antimatter in the universe. LANL scientists continue to lead an experiment at Fermilab to study whether anti-quarks are in orbit about the spin axis of the proton. Research groups at BNL and LBNL play leading roles in RHIC data analysis critical for determining the spin structure of the proton. Researchers at TJNAF are developing high current, polarized electron sources for next generation NP facilities.

Accelerator R&D research at universities and laboratories advance technology and core competencies essential for improving operations of the complex user facilities or developing new facilities within the NP program, including the development of transformative technology for the Nation, including innovative, efficient and cost-effective cryogenic systems, high gradient SRF cavities, and novel in-situ plasma processing of cryomodules. Researchers are also engaged in developing ML techniques focused on improving efficiencies of accelerator operations.

This activity also supports the Accelerate initiative which will support scientific research to accelerate the transition of science advances to energy technologies.

Operations

The Operations activity provides accelerator operations funding for CEBAF, which boasts unique features of continuous wave polarized beam to four experimental halls and serves over 1,700 U.S. and international users. Funding for this activity supports a team of accelerator physicists at TJNAF that operate CEBAF, as well as for power costs of operations and maintenance of the 12 GeV CEBAF. The highest priority investments in cryomodule refurbishment, spares and critical maintenance are supported to address and improve machine performance and reliability. The Request supports high priority accelerator improvements aimed at providing enhanced capabilities, and high priority capital equipment for research and facility instrumentation. Targeted efforts in developing advances in SRF technology to improve operations of the existing machine continue. The core competency in SRF technology plays a crucial role in supporting DOE projects and facility operations outside of nuclear physics and has broad applications from medicine to homeland security. TJNAF also has developed award-winning cryogenics techniques that have led to more cost-effective operations at TJNAF and several other SC facilities; their cryogenics expertise benefitted several SC superconducting accelerator projects. TJNAF accelerator physicists help train the next generation of accelerator physicists, enabled in part by a close partnership with nearby universities and other institutions with accelerator physics expertise. Accelerator scientists play critical roles in the design development of the EIC. The subprogram provides Experimental Support for scientific and technical staff, as well as for critical materials and supplies needed for the implementation, integration, assembly, and operation of the large and complex CEBAF experiments.

Nuclear Physics
Medium Energy Physics

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Medium Energy Physics	**$208,917**	**$197,485**	**-$11,432**
Research	$59,083	$55,555	-$3,528
Funding continues to support core research. Scientists, resident at TJNAF, RHIC, universities, and other national laboratories, will participate in high priority experiments to acquire data; develop, implement, and maintain scientific instrumentation; analyze data and publish experimental results; and train students in nuclear science and accelerator science. Funding supports analysis of RHIC polarized proton beam data to learn more about the origin of the proton's spin. Funding supports the development of detector design to be used at the EIC and further develop the scientific program. Funding continues to support researchers to pursue transformative accelerator science to improve operations of current and future NP facilities including applications of AI/ML. Research on Microelectronics is continued to study detector materials, devices, advances in front-end electronics, and integrated sensor/processor architectures. Scientists conduct research on quantum sensors to enable precision NP measurements, development of quantum sensors based on atomic-nuclear interactions. Funding supports the Accelerate Innovations in Emerging Technologies (Accelerate) initiative.		The Request will continue to support core research. Scientists, resident at TJNAF, RHIC, universities, and other national laboratories, will participate in high priority experiments to acquire data; develop, implement, and maintain scientific instrumentation; analyze data and publish experimental results; and train students in nuclear science and accelerator science. The Request will continue analysis of RHIC polarized proton beam data to learn more about the origin of the proton's spin. The Request will support the development of detector design to be used at the EIC and further develop the scientific program. The Request will continue to support researchers to pursue transformative accelerator science to improve operations of current and future NP facilities including applications of AI/ML. Research on Microelectronics is continued to study detector materials, devices, advances in front-end electronics, and integrated sensor/processor architectures. Scientists conduct research on quantum sensors to enable precision NP measurements, development of quantum sensors based on atomic-nuclear interactions. The Request supports the Accelerate initiative.	The Request will support high priority core scientific workforce at universities and national laboratories conducting research related to CEBAF, RHIC, EIC and other facilities, as well as the Accelerate initiative.

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Operations	$149,834	$141,930	-$7,904
Funding for operations of the CEBAF facility supports the continuation of the high priority experiments in the 12 GeV science program. Funding provides 4,100 operational hours (96 percent optimal funding) for research, tuning, and beam studies. Funding supports CEBAF operations, including mission readiness of the accelerator, all power and consumables of the site, cryogenics plant, activities to reduce helium consumption, activities to improve accelerator performance and reliability, high priority facility and instrumentation capital equipment, high priority accelerator improvement and GPP projects, and the key computing capabilities for data taking and analysis. Funding supports maintenance of critical core competencies and accelerator scientists, engineers, and technicians, and operations staff. Funding supports targeted facility capital equipment and accelerator improvements to modernize SRF equipment. Lab GPP investments advance the most urgent components of the Campus Strategy for infrastructure. Funding also supports the participation of accelerator scientists in accelerator R&D activities, including those for the EIC.		The Request for operations of the CEBAF facility will support the continuation of the high priority experiments in the 12 GeV science program. The Request will provide 3,350 operational hours (88 percent optimal funding) for research, beam development, and beam studies. The Request will support CEBAF operations, including mission readiness of the accelerator, all power and consumables of the site, cryogenics plant, activities to reduce helium consumption, activities to improve accelerator performance and reliability, high priority facility and instrumentation capital equipment, high priority accelerator improvement and GPP projects, and the key computing capabilities for data taking and analysis. The Request also will support maintenance of critical core competencies and accelerator scientists, engineers, and technicians, and operations staff. The Request will support targeted facility capital equipment and accelerator improvements to modernize SRF equipment. Lab GPP investments will advance the most urgent components of the Campus Strategy for infrastructure. The Request will also support the participation of accelerator scientists in accelerator R&D activities, including those for the EIC.	The Request will support CEBAF run time hours. The decrease in funding will reduce run time and only support the highest priority equipment and efforts to improve CEBAF reliability and performance.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Nuclear Physics
Heavy Ion Physics

Description

The Heavy Ion Physics subprogram focuses on studies of nuclear matter at extremely high densities and temperatures, directed primarily at answering overarching questions in nuclear physics, including:

- What are the phases of strongly interacting matter, and what roles do they play in the cosmos?
- What governs the transition of quarks and gluons into pions and nucleons?
- What determines the key features of QCD and their relation to the nature of gravity and space-time?

At the Relativistic Heavy Ion Collider (RHIC), scientists continue to pioneer the study of condensed quark-gluon matter at the extreme temperatures, characteristic of the infant universe. The goal is to explore and understand unique manifestations of QCD in this many-body environment and their influence on the universe's evolution. In the aftermath of collisions at RHIC and at the Large Hadron Collider (LHC) at CERN, researchers have seen signs of the same QGP that is believed to have existed shortly after the Big Bang. With careful measurements, scientists are accumulating data that offer insights into the processes early in the creation of the universe, and how protons, neutrons, and other bits of normal matter developed from that plasma. Important avenues of investigation are directed at learning more about the physical characteristics of the QGP including exploring the energy loss mechanism for quarks and gluons traversing the plasma, determining the speed of sound in the plasma, establishing the threshold conditions (minimum nucleus mass and energy) under which the plasma can be formed, and discovering whether a critical point exists demonstrating a first order phase transition between normal nuclear matter and the QGP.

RHIC places heavy ion research at the frontier of discovery in nuclear physics. RHIC is uniquely flexible, providing a full range of colliding nuclei at variable energies spanning the transition to the quark gluon plasma discovered at RHIC. The facility continues to set new records in performance for both integrated Au-Au luminosity at full energy and a number of other beam settings. This flexibility and performance enable a groundbreaking science program to answer outstanding questions about this exotic and fundamental form of matter and whether a critical point exists in the phase diagram of nuclear matter. Scientists participate in instrumentation upgrades, such as enhancements to the capabilities of the Solenoid Tracker at RHIC (STAR) detector and the super Pioneering High Energy Nuclear Interaction eXperiment (sPHENIX) detector, which will be commissioned in FY 2023. Accelerator physicists conduct accelerator R&D at RHIC in critical areas that include various types of cooling of high-energy hadron beams, high intensity polarized electron sources, and high-energy, high-current energy recovery linear accelerators. The RHIC facility is typically used by more than 1,000 DOE, National Science Foundation (NSF), and foreign agency-supported researchers annually.

A compelling, persistent, high scientific priority for the U.S. nuclear science community has been understanding how the fundamental properties of the proton such as its mass and spin are dynamically generated by the extraordinarily strong color fields resulting from dense systems of gluons in nucleons and nuclei. The answer to this question is key to addressing an outstanding grand challenge problem of modern physics: how QCD, the theory of the strong force, which explains all strongly interacting matter in terms of points-like quarks interacting via the exchange of gluons, acts in detail to generate the "macroscopic" properties of protons and neutrons. In 2018, a National Academies study gave a strong endorsement to a U.S.-based EIC and recognized its critical role in maintaining U.S. leadership in nuclear science and accelerator R&D[a]. In January 2020, BNL was selected as the location for the EIC, BNL is partnering with TJNAF to design and establish the EIC, and in June 2021, DOE approved CD-1, Approve Alternative Selection and Cost Range. Scientists and accelerator physicists from the Heavy Ion and the Medium Energy sub-programs are partnering to advance the EIC, both playing significant leadership roles in the development of the scientific agenda and implementation of the EIC.

Over the course of the acquisition of the EIC, RHIC operations funding will decrease as some scientific staff, engineers and technicians move from RHIC operations to the EIC project. This is a gradual movement to balance the need for the scientific and technical experts with RHIC while ramping up the EIC project. These individuals represent the scientific and technical workforce that are essential to the operations of a complex facility like RHIC and eventually, the EIC. They have critical core

[a] Report: https://www.nap.edu/read/25171/chapter/1

competencies in collider operations that cannot easily be replaced; their support is embedded in the EIC total project cost and they represent the core facility operations force of RHIC and the EIC. Throughout the EIC project, the temporary reprioritization of funds from the collider facility operations budget to the construction budget will reduce the amount of "new funds" needed to implement the EIC, enabling a cost-effective path forward to the implementation of this world-leading facility.

BNL hosts one of the five National Quantum Information Sciences Research Centers (NQISRCs) and focuses on building the fundamental tools necessary for the United States to create quantum computers that provide a true advantage over their classical counterparts. Scientists working in Heavy Ion physics leverage discovery opportunities in sensing, simulation, and computing at the intersections of nuclear physics and QIS.

Core competencies exist at NP facilities in the areas of beam and collider physics, hadron beam cooling, high field superconducting magnets, SRF, and ion source technologies. AI/ML applications are pursued to optimize operation of the complex accelerators and detectors at user facilities in the NP program. This research is essential for maintaining accelerator technology core competencies at SC-supported laboratories. Accelerator scientists also pursue accelerator science aimed at improving the operations of existing facilities.

Collaboration in the Heavy Ion subprogram at the LHC at CERN provides U.S. researchers the opportunity to investigate states of matter under substantially different initial conditions than those provided by RHIC, providing complementary information regarding the matter that existed during the infancy of the universe. Data collected by the A Large Ion Collider Experiment (ALICE), Compact Muon Solenoid (CMS), and ATLAS detectors confirm that the QGP discovered at RHIC is also seen at the higher energy, and comparisons of results from LHC to those from RHIC have led to important new insights. U.S. researchers have been making important scientific contributions to the emerging results from all three LHC experiments. In ALICE and CMS, U.S. researchers have been participating in developing and upgrading instrumentation for future heavy ion campaigns at the LHC.

<u>Research</u>
This activity supports high priority research at universities and at BNL, LBNL, LANL, and Oak Ridge National Laboratory (ORNL) to participate in efforts at RHIC and the LHC. NP fully supports U.S. commitments to the LHC "common funds," fees based on the level of U.S. scientist participation in the LHC program and the use of LHC computing capabilities, enabling the participation of researchers in the complementary heavy ion program at CERN. U.S. scientists work with their international peers in developing and implementing upgrades to the LHC scientific instrumentation. One such proposed upgrade is the CMS minimum ionizing particle timing detector (MTD) to enhance particle identification for understanding jet quenching, improving heavy flavor hadron measurements, and exploring collectivity in small systems. Heavy Ion research also supports the NQISRCs in partnership with the other SC programs.

The university and national laboratory research groups support personnel and graduate students for taking data within the RHIC heavy ion program, analyzing data, publishing results, developing, and implementing scientific equipment, and planning for future experiments. BNL, LBNL, and ORNL provide computing infrastructure for petabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. Scientists participate in the development of a world-leading scientific program for the future EIC.

Transformative accelerator R&D efforts are pursued, including advancements in ion source developments, SRF technology, and hadron beam cooling. Scientists and engineers also pursue accelerator science aimed at improving the operations of existing facilities and developing next-generation facilities for nuclear physics. Scientists develop cutting-edge techniques based on AI/ML of relevance to nuclear science research, accelerator facility operations and automated machine operations. NP has been supporting applications of artificial neural networks in the analysis of nuclear physics data for decades. Additionally, NP is supporting technical development at the intersections between real-time ML and control and the optimization of accelerator systems operations and detector design using AI/ML models.

The DOE Established Program to Stimulate Competitive Research (EPSCoR), that funds research in states and territories with historically lower levels of Federal academic research funding, is supported in the Heavy Ion subprogram. In FY 2024, the EPSCoR program will focus on EPSCoR State-National Laboratory Partnership awards to promote single principal investigators (PI) and small group interactions with the unique capabilities of the DOE national laboratory system and continued support of early career awards.

Operations

The Heavy Ion Operations activity supports the operations and power costs of the RHIC accelerator complex at BNL, which includes the Electron Beam Ion Source, Booster, and the Alternating Gradient Synchrotron accelerators that together serve as the injector for RHIC. Staff provides key experimental support to the facility, including the development, implementation, and commissioning of scientific equipment associated with the RHIC program. The Request will support high priority capital equipment and accelerator improvement projects at RHIC to promote enhanced and robust operations, such as upgrades to key accelerator infrastructure. The sPHENIX detector will be in full data-collection mode in FY 2024 and is the key instrument for the last RHIC data taking campaign. sPHENIX enables scientists to study how the near-perfect QGP liquid, which has the lowest shear viscosity ever observed, arises from the strongly interacting quarks and gluons from which it is formed.

RHIC operations have led to advances in accelerator physics which have, in turn, improved RHIC performance and enhanced NP capabilities. These core competencies provide collateral benefits to applications in industry, medicine, homeland security, and other scientific areas outside of NP. RHIC accelerator physicists are providing leadership and expertise to reduce technical risk of relevance to the EIC, including beam cooling techniques and energy recovery linacs. Accelerator physicists also play an important role in the training of next generation accelerator physicists, through support of graduate students and post-doctoral associates.

Funding for RHIC operations continues to be reprioritized to EIC as some scientific staff and experienced accelerator collider engineers and technicians move from RHIC operations to the EIC project. This is a gradual movement, to occur throughout the EIC project, to balance the need for the scientific experts with RHIC while ramping up the EIC project. These individuals represent the scientific and technical workforce that are essential to the operations of a complex facility like RHIC and eventually, the EIC. They have critical core competencies in collider operations that cannot easily be replaced and represent a part of the core facility operations workforce of RHIC and the EIC. The temporary reprioritization of funds from the collider facility operations budget to the construction budget will prioritize funding needed to implement the EIC, enabling a cost-effective path forward to the implementation of this world-leading facility.

RHIC operations allow for symbiotic, parallel, cost-effective operations of the Brookhaven Linac Isotope Producer Facility (BLIP), supported by the DOE Isotope Program to produce research and commercial isotopes critically needed by the Nation, and of the NASA Space Radiation Laboratory Program supported by NASA for the study of space radiation effects applicable to human space flight as well as electronics.

Projects

Other project costs (OPC) for the EIC support scientists and accelerator physicists to advance the conceptual design and conduct accelerator and detector R&D. Integration of laboratory core competencies and participation from across the national laboratory complex and universities continues. Accelerator and detector R&D focuses on reduction of technical risks and value engineering.

Nuclear Physics
Heavy Ion Physics

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Heavy Ion Physics	**$248,236**	**$226,499**	**-$21,737**
Research	$46,149	$47,454	+$1,305
Funding supports scientists resident at RHIC, universities, and other national laboratories to develop, fabricate, implement, and maintain scientific instrumentation; participate in experimental runs to acquire data; analyze data and publish experimental results; develop scientific plans and instrumentation for the EIC; and train students in nuclear science. U.S. scientists will participate in the high priority heavy ion efforts and instrumentation upgrades at the international ALICE, CMS, and ATLAS LHC experiments. Funding supports accelerator R&D relevant to NP programmatic needs. Research activities support the NQISRCs and AI/ML aimed at applications of artificial neural networks to nuclear physics research and the optimization of accelerator performance.		The Request will support scientists resident at RHIC, universities, and other national laboratories to develop, fabricate, implement, and maintain scientific instrumentation; participate in experimental runs to acquire data; analyze data and publish experimental results; develop scientific plans and instrumentation for the EIC; and train students in nuclear science. U.S. scientists will participate in the high priority heavy ion efforts and instrumentation upgrades at the international ALICE, CMS, and ATLAS LHC experiments. The Request will support accelerator R&D relevant to NP programmatic needs. Research activities support the NQISRCs and AI/ML aimed at applications of artificial neural networks to nuclear physics research and the optimization of accelerator performance. Funding supports EPSCoR State-National Laboratory Partnership awards and early career awards.	Funding will continue to support high priority core scientific workforce at universities and national laboratories to enhance high priority research at RHIC, the LHC, and for EIC science and detector development. Continued support for research in EPSCoR jurisdictions.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Operations $182,087	$176,195	-$5,892
Funding supports RHIC operations at 2,400 hours (96 percent optimal funding) limited by installation of the new sPHENIX detector. Funding supports the RHIC accelerator complex, including mission readiness and development of the experimental halls and instrumentation, mission readiness of the suite of accelerators, all power and consumables of the site, cryogenics plant, activities to reduce helium consumption, high priority facility and instrumentation capital equipment, high priority accelerator improvement projects, and computing capabilities for data taking and analysis. Support will provide critical core competencies and accelerator scientists, engineers, and technicians, for collider operations. Accelerator scientists conduct research aimed at improving the operations of the RHIC accelerator complex.	The Request will support RHIC operations at 2,580 hours (94 percent optimal funding). The Request will support the RHIC accelerator complex, including mission readiness and development of the experimental halls and instrumentation, mission readiness of the suite of accelerators, all power and consumables of the site, cryogenics plant, activities to reduce helium consumption, high priority facility and instrumentation capital equipment, high priority accelerator improvement projects, and computing capabilities for data taking and analysis. Support will provide critical core competencies and accelerator scientists, engineers, and technicians, for collider operations. Accelerator scientists conduct research aimed at improving the operations of the RHIC accelerator complex.	The Request for RHIC operations will support operations to initiate the first full year of science with sPHENIX and continue the science program with STAR. Reprioritization of effort to support EIC continues.
Projects $20,000	$2,850	-$17,150
The experienced scientists and engineers skilled in collider operations continue to transition from RHIC operations to support EIC activities.	OPC funds will support continued design efforts as well and research and development to increase technical readiness prior to the project's CD-2.	OPC support of EIC activities will continue at an anticipated lower rate as research and development activities wind down and preliminary design is advanced.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Description

The Nuclear Theory subprogram provides the theoretical support needed to interpret the wide range of data obtained from the experimental nuclear science subprograms and to advance new ideas and hypotheses that identify potential areas for future experimental investigations. One major theme of theoretical research is the development of an understanding of the mechanisms and effects of quark confinement and deconfinement. A quantitative description of these phenomena through QCD is one of this subprogram's greatest intellectual challenges. New theoretical and computational tools are also being developed by the community to describe nuclear many-body phenomena; these approaches will likely also see important applications in condensed matter physics and in other areas of the physical sciences. Another major research area is nuclear astrophysics, which includes efforts to understand the origins of the elements in the cosmos and what the nature of the neutrino may reveal about the evolution of the early universe.

This subprogram supports the Institute for Nuclear Theory (INT) at the University of Washington. It also supports topical collaborations within the university and national laboratory communities to address only the highest priority topics in nuclear theory that merit a concentrated, team-based theoretical effort.

The U.S. Nuclear Data Program (USNDP) aims to provide current, accurate, and authoritative data to workers in basic and applied areas of nuclear science and engineering. It addresses this goal primarily through maintaining and providing public access to extensive nuclear physics databases, which summarize and cross-correlate the results of over 100 years of research on nuclear science. These databases are an important national and international resource, and they currently serve approximately five million retrievals of nuclear data annually. The USNDP also addresses important gaps in nuclear data through targeted experiments and the development and use of theoretical models. The program involves the combined efforts of approximately 50 nuclear scientists at 10 national laboratories and universities and is managed by the National Nuclear Data Center (NNDC) at BNL. The NNDC is designated as an SC Public Reusable Research (PuRe) Data Resource, a designation commensurate with high standards of data management, resource operation, and scientific impact. The USNDP provides evaluated cross-section and decay data relevant to a broad suite of federal missions and topics. NP leads an interagency working group including the NNSA, NE, DOE IP, and other federal agencies to coordinate targeted experimental efforts.

Nuclear theorists also conduct research related to QIS and quantum computing (QC). This work is carried out in coordination with and support of other NP/SC efforts including R&D on quantum sensors to enable precision measurements, development of quantum sensors based on atomic-nuclear interactions, R&D on nuclear physics techniques to enhance qubit coherence times, and development of quantum computing algorithms applied to quantum mechanical systems and NP topical problems. In partnership with other SC programs, NP continues its role in jointly stewarding NQISRCs which focus on building the fundamental tools necessary for the United States to create quantum computers that provide a true advantage over their classical counterparts.

Scientists continue to develop cutting-edge techniques based on AI/ML to accelerate discovery in nuclear science research and optimize the efficiency of accelerator facility operations. NP applications of artificial neural networks in data analysis continue to be enhanced and made more powerful. Future "intelligent" experiments will seek to incorporate next generation AI advances into the optimization of detector design, detector hardware and electronics. The Request also supports technical development at the intersection between real-time ML and control and optimization of accelerator systems operations, with specific focus on improving the reliability and efficiency of accelerator operations.

The Nuclear Theory subprogram supports and leverages lattice quantum chromodynamics (LQCD) calculations that are critical for understanding and interpreting many of the experimental results from RHIC, LHC, and CEBAF. NP supports LQCD computing needs for dedicated computational resources with investments at TJNAF.

The Nuclear Theory subprogram also supports SciDAC, a collaborative program with ASCR that partners scientists and computer experts in research teams to address major scientific challenges that require supercomputer facilities performing at current technological limits. The NP SciDAC program operates on a five-year cycle and supports computationally intensive research projects jointly with other SC and DOE offices in areas of mutual interest.

The Nuclear Theory subprogram supports the RENEW initiative to provide undergraduate and graduate training opportunities for students and academic institutions not currently well represented in the U.S. S&T ecosystem. The Request includes funding for RENEW in the theory subprogram as well as the other NP subprograms with the distribution dependent on peer review results of topical proposals.

<u>Research</u>

This activity supports high priority research at ANL, BNL, LANL, LBNL, Lawrence Livermore National Laboratory (LLNL), ORNL, TJNAF, and universities. This research advances our fundamental understanding of nuclear physics, interpreting the results of experiments carried out under the auspices of the experimental nuclear physics program, and identifies and explores compelling new areas of research. The Request continues support of topical collaborations within available funds to bring together theorists to address specific emerging and high-priority theoretical challenges. The activity supports high priority efforts on FRIB theory, which is critical to theory research associated with the planned FRIB scientific program to optimize the interpretation of the experimental results. NP will prioritize transitioning ECP researchers, software, and technologies into core research efforts and DOE priority research areas as ECP concludes.

The Request supports research related to QIS and QC to provide technological and computational advances relevant to NP and other fields. Following exploratory QIS/QC workshops at the Institute for Nuclear Theory and at ANL, as well as a QC "test-bed" simulation to demonstrate proof-of-principle use of quantum computing for scientific applications. The Nuclear Science Advisory Committee published a report[b] in October 2019 to articulate further priority areas in QIS/QC where unique opportunities exist for nuclear physics contributions. For example, the report noted that the intersection of Quantum Field Theory and QC was an exciting opportunity for important advances achieved through nuclear physics research.

Support continues for the third year of SciDAC-5 awards initiated in FY 2022. In addition to addressing specific problems relevant for nuclear physics research, SciDAC projects continue to serve as critical research for highly trained scientists who can address national needs. A new round of topical collaborations awarded in FY 2023 is supported for a second year of these efforts.

Funding for AI/ML research continues in FY 2024. These activities help develop cutting-edge techniques based on AI of relevance to nuclear science research, accelerator facility operations, and automated machine operations.

The Request supports the activities of the USNDP to collect, evaluate, and disseminate nuclear physics data for basic nuclear research and for applied nuclear technologies and their development, providing for world-leading acquisition and dissemination of high-quality data for public consumption. U.S. efforts focus on improving the completeness and reliability of data already archived that is used for industry and for a variety of Federal missions, and the USNDP expands the effort to conduct experiments needed to address gaps in the data archives deemed of high priority and urgency. Examples of targeted measurements include gamma ray spectroscopy of relevance for medical isotope science; nuclear beta decay data and reactor decay heat data of relevance for optimizing the emergency cooling systems of nuclear reactors and for the control of fast breeder reactors, anti-neutrino data relevant for basic research, and uranium-238 cross section data using neutron-gamma coincidences important for several Federal missions. NP will collaborate with other Federal Agencies that are members of the NP-led Inter-Agency Nuclear Data Working Group, to carry out experimental measurements.

This activity also supports the Funding for the FAIR initiative which will provide focused investment on enhancing research on clean energy, climate, and related topics at minority serving institutions, including attention to underserved and environmental justice communities.

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[b] "*Nuclear Physics and Quantum Information Science*" Nuclear Science Advisory Committee, October 2015 (https://science.osti.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf).

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Nuclear Theory	**$67,873**	**$77,142**	**+$9,269**
Research	$67,873	$77,142	+$9,269
Funding supports high priority QIS efforts. LQCD computing investments continue at TJNAF. High priority theoretical research at universities and national laboratories is supported for the interpretation of experimental results obtained at NP facilities, and the exploration of new ideas and hypotheses that identify potential areas for future experimental investigations. Theorists focuses on applying QCD to a wide range of problems from nucleon structure and hadron spectroscopy, through the force between nucleons, to the structure of light nuclei. Advanced dynamic calculations to describe relativistic nuclear collisions and nuclear structure and reactions continues to focus on activities related to the research program at the upgraded 12 GeV CEBAF facility, the research program at FRIB, and ongoing and planned RHIC experiments. Funding supports the second year of SciDAC-5 grants and the first year of theory topical collaborations. Funding supports investments in an initiative to develop cutting-edge AI/ML techniques of relevance to nuclear science research, and accelerator facility operations.		The Request will support high priority QIS efforts. LQCD computing investments continue at TJNAF. Funding will support high priority theoretical research at universities and national laboratories for the interpretation of experimental results obtained at NP facilities, and the exploration of new ideas and hypotheses that identify potential areas for future experimental investigations. Theorists will focus on applying QCD to a wide range of problems from nucleon structure and hadron spectroscopy, through the force between nucleons, to the structure of light nuclei. Advanced dynamic calculations to describe relativistic nuclear collisions and nuclear structure and reactions will continue to focus on activities related to the research program at the upgraded 12 GeV CEBAF facility, the research program at FRIB, and ongoing and planned RHIC experiments. The Request will support the third year of SciDAC-5 grants, as well as the second year of theory topical collaborations. Funding will target investments in an initiative to develop cutting-edge AI/ML techniques of relevance to nuclear science research, and accelerator facility operations.	Funding will support the highest priority research in nuclear theory, growth of the FAIR and RENEW initiatives, transition of ECP related activities to core, and DOE priority research areas.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
This activity also supports the RENEW initiative to provide undergraduate and graduate training opportunities for students and academic institutions not currently well represented in the U.S. S&T ecosystem. Funding also supports the FAIR initiative.	The RENEW initiative expands targeted efforts to increase participation and retention of individuals from underrepresented groups in SC research activities, including a RENEW graduate fellowship. The Request grows support for the FAIR initiative. Within available resources, NP will prioritize transitioning ECP researchers, software, and technologies into core research efforts and DOE priority research areas as ECP concludes.	
Funding continues the expanded USNDP efforts to collect, evaluate, and disseminate nuclear physics data for basic nuclear research and for applied nuclear technologies and their development initiated in FY 2022.	The Request will continue the expanded USNDP efforts to collect, evaluate, and disseminate nuclear physics data for basic nuclear research and for applied nuclear technologies and their development.	Funding will support nuclear data efforts of the USNDP.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Description

The Low Energy Physics subprogram includes two scientific activities that focus on using nuclear interactions and decays to answer overarching questions related to Nuclear Structure and Nuclear Astrophysics, and Fundamental Symmetries.

Nuclear Structure and Nuclear Astrophysics

Questions associated with Nuclear Structure and Nuclear Astrophysics include:

- What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes?
- What is the origin of simple patterns in complex nuclei?
- What is the nature of neutron stars and dense nuclear matter?
- What are the origins of the elements in the cosmos?
- What are the nuclear reactions that drive stars and stellar explosions?

The Nuclear Structure and Nuclear Astrophysics activities address these questions through support of research to develop a comprehensive description of nuclei using beams of stable and rare isotopes to yield new insights and reveal new nuclear phenomena. The activities also measure the cross sections of the nuclear reactions that power stars and lead to spectacular stellar explosions, which are responsible for the synthesis of the elements.

ATLAS, at ANL, is an SC scientific user facility providing research opportunities in Nuclear Structure and Nuclear Astrophysics, serving approximately 300 domestic and international scientists per year. ATLAS is the world's premiere facility for stable beams and provides high-quality beams of all the stable elements up to uranium, as well as selected beams of short-lived (radioactive) nuclei to study nuclear properties under extreme conditions and reactions of interest to nuclear astrophysics, using the Neutron-generator Upgrade to the Californium Rare Ion Breeder Upgrade (nuCARIBU) ion source. Technologically cutting-edge and unique instrumentation are a hallmark of ATLAS, and the facility continues to be significantly oversubscribed by the user community. ATLAS is also an essential training ground for scientists and students. The facility nurtures an expert core competency in accelerator science with SRF cavities for heavy ions that are relevant to next generation high-performance proton and heavy ion linacs. This competency is important to the SC mission and international stable and radioactive ion beam facilities. ATLAS stewards a target development laboratory, the Center for Accelerator Target Science (CATS), a national asset for the low energy community. Investments to increase ATLAS capabilities provide unique research opportunities including a cost-effective Multi-User Upgrade (MUU) to address a backlog of compelling experiments.

The FRIB at Michigan State University (MSU) became an SC scientific user facility in FY 2020, with FY 2023 planned as its first full year of operations. FRIB provides beams of rare isotopes with neutron and proton numbers far from those of stable nuclei to test the limits of nuclear existence and advance understanding of the atomic nucleus and the evolution of the cosmos. The GRETA MIE is one of the primary tools that the nuclear science community has identified as necessary to leverage the capabilities of FRIB. GRETA's unprecedented combination of full coverage with high efficiency, and excellent energy and position resolution, will extend the reach of FRIB to study the nuclear landscape, provide new opportunities to discover and characterize key nuclei for electric dipole moment searches, and open new areas of study in nuclear astrophysics. The High Rigidity Spectrometer (HRS) will exploit FRIB's fast beam capabilities, enabling the most sensitive experiments across the entire chart of nuclei with the most neutron-rich nuclei available.

Scientists participate in AI/ML research, conducting R&D targeting automated optimization of accelerator availability, performance, and operation, as well as software development enabling AI/ML-driven discovery.

Scientists participate in the international effort to discover and characterize new "super heavy" elements in the periodic table. U.S. researchers played a prominent role in the discovery of Elements 115, 117, and 118, and Element 117 was named Tennessine to acknowledge the leadership role of the U.S. in these efforts. Research is ongoing to characterize these new elements and to discover Element 120. Past and future experiments were/are made viable by the provision of rare isotopes produced at the High Flux Isotope Reactor (HFIR) through the DOE Isotope Program. NP also supports operations of the LBNL 88-Inch Cyclotron to provide beams for an in-house nuclear science program focused on studying the properties of newly discovered elements on the periodic table, as well as conducting independent searches for new super-heavy elements. DOD and NASA exploit materials irradiation capabilities at the 88-Inch Cyclotron to develop radiation-resistant electronics for their missions.

There are three university Centers of Excellence within the Low Energy subprogram, each with specific goals and unique physics programs: the Cyclotron Institute at Texas A&M University (TAMU), the four facilities at the Triangle Universities Nuclear Laboratory (TUNL) at Duke University, and unique expertise and capabilities for instrumentation development at the Center for Experimental Nuclear Physics and Astrophysics (CENPA) at the University of Washington.

Fundamental Symmetries

Questions related to Fundamental Symmetries of nature addressed in low energy nuclear physics experiments include:

- What is the nature of neutrinos, what are their masses, and what role have they played in creating the imbalance between matter and antimatter in our universe? Is there evidence from the electric-dipole moments of atomic nuclei and the neutron that indicate our current understanding of the fundamental laws governing nuclear physics is incomplete?
- Will precise measurements in electron scattering and the decay of nuclei indicate the existence of forces that were present at the dawn of the universe, and disappeared from view as the universe evolved?

The Fundamental Symmetries activities address these questions through precision studies using neutron and electron beams and decays of nuclei, including beta decay, double-beta decay, and neutrino-less double beta decay (NLDBD). U.S. scientists are world leaders in the global research effort aimed at neutrino science and owing to the importance of nuclear beta decay in understanding neutrino properties, NP is the SC steward of neutrino mass measurements and NLDBD. Often in partnership with NSF, NP has invested in neutrino experiments both domestically and overseas, playing critical roles in international experiments that depend on U.S. leadership for their ultimate success: e.g., the Cryogenic Underground Observatory for Rare Events (CUORE) and the Karlsruhe Tritium Neutrino Experiment (KATRIN). In partnership with NSF, NP also participates in the international LEGEND-200 experiment. The NSAC 2015 LRP recommended "the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment." NLDBD can only occur if neutrinos are their own anti-particles. The observation of such events would have profound, game changing consequences for present understanding of the physical universe. NP has invested in R&D on candidate technologies for next–generation ton-scale experiments, including crystals of enriched germanium (LEGEND-1000), liquid xenon (nEXO), and lithium molybdenate crystals (CUPID). The Request will provide support for ton-scale research based on one or more of these technologies to progress toward CD-1, Approve Alternative Selection and Cost Range. The NLDBD MIE received CD-0, Approval of Mission Need, in November 2018.

Very precise measurements in parity violating electron scattering, the decay of nuclei, and the properties of neutrons provide sensitivity to new forces and address questions about the matter/anti-matter imbalance rivaling, and even exceeding, the reach of high energy colliders. The MOLLER MIE will measure the parity-violating asymmetry in electron-electron scattering at CEBAF which is uniquely sensitive to the possible existence of new as-yet unforeseen particles. Evidence for electric dipole moments of the neutron and atoms violate time reversal invariance and would shed light on the matter/anti-matter imbalance in the universe. Beams of cold and ultracold neutrons with the dedicated Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source (SNS) are used to study fundamental properties of neutrons, including the flagship experiment to measure the electric dipole moment of the neutron.

Scientists engaged in Fundamental Symmetries research are particularly well positioned with their expertise in rare signal detection, to engage in research on QIS and QC. They contribute to R&D on quantum sensors to enable precision NP measurements, development of quantum sensors based on atomic-nuclear interactions, and development of quantum computing algorithms applied to quantum mechanical systems and NP topical problems.

Nuclear Structure and Nuclear Astrophysics Research

This activity supports high priority research groups at ANL, LBNL, LLNL, and ORNL, and at universities. Scientists develop, fabricate, and use specialized instrumentation at ATLAS, and participate in the acquisition and analysis of data. Scientists design, fabricate, install, and commission instrumentation at FRIB for use in the scientific program. The Request supports leading researchers who worked at other facilities to help lead the FRIB scientific mission. Progress continues on the GRETA MIE, although the project received final funding in FY 2023 and no new funds are requested in FY 2024. It also continues implementation of the HRS. Scientists participate in research to characterize and discover new super-heavy elements at international facilities and the 88-Inch Cyclotron. The Request will provide support to the university Centers of Excellence at TUNL and TAMU for the conduct of nuclear structure and nuclear astrophysics experiments at these niche facilities. Accelerator scientists participate in transformative accelerator R&D, particularly in the development of next generation ion sources for accelerators. Scientists utilize AI/ML advances to improve machine performance and reliability.

Fundamental Symmetries Research

The activity supports high priority research at BNL, LANL, LBNL, LLNL, ORNL, Pacific Northwest National Laboratory, and SLAC National Accelerator Laboratory, and at universities. R&D continues for a challenging experiment to measure the electric dipole moment of the neutron, which is sensitive to a wide range of underlying new physics and is a test of charge-parity violation. Other experiments at the FNPB SNS continue, along with minor construction activities in support of this research. First-generation NLDBD experiments finalize analysis of data, such as the CUORE experiment at Gran Sasso Laboratory in Italy. Engineering and design efforts continue for international ton-scale NLDBD research, along with targeted R&D. Progress continues on the MOLLER MIE, although the project received final planned funding in FY 2023 and no new funds are requested in FY 2024. Scientists participate in the operations of the KATRIN experiment at the Karlsruhe Institute of Technology in Karlsruhe, Germany to provide a measurement of the neutrino mass. University Centers of Excellence at TUNL, CENPA, and TAMU with unique capabilities are exploited to advance research in Fundamental Symmetries. Researchers conduct NP research of relevance to QIS, with a focus on novel quantum sensors.

Nuclear Structure and Nuclear Astrophysics Operations

The activity supports facility and operations costs associated with ATLAS, FRIB, and the 88-Inch Cyclotron. ATLAS provides highly reliable and cost-effective stable and selected radioactive beams and specialized instrumentation. Funding provides support for the operations and power costs of the ATLAS, and targeted support for high priority accelerator and scientific instrumentation capital equipment, accelerator improvement projects, and experimental support. The ATLAS core competency in accelerator science is maintained that are important to the next generation of high-performance proton and heavy ion linacs. Critical efforts to address facility oversubscription and increase available beam time continue with the implementation of the cost-effective MUU Accelerator Improvement Project.

The Request supports FRIB operations to provide a reliable source of rare isotopes using in-flight production methods. The Request supports beam time for the highest priority experiments, improvements to scientific instrumentation and experimental capabilities, and accelerator enhancements to support progress towards reaching full power.

The Request also sustains operations of the 88-Inch Cyclotron for a focused in-house nuclear physics program which includes characterization and searches for new elements and nuclear data measurements.

Nuclear Physics
Low Energy Physics

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Low Energy Physics	**$230,170**	**$215,292**	**-$14,878**
Research	$77,651	$78,409	+$758
Funding supports high priority university and laboratory nuclear structure and nuclear astrophysics efforts at ATLAS and installation and commissioning of instrumentation for the FRIB scientific program. Funding targets research for critical FRIB scientific personnel to lead the scientific program at FRIB. Scientists continue to participate in the characterization of recently discovered elements and search for new ones. Research will continue at the university-based Centers of Excellence at TUNL, CENPA, and TAMU. Scientists utilize AI/ML that can promote automated platforms to improve machine performance and reliability and advance detector design and data processing.		The Request will support high priority university and laboratory nuclear structure and nuclear astrophysics efforts at ATLAS and FRIB. Scientists will participate in the characterization of recently discovered elements and search for new ones. Research will continue at the university-based Centers of Excellence at TUNL, CENPA, and TAMU. Scientists utilize AI/ML that can promote automated platforms to improve machine performance and reliability and advance detector design and data processing.	The Request will support the highest priority research efforts and essential workforce at universities and national laboratories, with a focus on conducting experiments at ATLAS and FRIB.
High priority research in NLDBD will continue with a strategic mix of efforts for selection in FY 2023. Funding supports U.S. participation in the operations of the international KATRIN experiment.		High priority research in NLDBD will continue with a strategic mix of efforts for selection in FY 2024. The Request will continue support for U.S. participation in the operations of the international KATRIN experiment.	The Request will support the highest priority research efforts and essential workforce at universities and national laboratories.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Operations $128,579	$127,624	-$955
ATLAS operates for 5,950 hours (96 percent of optimal funding). Funding supports operations, staff, maintenance, and high priority accelerator improvement projects and capital equipment for the facility and scientific instrumentation, including the development of a multi-user capability. Funding also supports the second year of operations at FRIB for 3,600 hours (99 percent of optimal funding) to execute the first full year of the scientific program. Funding continues operations of the 88-Inch Cyclotron for high priority experiments studying newly discovered elements.	ATLAS will operate for 5,800 hours (91 percent of optimal funding). The Request will fund operations, staff, maintenance, and high priority accelerator improvement projects and capital equipment for the facility and scientific instrumentation, including the development of a multi-user capability. The Request will also support the second year of operations at FRIB for 3,350 hours (94 percent of optimal funding) to execute the first full year of the scientific program. Funding will sustain operations of the 88-Inch Cyclotron for high priority experiments studying newly discovered elements.	Funding will support FRIB, ATLAS, and 88-Inch Cyclotron.
Projects $23,940	$9,259	-$14,681
Funding continues support for the GRETA MIE, MOLLER MIE, NLDBD MIE, and the HRS research project. The GRETA and MOLLER MIEs received their final funding allocation.	The Request will continue support for the NLDBD MIE and the HRS research project.	The GRETA and MOLLER MIEs complete their baselined and planned funding profiles with the FY 2023 Enacted Appropriations.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Description

This subprogram supports all line-item construction for the entire NP program. All Total Estimated Costs (TEC) are funded in this subprogram, including engineering, design, and construction. OPC's are funded in the relevant subprograms. The FY 2024 Request continues the construction effort for the EIC, which is to be located at BNL. The estimated Total Project Cost (TPC) range for the EIC project is $1.7 billion to $2.8 billion. BNL has teamed with TJNAF to lead the development and implementation of the EIC. The EIC scope, cost, and schedule include an electron injector, rapid cycling synchrotron, an electron storage ring, modifications to one of the two RHIC ion rings, one interaction region with a detector, support buildings, and other infrastructure. Improvements will accommodate a second interaction region and its detector, although they are not part of the project scope. The project is expected to attract international collaboration and contributions.

EIC acquisition, will increasingly rely on RHIC scientists, engineers, and technicians as RHIC activities ramp down. This workforce with critical core competencies in collider operations remains essential to RHIC now and eventually EIC operations. They cannot easily be replaced. The temporary reprioritization of funds from the collider facility operations budget to the construction budget will supplement funding needed to implement the EIC, enabling a cost-effective path forward to the implementation of this world-leading facility.

Since the release of the 2002 LRP for Nuclear Science, a high priority for the U.S. nuclear science community has been understanding how the fundamental properties of the proton, such as its mass and spin, are dynamically generated by the extraordinarily strong color fields resulting from dense systems of gluons in nucleons and nuclei. The answer to this question is key to addressing an outstanding grand challenge problem of modern physics: how quantum chromodynamics, the theory of the strong force, which explains all strongly interacting matter in terms of points like quarks interacting via the exchange of gluons, acts to generate the "macroscopic" properties of protons and neutrons. The 2015 LRP for Nuclear Science concluded, "…a high energy, polarized electron ion collider is the highest priority for new facility construction…" A National Academies study, charged to independently assess the impact, uniqueness, and merit of the science that would be enabled by U.S. construction of an electron-ion collider, gave a strong endorsement to a U.S.-based EIC, and recognized its critical role in maintaining U.S. leadership in nuclear science and accelerator R&D. Scientists and accelerator physicists from both the Medium Energy and Heavy Ion subprograms are actively engaged in the development of the scientific agenda, design of the facility and development of scientific instrumentation related to a proposed EIC. Critical Decision-0 (CD-0), Approve Mission Need, was received on December 19, 2019, followed by CD-1, Approve Alternative Selection and Cost Range on June 29, 2021.

Nuclear Physics
Construction

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Construction	**$50,000**	**$95,000**	**+$45,000**
20-SC-52 Electron Ion Collider (EIC), BNL	$50,000	$95,000	+$45,000
Funding continues TEC support for the EIC. The funds are for engineering and design to reduce technical risk after completion of the conceptual design. RHIC operations includes a "reprioritization" of expert workforce from the RHIC facilities operations budget to support both the EIC OPC and TEC request.		The Request will continue TEC funding for the EIC. The funds will be used for engineering and design to reduce technical risk after completion of the conceptual design and limited long lead procurements. RHIC operations includes a "reprioritization" of expert workforce from the RHIC facilities operations budget to support the EIC OPC and TEC request.	The ramp-up of funding will support increased engineering and design efforts and limited long lead procurements as the project team advances towards establishing a performance baseline.

Nuclear Physics
Capital Summary

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2022 IRA Supp.	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Capital Operating Expenses							
Capital Equipment	N/A	N/A	29,771	78,760	34,988	20,307	-14,681
Minor Construction Activities							
General Plant Projects	N/A	N/A	1,626	–	2,642	2,642	–
Accelerator Improvement Projects	N/A	N/A	5,159	–	5,211	5,211	–
Total, Capital Operating Expenses	**N/A**	**N/A**	**36,556**	**78,760**	**42,841**	**28,160**	**-14,681**

Capital Equipment

	(dollars in thousands)						
	Total	**Prior Years**	**FY 2022 Enacted**	**FY 2022 IRA Supp.**	**FY 2023 Enacted**	**FY 2024 Request**	**FY 2024 Request vs FY 2023 Enacted**
Capital Equipment							
Major Items of Equipment							
Heavy Ion Physics							
Super Pioneering High Energy Nuclear Interaction Experiment (sPHENIX)	20,577	20,364	213	–	–	–	–
Low Energy Physics							
Gamma-Ray Energy Tracking Array (GRETA), LBNL	57,700	25,500	9,000	7,700	15,500	–	-15,500
High Rigidity Spectrometer	121,830	4,240	3,000	31,840	3,000	6,259	+3,259
MOLLER	47,220	7,000	5,000	31,220	4,000	–	-4,000
Ton-Scale Neutrinoless Double Beta Decay (NLDBD) MIE	626,700	2,400	400	8,000	1,440	3,000	+1,560
Total, MIEs	N/A	N/A	17,613	78,760	23,940	9,259	-14,681
Total, Non-MIE Capital Equipment	N/A	N/A	12,158	–	11,048	11,048	–
Total, Capital Equipment	**N/A**	**N/A**	**29,771**	**78,760**	**34,988**	**20,307**	**-14,681**

Notes:

- *The Capital Equipment table includes MIEs located at a DOE facility with a Total Estimated Cost (TEC) > $5M and MIEs not located at a DOE facility with a TEC >$2M.*
- *The High Rigidity Spectrometer (HRS) is not an MIE, but a research project supported on a cooperative agreement with Michigan State University.*

Minor Construction Activities

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
General Plant Projects (GPP)						
GPPs (greater than or equal to $5M and less than $30M)						
nEDM Experimental Building 2 (EB-2)	9,257	–	–	1,000	1,000	–
Total GPPs (greater than or equal to $5M and less than $30M)	N/A	N/A	–	1,000	1,000	–
Total GPPs less than $5M	N/A	N/A	1,626	1,642	1,642	–
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**1,626**	**2,642**	**2,642**	**–**
Accelerator Improvement Projects (AIP)						
Total AIPs less than $5M	N/A	N/A	5,159	5,211	5,211	–
Total, Accelerator Improvement Projects (AIP)	**N/A**	**N/A**	**5,159**	**5,211**	**5,211**	**–**
Total, Minor Construction Activities	**N/A**	**N/A**	**6,785**	**7,853**	**7,853**	**–**

Note:

- *GPP activities less than $5M include design and construction for additions and/or improvements to land, buildings, replacements or addition to roads, and general area improvements. AIP activities less than $5M include minor construction at an existing accelerator facility.*

Nuclear Physics
Major Items of Equipment Description(s)

Heavy Ion Physics MIE:

Super Pioneering High Energy Nuclear Interaction Experiment (sPHENIX)

sPHENIX directly supports the NP mission by using precision, high rate jet measurements to further characterize the quark-gluon plasma (QGP) discovered at RHIC in order to understand the anomalous energy loss observed in the QGP. CD-0 was approved September 13, 2016, and Project Decision (PD)-2/3, which approves the performance baseline and start of construction, was approved on September 19, 2019, with a TPC $27,000,000. This MIE was funded within the existing funds for RHIC operations. Operating funds that are typically used to maintain and operate the PHENIX detector were used to upgrade the detector sPHENIX adds electron and hadron calorimeters to the existing silicon tracking capabilities and makes use of a recycled solenoid magnet for a cost effective upgrade. Final funding for sPHENIX was provided in the FY 2022 Enacted Appropriations. The project completed within cost and on schedule in FY 2023.

Low Energy Physics: Nuclear Structure and Nuclear Astrophysics MIE and Research Project:

Gamma-Ray Energy Tracking Array (GRETA) MIE

GRETA directly supports the NP mission by addressing the goal to understand the structure of nuclear matter, the processes of nuclear astrophysics, and the nature of the cosmos. A successful implementation of this detector will represent a major advance in gamma-ray tracking detector technology that will impact nuclear science, as well as detection techniques in homeland security and medicine. GRETA will provide unprecedented gains in detection sensitivity, addressing several high priority scientific topics, including how weak binding and extreme proton-to-neutron asymmetries affect nuclear properties and how the properties of nuclei evolve with changes in excitation energy and angular momentum. GRETA will provide transformational improvements in efficiency, peak-to-total ratio, and higher position resolution than the current generation of detector arrays. In particular, the capability of reconstructing the position of the interaction with millimeter resolution will fully exploit the physics opportunities of FRIB. Without GRETA, beam-times necessary for the proposed experiments will be expanded significantly, and some proposed experiments will not be feasible at all. CD-0 for GRETA was approved September 15, 2015 and CD-1 was obtained October 4, 2017. CD-3a, which approves long lead procurements, was obtained August 16, 2018. CD-2/3 was obtained October 7, 2020 with a TPC of $58,300,000. The FY 2023 Enacted appropriation represented the last year of planned funding for the GRETA MIE. CD-4 is scheduled for March 2028.

High Rigidity Spectrometer (HRS) Research Project

The HRS at FRIB will increase the scientific potential of state-of-the-art and community-priority devices, such as GRETA, and other ancillary detectors. FRIB is the world's premier rare-isotope beam facility capable of producing approximately 80 percent of the isotopes predicted to exist. The scientific impact of the FRIB fast beam science program will be enhanced by luminosity gain factors of between two and one hundred for neutron-rich isotopes, with the largest gains for the most neutron-rich species, by construction of the HRS. The HRS will allow experiments with beams of rare isotopes at the maximum production rates for fragmentation or in-flight fission. This enhancement in experimental sensitivity provides access to critical isotopes not available otherwise. The 2015 NSAC LRP recognized that the "HRS…will be essential to realize the scientific reach of FRIB." The HRS is being funded through a cooperative agreement with MSU and is not a capital asset (MIE). CD-0 was approved November 2018. CD-1 was approved in September 2020, with a TPC range of $85,000,000 to $111,400,000. The FY 2024 Request for the HRS of $6,259,000 will support the management team, coordination of collaboration activities and allow preliminary engineering and design work towards future critical decision points.

Low Energy Physics: Fundamental Symmetries MIEs:

Measurement of a Lepton-Lepton Electroweak Reaction (MOLLER) MIE

The MOLLER experiment directly supports the NP mission by measuring the parity-violating asymmetry in polarized electron-electron (Møller) scattering. This extremely small asymmetry is predicted to be on the order of 35 parts per billion (ppb), which requires unprecedented experimental techniques employed for this experiment. CD-0 was approved December 2016. CD-1 was approved in December 2020 with a TPC range of $42,000,000 to $60,100,000. The project is working on preliminary engineering and design in advance of a combined CD-2/3 planned in Q2 of FY 2023. CD-4 is expected in Q4 of FY2027. The MOLLER experiment is an ultra-precise measurement of the weak mixing angle using Møller scattering which will improve on existing measurements by a factor of five, yielding the most precise measurement of the weak mixing angle at low or high energy anticipated over the next decade. This new result would be sensitive to the interference of the electromagnetic amplitude with new neutral current amplitudes as weak as approximately 10^{-3} G_F (Fermi Factor) from as yet undiscovered dynamics beyond the Standard Model. The resulting reach for scientific discovery is far greater, for at least a decade, than any existing or proposed experiment which searches for new physics signaled by a departure from the expected before vs after conservation of flavor, charge and parity in fundamental particle interactions, and yields a unique window to new physics at MeV and multi-TeV scales, complementary to direct searches at high energy colliders such as the Large Hadron Collider (LHC). The FY 2023 Enacted appropriation represented the last year of planned funding for the MOLLER MIE.

Ton-Scale Neutrino-less Double Beta Decay (NLDBD) Program MIE
The Ton-Scale NLDBD Program, implemented by deploying experiments instrumenting a large volume of a specially selected isotope to detect neutrino-less nuclear beta decays (where within a single nucleus, two neutrons decay into two protons and two electrons with no neutrinos emitted), directly supports NP's mission to explore all forms of nuclear matter. NLDBD can only occur if neutrinos are their own anti-particles and the observation of "lepton number violation" in such neutrino-less beta decay events would have profound consequences for present understanding of the physical universe. For example, one exciting prospect is that the observation of NLDBD would elucidate the mechanism, completely unknown at present, by which the mass of the neutrino is generated. The observation of lepton number violation would also have major implication for the present-day matter/anti-matter asymmetry which has perplexed modern physics for decades. Several demonstrator efforts using smaller volumes of isotopes and various technologies (bolometry in tellurium dioxide crystals, light collection in liquid xenon, charge collection in enriched germanium-76) have been in progress for several years, and all are in the process of delivering new state-of-the-art lifetime limits for neutrino-less double beta decay which are of order a few times 10^{25} years. The goal of the ton-scale program is to reach a lifetime limit of 10^{28} years with high confidence. For reference, the "lifetime limit" discussed is the time one might have to wait to observe neutrino-less double beta decay if observing a single nucleus only. Fortunately, in the ton of isotope planned for the ton-scale neutrino-less double beta decay experiments there are many trillions of nuclei. Thus, such decays, if they exist, should be observable on a much more reasonable timescale (five to ten years) similar to other large modern physics experiments. CD-0 was approved in November 2018 with a TPC range of $215,000,000 to $250,000,000. The FY 2024 Request of $3,000,000 will support the management teams and collaboration activities.

General Plant Projects $5 Million to less than $30 Million

Project Name:	nEDM Experimental Building 2 (EB-2)
Location/Site:	Oak Ridge National Laboratory
Type:	GPP
Total Estimated Cost:	$9,257,032
Construction Design:	$0
Project Description:	Minor construction of an experimental building at Oak Ridge National Laboratory is needed to support neutron electric dipole moment research. This new experimental building will allow researchers to continue the challenging experiment to measure the electric dipole moment of the neutron, which is sensitive to a wide range of underlying new physics and is a test of charge-parity violation.

Nuclear Physics
Construction Projects Summary

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2022 IRA Supp.	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
20-SC-52, Electron Ion Collider							
Total Estimated Cost (TEC)	2,126,000	6,000	20,000	128,240	50,000	95,000	+45,000
Other Project Cost (OPC)	292,450	34,650	24,800	10,000	20,000	2,850	-17,150
Total Project Cost (TPC)	**2,418,450**	**40,650**	**44,800**	**138,240**	**70,000**	**97,850**	**+27,850**
Total, Construction							
Total Estimated Cost (TEC)	**N/A**	**N/A**	**20,000**	**128,240**	**50,000**	**95,000**	**+45,000**
Other Project Cost (OPC)	**N/A**	**N/A**	**24,800**	**10,000**	**20,000**	**2,850**	**-17,150**
Total Project Cost (TPC)	**N/A**	**N/A**	**44,800**	**138,240**	**70,000**	**97,850**	**+27,850**

Nuclear Physics
Scientific User Facility Operations

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

(dollars in thousands)

	FY 2022 Enacted	FY 2022 Current	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Scientific User Facilities - Type A					
Relativistic Heavy Ion Collider	**183,943**	**178,321**	**182,087**	**176,195**	**-5,892**
Number of Users	1,010	954	1,010	1,010	–
Achieved Operating Hours	–	2,910	–	–	–
Planned Operating Hours	2,850	2,910	2,400	2,580	+180
Continuous Electron Beam Accelerator Facility	**142,709**	**138,335**	**149,834**	**141,930**	**-7,904**
Number of Users	1,620	1,889	1,730	1,730	–
Achieved Operating Hours	–	4,154	–	–	–
Planned Operating Hours	3,790	4,154	4,100	3,350	-750
Facility for Rare Isotope Beams	**79,811**	**77,000**	**98,388**	**96,266**	**-2,122**
Number of Users	605	600	650	755	+105
Achieved Operating Hours	–	3,332	–	–	–
Planned Operating Hours	2,310	3,332	3,600	3,350	-250

	FY 2022 Enacted	FY 2022 Current	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
	(dollars in thousands)				
Argonne Tandem Linac Accelerator System	**23,148**	**22,443**	**24,350**	**24,351**	**+1**
Number of Users	305	348	340	340	–
Achieved Operating Hours	–	6,426	–	–	–
Planned Operating Hours	5,800	6,426	5,950	5,800	-150
Total, Facilities	**429,611**	**416,099**	**454,659**	**438,742**	**-15,917**
Number of Users	3,540	3,791	3,730	3,835	+105
Achieved Operating Hours	–	16,822	–	–	–
Planned Operating Hours	14,750	16,822	16,050	15,080	-970

Notes:

- *Achieved Operating Hours and Unscheduled Downtime Hours will only be reflected in the Congressional budget cycle which provides actuals.*
- *For FY 2022, FRIB planned operating hours and optimal hours include 800 hours of operations (commissioning) that are supported from FRIB construction funding that are part of the project TPC. FY 2022 is the first year of operations after project completion.*
- *For FY 2023, the dollar values for the facilities do not include research amounts.*

Nuclear Physics
Scientific Employment

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Number of Permanent Ph.Ds (FTEs)	864	856	860	+4
Number of Postdoctoral Associates (FTEs)	362	366	372	+6
Number of Graduate Students (FTEs)	543	524	529	+5
Number of Other Scientific Employment (FTEs)	1,006	1,023	1,028	+5
Total Scientific Employment (FTEs)	**2,775**	**2,769**	**2,789**	**+20**

Note:
- *Other Scientific Employment (FTEs) includes technicians, engineers, computer professionals and other support staff.*

20-SC-52 Electron Ion Collider (EIC), BNL
Brookhaven National Laboratory, BNL
Project is for Design and Construction

1. Summary, Significant Changes, and Schedule and Cost History

Summary

The FY 2024 Request for the EIC is $95,000,000 of TEC funding and $2,850,000 of OPC funding. The current TPC range is $1,700,000,000 to $2,800,000,000. The preliminary TPC estimate for the project is $2,418,450,000.

Significant Changes

The EIC was initiated in FY 2020. The project most recently received Critical Decision (CD)-1, Approve Alternative Selection and Cost Range, on June 29, 2021. In this Project Data Sheet (PDS), the estimated completion date (CD-4) has shifted to Q3 FY 2034 that includes schedule contingency recommended by peer review. In addition, the preliminary TPC in this PDS reflects continued elaboration of the project scope and shows an increase over the point estimate in the FY 2022 PDS, however, the point estimate remains within the cost range. The project expects CD-2, Approve Performance Baseline, in Q2 FY 2024.

In March 2022, an expert panel issued a report recommending a path forward after reviewing three detector collaboration proposals. In FY 2022, the EIC team has focused on preliminary design of the infrastructure, collider machine, and detector instrumentation. The team is also developing a list of possible long-lead procurements and considering requesting a CD-3A, Approve Long Lead Procurement, in conjunction with CD-2. Through the Inflation Reduction Act the project received $10,000,000 OPC and $128,240,000 TEC at the end of FY 2022. The funds will support long lead procurements following a CD-3A while later reducing the peak requests for new funding. FY 2023 activities include planning and design for conventional infrastructure and technical systems, research and development to increase technical readiness for certain detector and technical scope, and fostering relations with potential in-kind contributors. FY 2024 funding will support the development and completion of the preliminary design and research and development to validate technical assumptions and to reduce project risk prior to start of construction.

A Federal Project Director (FPD) has been assigned to this project and has approved this project data sheet. The FPD is certified at Level 3, and the accrual of qualifications for Level 4 certification is in process.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2024	12/19/19	01/12/21	6/29/2021	2Q FY 2024	2Q FY 2025	2Q FY 2025	3Q FY 2034

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range; **Conceptual Design Complete** – Actual date the conceptual design was completed (if applicable); **CD-1** – Approve Alternative Selection and Cost Range; **CD-2** – Approve Performance Baseline; **Final Design Complete** – Estimated/Actual date the project design will be/was complete(d); **CD-3** – Approve Start of Construction; **D&D Complete** – Completion of D&D work; **CD-4** – Approve Start of Operations or Project Closeout.

Fiscal Year	Performance Baseline Validation	CD-3A
FY 2024	TBD	2Q FY 2024

CD-3A – Approve Long-Lead Procurements, for specialty materials procurement, including electrical infrastructure, magnets, refrigerators for the satellite cryogenics plant, and components for the injector, radio frequency power amplifier, and the detector.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2023	413,000	1,648,000	2,061,000	187,650	187,650	2,248,650
FY 2024	256,000	1,870,000	2,126,000	292,450	292,450	2,418,450

Note:
- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

2. Project Scope and Justification

Scope
The scope of this project is to design and build the EIC at BNL that will fulfill the scientific gap as identified in the 2015 NSAC LRP. BNL is partnering with TJNAF in the implementation of the EIC. The EIC will have performance parameters that include a high beam polarization of greater than 70 percent from both electrons and light ions, and the capability to accommodate ion beams from deuterons to the heaviest stable nuclei. The EIC will also have variable center of mass energies from 20 to 100 GeV and upgradable to 140 GeV, high collision luminosity from 10^{33} -10^{34} $cm^{-2}s^{-1}$, one detector and one interaction region at project completion, and the capacity to accommodate a second interaction region and a second detector.

The scope also includes a new electron injection system and storage ring while taking full advantage of the existing infrastructure by modifying the existing hadron facility of the RHIC infrastructure at BNL.

The electron system will include a highly polarized room temperature photo-electron gun and a 400 MeV linac to be installed in an existing available straight section of the RHIC tunnel. It will include a transfer line that brings the electrons into the storage ring at the energy of 5 to 18 GeV that will be installed in the existing 2.4-mile circular RHIC tunnel.

Modifications to the existing hadron system include the injection, transfer line and storage ring to increase beam energy to 275 GeV. It will include a strong-hadron-cooling system to reduce and maintain the hadron beam emittance to the level needed to operate with the anticipated luminosity of 10^{33} -10^{34} $cm^{-2}s^{-1}$.

The interaction region will have superconducting final focusing magnets, crab cavities, and spin rotators to provide longitudinally polarized beams for collisions, where the outgoing particles will be collected by one detector.

An enhanced 2 K liquid helium cryogenic plant is provided for the superconducting radiofrequency cavities, with enhanced water-cooling capacity and cooling towers and chillers to stabilize the environment in the existing tunnel. Civil construction will also include electrical systems, service buildings, and access roads.

It is anticipated that non-DOE funding sources such as international collaborators, the National Science Foundation, and the State of New York, will contribute to the EIC Project. The timeframe for commitments by non-DOE contributors will vary throughout the life of the project and become more certain as planning for the project progresses. All non-DOE funding sources will be closely coordinated with the Office of Nuclear Physics and will be incorporated into the project through the change control process once baselined.

Justification
The last three NSAC LRP reports have supported the EIC with recommendations ranging from investing in accelerator research and development (R&D) in the 2002 NSAC LRP, to reducing technical risks in the 2007 NSAC LRP, to the actual construction of a U.S.-based EIC in the 2015 NSAC LRP. Specifically, the 2015 NSAC LRP for Nuclear Science recommended a high-energy, high-luminosity polarized EIC as the highest priority for new facility construction following the completion of the Facility for Rare Isotope Beams. Consistent with that vision, in 2016 NP commissioned a National Academies of Sciences,

Engineering, and Medicine study by an independent panel of experts to assess the uniqueness and scientific merit of such a facility. The report, released in July 2018, strongly supports the scientific case for building a U.S. based EIC, documenting that an EIC will advance the understanding of the origins of nucleon mass, the origin of the spin properties of nucleons, and the behavior of gluons.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets.*

Key Performance Parameters (KPPs)

The KPPs are preliminary and may change prior to setting the performance baseline at CD-2. The Threshold KPPs represent the minimum acceptable performance that the project must achieve for success. The Objective KPPs represent the project performance stretch goal. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Approve Project Completion.

Performance Measure	Threshold	Objective
Center-of-Mass	Center-of-mass energy measured in the range of 20 GeV- 100 GeV.	Center-of-mass energy measured in the range of 20 GeV- 140 GeV.
Accelerator	Accelerator installed and capable of delivering beams of protons and a heavy nucleus such as Au.	Ability to deliver a versatile choice of beams from protons and light ions to heavy ions such as Au.
Detector	Detector installed and ready for beam operations.	Inelastic scattering events in the e-p and e-A collisions measured in Detector.
Polarization	Hadron beam polarization of > 50 percent and electron beam polarization of > 40 percent measured at E_{cm} = 100 GeV.	Hadron beam polarization of > 60 percent and electron beam polarization of > 50 percent measured at E_{cm} = 100 GeV.
Luminosity	Luminosity for e-p collisions measured up to 1.0×10^{32} cm^{-2} s^{-1}.	Luminosity greater than 1.0×10^{33} cm^{-2} s^{-1}.

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	6,000	6,000	5,750	–
FY 2022	20,000	20,000	19,750	–
FY 2022 - IRA Supp.	70,000	70,000	–	–
FY 2023	50,000	50,000	49,500	50,000
FY 2024	87,000	87,000	48,000	20,000
Outyears	23,000	23,000	63,000	–
Total, Design (TEC)	**256,000**	**256,000**	**186,000**	**70,000**
Construction (TEC)				
FY 2022 - IRA Supp.	58,240	58,240	–	–
FY 2024	8,000	8,000	2,000	58,240
Outyears	1,803,760	1,803,760	1,809,760	–
Total, Construction (TEC)	**1,870,000**	**1,870,000**	**1,811,760**	**58,240**
Total Estimated Cost (TEC)				
Prior Years	6,000	6,000	5,750	–
FY 2022	20,000	20,000	19,750	–
FY 2022 - IRA Supp.	128,240	128,240	–	–
FY 2023	50,000	50,000	49,500	50,000
FY 2024	95,000	95,000	50,000	78,240
Outyears	1,826,760	1,826,760	1,872,760	–
Total, TEC	**2,126,000**	**2,126,000**	**1,997,760**	**128,240**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	34,650	34,650	30,270	–
FY 2022	24,800	24,800	26,230	–
FY 2022 - IRA Supp.	10,000	10,000	–	–
FY 2023	20,000	20,000	21,500	10,000
FY 2024	2,850	2,850	2,000	–
Outyears	200,150	200,150	202,450	–
Total, OPC	**292,450**	**292,450**	**282,450**	**10,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	40,650	40,650	36,020	–
FY 2022	44,800	44,800	45,980	–
FY 2022 - IRA Supp.	138,240	138,240	–	–
FY 2023	70,000	70,000	71,000	60,000
FY 2024	97,850	97,850	52,000	78,240
Outyears	2,026,910	2,026,910	2,075,210	–
Total, TPC	**2,418,450**	**2,418,450**	**2,280,210**	**138,240**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	173,000	291,000	**N/A**
Design - Contingency	83,000	122,000	**N/A**
Total, Design (TEC)	**256,000**	**413,000**	**N/A**
Construction	1,262,000	1,127,000	**N/A**
Construction - Contingency	608,000	521,000	**N/A**
Total, Construction (TEC)	**1,870,000**	**1,648,000**	**N/A**
Total, TEC	**2,126,000**	**2,061,000**	**N/A**
Contingency, TEC	*691,000*	*643,000*	***N/A***
Other Project Cost (OPC)			
R&D	97,450	46,650	**N/A**
Conceptual Design	11,000	11,000	**N/A**
Other OPC Costs	184,000	130,000	**N/A**
Total, Except D&D (OPC)	**292,450**	**187,650**	**N/A**
Total, OPC	**292,450**	**187,650**	**N/A**
Contingency, OPC	***N/A***	*N/A*	***N/A***
Total, TPC	**2,418,450**	**2,248,650**	**N/A**
Total, Contingency (TEC+OPC)	***691,000***	***643,000***	***N/A***

Note:

- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

5. **Schedule of Appropriations Requests**

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2022 IRA Supp.	FY 2023	FY 2024	Outyears	Total
FY 2023	TEC	6,000	5,000	—	20,000	—	2,030,000	2,061,000
	OPC	34,650	24,650	—	10,000	—	118,350	187,650
	TPC	40,650	29,650	—	30,000	—	2,148,350	2,248,650
FY 2024	TEC	6,000	20,000	128,240	50,000	95,000	1,826,760	2,126,000
	OPC	34,650	24,800	10,000	20,000	2,850	200,150	292,450
	TPC	40,650	44,800	138,240	70,000	97,850	2,026,910	2,418,450

6. **Related Operations and Maintenance Funding Requirements**

Over the course of the acquisition of the EIC, experienced RHIC scientists, engineers, and technicians will assume EIC project responsibilities. A gradual transition will balance the need for the scientific experts to continue to support RHIC while ramping up the EIC project. These individuals represent the scientific and technical workforce that are essential to the operations of a complex facility like RHIC and eventually, the EIC. They have critical core competencies in collider operations that cannot easily be replaced, and they represent the core facility operations force of RHIC and the EIC. In the FY 2024 Request, RHIC Operations includes a "reprioritization" of the expert workforce from the RHIC facility operations budget to support the project under the EIC OPC and TEC request. The temporary reprioritization of funds from the facility operations budget to the construction budget will reduce the amount of "new funds" needed to implement the EIC, enabling a cost-effective path forward to the implementation of this world-leading facility. As the EIC nears CD-4 when the machine will be restarted, the scientists, engineers and technicians that are needed to operate the EIC will be transferred back to the facility operations budget.

Start of Operation or Beneficial Occupancy	Q3 FY 2034
Expected Useful Life	50 years
Expected Future Start of D&D of this capital asset	Q3 FY 2084

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	**Current Total Estimate**	**Previous Total Estimate**	**Current Total Estimate**
Operations, Maintenance and Repair	167,000	167,000	13,500,000	13,500,000

7. D&D Information

As part of the upgrade and renovation of the existing accelerator facilities, up to 150,000 square feet of new industrial space will be built as service buildings to house mechanical and electrical equipment. The new area being constructed in this project is not replacing existing facilities.

	Square Feet
New area being constructed by this project at BNL	150,000
Area of D&D in this project at BNL	0
Area at BNL to be transferred, sold, and/or D&D outside the project, including area previously "banked"	N/A
Area of D&D in this project at other sites	N/A
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	N/A
Total area eliminated	0

8. Acquisition Approach

SC selected Brookhaven National Laboratory (BNL) as the site for the EIC on January 9, 2020. NP approved the Acquisition Strategy in conjunction with CD-1. DOE will utilize the expertise of the Management and Operating contractors at BNL and TJNAF to manage the project including the design, fabrication, monitoring cost and schedule, and delivering the technical performance specified in the KPPs. A certified Earned Value Management System based on those that already exist at both laboratories and will evaluate project progress and ensure consistency with DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets.