High Energy Physics

Overview
The High Energy Physics (HEP) program supports research which brings unique expertise to the Genesis Mission, Quantum Information Science (QIS), and microelectronics and harnesses these tools to understand the fundamental constituents of the universe pursuing the discovery science mission laid out in the 2023 P5 report. HEP uniquely integrates new technologies into larger collaborative research efforts, meeting real-world challenges on the road to widespread deployment scales. As part of the Genesis Mission Platform, HEP hosts exabytes of calibrated scientific datasets collected and curated over decades on computing systems that serve the needs of widely-distributed thousand person collaborations. As early adopters and developers of Artificial Intelligence (AI) methods, HEP scientists employ unique datasets to understand and push the limits of fundamental AI techniques. HEP is pushing QIS to achieve unprecedented precision by measuring rare and weak signals from our universe and integrating these new capabilities into pathfinder experiments across our frontiers. In QIS and Genesis Mission, HEP scientists work to identify the next phase of development and ensure that the United States hosts the foremost sites of international excellence in these fields such as the National QIS Research Centers and Microelectronics Science Research Centers.

The HEP program is dedicated to unraveling the mysteries of the universe by exploring the fundamental building blocks of matter and energy. Through groundbreaking scientific discoveries in particle physics and the management of top-tier scientific facilities, HEP plays a crucial role in advancing research and technology development. By ensuring the timely completion of significant projects and maintaining state-of-the-art facilities, HEP contributes to positioning the U.S. as a leader in global particle physics research and collaboration.

Our current understanding of the elementary constituents of matter and energy, as well as the forces that govern them, is encapsulated in the Standard Model of particle physics. However, experimental measurements indicate that the Standard Model is incomplete, hinting at the possibility of uncovering new physics through future experiments. In December 2022, the Department of Energy (DOE) and National Science Foundation (NSF) charged the High Energy Physics Advisory Panel (HEPAP) to assemble a new Particle Physics Project Prioritization Panel (P5) subpanel to formulate a ten-year plan for the field. At the December 2023 HEPAP meeting, the subpanel presented the new 2023 P5 report, "Exploring the Quantum Universe: Pathways to Innovation and Discovery in Particle Physics,"[a] which HEPAP unanimously approved. The report emphasized finishing ongoing major HEP projects. The 2023 P5 report outlines six core science drivers that offer promising pathways towards unraveling the mysteries beyond the Standard Model.

- Reveal the secrets of the Higgs boson,
- Elucidate the mysteries of neutrinos,
- Search for direct evidence of new particles,
- Pursue quantum imprints of new phenomena,
- Determine the nature of dark matter,
- Understand what drives cosmic evolution.

Highlights of the FY 2027 Request
The HEP FY 2027 Request of $1,120.5 million is a decrease of $114.7 million below the FY 2026 Enacted level. This funding will prioritize fundamental research, operation and maintenance of scientific user facilities, facility upgrades, and projects outlined in the 2023 P5 report.

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[a] https://science.osti.gov/-/media/hep/hepap/pdf/Reports/2024/2023_P5_Report_Single_Pages.pdf

Research
The Request will provide continued support for HEP core competencies in theoretical and experimental activities and world-leading advanced technology research and development (R&D) in pursuit of discovery science. Funding will also enable key advances in SC cross-cutting initiatives including:

- AI/ML: Contribute to making the Genesis Mission a success and curate AI-ready datasets, develop transformative AI models to extract rare particle signatures from increasingly high volumes of data, operate accelerators and detectors in real-time and extremely high data-rate environments, and create more realistic and accurate simulations of complex physical processes.
- QIS: Co-develop quantum information experiment, theory, and technology research aligned with HEP science drivers and explore new capabilities in quantum sensing and computing. HEP will continue to support the SC-wide National QIS Research Centers.
- Microelectronics: Accelerate R&D into sensor materials, detector devices, advances in front-end electronics, including AI-enabled edge computing; provide adaptation to high-radiation, cryogenic temperature, or low radioactive background environments. HEP will co-support the multi-disciplinary, multi-team awards that comprise the cross-SC Microelectronics Science Research Centers (MSRCs).

Facility Operations
The Request will support three scientific user facilities: the Fermilab Accelerator Complex, the Facility for Advanced Accelerator Experimental Tests II (FACET-II), and the Brookhaven Accelerator Test Facility (ATF). These facilities will operate 2,800, 2,080, and 2,250 hours, respectively. BeamNetUS will provide user access to thirteen U.S. beam test facilities. HEP also supports laboratory-based accelerator and detector test facilities, and supports the maintenance and operations of large-scale experiments and facilities that are not based at a DOE national laboratory, such as the U.S. A Toroidal LHC Apparatus (ATLAS) and Compact Muon Solenoid (CMS) detectors at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland; Sanford Underground Research Facility (SURF) in Lead, South Dakota; the NSF-DOE Vera C. Rubin Observatory in Chile; and the Dark Energy Spectroscopic Instrument (DESI) mounted on NSF's Mayall telescope at Kitt Peak National Observatory in Arizona.

Projects
The Request will support the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE-US) and Proton Improvement Plan II (PIP-II) construction projects. The Request will also support three Major Item of Equipment (MIE) projects: 1) Accelerator Controls Operations Research Network (ACORN), 2) High-Luminosity Large Hadron Collider (HL-LHC) ATLAS Detector Upgrade, and 3) HL-LHC CMS Detector Upgrade.

High Energy Physics
Funding

(dollars in thousands)

	FY 2025 Enacted	FY 2026 Enacted	FY 2027 Request	FY 2027 Request vs FY 2026 Enacted
High Energy Physics				
Energy Frontier, Research	66,835	52,757	23,627	-29,130
Energy Frontier, Facility Operations and Experimental Support	51,750	50,400	55,000	+4,600
Energy Frontier, Projects	33,700	28,400	11,812	-16,588
Total, Energy Frontier Experimental Physics	**152,285**	**131,557**	**90,439**	**-41,118**
Intensity Frontier, Research	58,103	48,533	24,832	-23,701
Intensity Frontier, Facility Operations and Experimental Support	221,000	226,900	243,439	+16,539
Intensity Frontier, Projects	10,000	10,000	21,000	+11,000
Total, Intensity Frontier Experimental Physics	**289,103**	**285,433**	**289,271**	**+3,838**
Cosmic Frontier, Research	47,409	43,040	19,094	-23,946
Cosmic Frontier, Facility Operations and Experimental Support	56,500	52,543	55,700	+3,157
Cosmic Frontier, Projects	4,500	–	–	–
Total, Cosmic Frontier Experimental Physics	**108,409**	**95,583**	**74,794**	**-20,789**
Theoretical, Computational, and Interdisciplinary Physics, Research	169,042	–	–	–
Theoretical,Comp,&InterPhy,Facility Operations and Experimental Supp	8,845	–	–	–
Total, Theoretical, Computational, and Interdisciplinary Physics	**177,887**	**–**	**–**	**–**
Advanced Technology R&D, Research	72,886	–	–	–
Advanced Technology R&D, Facility Operations and Experimental Support	48,000	–	–	–
Total, Advanced Technology R&D	**120,886**	**–**	**–**	**–**
Theoretical and Interdisciplinary Physics, Research	–	44,039	21,792	-22,247
Total, Theoretical and Interdisciplinary Physics	**–**	**44,039**	**21,792**	**-22,247**
Accelerator & Technology R&D, Research	–	242,247	193,549	-48,698
Accel & Tech R&D, Facility Operations & Experimental Support	–	62,297	40,613	-21,684
Total, Accelerator & Technology R&D	**–**	**304,544**	**234,162**	**-70,382**
Subtotal, High Energy Physics	**848,570**	**861,156**	**710,458**	**-150,698**

(dollars in thousands)

	FY 2025 Enacted	FY 2026 Enacted	FY 2027 Request	FY 2027 Request vs FY 2026 Enacted
Construction				
18-SC-42 Proton Improvement Plan II (PIP-II), FNAL	125,000	114,000	105,000	-9,000
11-SC-40 Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment	251,000	260,000	305,000	+45,000
Subtotal, Construction	**376,000**	**374,000**	**410,000**	**+36,000**
Total, High Energy Physics	**1,224,570**	**1,235,156**	**1,120,458**	**-114,698**

High Energy Physics
Explanation of Major Changes

	(dollars in thousands) FY 2027 Request vs FY 2026 Enacted
Energy Frontier Experimental Physics The Request will decrease due to the planned reduction for the HL-LHC ATLAS and CMS Detector Upgrade Projects, in accordance with their baselined funding profiles. Concurrently, funding will increase to prioritize essential upgrades to the U.S.-based software and computing infrastructure. This ensures efficient analysis of the HL-LHC's exponentially large datasets and allows for a strategic focus of research funding on the highest impact areas.	**-41,118**
Intensity Frontier Experimental Physics The Request includes targeted increases to ramp up the ACORN project hardware procurement, provide Other Project Costs (OPC) for PIP-II consumables, and enhance support for SURF and the Fermilab Accelerator Complex. This increased support will enable the latter to operate 2,800 hours annually, including critical General Plant Projects (GPPs) and Accelerator Improvement Projects (AIPs). These increases are offset by rebalancing programmatic priorities within research. Concurrently, research funding will strategically focus on maximizing scientific return from ongoing experiments and making critical contributions to the LBNF/DUNE project.	**+3,838**
Cosmic Frontier Experimental Physics The Request strategically focuses resources on maximizing scientific return from leading dark energy, dark matter, and Cosmic Microwave Background (CMB) experiments. Funding for research decreases while operations increases to prioritize data collection and production from the NSF-DOE Vera C. Rubin Observatory, DESI, and SuperCDMS-SNOLAB, utilizing AI/ML to improve efficiency and accelerate discoveries in dark energy and dark matter.	**-20,789**
Theoretical and Interdisciplinary Physics The Request will prioritize maintaining HEP research capacity, workforce training, and career pathways for individuals and institutions, strategically focusing support on key theoretical research groups to sustain momentum in the most promising areas of high energy physics.	**-22,247**

	(dollars in thousands)
	FY 2027 Request vs FY 2026 Enacted
Accelerator & Technology R&D The FY 2027 Request for Accelerator & Technology R&D reflects an overall programmatic change. Strategic investment is directed to the Genesis Mission to expand distributed computing activities and curate AI-ready data from experiments and facilities. The Request will also support FACET-II and ATF to operate 2,080 and 2,250 hours, respectively, and will support BeamNetUS. Remaining budget changes allow the subprogram to focus resources on strategic priorities within General Accelerator R&D, Computational HEP, and Detector R&D, enhancing its highest impact areas and delivering world-leading scientific contributions despite overall programmatic constraints.	**-70,382**
Construction The Request will increase support for LBNF/DUNE for ongoing construction of Far Site Conventional Facilities—Buildings and Site Infrastructure, continued installation of far detector components and cryogenic infrastructure, and the design and reviews needed to transition into the execution phases of Near Site Conventional Facilities and Beamline and Near Detector; while decreasing support for PIP-II in accordance with the baselined funding profiles.	**+36,000**
Total, High Energy Physics	**-114,698**

Basic and Applied R&D Coordination
The General Accelerator R&D (GARD), Accelerator Stewardship, Accelerator Development, AI/ML, and QIS activities advance crosscutting technology R&D and supply chain risk reduction efforts that support the mission of HEP and other Office of Science programs.

Technology R&D activities are guided by experts from DOE, other federal agencies, universities, national laboratories, and the private sector who help identify key research areas and supply chain needs beyond the SC research mission. Cross-cutting accelerator R&D is closely coordinated within SC and with partner agencies[b] to ensure federal stakeholders have input in crafting funding opportunity announcements, reviewing applications, and evaluating the efficacy and impact of funded activities. To ensure commercial viability, funded activities are expected to include collaboration with one or more U.S. companies to guide the early-stage R&D. Coordination across the U.S. government occurs through interagency discussions and via the Presidential Council of Advisors on Science and Technology (PCAST) and the National Quantum Coordination Office.

Formulation of the GARD activity is based on input from the community, including high-level advice on long term facility goals from HEPAP and P5, and more detailed technical advice developed through a series of Roadmap Workshops[c]. Formulation of the Accelerator Stewardship, Accelerator Development, and AI/ML activities are based on guidance from other SC Programs, federal advisory committee reports, community input, data capture, and Basic Research Needs workshops[d] held in conjunction with other federal agencies.

To maximize impact, the HEP QIS research activity collaborates with the Department of Commerce's National Institute of Standards and Technology on both quantum metrology and quantum sensor development and with NASA on quantum computing and sensing. The SC National QIS Research Center (NQISRC) efforts engage industry to connect use-inspired research with development efforts, and it utilizes partnerships to improve technology for quantum computing and networking.

Program Accomplishments
Vera C. Rubin Observatory begins its 10-year Legacy Survey of Space and Time (LSST) (Cosmic Frontier Experimental Physics)
In FY 2026, NSF-DOE Vera C. Rubin Observatory began its ten-year wide-field, ground-based, optical and near-infrared imaging Legacy Survey of Space and Time (LSST), providing an unprecedented data set that will be used by the Dark Energy Science Collaboration (DESC) to probe the mysteries of dark energy and dark matter, along with enabling scientific studies by the wider astronomical community. Data preview 2 (DP2) using data from the science verification and commissioning phases taken in FY 2025 was released in FY 2026. Data release 1 (DR1), with early data from the full LSST dataset will be released in FY 2027, enabling early cosmology results. In June 2025, Rubin successfully unveiled its first science images[e] to a global audience, demonstrating its capability to capture vast swaths of the night sky with exceptional clarity. Its 8.4-meter primary mirror and 3.2-gigapixel camera, the largest digital camera ever built, will image the entire visible southern sky every few nights. The resulting LSST dataset will allow DESC to constrain cosmological

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[b] Specifically, with the National Institutes of Health/National Cancer Institute (NIH/NCI); ultrafast laser technology R&D with the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA); and microwave and high power accelerator R&D coordinated with the National Nuclear Security Administration (NNSA) and DOD, the Department of Homeland Security's Domestic Nuclear Detection Office in the Countering Weapons of Mass Destruction Office (DHS/CWMD), Department of Commerce's National Institute of Standards and Technology (NIST) and the National Science Foundation/Mathematical and Physical Sciences (NSF/MPS) Division.
[c] Roadmap Workshop reports may be found at https://science.osti.gov/hep/Community-Resources/Reports
[d] Basic Research Needs workshop reports may be found at https://science.osti.gov/ardap/Resources
[e] https://www.energy.gov/science/articles/ever-changing-universe-revealed-first-imagery-nsf-doe-vera-c-rubin-observatory

parameters with unparalleled precision, test alternative models of dark energy, and search for deviations from the standard cosmological model.

High Energy Physics Hardware-Aware Artificial Intelligence Research (Artificial Intelligence and Machine Learning)
The Office of High Energy Physics held a Hardware-Aware AI Research review for ambitious applications to develop AI systems that require expert knowledge of particle physics detectors and facilities. Among the projects selected from this review, a multi-laboratory award was made to seven DOE national laboratories for the project titled, "ML-Enhanced Online Monitoring and Control of HEP Accelerators at the Scientific Frontier." This project will develop AI that will enable real-time control of particle accelerators, AI-expert systems to assist human operators of complex DOE Office of Science supported experiments and facilities, and AI to develop novel low power Application Specific Integrated Circuits (ASICs) necessary to process the torrent of data from future experiments. Collectively, the selected projects are expected to bring AI to the edge of future DOE SC experiments and facilities to efficiently deliver more impactful science.

LBNL uses quantum computers to watch fundamental physics (Quantum Information Science)
Lawrence Berkeley National Laboratory is working to use quantum computers to simulate a class of problems known as lattice gauge theories, which includes the strong nuclear force. Traditionally, these problems require very large amounts of supercomputer time. In classical computing, it is particularly difficult to access non-equilibrium states, and many calculations are limited to looking at "steady-state" behavior. Quantum computers are not subject to these limitations, raising the exciting prospect that they could allow for a real-time simulation of processes like the formation of protons and neutrons, allowing us to observe the detailed dynamics of how fundamental physics gives rise to the building blocks of matter, particularly in extreme environments like just after the Big Bang. LBNL researchers have realized new theoretical models that reduce the amount of quantum simulation power required to implement these models by 17-19 orders of magnitude.[f] Additionally, they were able to demonstrate the observation of a phenomenon known as "string-breaking" on a 133-qubit superconducting quantum computer. This work was supported by HEP's Quantum Information Science Enabled Discovery (QuantISED) program.

Muon g-2 announces most precise measurement of the magnetic anomaly of the muon (Intensity Frontier Experimental Physics)
The Muon g-2 experiment conducted that the Fermilab National Accelerator Laboratory has released their third and final measurement of the muon magnetic anomaly[g]. The final result is in perfect agreement with the experiment's previous results and is the world's most precise measurement yet of the magnetic moment of the muon. This long-awaited value is the world's most precise measurement of the muon magnetic anomaly at 127 parts-per-billion, surpassing even the original experimental design goal of 140 parts-per-billion. The Muon g-2 collaboration presented the third and final measurement of the muon magnetic anomaly in Ramsey Auditorium on June 3, 2025.

DOE-supported researchers on the Dark Energy Spectroscopic Instrument (DESI) experiment used AI/ML techniques to show that dark energy is not static but evolves with time (Cosmic Frontier Experimental Physics)
DESI's 2025 results using data from almost 15 million galaxies and quasars taken during its first 3 years of operations provide the most precise measurement of our expanding universe, indicating a dark energy that is evolving over time, instead of being a cosmological constant as first postulated by Einstein. DESI's first cosmological publication exceeded 1,000 citations, making it the most cited HEP result of the year. From its location at NSF's Kitt Peak National Observatory, DESI uses a state-of-the-art robotic fiber-fed focal plane that captures light from 5,000 galaxies simultaneously and ten 3-channel spectrographs to make the most accurate 3-

[f] https://arxiv.org/abs/2503.11888
[g] https://news.fnal.gov/2025/06/muon-g-2-most-precise-measurement-of-muon-magnetic-anomaly/

dimensional map of the universe to date. The data were used to unravel the history of cosmic accelerations over 11 billion years, from the present to when the universe was less than 3 billion years old, revealing the nature of dark energy, which causes the acceleration of the expansion of the universe. Combinations of DESI baryon acoustic oscillation data with CMB data (Planck experiment) point to a time-varying dark energy with a confidence level of 3.1 sigma. When combined with various supernova data sets, this increases to 2.8 to 4.2 sigma. This counters the assumption that Einstein's cosmological constant is in fact a constant, with a 0.3 percent accuracy averaged over DESI's full redshift range. At best, the leading standard model of cosmology (Lambda-CDM), with its relative fractions of dark energy and cold dark matter is incomplete, and at worst, it is incorrect. As DESI continues its planned 7-year survey to map the cosmos from the early universe to the present day, it will continue to provide more refined results leading to unparalleled insights that revolutionize our understanding of the composition, history and fate of the universe.

High Energy Physics
Energy Frontier Experimental Physics

Description

The Energy Frontier Experimental Physics subprogram supports U.S. researchers at the international Large Hadron Collider (LHC), participating in the ATLAS and CMS experiments. These large, international collaborations greatly benefit from U.S. researchers' contributions, who represent approximately 20-25 percent of the ATLAS and CMS collaborations and play key leadership roles. This subprogram addresses four of the six P5 science drivers, as detailed below.

- ***Reveal the secrets of the Higgs boson***
  LHC experiments measure the Higgs boson's properties with exquisite precision to determine if it behaves as predicted by the Standard Model.
- ***Search for direct evidence of new particles***
  Direct searches at the LHC aim to discover new particles, leveraging increased collision rates to enable more precise studies. Over a decade of LHC running has produced vast datasets, which have been crucial for innovative analyses.
- ***Pursue quantum imprints of new phenomena***
  LHC researchers probe for evidence of physics beyond the Standard Model. Upgraded LHC detectors will be more sensitive to potential deviations from the Standard Model.
- ***Determine the nature of dark matter***
  LHC collisions could potentially produce dark matter particles, inferring their properties through the behavior of the other particles. Such "indirect" detection complements experiments at the Cosmic and Intensity Frontiers.

Research

This activity supports scientists at research institutions and the DOE national laboratories who work on the ATLAS and CMS experiments by serving in many expert roles – from designing equipment to analyzing data and publishing results. Advanced computational techniques, including AI/ML, contribute to:

- **Analyzing Higgs boson decay patterns:** Precisely measuring the characteristic properties of the Higgs particle, revealing subtle deviations from the Standard Model and providing insights into new physics.
- **Processing enormous volumes of LHC data:** Identifying new particle signatures, suppressing background noise, and optimizing search strategies.
- **Investigating complex collision events:** Exploring challenging collision topologies, detecting subtle imprints of new phenomena, and identifying deviations from expected particle behavior.
- **Searching for dark matter signatures:** Pinpointing potential dark matter signals in LHC collision data.
- **Future colliders R&D:** Physics studies and pre-conceptual R&D to advance the design of international future colliders, such as the Future Circular Collider[h], hosted by CERN, and a Muon Collider[i], potentially hosted in the U.S.

Facility Operations and Experimental Support

The U.S. LHC Detector Operations activity maintains U.S.-built components of the large multi-purpose ATLAS and CMS detectors and supports the U.S.-based computer infrastructure used to analyze LHC data, including the Tier 1 computing centers at Brookhaven National Laboratory (BNL) and FNAL for each respective experiment. These centers provide 24/7 support, store and manage data, perform reprocessing, and store output.

[h] A future electron-positron collider is expected to provide large samples of Higgs bosons, enabling more precise measurements of the particle, exploring new direct production processes, and offering indirect sensitivity to higher energy scales.
[i] A 10 TeV parton center-of-momentum muon collider could provide unparalleled increases in the ability to produce and search for new particles compared to existing capabilities.

Projects

CERN is upgrading the LHC to the High-Luminosity LHC (HL-LHC), increasing the collision rate and the amount of data collected to enable unprecedented precision measurements and explore new physics. HEP contributed to the accelerator project by building and delivering the next-generation superconducting accelerator components, leveraging U.S. expertise. The HL-LHC will create challenging detector conditions, making the HL-LHC ATLAS and CMS Detector Upgrades critical investments to ensure continued operation and maximize scientific return.

Activities and Explanation of Changes

(dollars in thousands)

FY 2026 Enacted	FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Energy Frontier Experimental Physics $131,557	**$90,439**	**-$41,118**
Research $52,757	$23,627	-$29,130
Funding continues support for researchers actively involved in the ATLAS and CMS experiments, prioritizing the use of AI/ML techniques to sustain progress in fundamental physics discovery.	The Request will continue support for researchers actively involved in the ATLAS and CMS experiments, prioritizing the use of AI/ML techniques to sustain progress in fundamental physics discovery. Support will also continue targeted physics studies and pre-conceptual R&D efforts that advance the proposed future colliders.	Research activity will strategically focus on the highest impact areas within the Energy Frontier subprogram. Research funding will prioritize exploring new physics using innovative AI/ML tools at the LHC and making critical contributions to the HL-LHC detector upgrades, while continuing focused efforts on future collider pre-conceptual R&D.
Facility Operations and Experimental Support $50,400	$55,000	+$4,600
Funding continues to support vital LHC detector components and computing infrastructure, utilizing AI/ML to optimize performance and ensure reliable, high-quality data for U.S. researchers.	The Request will support vital ATLAS and CMS detector maintenance activities and planned refurbishments of the U.S. computing infrastructure during an extended four-year long technical stop of the LHC, beginning in July 2026. AI/ML tools will continue to be deployed to optimize performance and ensure reliable, future high-quality HL-LHC data for U.S. researchers.	Increased funding will prioritize essential upgrades to the U.S.-based software and computing infrastructure to ensure the efficient analysis of the HL-LHC's exponentially larger datasets. This includes support for vital ATLAS and CMS detector integration and commissioning efforts for delivered components of the U.S.-built HL-LHC detector upgrades, critical during the extended technical stop.

(dollars in thousands)

FY 2026 Enacted	FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Projects $28,400	$11,812	-$16,588
Funding supports fabrication activities for the HL-LHC ATLAS and the HL-LHC CMS Detector Upgrades.	The Request will support the completion of the fabrication activities for the HL-LHC ATLAS and the HL-LHC CMS Detector Upgrades, with U.S.-built components being delivered to the experiments for their installation and integration.	Funding will support the final critical phase of U.S. contributions to the HL-LHC detector upgrades. The reduced funding level reflects progress towards the completion of fabrication under the planned project profile and the delivery of U.S.-built components, enabling their installation and integration by collaborators on the experiments.

Description

The Intensity Frontier Experimental Physics subprogram investigates rare processes using high-power beams and intense sources to make precision measurements of fundamental particle properties. These measurements probe for new phenomena not directly observable at the Energy Frontier, either because these phenomena occur at much higher energy or involve extremely weak interactions. This subprogram addresses four of the six P5 science drivers, as detailed below.

- ***Elucidate the mysteries of neutrinos***
  Research into fundamental neutrino properties may reveal important clues about the unification of forces and the early history of the universe, addressing the Standard Model's limitations regarding neutrino mass and oscillations.
- ***Search for direct evidence of new particles***
  Experiments seeking direct evidence for new particles, whether heavy particles produced at colliders or light particles produced with high intensity, can ignite major paradigmatic shifts.
- ***Pursue quantum imprints of new phenomena***
  Experiments using intense particle beams can reveal quantum imprints of new phenomena beyond the reach of Energy Frontier accelerators. The physics of quarks and leptons is particularly sensitive to these imprints.
- ***Determine the nature of dark matter***
  Experiments with highly efficient detectors within intense accelerator beams offer an opportunity to explore theoretical models with new particles and forces that rarely interact with normal matter.

<u>Research</u>

This activity supports scientists at research institutions and DOE national laboratories who work in many roles on experiments involving neutrinos, muons, and rare processes – from designing equipment to analyzing data. A major focus is accelerator-based neutrino physics at Fermi National Accelerator Laboratory (FNAL), including the current Short-Baseline Neutrino (SBN) program, which searches for neutrino types beyond the three currently described in the Standard Model, and the LBNF/DUNE, a future U.S.-hosted world-leading neutrino research facility. Advanced computational techniques, including AI/ML, contribute to:

- **Enhanced data processing:** AI/ML algorithms are being used to efficiently process the massive datasets generated by neutrino experiments, accelerating the search for new physics.
- **Improved signal identification:** AI/ML techniques enhance the ability to distinguish faint signals from background noise, increasing the sensitivity of rare decay experiments.
- **Optimized detector performance:** AI/ML is being used to monitor and optimize detector performance, maximizing data quality and experiment up time.

<u>Facility Operations and Experimental Support</u>

This activity covers the costs of managing Intensity Frontier facilities and running experiments, including the Fermilab Accelerator Complex User Facility, the South Dakota Science and Technology Authority (SDSTA) cooperative agreement, and LBNF/DUNE-US Operations.

The Fermilab Accelerator Complex encompasses the operation of all accelerators and beamlines at FNAL; the technical infrastructure supporting the accelerator complex and operation of detectors; scientific computing; and user support. Facility improvements are managed via Accelerator Improvement Project (AIP) and General Plant Project (GPP) portfolios. AI/ML is widely applied in areas such as data analysis and accelerator controls to enhance efficiency, improve accuracy, and unlock new insights from complex datasets.

The SDSTA cooperative agreement funds basic services and critical infrastructure upgrades at the Sanford Underground Research Facility (SURF) in South Dakota. SURF will be the future home of the DUNE far site detectors, which are currently under construction.

LBNF/DUNE-US Operations supports ongoing scientific and technical activities essential for the future operation of DUNE. These activities, which must be performed well in advance of physics data taking, include the development of complex software and computing systems, notably those incorporating AI/ML. This funding is distinct from the support provided to the Fermilab Accelerator Complex, the host facility SURF, or the capital expenditures of the LBNF/DUNE Project.

Projects

FNAL is upgrading its outdated accelerator control system with a modern system capable of utilizing advances in AI/ML to control its high-performance accelerators providing added flexibility, greater scientific productivity, and enhanced efficiency of operations. The Accelerator Controls Operations Research Network (ACORN) project is critical for upgrading obsolete hardware and software systems that are necessary for operations of PIP-II and LBNF.

Activities and Explanation of Changes

(dollars in thousands)

FY 2026 Enacted		FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Intensity Frontier Experimental Physics	**$285,433**	**$289,271**	**+$3,838**
Research	$48,533	$24,832	-$23,701
Funding maintains support for researchers actively involved in ongoing experiments and future projects, prioritizing the use of AI/ML techniques to sustain progress in fundamental physics discovery.		The Request will support researchers actively involved in the ongoing experiments and future projects. Emphasis will be placed on collaborative efforts and the efficient application of AI/ML to drive discoveries within the leading experiments.	Research activity will strategically focus on the highest impact areas within the Intensity Frontier subprogram. Research funding will prioritize exploring new physics from operating neutrino experiments and making critical contributions to the LBNF/DUNE project.
Facility Operations and Experimental Support	$226,900	$243,439	+$16,539
Funding continues supporting the Fermilab Accelerator Complex and SURF, carefully balancing the operational needs of the user community with the need to reduce deferred maintenance and to advance modernization efforts, such as AI/ML upgrades.		The Request will continue supporting the Fermilab Accelerator Complex and SURF, carefully balancing the operational needs of the user community with the need to reduce deferred maintenance, including a GPP to replace a 354kV substation transformer that provides power to the accelerator, and to advance modernization efforts, such as AI/ML upgrades. The Request will also support critical activities, like developing software and computing infrastructure, essential for the timely operation of DUNE.	Increased funding will prioritize critical infrastructure modernization at SURF and the Fermilab Accelerator Complex, including addressing deferred maintenance, essential for sustaining high-quality operational support for the user community.

(dollars in thousands)

FY 2026 Enacted		FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Projects	$10,000	$21,000	+$11,000
Funding supports the ACORN MIE system design and other related engineering activities.		The Request will support major hardware procurements for ACORN and will support new consumable costs as PIP-II transfers major subsystems to operations.	Increased funding will support the ramp-up in ACORN hardware procurement. This increase will also provide OPC funding for consumables, supporting PIP-II's transition to operational status.

Description

The Cosmic Frontier Experimental Physics subprogram uses measurements and observations from naturally occurring data to probe fundamental physics questions about dark matter, dark energy, the cosmic inflationary era, and neutrino properties; and to search for new phenomena. Experiments are conducted at ground-based observatories and facilities, space-based missions, and detectors deep underground. This subprogram addresses four of the six P5 science drivers as described below:

- ***Determine the nature of dark matter***
  Direct-detection experiments search for dark matter particles, complementing accelerator-based searches performed in the Energy and Intensity Frontiers.
- ***Understand what drives cosmic evolution***
  Spectroscopic and imaging surveys of galaxies will determine the nature of dark energy. Measurements of the CMB signal and light from distant galaxies map cosmic acceleration and inform researchers about the era of inflation.
- ***Elucidate the mysteries of neutrinos***
  Dark energy experiments using large-scale structures and the CMB will constrain neutrino properties, complementing measurements in the Intensity Frontier.
- ***Search for Direct Evidence of New Particles***
  Studies of the CMB may reveal relic particles from the early universe, leaving imprints that can be investigated.

Research

This activity supports scientists at research institutions and DOE national laboratories across the U.S. These scientists work together on projects in many roles – from designing experiments to analyzing data. Advanced computational techniques, including AI/ML, contribute to:

- **Accelerate data analysis**: Handle the massive datasets generated by these experiments, identifying patterns and anomalies that would be impossible for humans to find manually.
- **Optimize experimental design**: Use AI/ML to simulate different experimental configurations and identify the most efficient and effective designs.
- **Automate operations**: Use AI/ML techniques to optimize in real time the data collection from very sensitive and complex experimental systems more efficiently than could be done by traditional computing algorithms.
- **Improve simulations**: Create more realistic and accurate simulations of complex physical processes, such as the behavior of dark matter particles or the evolution of the universe.

Major experiments like the Dark Energy Spectroscopic Instrument (DESI) and facilities such as the NSF-DOE Vera C. Rubin Observatory are driving progress in understanding dark energy. This activity also leads the global effort to detect and characterize dark matter through experiments like LZ and SuperCDMS-SNOLAB.

Facility Operations and Experimental Support

This activity covers the costs of running Cosmic Frontier experiments, including maintenance, operation, and data collection, handling, and dissemination. DESI is located on the NSF's Mayall Telescope in Arizona and managed by LBNL. DOE and NSF jointly operate the Rubin Observatory in Chile, with SLAC managing DOE's responsibilities. The LZ and SuperCDMS-SNOLAB dark matter experiments are located deep underground. LBNL manages LZ operations at SURF in South Dakota, and SLAC manages DOE's responsibilities for SuperCDMS-SNOLAB at the Sudbury Neutrino Observatory in Canada, in partnership with NSF and Canada[j].

[j] Canadian funding for SuperCDMS-SNOLAB operations is provided by the Ministry for Innovation, Science, and Economic Development through the Canada Foundation for Innovation (CFI).

Activities and Explanation of Changes

(dollars in thousands)

FY 2026 Enacted		FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Cosmic Frontier Experimental Physics	**$95,583**	**$74,794**	**-$20,789**
Research	$43,040	$19,094	-$23,946
Funding continues to support researchers exploring dark energy and dark matter, emphasizing collaborative efforts and the efficient application of AI/ML to drive discoveries within the leading experiments.		The Request will continue to support researchers exploring dark energy, dark matter, and inflation using the CMB. Emphasis will be placed on collaborative efforts and the efficient application of AI/ML to drive discoveries within the leading experiments.	Research funding will strategically focus on the highest impact areas within the Cosmic Frontier subprogram. Research funding will prioritize discoveries in dark energy and dark matter.
Facility Operations and Experimental Support	$52,543	$55,700	+$3,157
Funding continues to support the collection, processing, and analysis of data from leading Cosmic Frontier experiments.		The Request will continue to support the enhanced collection, processing, and analysis of data from leading Cosmic Frontier experiments.	Increased funding will support the optimal operation of key Cosmic Frontier experiments, particularly the Rubin Observatory, DESI, and SuperCDMS-SNOLAB.

High Energy Physics
Theoretical and Interdisciplinary Physics

Description

The Theoretical and Interdisciplinary Physics subprogram develops the mathematical, phenomenological, and computational tools needed to understand the behavior of particles and fields, as well as the fundamental nature of space and time. This theoretical research is essential for interpreting experimental results in other HEP subprograms, directly contributing to all six P5 science drivers and supporting the Energy, Intensity, Cosmic Frontiers, and Accelerator and Technology R&D. This subprogram also promotes connections with new research areas (e.g., AI/ML, QIS) and institutions through workshops, collaborations, and workforce training programs.

<u>Theory</u>

The HEP theory activity supports world-leading research groups at research institutions and national laboratories, enabling them to address key HEP research areas. Laboratory groups focus on data-driven investigations and calculations of experimentally observable quantities. Research institutions focus on building models of physics beyond the Standard Model and studying their phenomenology and on mathematical theory (e.g., string theory, quantum field theory), aiming to develop a more complete understanding of the universe. Specific examples of AI/ML and QIS applications include:

- **Accelerated computations and data analysis:** Using AI/ML to speed up calculations and extract insights from datasets, identifying potential signatures of new physics.
- **Model building with AI/ML:** Employing AI/ML to explore models beyond the Standard Model and identify those consistent with data.
- **Quantum simulations:** Utilizing quantum computers to simulate complex quantum systems, including quantum field theories.
- **QIS-inspired theoretical techniques:** Developing non-perturbative techniques in field theory and quantum gravity using QIS to understand fundamental aspects of the universe.

<u>Mission-Critical Talent Pathways</u>

This activity expands participation in HEP through strategic talent pipelines and use-inspired research, including:

- **DOE Established Program to Stimulate Competitive Research (EPSCoR):** Strengthens research capacity in U.S. states and territories with limited federal research funding, thereby reaching communities and institutions with limited involvement in the HEP portfolio.
- **Science Accelerating Growth and Engagement (SAGE) Journey internships:** Attract undergraduate talent to DOE national laboratories, providing early-stage skill training through hands-on research experiences. This low-risk, high-reward program is designed to develop talent to fill mission-critical needs, offering a fast track to potential full-time positions upon degree completion.
- **Veteran Applied Laboratory Occupational Retraining (VALOR)**: Provides technical readiness and skill transition for veterans entering civilian careers. Through specialized training and career placement at FNAL, VALOR participants fill vital operational and mission-support roles within the lab infrastructure, ensuring facility reliability and safety.

Activities and Explanation of Changes

(dollars in thousands)

FY 2026 Enacted		FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Theoretical and Interdisciplinary Physics	**$44,039**	**$21,792**	**-$22,247**
Research	$44,039	$21,792	-$22,247
Theory	*$40,964*	*$18,792*	*-$22,172*
Funding continues to support world-leading theoretical particle physics research.		The Request will continue to support world-leading theoretical particle physics research.	Research activity will strategically focus on the highest impact theoretical research groups. Research funding will prioritize efforts that leverage the innovative application of AI/ML and QIS to sustain momentum in the most promising areas of high energy physics.
Mission-Critical Talent Pathways	*$3,075*	*$3,000*	*-$75*
Funding continues to support HEP awards through EPSCoR, and internships through SAGE Journey and VALOR.		The Request will continue to support HEP awards through EPSCoR, and internships through SAGE Journey and VALOR.	Research funding will prioritize new HEP awards through EPSCoR.

Description

The Accelerator and Technology R&D subprogram supports the cutting-edge basic research necessary to develop 21st century tools of science. The subprogram supports R&D in a wide range of areas, including: the physics of particle beams, accelerator technology, particle and radiation detection, computational methods for HEP, QIS, the Genesis Mission, and microelectronics. It also funds world-leading scientific facilities at five DOE national laboratories. Technologies developed through this subprogram contribute to all six P5 science drivers, provide broad benefits for science and society, and provide advanced training to develop a highly skilled workforce in scientific and technical fields. This subprogram achieves its goals through targeted activities in General Accelerator R&D, Accelerator Stewardship, Accelerator Development, Detector R&D, Computational HEP, Genesis Mission, QIS, and Microelectronics.

General Accelerator R&D

The GARD activity supports the fundamental science research underpinning particle accelerators, colliders, storage rings, and charged particle beams to enable future HEP discoveries. GARD also funds curiosity-driven accelerator R&D and invests in Office of Science (SC) facilities to maintain U.S. leadership. Long-term goals include dramatically improving accelerator performance—optimizing beam energy, intensity, quality, and control—while reducing cost and size. This R&D enables upgrades to existing accelerator systems, develops future HEP facilities, and provides critical accelerator components for future colliders. GARD supports scientists and engineers at research institutions and DOE national laboratories across five key areas: accelerator and beam physics, advanced acceleration concepts, particle sources and targetry, radio-frequency (RF) acceleration technology, and superconducting magnets and materials. As a cross-SC effort involving all relevant SC national laboratories and U.S. universities, GARD guides research via community-commissioned roadmaps for its thrust areas[k]. GARD also supports the graduate Traineeship Program for Accelerator Science and Engineering; this activity revitalizes education, training, and innovation in accelerator physics, developing a highly skilled workforce that benefits HEP, other SC programs, and various DOE initiatives that utilize such technologies.

Accelerator Stewardship

This activity supports use-inspired accelerator technology R&D with a wide range of applications that make use of accelerators in discovery science, medicine, industry, security, and environmental science. The activity also facilitates private sector access to a network of thirteen unique state-of-the-art accelerator R&D facilities through BeamNetUS[l], which offer complementary capabilities for research in areas such as plasma physics, material science, and advanced beam technologies. Research activities support public-private collaboration in cross-cutting accelerator technologies encompassing a wide range of areas: superconducting accelerators, beam physics, new particle sources, advanced high-intensity laser technology, high-efficiency RF power sources, and AI/ML-based accelerator controls. R&D topics are identified by Basic Research Needs Workshops[m] and implemented in close alignment with Administration priorities.

Accelerator Development

This activity fosters partnerships between industry, academia, and DOE national laboratories. These collaborations address specific supply chain vulnerabilities for scientific facilities supported by the Office of Science. Strengthening domestic accelerator technology suppliers enhances their ability to produce advanced components and drive innovation, ultimately supporting the SC mission to conduct world-leading scientific

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[k] Reports may be found at https://science.osti.gov/hep/Community-Resources/Reports
[l] https://www.beamnetus.org/
[m] Reports may be found at https://science.osti.gov/ardap/Resources

research. Focus areas include advanced superconducting wire and cable, superconducting RF cavities, novel materials, and high efficiency RF power sources for accelerators. Vulnerabilities addressed by the Accelerator Development program are identified by the SC programs on a tri-annual basis.

Detector R&D

This activity supports the development of the next generation instrumentation, particle detectors, and devices that function in extreme radiation and temperature environments. This is essential for maintaining U.S. scientific leadership as the field of HEP is expanding into new research areas by leveraging state-of-the-art technologies such as quantum sensors and advanced microelectronics, including real-time AI/ML in front-end electronics. This activity also supports the graduate Traineeship Program for HEP Instrumentation. This program aims to revitalize education, training, and innovation in the physics of particle detectors and next generation instrumentation.

Computational HEP

Advanced computing R&D enables HEP scientific discoveries inaccessible through experiments, observations, or traditional theoretical methods. This activity supports the multi-laboratory HEP Center for Computational Excellence (CCE), which propels HEP computing forward by developing common software tools, adapting HEP applications for the latest high-performance computing platforms (including exascale systems), and facilitating HEP's involvement in the Genesis Mission. Computational HEP also partners with the Office of Science's Advanced Scientific Computing Research (ASCR) program through Scientific Discovery through Advanced Computing (SciDAC), ensuring optimized HEP computing ecosystems for both immediate and long-term needs. This R&D includes high fidelity modeling and simulation, vital for developing and validating AI/ML methods and techniques, and funds a graduate Traineeship Program in Computational High Energy Physics, training scientists in critical skills like AI/ML and exascale software development.

Artificial Intelligence and Machine Learning

HEP AI/ML activities strategically support the Genesis Mission. Through partnerships, HEP develops and shapes the Platform's computing ecosystem to meet its data intensive and large user needs. This involves curating exabyte scale AI-ready data and developing transformational models and techniques that significantly enhance HEP research and drive new discoveries. HEP engages broadly in the Genesis Mission, from simulation and theoretical modeling to experiment design, real-time facility operations, and AI-ready infrastructure that couples world-leading computing and experimental facilities. This activity focuses on HEP's unique contributions and the integration of cutting-edge AI technologies for a clear AI advantage in the HEP mission.

Quantum Information Science

This activity supports QIS research and technology development that either extends the scientific reach of HEP or uses HEP techniques to improve our understanding of quantum systems. The HEP QIS research activities focus on topics in fundamental Quantum Theory, advancing Quantum Sensing and Computing for HEP applications, and deploying "pathfinder" experiments that demonstrate new capabilities and expand the discovery space for both HEP and QIS. The five National QIS Research Centers, jointly supported by multiple Office of Science programs, translate fundamental research into practical QIS applications and foster collaborations that support the overall Office of Science mission.

Microelectronics

This activity supports multi-disciplinary microelectronics technologies for sensing, communication, edge computing, and power, aiming for transformative advances in energy efficiency and resilience for HEP and broader Office of Science applications. HEP contributes to the cross-SC Microelectronics Science Research Centers (MSRCs), a network of multiple team awards that directly support research in energy efficiency for microelectronics or their operation in extreme radiation and temperature environments. These teams draw researchers from national laboratories, universities, and industry in which materials, chemistry, devices, systems, architectures, and algorithms and software are developed in tandem.

Facility Operations and Experimental Support

This activity supports the maintenance and operation of two Office of Science user facilities: FACET-II (a world-leading electron beam-driven plasma wakefield acceleration facility at SLAC National Accelerator Laboratory), and the Accelerator Test Facility (ATF) at Brookhaven National Laboratory. This activity also supports accelerator and detector test facilities at FNAL and Lawrence Berkeley National Laboratory. The activity also supports the BeamNetUS program, which provides limited user access to thirteen beam test facilities across the nation. AI/ML techniques are being integrated into these facilities to optimize beam performance, automate control systems, dynamically adjust resource deployment, and accelerate data analysis.

Activities and Explanation of Changes

(dollars in thousands)

FY 2026 Enacted		FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Accelerator & Technology R&D	**$304,544**	**$234,162**	**-$70,382**
Research	$242,247	$193,549	-$48,698
General Accelerator R&D	*$42,350*	*$13,069*	*-$29,281*
Funding maintains support for key expertise while sustaining essential aspects of accelerator R&D, including the Traineeship Program for Accelerator Science and Engineering.		The Request will maintain support for key expertise while sustaining essential aspects of accelerator R&D, including the Traineeship Program for Accelerator Science and Engineering, and collider R&D. Emphasis will be placed on collaborative efforts that drive discoveries within priority program areas.	Research funding will prioritize core R&D expertise and the Traineeship Program. Resources will focus on high-priority areas like high-field magnets and high-power targets, enabling strategic R&D for future accelerator technologies.
HEP Accelerator Stewardship	*$13,055*	*$7,816*	*-$5,239*
Funding maintains targeted support for key research activities, emphasizing advancements in superconducting magnets, beam physics, and data analytics-based accelerator controls across various research sectors.		The Request will maintain targeted support for key research activities, emphasizing advancements in superconducting accelerators, advanced laser technology, beam physics, and AI/ML-based accelerator controls.	Research funding will prioritize high-impact cross-cutting research in science, medicine, security, and industry, strengthening U.S. competitiveness. With projects rolling off, new R&D will target advancements in superconducting accelerators, advanced laser technology, beam physics, and AI/ML-based accelerator controls.
Accelerator Development	*$3,966*	*$2,867*	*-$1,099*
Funding continues to support efforts to work with and strengthen domestic suppliers for critical accelerator technologies and ongoing business sector studies to inform future collaborations and strategic insights.		The Request will support efforts to strengthen domestic suppliers for critical accelerator technologies.	Research funding will begin new partnerships as older partnerships conclude, ensuring a continuous and responsive approach to supply chain vulnerabilities.

(dollars in thousands)

FY 2026 Enacted	FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Detector R&D *$11,075*	*$10,268*	*-$807*
Funding maintains support for key expertise while sustaining essential aspects of Detector R&D, including the Traineeship Program in HEP Instrumentation.	The Request will maintain support for key expertise while sustaining core aspects of Detector R&D, including the Traineeship Program in HEP Instrumentation. Emphasis will be placed on collaborative efforts that drive discoveries within priority program areas.	Research funding will strategically focus on advanced particle detector technology in key areas such as novel devices and new modalities for calorimetry, tracking, and fast timing.
Computational HEP *$18,939*	*$8,994*	*-$9,945*
Funding maintains support for key expertise while sustaining essential aspects of Computational HEP, including the Traineeship Program in Computational HEP.	The Request will prioritize computationally advanced tools and methods that maximize HEP discovery science, while continuing support for critical expertise in advanced computing and the Traineeship Program in Computational HEP.	Research funding will prioritize essential R&D, strategically shifting focus towards implementation and adaptation of AI/ML tools necessary for advancing HEP discovery science.
Artificial Intelligence and Machine Learning *$80,851*	*$80,160*	*-$691*
Funding supports key advances from the use of AI/ML, enabling the management and analysis of vast datasets, the optimization of complex detector and particle beam systems, and the acceleration of scientific discovery through identification of subtle patterns and anomalies.	The Request will expand the HEP role in the Genesis Mission and focus the HEP AI/ML activities around collaborations to develop AI-ready datasets and transformative AI models. This activity will continue to develop the critical expertise in AI/ML necessary to develop future cutting-edge HEP facilities and experiments.	Research funding will prioritize the growth of HEP AI/ML activities in the Genesis Mission. HEP will make further investments to expand the availability of AI-ready datasets, while continuing R&D that makes use of them, to realize an AI advantage for HEP's world leading endeavors.
Quantum Information Science *$57,066*	*$59,919*	*+$2,853*
Funding supports interdisciplinary HEP QIS efforts through individual research grants and the National QIS Research Centers.	The Request will support interdisciplinary HEP QIS efforts through individual research grants and the National QIS Research Centers, including by expanding the HEP QIS portfolio to include new approaches in quantum sensing and computing with broad	Increased research funding will support a new effort in HEP QIS to provide annual funding opportunities to researchers to allow for quick responses to new developments and maintain an agile orientation to new research opportunities.

(dollars in thousands)

FY 2026 Enacted	FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
	potential impact both within HEP and in the National Quantum Initiative more broadly.	
Microelectronics *$14,945*	*$10,456*	*-$4,489*
Funding continues supporting microelectronics development at multiple national laboratories and universities as well as support for the Microelectronics Science Research Center projects.	The Request will continue supporting microelectronics development at multiple national laboratories and universities as well as support for the Microelectronics Science Research Center projects.	Research funding will prioritize the highest-impact R&D efforts, focusing support on the national laboratories and the Microelectronics Science Research Centers.
Facility Operations and Experimental Support $62,297	$40,613	-$21,684
Funding continues support for FACET-II at SLAC and ATF at BNL, key accelerator and detector test facilities at DOE national laboratories., and user access to nine test facilities through BeamNetUS.	The Request will continue support for FACET-II at SLAC and ATF at BNL, key accelerator and detector fabrication and test facilities at DOE national laboratories, and user access to thirteen beam test facilities through BeamNetUS. Emphasis will be placed on operations of facilities that drive discoveries within priority program areas.	Funding to support user activity at the network of test facilities will ramp down as others, including BeamNetUS, is strategically sustained and expanded, upholding world-leading support for HEP research.

Description

This subprogram supports line-item construction for the entire HEP program. All Total Estimated Costs (TEC) are funded in this subprogram, including engineering, design, and construction.

18-SC-42, Proton Improvement Plan II (PIP-II), FNAL

The PIP-II construction project is enhancing the Fermilab Accelerator Complex to enable higher-power proton beams for neutrino production, facilitating groundbreaking neutrino physics discoveries. Construction includes a new 800 MeV superconducting radio-frequency (SRF) proton linear accelerator and beam transfer line, along with modifications to the existing FNAL Booster, Recycler, and Main Injector synchrotrons. International, in-kind contributions will provide some components and the cryoplant. PIP-II received Critical Decision (CD)-3 approval on April 18, 2022, with a Total Project Cost (TPC) of $978,000,000. The CD-4 milestone date is 1Q FY 2033.

11-SC-40, Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment, FNAL

The LBNF/DUNE-US construction project is a federal, state, private, and international partnership focused on advancing particle accelerators and detector technologies to enable groundbreaking research into neutrinos, the universe’s most abundant yet enigmatic particles. LBNF/DUNE will investigate how muon neutrinos transform as they travel 800 miles from FNAL, where they are produced in a high-energy proton beam, to a massive detector in South Dakota. By analyzing these rare, flavor-changing transformations, the experiment aims to unravel the fundamental properties of neutrinos and address the puzzling matter-antimatter imbalance in the universe.

The LBNF/DUNE-US project is a national flagship particle physics initiative, representing the first multi-billion-dollar international science facility hosted by the United States. LBNF/DUNE-US comprises two key collaborative efforts: LBNF, responsible for the neutrino beamline at FNAL and the neutrino detector infrastructure at the Sanford Underground Research Facility (SURF) in South Dakota; and DUNE, an international collaboration defining the experiment’s scientific goals, technical requirements, detector design, construction, commissioning, and subsequent research.

The DOE High Energy Physics program manages both LBNF and DUNE as a single line-item construction project: LBNF/DUNE-US. Under the leadership of DOE and FNAL, and with participation from international partners including CERN, LBNF will construct a megawatt-class neutrino source (“Near Site”) at FNAL and underground caverns with cryogenic facilities (“Far Site”) in South Dakota to house the DUNE detectors. DUNE involves over 1,400 scientists and engineers from more than 200 institutions across 35+ countries, with the DOE funding approximately half of DUNE under the designation DUNE-US.

The LBNF/DUNE-US project received approval for CD-1RR (Update cost range, reaffirm the alternative selection, and approve a new tailoring strategy for baselining the project into five subprojects) on February 16, 2023, with a TPC Point Estimate of $3,277,000,000. The five subprojects are:

- Far Site Conventional Facilities – Excavation (FSCF-EXC)
- Far Site Conventional Facilities – Buildings and Site Infrastructure (FSCF-BSI)
- Far Detectors and Cryogenic Infrastructure (FDC)
- Near Site Conventional Facilities and Beamline (NSCF+B)
- Near Detector (ND)

The TPC Point Estimate will be refined as the project matures. When the last subproject is baselined, the LBNF/DUNE-US TPC will be the aggregate of all subproject TPCs plus any contingency being held by the parent LBNF/DUNE-US project.

Activities and Explanation of Changes

(dollars in thousands)

FY 2026 Enacted		FY 2027 Request	Explanation of Changes FY 2027 Request vs FY 2026 Enacted
Construction	**$374,000**	**$410,000**	**+$36,000**
18-SC-42, Proton Improvement Plan II (PIP-II), FNAL	$114,000	$105,000	-$9,000
Funding supports ongoing construction of the linac building and the fabrication and testing of production RF cavities, cryomodules, and related technical systems.		The Request will support completion of the Booster connection tunnel, continued cavity fabrication and cryomodule assembly, cryomodule installation, beamline installation, and the beginning of commissioning of the injector and warm front end.	The funding decrease is consistent with the baselined funding profile.
11-SC-40, Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment, FNAL	$260,000	$305,000	+$45,000
Funding supports ongoing construction of FSCF-BSI, begin installation of far detector components at FDC, and the design and prototyping activities for NSCF+B and ND.		The Request will support ongoing construction of FSCF-BSI, continue installation of far detector components and cryogenic infrastructure at FDC, and the design and reviews needed to transition into the execution phases of NSCF+B and ND.	Increased funding is critical to accelerate the construction and installation progress, enabling achievement of key FY 2027 project milestones. This ensures timely project completion and scientific payoff.

High Energy Physics
Capital Summary

(dollars in thousands)

	Total	Prior Years	FY 2025 Enacted	FY 2026 Enacted	FY 2027 Request	FY 2027 Request vs FY 2026 Enacted
Capital Operating Expenses						
Capital Equipment	N/A	N/A	58,924	49,225	47,612	-1,613
Minor Construction Activities						
General Plant Projects	N/A	N/A	5,000	13,500	6,000	-7,500
Accelerator Improvement Projects	N/A	N/A	–	–	9,000	+9,000
Total, Capital Operating Expenses	**N/A**	**N/A**	**63,924**	**62,725**	**62,612**	**-113**

High Energy Physics
Capital Equipment

	(dollars in thousands)					
	Total	**Prior Years**	**FY 2025 Enacted**	**FY 2026 Enacted**	**FY 2027 Request**	**FY 2027 Request vs FY 2026 Enacted**
Capital Equipment						
Major Items of Equipment						
Energy Frontier Experimental Physics						
High Luminosity Large Hadron Collider ATLAS Upgrade Project	183,485	146,985	16,200	15,300	5,000	-10,300
High Luminosity Large Hadron Collider CMS Upgrade Project	169,750	132,338	17,500	13,100	6,812	-6,288
Intensity Frontier Experimental Physics						
Accelerator Controls Operations Research Network	93,000	–	1,000	5,000	15,000	+10,000
Total, MIEs	446,235	279,323	34,700	33,400	26,812	-6,588
Total, Non-MIE Capital Equipment	N/A	N/A	24,224	15,825	20,800	+4,975
Total, Capital Equipment	**N/A**	**N/A**	**58,924**	**49,225**	**47,612**	**-1,613**

Note:
- *The Capital Equipment table includes MIEs with a Total Estimated Cost (TEC) > $10M.*

High Energy Physics
Minor Construction Activities

(dollars in thousands)

	Total	Prior Years	FY 2025 Enacted	FY 2026 Enacted	FY 2027 Request	FY 2027 Request vs FY 2026 Enacted
General Plant Projects (GPP)						
GPPs (greater than $5M and $34M or less)						
High Voltage Transformer Replacement 2027	6,000	–	–	–	6,000	+6,000
Total GPPs (greater than $5M and $34M or less)	6,000	N/A	–	–	6,000	+6,000
Total GPPs $5M or less	N/A	N/A	5,000	13,500	–	-13,500
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**5,000**	**13,500**	**6,000**	**-7,500**
Accelerator Improvement Projects (AIP)						
Total AIPs $5M or less	N/A	N/A	–	–	9,000	+9,000
Total, Accelerator Improvement Projects (AIP)	**N/A**	**N/A**	**–**	**–**	**9,000**	**+9,000**
Total, Minor Construction Activities	**N/A**	**N/A**	**5,000**	**13,500**	**15,000**	**+1,500**

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

High Energy Physics
Major Items of Equipment Description(s)

Energy Frontier Experimental Physics MIEs:

High-Luminosity Large Hadron Collider ATLAS Detector Upgrade Project (HL-LHC ATLAS)

The HL-LHC ATLAS Detector Upgrade Project received CD-2/3 approval on January 31, 2023, with a TPC of $200,000,000. Compared to the data-taking period prior to the HL-LHC upgrades, the ATLAS detector will be capable of collecting at least ten times more data. To enable the ATLAS detector to operate for an additional decade under such intense conditions, its silicon pixel and strip tracker, muon, and calorimeter detectors, along with its trigger and data acquisition systems, are being upgraded.[n] The FY 2027 Request for TEC funding of $5,000,000 marks the final year of funding needed, directed towards finalizing fabrication activities of U.S.-built deliverables. As components are completed, they will be delivered to the international ATLAS experiment for installation and integration into the overall upgraded detector.

High-Luminosity Large Hadron Collider CMS Detector Upgrade Project (HL-LHC CMS)

The HL-LHC CMS Detector Upgrade Project received CD-2/3 approval on April 4, 2023, with a TPC of $200,000,000. Compared to the data-taking period prior to the HL-LHC upgrades, the CMS detector will be capable of collecting at least ten times more data. To enable the CMS detector to operate for an additional decade under such intense conditions, its silicon pixel tracker and outer tracker, muon, and calorimeter detectors, along with its trigger and data acquisition systems, are being upgraded; and a novel timing detector is being added.[o] The FY 2027 Request for TEC funding of $6,812,000 marks the final year of funding needed, directed towards finalizing fabrication activities of U.S.-built deliverables. As components are completed, they will be delivered to the international CMS experiment for installation and integration into the overall upgraded detector.

Intensity Frontier Experimental Physics MIE:

Accelerator Controls Operations Research Network (ACORN)

The ACORN project received CD-0 approval on August 28, 2020, with an estimated cost range of $100,000,000 to $142,000,000. In FY 2026, HEP delegated the ACORN project to lab management. This project will replace FNAL's outdated accelerator control system with a modern system compatible with PIP-II. This new system will be capable of utilizing advances in AI/ML to enable high-performance accelerator operations for the future. The control system of the Fermilab Accelerator Complex initiates particle beam production; controls beam energy and intensity; steers particle beams to their ultimate destination; measures beam parameters; and monitors beam transport through the complex to ensure safe, reliable, and effective operations. The FY 2027 Request for TEC funding of $15,000,000 will support system design, software development, and procurement of control system hardware.

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[n] The National Science Foundation (NSF) approved support for a Major Research Equipment and Facility Construction (MREFC) project in FY 2020 to provide different scope to the HL-LHC ATLAS and HL-LHC CMS detector upgrades. DOE and NSF are coordinating their contributions to avoid duplication.

[o] The ATLAS and CMS detectors share a similar technical configuration, but employ different types of tracker subsystems, calorimeters, muon detector subsystems, and triggers.

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

High Voltage Transformer Replacement
General Plant Project Details

Project Name:	High Voltage Transformer Replacement 2027
Location/Site:	Fermilab Accelerator Complex
Type:	GPP
Total Estimated Cost:	$6,000,000
Construction Design:	$0
Project Description:	The 345kV on-site substations are beyond their end of life. The substations are a critical part of the infrastructure needed to run the accelerator complex. This project would replace a single 345kV transformer.

High Energy Physics
Construction Projects Summary

(dollars in thousands)

	Total	Prior Years	FY 2025 Enacted	FY 2026 Enacted	FY 2027 Request	FY 2027 Request vs FY 2026 Enacted
18-SC-42, Proton Improvement Plan II (PIP-II), FNAL						
Total Estimated Cost (TEC)	891,200	505,000	125,000	114,000	105,000	-9,000
Other Project Cost (OPC)	86,800	73,594	-	-	6,000	+6,000
Total Project Cost (TPC)	**978,000**	**578,594**	**125,000**	**114,000**	**111,000**	**-3,000**
11-SC-40, Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment						
Total Estimated Cost (TEC)	3,169,955	1,406,781	251,000	260,000	305,000	+45,000
Other Project Cost (OPC)	107,045	105,625	-	-	-	-
Total Project Cost (TPC)	**3,277,000**	**1,512,406**	**251,000**	**260,000**	**305,000**	**+45,000**
Total, Construction						
Total Estimated Cost (TEC)	**4,061,155**	**1,911,781**	**376,000**	**374,000**	**410,000**	**+36,000**
Other Project Cost (OPC)	**193,845**	**179,219**	**-**	**-**	**6,000**	**+6,000**
Total Project Cost (TPC)	**4,255,000**	**2,091,000**	**376,000**	**374,000**	**416,000**	**+42,000**

High Energy 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 2025 Enacted	FY 2025 Current	FY 2026 Enacted	FY 2027 Request	FY 2027 Request vs FY 2026 Enacted
Scientific User Facilities - Type A					
Fermilab Accelerator Complex	**181,500**	**170,222**	**166,500**	**174,089**	**+7,589**
Number of Users	1,020	2,213	2,213	2,213	–
Achieved Operating Hours	–	4,403	–	–	–
Planned Operating Hours	5,376	4,580	4,480	2,800	-1,680
Unscheduled Down Time Hours	–	295	–	–	–
Accelerator Test Facility	**–**	**–**	**4,347**	**6,393**	**+2,046**
Number of Users	–	–	22	101	+79
Planned Operating Hours	–	–	360	2,250	+1,890
Facility for Advanced Accelerator Experimental Tests II (FACET II)	**13,000**	**11,378**	**14,500**	**10,000**	**-4,500**
Number of Users	152	133	152	100	-52
Achieved Operating Hours	–	2,625	–	–	–
Planned Operating Hours	2,640	3,120	3,120	2,080	-1,040
Unscheduled Down Time Hours	–	1,128	–	–	–
Total, Facilities	**194,500**	**181,600**	**185,347**	**190,482**	**+5,135**
Number of Users	1,172	2,346	2,387	2,414	+27
Achieved Operating Hours	–	7,028	–	–	–
Planned Operating Hours	8,016	7,700	7,960	7,130	-830
Unscheduled Down Time Hours	–	1,423	–	–	–

Note:

- *Percent optimal operations defines what is achieved at this funding level. This includes staffing, up-to-date equipment and software, operations and maintenance, and appropriate investments to maintain world leadership.*
- *In FY 2025, funding, hours, and users for the Accelerator Test Facility were requested within the Accelerator R&D and Production program. For FY 2025 Current, $7,765,000, achieved 480 hours, 59 users, with 88 unscheduled downtime hours.*
- *In FY 2026, the Fermilab Accelerator Complex will be running the Booster Neutrino Beamline with the possibility of up to 16 weeks of Main Injector running if the critical substation transformer repairs are completed on schedule.*
- *In FY 2027, the Fermilab Accelerator Complex, for 20 weeks, will operate the Booster Neutrino Beam and commission Mu2e. The Main Injector will also run once transformer replacement is complete and as funding allows. Following this run, all efforts will shift to the extensive repairs and refurbishment required to prepare the Complex for LBNF/DUNE operations.*

High Energy Physics
Scientific Employment

	FY 2025 Enacted	FY 2026 Enacted	FY 2027 Request	FY 2027 Request vs FY 2026 Enacted
Number of Permanent Ph.Ds (FTEs)	722	676	465	-211
Number of Postdoctoral Associates (FTEs)	349	327	227	-100
Number of Graduate Students (FTEs)	489	448	332	-116
Number of Other Scientific Employment (FTEs)	1,477	1,432	1,485	+53
Total Scientific Employment (FTEs)	**3,037**	**2,883**	**2,509**	**-374**

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

18-SC-42, Proton Improvement Plan II (PIP-II), FNAL
Fermi National Accelerator Laboratory, FNAL
Project is for Design and Construction

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

Summary

The FY 2027 Request for the Proton Improvement Project II (PIP-II) is $105,000,000 in Total Estimated Cost (TEC) funding, part of an approved Total Project Cost (TPC) of $978,000,000. PIP-II will enhance the Fermilab Accelerator Complex to deliver higher-power proton beams for groundbreaking discoveries in neutrino physics. The project involves designing and constructing an 800 megaelectronvolt (MeV) superconducting radio frequency (SRF) proton linear accelerator and beam transfer line. It also includes modifying existing FNAL Booster, Recycler, and Main Injector synchrotrons. downstream from the new linear accelerator to accept the increased beam intensity. International in-kind contributions will provide certain components and the cryo-plant.

Significant Changes

Initiated in FY 2018, PIP-II received Critical Decision (CD)-3 (Approve Construction) approval on April 18, 2022. CD-4 (Project Completion) is planned for 1Q FY 2033.

Anticipated international in-kind technical contributions total $330,000,000 (DOE equivalent costing). Legally binding agreements are in place with all partnering countries, except for the French Atomic Energy Commission (CEA), whose agreement is expected in 2026. Non-binding Project Planning Documents (PPDs) providing additional technical details have been signed with Italian, Polish, and UK partner institutions. The signed PPD with India's Department of Atomic Energy laboratories is expected in 2026.

Significant project cost contingency usage through 4Q FY 2025 addressed changes in international in-kind contributions, bringing cryogenic distribution systems (distribution valve box, tunnel transfer lines) and portions of the radiofrequency power system (some solid-state power amplifiers) into DOE scope.

The FY 2025 Enacted funding supported linac building civil construction, prototype development and testing of SRF cavities and cryomodules, and testing of initial production cryomodules from international partners.

The FY 2026 Enacted supports completion of linac building civil construction, fabrication and testing of production SRF cavities, cryomodules, and other technical systems, and initiation of Booster connection tunnel civil construction.

The FY 2027 Request will support completion of the Booster connection tunnel, continued SRF cavity fabrication and cryomodule assembly, cryomodule and beamline installation, and the start of injector and warm front-end commissioning. Other Project Costs (OPC) funding will resume to procure consumables for subsystem commissioning.

A Level III certified Federal Project Director has been assigned and approved this construction project datasheet.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2027	11/12/15	7/23/18	7/23/18	12/14/20	4/18/22	4/18/22	1Q FY 2033

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 2027	12/14/20	3/16/21

CD-3A – Approve long-lead procurement of niobium for superconducting radio frequency (SRF) cavities and other long lead components for SRF cryomodules

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2026	135,895	755,305	891,200	86,800	86,800	978,000
FY 2027	135,895	755,305	891,200	86,800	86,800	978,000

2. Project Scope and Justification

Scope

Specific scope elements of the PIP-II project include construction of (a) the superconducting radio frequency (SRF) linac, (b) cryoplant to support SRF operation, (c) beam transfer line, (d) modifications to the Booster, Recycler and Main Injector synchrotrons, and (e) conventional facilities:

a) 800-MeV Superconducting H^- linac consisting of a 2.1 MeV warm (normal-conducting) front-end injector and five types of SRF cryomodules that are continuous wave capable but operating initially in pulsed mode. The cryomodules include Half Wave Resonator cavities (HWR) at 162.5 MHz, two types of Single Spoke Resonator cavities (SSR1 and SSR2) at 325 MHz, Low-Beta and High-Beta elliptical cavities at 650 MHz (LB-650 and HB-650). The warm front-end injector consists of an H^- ion source, Low Energy Beam Transport (LEBT), Radiofrequency Quadrupole (RFQ) and Medium Energy Beam Transport (MEBT) that prepare the beam for injection into the SRF cryomodules. The scope includes the associated electronic power sources, instrumentation, and controls to support linac operation.

   The PIP-II Injector Test Facility at FNAL is an R&D prototype for the low-energy proton injector at the front-end of the linac, consisting of H^- ion source, LEBT, RFQ, MEBT, HWR, and one SSR1 cryomodule. It was developed to reduce technical risks for the project, with participation and in-kind contributions from the India Department of Atomic Energy (DAE) Labs. The Test Facility has successfully completed its program and has been converted to a cryomodule test stand for testing the cryomodules for the project.

b) Cryoplant with storage and distribution system to support SRF linac operation. The cryoplant is an in-kind contribution by the India DAE Labs that is similar to the cryoplant being designed and constructed for a high-intensity superconducting proton accelerator project in India.[p]

c) Beam Transfer Line from the linac to the Booster Synchrotron, including accommodation of a beam dump and future delivery of beam to the FNAL Muon Campus.

d) Modification of the Booster, Recycler and Main Injector synchrotrons to accommodate a 50 percent increase in beam intensity and construction of a new injection area in the Booster to accommodate 800-megaelectronvolt (MeV) injection.

e) Civil construction of conventional facilities, including housings, service buildings, roads, access points and utilities with the special capabilities required for the linac and beam transport line. A portion of the civil construction scope comprises the ECF subproject. That subproject scope includes the cryogenics plant building and site work. The ECF subproject was initiated in FY 2020 with a total estimated cost of \$36,000,000 and was completed January 16th, 2025 for a total costs of \$29,168,000. The remaining subproject funds were redistributed to the PIP-II project contingency for remaining project risks.

Significant pieces of the linac and cryogenic scope (a and b above) will be delivered as in-kind international contributions not funded by DOE. These include assembly and/or fabrication of linac SRF components and the cryoplant. The rationale or motivation behind these contributions are institutional and/or industrial technical capability, and interest in SRF technology, as well as interest in LBNF/DUNE. The construction phase scope of in-kind contributions is divided between U.S. DOE national laboratories, India Department of Atomic Energy (DAE) Labs, Italy National Institute for Nuclear Physics (INFN) Labs, French Atomic Energy Commission (CEA) and National Center for Scientific Research (CNRS)-National Institute of Nuclear and Particle Physics (IN2P3) Labs, UK Science & Technology Facilities Council (STFC) Labs, and Wroclaw University of Science and Technology in Poland, tentatively as indicated in the following table of Scope Responsibilities for PIP-II.

Construction-phase Scope Responsibilities for PIP-II Linac RF Components

Components	Quan-tity	Freq. (MHz)	SRF Cavities	Responsibility for Cavity Fabrication	Responsibility for Module Assembly	Responsibility for RF Amplifiers	Cryogenic Cooling Source and Distribution System
RFQ	1	162.5	N/A	N/A	U.S. DOE (LBNL)	U.S. DOE (FNAL)	N/A
HWR Cryomodule	1	162.5	8	U.S. DOE (ANL)	U.S. DOE (ANL)	U.S. DOE (FNAL)	India DAE Labs, Poland WUST, U.S. DOE (FNAL)
SSR1 Cryomodule	2	325	16	U.S. DOE (FNAL), India DAE Labs	U.S. DOE (FNAL)	India DAE Labs	India DAE Labs, U.S. DOE (FNAL)
SSR2 Cryomodule	7	325	35	U.S. DOE (FNAL),	U.S. DOE (FNAL)	India DAE Labs,	India DAE Labs,

[p] See Section 8.

				France CNRS (IN2P3 Lab)		U.S. DOE (FNAL)	U.S. DOE (FNAL)
LB-650 Cryomodule	9	650	36	Italy INFN (LASA)	France CEA (Saclay Lab)	India DAE Labs, U.S. DOE (FNAL)	India DAE Labs, U.S. DOE (FNAL)
HB-650 Cryomodule	4	650	24	UK STFC Labs	UK STFC Labs, U.S. DOE (FNAL)	India DAE Labs, U.S. DOE (FNAL)	India DAE Labs, U.S. DOE (FNAL)

Justification

The PIP-II project will enhance the Fermilab Accelerator Complex by providing the capability to deliver higher-power proton beams to the neutrino-generating target that serves the LBNF/DUNE program for groundbreaking discovery in neutrino physics, a major field of fundamental research in high energy particle physics. Increasing the neutrino beam intensity requires increasing the proton beam power on target. PIP-II will raise the proton beam power from 800 kW to 1,200 kW over an energy range of 60-120 GeV and will enable the eventual increase to 2,400 kW with upgrades to the Booster accelerator. The PIP-II project will provide more flexibility for future science-driven upgrades to the entire accelerator complex and increase the system's overall reliability by addressing some of the accelerator complex's elements that are far beyond their design life.

PIP-II was identified as one of the highest priorities in the 10-year strategic plan for U.S. High Energy Physics developed by the High Energy Physics Program Prioritization Panel (P5) and unanimously approved by the High Energy Physics Advisory Panel (HEPAP), advising DOE and NSF, in 2014.[q]

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 Threshold KPPs represent the minimum acceptable performance that the project must achieve. The Objective KPPs represent the desired project performance. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion.

Performance Measure	Threshold	Objective
Linac Beam Energy	H- beam will be accelerated to 600 MeV.	H- beam will be accelerated to 700 MeV. Linac systems required for 800 MeV will be installed and tested.
Linac Beam Intensity	H- beam will be delivered to the beam absorber at the end of the linac.	H- beam with intensity of 1.3 x 10^{12} particles per pulse at 20 Hz pulse-repetition rate will be delivered to the Beam Transfer Line absorber.

[q] "Building for Discovery: Strategic Plan for U.S. Particle Physics in the Global Context," HEPAP, 2014.

Performance Measure	Threshold	Objective
Booster, Recycler and Main Injector Synchrotron Upgrades	Upgrades of the Booster, Recycler and Main Injector Synchrotrons, required to support delivery of 1.2 MW onto the LBNF target, will be installed and tested without beam.	Linac beam will be injected into and circulated in the Booster.

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	135,895	135,895	135,895	—
Total, Design (TEC)	**135,895**	**135,895**	**135,895**	**—**
Construction (TEC)				
Prior Years	359,105	359,105	182,963	—
Prior Years - IRA Supp.	10,000	10,000	—	8,021
FY 2025	125,000	125,000	139,112	1,969
FY 2026	114,000	114,000	131,733	10
FY 2027	105,000	105,000	120,632	—
Outyears	42,200	42,200	170,865	—
Total, Construction (TEC)	**755,305**	**755,305**	**745,305**	**10,000**
Total Estimated Cost (TEC)				
Prior Years	495,000	495,000	318,858	—
Prior Years - IRA Supp.	10,000	10,000	—	8,021
FY 2025	125,000	125,000	139,112	1,969
FY 2026	114,000	114,000	131,733	10
FY 2027	105,000	105,000	120,632	—
Outyears	42,200	42,200	170,865	—
Total, Total Estimated Cost (TEC)	**891,200**	**891,200**	**881,200**	**10,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	73,594	73,594	73,421	–
FY 2027	6,000	6,000	619	–

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Outyears	7,206	7,206	12,760	–
Total, Other Project Cost (OPC)	**86,800**	**86,800**	**86,800**	**–**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	568,594	568,594	392,279	–
Prior Years - IRA Supp.	10,000	10,000	–	8,021
FY 2025	125,000	125,000	139,112	1,969
FY 2026	114,000	114,000	131,733	10
FY 2027	111,000	111,000	121,251	–
Outyears	49,406	49,406	183,625	–
Total, TPC	**978,000**	**978,000**	**968,000**	**10,000**

Note:
- *Prior Years reflect actual costs; remaining years are cost estimates.*

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	135,895	135,895	146,314
Design - Contingency	N/A	N/A	30,686
Total, Design (TEC)	**135,895**	**135,895**	**177,000**
Construction_No_Detail	186,000	182,000	124,009
Site Preparation	13,000	13,000	12,783
Equipment	493,918	455,305	378,705
Construction Contingency	62,387	105,000	198,703
Total, Construction (TEC)	**755,305**	**755,305**	**714,200**
Total, TEC	**891,200**	**891,200**	**891,200**
Contingency, TEC	*62,387*	*105,000*	*229,389*
Other Project Cost (OPC)			
R&D	67,117	67,117	67,117
Conceptual Planning	8,324	8,324	8,324
Conceptual Design	2,855	2,855	2,855

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
OPC - Contingency	8,504	8,504	8,504
Total, Except D&D (OPC)	**86,800**	**86,800**	**86,800**
Total, OPC	**86,800**	**86,800**	**86,800**
Contingency, OPC	*8,504*	*8,504*	*8,504*
Total, TPC	**978,000**	**978,000**	**978,000**
Total, Contingency (TEC+OPC)	***70,891***	***113,504***	***237,893***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2025	FY 2026	FY 2027	Outyears	Total
FY 2026	TEC	505,000	125,000	114,000	—	147,200	891,200
	OPC	73,594	—	—	—	13,206	86,800
	TPC	578,594	125,000	114,000	—	160,406	978,000
FY 2027	TEC	505,000	125,000	114,000	105,000	42,200	891,200
	OPC	73,594	—	—	6,000	7,206	86,800
	TPC	578,594	125,000	114,000	111,000	49,406	978,000

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	1Q FY 2033
Expected Useful Life	20 years
Expected Future Start of D&D of this capital asset	1Q FY 2053

FNAL will operate the PIP-II linac as an integral part of the entire Fermilab Accelerator Complex. Related funding estimates for operations, utilities, maintenance, and repairs are incremental to the balance of the FNAL accelerator complex for which the present cost of operation, utilities, maintenance, and repairs is approximately $100,000,000 annually.

Related Funding Requirements
(dollars in thousands)

	Annual Costs		**Life Cycle Costs**	
	Previous Total Estimate	**Current Total Estimate**	**Previous Total Estimate**	**Current Total Estimate**
Operations	4,000	4,000	80,000	80,000
Utilities	3,000	3,000	60,000	60,000
Maintenance and Repair	2,000	2,000	40,000	40,000
Total, Operations and Maintenance	9,000	9,000	180,000	180,000

7. D&D Information

The new area being constructed in this project is not replacing existing facilities.

	Square Feet
New area being constructed by this project at FNAL	127,676
Area of D&D in this project at FNAL	—
Area at FNAL to be transferred, sold, and/or D&D outside the project, including area previously "banked"	—
Area of D&D in this project at other sites	—
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	127,676
Total area eliminated	—

The one-for-one replacement will be met through banked space. A waiver from the one-for-one requirement to eliminate excess space at FNAL to offset PIP-II and other projects was approved by DOE Headquarters on November 12, 2009. The waiver identified and transferred to FNAL 575,104 square feet of excess space to accommodate new facilities including Mu2e, LBNF, DUNE, and other facilities, planned or anticipated for future experiments, from space that was banked at other DOE facilities. The PIP-II Project is following all current DOE procedures for tracking and reporting space utilization.

8. Acquisition Approach

DOE is acquiring the PIP-II project through Fermi Forward Discovery Group (FFDG), the Management and Operating (M&O) contractor responsible for FNAL, rather than have the DOE compete a contract for fabrication to a third party. FFDG has a strong relationship with the high energy physics community and its leadership, including many FNAL scientists and engineers. This arrangement will facilitate close cooperation and coordination for PIP-II with an experienced team of project leaders managed by FFDG, which will have primary responsibility for oversight of all subcontracts required to execute the project. The arrangement is expected to include subcontracts for the purchase of components from third party vendors as well as delivery of in-kind contributions from non-DOE partners.

Project partners will deliver significant pieces of scope as in-kind international contributions, not funded by U.S. DOE. The rationale or motivation behind these contributions are institutional and/or industrial technical capability, long-standing collaborations in the physics programs at FNAL that PIP-II will support, and interest in SRF technology. Scientific institutions from several countries, tabulated below, are engaged in discussion of potential PIP-II scope contributions within the framework of international, government-to-government science and technology agreements.

Scientific Agencies and Institutions Discussing Contributions of Scope for PIP-II

Country	Funding Agency	Institutions
U.S.	Department of Energy	Fermi National Accelerator Laboratory; Lawrence Berkeley National Laboratory; Argonne National Laboratory
India	Department of Atomic Energy	Bhabha Atomic Research Centre, Mumbai; Inter University Accelerator Centre, New Delhi;

Scientific Agencies and Institutions Discussing Contributions of Scope for PIP-II

Country	Funding Agency	Institutions
		Raja Ramanna Centre for Advanced Technology, Indore; Variable Energy Cyclotron Centre, Kolkata
Italy	National Institute for Nuclear Physics	Laboratory for Accelerators and Applied Superconductivity, Milan
France	Atomic Energy Commission National Center for Scientific Research	Saclay Nuclear Research Center; National Institute of Nuclear & Particle Physics, Paris
UK	Science & Technology Facilities Council	Daresbury Laboratory
Poland	Wroclaw University of Science and Technology	Wroclaw University of Science and Technology

For example, joint participation by U.S. DOE and the India DAE in the development and construction of high intensity superconducting proton accelerator projects at FNAL and in India is codified in Annex I to the "Implementing Agreement between DOE and Indian Department of Atomic Energy in the Area of Accelerator and Particle Detector Research and Development for Discovery Science for High Intensity Proton Accelerators," signed in January 2015 by the U.S. Secretary of Energy and the India Chairman of DAE. FNAL and DAE Labs subsequently developed a "Joint R&D Document" outlining the specific roles and goals of the collaborators during the R&D phase of the PIP-II project. This R&D agreement is expected to lead to a similar agreement for the construction phase, describing roles and in-kind contributions. DOE and FNAL have signed similar agreements with Poland, Italy, France (CNRS and IN2P3), and UK for PIP-II. DOE is coordinating with France (CEA) to develop and sign a PIP-II cooperative agreement in FY 2026; the PPD is expected to be signed the year after.

SC in coordination with FNAL has put mechanisms into place to facilitate joint consultation between the partnering funding agencies, such that coordinated oversight and actions will ensure the success of the overall program. SC is successfully employing similar mechanisms for international partnering for the DOE LBNF/DUNE-US project and for DOE participation in LHC-related projects hosted by CERN.

Domestic engineering and construction subcontractors will perform the civil construction at FNAL. FNAL is utilizing a firm fixed-price contract for architectural-engineering services to complete all remaining designs for conventional facilities with an option for construction support. The general construction subcontract has been placed on a firm-fixed-price basis, and work has begun at the laboratory.

All subcontracts will be competitively bid and awarded based on best value to the government. Fermi Site Office provides contract oversight for FFDG's plans and performance. Project performance metrics for FFDG are typically included in the M&O contractor's annual performance evaluation and measurement plan.

11-SC-40, Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment, FNAL
Fermi National Accelerator Laboratory, FNAL
Project is for Design and Construction

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

Summary

The Deep Underground Neutrino Experiment (DUNE) is an international flagship experiment to unlock the mysteries of neutrinos. DUNE will be installed in the Long-Baseline Neutrino Facility (LBNF). DUNE scientists could potentially transform our understanding about the nature of matter and the evolution of the universe. Department of Energy's Fermilab serves as the host laboratory and "near site" for DUNE, in partnership with funding agencies and more than 1,400 scientists and engineers[r] globally. The Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE-US) is the line-item project that enables the facilities and technologies needed to operate the experiment.

The FY 2027 Request for Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE-US) project is $305,000,000 of Total Estimated Cost (TEC) funding.

To improve planning and management control, the LBNF/DUNE-US scope is organized into five subprojects. The CD-1 Reaffirmation (CD-1RR), approved on February 16, 2023, established the subproject strategy and a cost range of $3,160,000,000 to $3,677,000,000. At CD-1RR approval, the Total Project Cost (TPC) Point Estimate was $3,277,000,000. This estimate was for planning purposes and will be refined as the project matures and each subproject is baselined. The aggregate of the baselined subproject TPCs must remain below the upper end of the approved cost range. The final LBNF/DUNE-US TPC, once all subprojects are baselined, will be the sum of all subproject TPCs plus any contingency being held by the parent project. As the project matures, the distribution of Project Engineering and Design (PED) and construction funds is refined for accuracy. Additionally, earlier PED investments, such as prototyping, have reduced risks and costs for future execution phases.

The five subprojects are:

- Far Site Conventional Facilities – Excavation (FSCF-EXC)
- Far Site Conventional Facilities – Buildings and Site Infrastructure (FSCF-BSI)
- Far Detectors and Cryogenic Infrastructure (FDC)
- Near Site Conventional Facilities and Beamline (NSCF+B)
- Near Detector (ND)

Significant Changes

The FY 2025 funding supported construction of FSCF-BSI; continued long-lead procurements for FDC and NSCF+B subprojects; and advanced design and other planning efforts for NSCF+B and ND.

The FY 2026 funding will continue to support FSCF-BSI construction; complete the FSCF-EXC scope; continue long-lead procurements for FDC; initiate installation of far detector components at FDC; support design and prototyping activities for NSCF+B and ND; facilitate preparations for baselining Near Site subprojects; and assist with preparations to award construction subcontracts for the Near Site facilities.

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[r] https://lbnf-dune.fnal.gov/people/dune-collaboration/

The FY 2027 Request will continue FSCF-BSI construction; proceed with fabrication and assembly of FDC long-lead procurements; support installation of far detector components and cryogenic infrastructure at FDC; and facilitate design and reviews to transition into the execution phases of NSCF+B and ND.

A Federal Project Director with a certification level 4 is assigned to this project and has approved this CPDS.

Critical Milestone History

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
LBNF/DUNE-Overall	1/8/10	11/5/15	11/5/15	4Q FY 2027	1Q FY 2027	4Q FY 2027	1Q FY 2035
Far Site Conventional Facilities-Excavation	–	–	–	8/19/22	12/31/20	8/19/22	1Q FY 2027
Far Site Conventional Facilities-Buildings and Site Infrastructure	–	–	–	3/25/23	11/20/20	3/25/23	4Q FY 2028
Far Detectors and Cryogenic Infrastructure	–	–	–	3Q FY 2026	2Q FY 2026	3Q FY 2026	2Q FY 2034
Near Site Conventional Facilities and Beamline	–	–	–	4Q FY 2027	1Q FY 2027	4Q FY 2027	2Q FY 2034
Near Detector	–	–	–	1Q FY 2027	1Q FY 2027	4Q FY 2027	1Q FY 2035

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.

	Performance Baseline Validation	CD-1R	CD-1RR	CD-3A	CD-3B	CD-3C
LBNF/DUNE-Overall	4Q FY 2027	11/5/15	2/16/23	3/25/23	2/28/24	2/21/25
Far Site Conventional Facilities-Excavation	8/19/22	—	2/16/23	10/27/20	–	–
Far Site Conventional Facilities-Buildings and Site Infrastructure	3/25/23	—	2/16/23	–	–	–
Far Detectors and Cryogenic Infrastructure	3Q FY 2026	—	2/16/23	2/21/23	2/28/24	2/21/25
Near Site Conventional Facilities and Beamline	4Q FY 2027	—	2/16/23	3/25/23	–	–

	Performance Baseline Validation	CD-1R	CD-1RR	CD-3A	CD-3B	CD-3C
Near Detector	1Q FY 2027	—	2/16/23	–	–	–

CD-1R – Refresh of CD-1 approval for the new Conceptual Design.

CD-1RR – Update cost range, reaffirm the alternative selection, and approve a new tailoring strategy for baselining the project in multiple subprojects.
CD-3A – Approve initial construction and long lead procurements to mitigate risks and avoid delays. The CD-3a scope for the Far Site Conventional Facilities- Excavation Subproject was for initial construction activities, including systems to prepare for large-scale cavern excavation, excavation of ancillary spaces, and establishing underground ventilation paths. The CD-3A scope for the Far Detectors and Cryogenic Infrastructure subproject is long-lead procurement of certain components of the detector electronics, photon detectors, and the anode plane assemblies. The CD-3A scope for the Near Site Conventional Facilities and Beamline subproject is long-lead procurement of shielding and accelerator kicker components, early fabrication of magnetic horn components, and wetlands work that must be completed before the corresponding USACE permit expires.
CD-3B – Approve long lead procurements to mitigate risks and avoid delays. The CD-3B scope for the Far Detectors and Cryogenic Infrastructure subproject is long-lead procurement of certain components of cryogenic systems, detector systems, and infrastructure items to support the detectors.
CD-3C – Approve long lead procurements to mitigate risks and avoid delays. The proposed CD-3C scope for the Far Detectors and Cryogenic Infrastructure subproject is long-lead procurement of certain components of cryogenic systems, detector systems, and infrastructure items to support the detectors.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2026	705,838	2,464,117	3,169,955	107,045	107,045	3,277,000
FY 2027	715,838	2,454,117	3,169,955	107,045	107,045	3,277,000

Notes:
- *As some subprojects are Pre-CD-2, all estimates are preliminary. The approved TPC range for CD-1RR is $3,160,000,000 to $3,677,000,000.*
- *No construction, other than site preparation and approved long-lead procurement, will be performed prior to validation of the Performance Baseline and approval of CD-3 for each subproject.*

2. Project Scope and Justification

Scope

The LBNF/DUNE-US construction project is a federal, state, private, and international partnership developing and implementing particle accelerator and detector technologies, to enable world-leading research into the fundamental physics of neutrinos, which are the most ubiquitous and mysterious particles in the universe. Neutrinos are intimately involved in nuclear decay processes and high energy nuclear reactions. LBNF/DUNE will study the transformations of muon neutrinos into electron neutrinos. Muon neutrinos produced in a high-energy beam at FNAL undergo transformations as they travel 800 miles to large underground detectors in South Dakota. Analyzing these rare, in-flight neutrino transformations is expected to illuminate the fundamental physics of neutrinos and address the puzzling matter-antimatter asymmetry crucial for our matter-dominated universe.

LBNF/DUNE will comprise a neutrino beam, massive neutrino detectors and associated cryogenics infrastructure. The beamline will be generated through new construction and modifications to the existing Fermilab Accelerator Complex. This process involves the acceleration of a primary proton beam, its interaction with a target to produce a secondary particle beam, and the subsequent decay of these particles into neutrinos within a hundreds-of-meters decay tunnel. A smaller neutrino detector will be located at FNAL to monitor the neutrino beam near its source. The massive "far site" detectors and their associated cryogenics infrastructure will be housed in large underground caverns, 4850 feet below the surface, at the Sanford Underground Research Facility (SURF), located approximately 800 miles from the beam source. The Neutrinos at the Main Injector (NuMI) beam at FNAL is an existing example of this type of neutrino beam facility. The new LBNF beamline will, however, provide a neutrino beam of greater intensity than the NuMI beam, pointing to much larger far detector modules at a greater distance than utilized by NuMI experiments.

For the LBNF/DUNE-US project, FNAL is responsible for design, construction, and operation of the major components which enable the DUNE research program including: the primary proton beam, neutrino production target, focusing structures, decay pipe, absorbers and corresponding beam instrumentation; the conventional facilities and experiment infrastructure on the FNAL site required for the near detector; and the conventional facilities and experiment infrastructure at SURF for the large detectors including the cryostats and cryogenics systems. LBNF/DUNE-US provides detector components for the DUNE research program and supports the installation and integration of detector components provided by international partners.

<u>Justification</u>

As part of implementation of High Energy Physics Advisory Panel (HEPAP)-Particle Physics Project Prioritization Panel (P5) recommendations the LBNF/DUNE-US project comprises a national flagship particle physics initiative and consists of two multinational collaborative efforts:

- LBNF is responsible for delivering the beamline and other experimental and civil infrastructure at FNAL and at SURF in South Dakota. SURF, operated by the South Dakota Science and Technology Authority (SDSTA), an agency of the State of South Dakota, hosts experiments supported by DOE, NSF, and major research universities.

- DUNE is an international scientific collaboration responsible for defining the scientific goals and technical requirements for the beam and detectors, as well as the design, fabrication of detector components and subsequent research program. The U.S. contributes to DUNE along with other international funding agencies; hence DUNE-US is the project component of this overall effort. DOE and FNAL host the international DUNE research program.

DOE's High Energy Physics program manages the DOE contributions to both construction activities as a single, line-item construction project—LBNF/DUNE-US. LBNF, with DOE/FNAL leadership, and minority participation by international partners including CERN, will construct a megawatt-class neutrino source and related facilities at FNAL (the "Near Site"), as well as underground caverns and cryogenic facilities in South Dakota (the "Far Site") needed to house the DUNE detectors. DOE will fund approximately one half of the DUNE detectors, excluding the cryostats, which will be provided by CERN. The project continues to refine its design and cost estimates as the U.S. DOE contributions to the multinational effort become better understood. The cost estimate for DOE contributions will be updated as planning continues in preparation for baselining each subproject.

FNAL and DOE have confirmed contributions to LBNF documented in international agreements from CERN, the UK, and other international partners. For the DUNE detectors, the collaboration put in place a process to complete a technical design of the detectors and divide the work of building the detectors between the collaborating institutions. The review of the detector design with a complete set of funding responsibilities by the Long Baseline Neutrino Committee began in 2019, and development of the set of funding responsibilities continues to advance appropriately. Commitments for detector contributions and associated planning are being finalized in advance of each relevant subproject being baselined. SC will manage all DOE contributions to the facility and the detectors according to DOE Order 413.3B, and FNAL will provide unified project management reporting.

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*.

<u>Key Performance Parameters (KPPs)</u>
The KPPs are preliminary and will be finalized and approved with each subproject.
The Threshold KPPs represent the minimum acceptable performance that the project must achieve. The Objective KPPs represent the desired project performance. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion. KPPs for each subproject are finalized with the approval of relevant subproject CD-2.

Performance Measure	Threshold	Objective
Far Site Conventional Facilities – Excavation (FSCF-EXC)	1) Provide power capacity at the 4850L capable of supporting 10 MW demand. 2) Provide a ventilation route capable of exhausting 200,000 Cubic Feet per Minute though the spray chamber. 3) Complete the Ross Shaft brow enlargement and the excavation of all ancillary spaces and access drifts to create a minimum of 71,500 Gross Square Feet (GSF). 4) Complete the excavation of three caverns with the following volumes including all required ground support, shotcrete placement and networked geotechnical monitoring system: a. North cavern (102,000 Cubic Yards (CY)) b. South cavern (102,000 CY) c. Central utility cavern (46,800 CY) 5) Provide a minimum of 170,000 GSF of concrete floor.	All Threshold KPPs
Far Site Conventional Facilities – Buildings and Site	1) 1200A at 12.47kV power capacity installed in the CUC (sufficient to support four cryostats/detectors). 2) Power distribution at 120/240V, 480V, and 4160V installed at the 4850L to support two	Expanded power distribution and chilled water systems installed to support four cryostats/detectors. This adds 400 tons (1.4 MW) for a total of 2000 tons (7 MW) of chilled water capacity and

Performance Measure	Threshold	Objective
Infrastructure (FSCF-BSI)	detectors, along with all general use power installed at the 4850L and 4910L. 3) Heat rejection cooling tower installed with 2,000-ton (7 MW) rejection capacity (sufficient to support four detectors. 4) 1,600 tons (5.6 MW) chilled water capacity installed to support two detectors and all general cooling loads at the 4850L.	transformers/power distribution specific to detectors 3 and 4.
Far Detector – Horizontal Drift Detector Components (FDC)	Fabricate, deliver to SURF, and install the deliverables for the Horizontal Drift detector providing coverage for at least 95 percent of the detector volume. This includes: the Anode Plane Assemblies, High Voltage field cage structures and Cathode Planes; TPC electronics; components of the Photon Detector System; and purity monitors for one horizontal-drift Liquid Argon (LAr) TPC. Deliver and install the corresponding detector parts, DAQ servers and services outside the cryostat.	Fabricate, deliver to SURF, and install the deliverables for the Horizontal Drift Detector providing full (100 percent) coverage.
Far Detector – Vertical Drift Detector Components (FDC)	Fabricate, deliver to SURF, and install the deliverables for the Vertical Drift Detector providing coverage for at least 95 percent of the detector volume. This includes: the Charge Readout Planes for the bottom drift volume, High Voltage field cage structures; electronics for the readout of the bottom charge readout planes; components of the Photon Detector System; and purity monitors for one vertical-drift LAr TPC. Deliver and install the corresponding detector parts, DAQ servers and services outside the cryostat.	Fabricate, deliver to SURF, and install the deliverables for the Vertical Drift Detector providing full (100 percent) coverage.
Far Site Cryogenic Infrastructure (FDC)	1) Design, procure, install and commission the Nitrogen refrigeration system capable of providing 300 kW cooling capacity to the detector modules. 2) Install and commission surface receiving facilities for cryogenic liquids. 3) Install and commission the Argon purification, circulation, regeneration, and condenser system for two cryostat detectors.	In addition to the threshold KPPs: 1) Commit funds for the procurement of the remaining 70 percent of the LAr for the first FD module.

Performance Measure	Threshold	Objective
	4) Install and test internal cryogenics for Gaseous Argon/LAr distribution. 5) Provide operational readiness clearance for the operation of the cryogenic systems and for filling with LAr the first two cryostats. 6) Set up the contract with options to procure the necessary amount of LAr for each of the Far Detectors' (Horizontal and Vertical drift) LAr TPC modules, per FDC Requirements. 7) Commit funds for procuring 30 percent of the LAr for each of the two far detectors.	
Far Site Far Detector Integration (FDC)* *Note that the KPPs defined for Far Detector Horizontal and Vertical Detector Components and the Cryogenic Infrastructure are pre-requisites to the KPPs for the Far Detector Integration.	1) Prior to final cryostat closure, demonstrate continuous readout of the TPC electronics and the photon detector system at room temperature, via the data acquisition system, for one week. This demonstration must achieve a live time of at least 50 percent and a minimum of 95 percent fully functional electronic readout channels. 2) Close both cryostats in preparation for purging and filling. Purge and fill both cryostats to a minimum level (30 percent) and demonstrate LAr recirculation and purification.	1) Prior to the final closure of the two cryostats, demonstrate, at room temperature, continuous readout of the TPC electronics and of the photon detector system through the data acquisition system for one week with a live time of at least 90 percent and a minimum of 99 percent fully functional electronic readout channels. 2) Completely fill the first cryostat and demonstrate LAr recirculation and purification. 3) Establish an electrical field in the drift volume of at least 250 V/cm with a live time of at least 80 percent. 4) Demonstrate that all the channels can continue to be read out in each detector module after the cryostats are filled. Observe signals from cosmic ray tracks with the charge and light detection systems. Demonstrate coincidences between TPC and photon detector signals.

Performance Measure	Threshold	Objective
		5) Perform measurements of the electron lifetime in LAr using the purity monitors for each of the two cryostats.
Near Site Conventional Facilities and Beamline (NSCF+B)	1) Primary Beamline: • Conventional facilities and beamline constructed to be capable of 2.4MW operation • Beamline under vacuum with all magnets ramped on 120 GeV operations cycle 2) Neutrino Beamline: • Conventional facilities constructed to support 2.4MW proton beam • Target Hall to support a three-horn focusing system optimized for oscillation science • Decay Region minimum 635 ft in length • Shielding and absorbers constructed to support 2.4MW operation • Horns, target, radioactive water system, and beam windows fabricated for 1.2 MW proton beam • Operation of target pile, decay pipe, horn, and absorber cooling systems • Two-horn focusing system pulsed in situ to 240kA • Target cooling system flow demonstrated in situ • Target shield pile sealed to outside air 3) ND Complex: • Cavern space with minimum volume of 700,000 cubic ft • Power infrastructure has a capacity of 2,700kVA running load	1) Primary Beamline: • 120GeV protons delivered to the absorber with the target removed 2) Neutrino Beamline: • Three horns pulsed in situ to 300kA • Muons observed downstream of absorber 3) Near Detector Complex • All threshold KPPs

Performance Measure	Threshold	Objective
	• Cooling infrastructure includes a minimum of 650 tons of chiller capacity	
Near Detector	Hardware installed for a neutrino beam monitor capable of detecting a 1 percent shift in the horn current within a period of one week of nominal 1.2MW exposure, with performance verified by simulation.	1) All Threshold KPPs using parts and components provided by both the project and international partners (in-kind). 2) Deliver a LAr Time Projection Chamber (TPC) detector system capable of measuring neutrino interactions in argon at the near site, with performance like that specified for the Far Detector, to directly support long-baseline physics measurements in the DUNE FD. 3) Enable movement of the LAr TPC near detector system to an off-axis location. 4) Enable monitoring of the on-axis neutrino beam when the LAr TPC near detector system is off-axis position.

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	632,418	632,418	491,779	—
FY 2025	46,260	46,260	73,583	—
FY 2026	29,910	29,910	121,061	—
FY 2027	3,060	3,060	24,734	—
Outyears	4,190	4,190	4,681	—
Total, Design (TEC)	**715,838**	**715,838**	**715,838**	**—**
Construction (TEC)				

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Prior Years	649,363	649,363	492,514	—
Prior Years - IRA Supp.	125,000	125,000	—	19,902
FY 2025	204,740	204,740	89,715	83,553
FY 2026	230,090	230,090	376,564	21,545
FY 2027	301,940	301,940	152,817	—
Outyears	942,984	942,984	1,217,507	—
Total, Construction (TEC)	**2,454,117**	**2,454,117**	**2,329,117**	**125,000**
Total Estimated Cost (TEC)				
Prior Years	1,281,781	1,281,781	984,293	—
Prior Years - IRA Supp.	125,000	125,000	—	19,902
FY 2025	251,000	251,000	163,298	83,553
FY 2026	260,000	260,000	497,625	21,545
FY 2027	305,000	305,000	177,551	—
Outyears	947,174	947,174	1,222,188	—
Total, Total Estimated Cost (TEC)	**3,169,955**	**3,169,955**	**3,044,955**	**125,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	105,625	105,625	94,479	–
FY 2025	–	–	362	–
FY 2026	–	–	7,017	–
FY 2027	–	–	1,350	–
Outyears	1,420	1,420	3,837	–
Total, Other Project Cost (OPC)	**107,045**	**107,045**	**107,045**	**–**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	1,387,406	1,387,406	1,078,772	–
Prior Years - IRA Supp.	125,000	125,000	–	19,902
FY 2025	251,000	251,000	163,660	83,553

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
FY 2026	260,000	260,000	504,642	21,545
FY 2027	305,000	305,000	178,901	–
Outyears	948,594	948,594	1,226,025	–
Total, TPC	**3,277,000**	**3,277,000**	**3,152,000**	**125,000**

Note:
- *Prior Years reflect actual costs; remaining years are cost estimates.*

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	701,246	691,246	**N/A**
Design - Contingency	14,592	14,592	**N/A**
Total, Design (TEC)	**715,838**	**705,838**	**N/A**
Construction_No_Detail	1,359,163	1,369,163	**N/A**
Equipment	594,984	594,984	**N/A**
Construction Contingency	499,970	499,970	**N/A**
Total, Construction (TEC)	**2,454,117**	**2,464,117**	**N/A**
Total, TEC	**3,169,955**	**3,169,955**	**N/A**
Contingency, TEC	*514,562*	*514,562*	***N/A***
Other Project Cost (OPC)			
R&D	16,000	16,000	**N/A**
Conceptual Planning	44,958	44,958	**N/A**
Conceptual Design	31,977	31,977	**N/A**
Other OPC Costs	11,220	11,220	**N/A**
OPC - Contingency	2,890	2,890	**N/A**
Total, Except D&D (OPC)	**107,045**	**107,045**	**N/A**
Total, OPC	**107,045**	**107,045**	**N/A**
Contingency, OPC	*2,890*	*2,890*	***N/A***
Total, TPC	**3,277,000**	**3,277,000**	**N/A**
Total, Contingency (TEC+OPC)	***517,452***	***517,452***	***N/A***

Notes:
- *Each subproject will have a validated baseline at the time of each subproject's CD-2 approval.*

- *Construction involves excavation of caverns at SURF, 4,850 ft. below the surface, for technical equipment including particle detectors and cryogenic systems and construction of the housing for the neutrino-production beam line and the near detector.*
- *Technical equipment in the DOE scope, estimated here, will be supplemented by in-kind contributions of additional technical equipment, for the accelerator beam and particle detectors, from non-DOE partners as described in Section 2.*
- *"Other OPC Costs" include execution support costs including electrical power for construction* and equipment installation.

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2025	FY 2026	FY 2027	Outyears	Total
FY 2026	TEC	1,406,781	251,000	251,000	—	1,261,174	3,169,955
	OPC	105,625	—	—	—	1,420	107,045
	TPC	1,512,406	251,000	251,000	—	1,262,594	3,277,000
FY 2027	TEC	1,406,781	251,000	260,000	305,000	947,174	3,169,955
	OPC	105,625	—	—	—	1,420	107,045
	TPC	1,512,406	251,000	260,000	305,000	948,594	3,277,000

Note:
- *All estimates are preliminary.*

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	1Q FY 2035
Expected Useful Life	20 years
Expected Future Start of D&D of this capital asset	1Q FY 2055

Operations and maintenance funding of this experiment will be integrated into the existing Fermilab Accelerator Complex Users Facility. Annual related funding estimates include the incremental cost of 20 years of full operation, utilities, maintenance, and repairs with the accelerator beam on. The estimates also include operations and maintenance for the remote site of the large detector. New operations and maintenance estimates were developed in 2022 based on a new study and detailed estimating. Current estimate represents an average annual cost in FY 2022 dollars.

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations	22,000	22,000	440,000	440,000
Utilities	6,000	6,000	120,000	120,000
Maintenance and Repair	14,000	14,000	280,000	280,000
Total, Operations and Maintenance	42,000	42,000	840,000	840,000

7. D&D Information

The new area constructed in this project replaces existing facilities.

	Square Feet
New area being constructed by this project at FNAL	79,100
New area being constructed by this project at Sanford Underground Research Facility (SURF)	185,700
Area of D&D in this project at FNAL	—
Area at FNAL to be transferred, sold, and/or D&D outside the project, including area previously “banked”	79,100
Area of D&D in this project at other sites	—
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously “banked”	185,700
Total area eliminated	—

The new facility square footage estimates are based on the current design and updating the calculation to be consistent with DOE’s real estate guidance. New facilities information will be identified and reported in accordance with DOE guidance.

8. Acquisition Approach

The Acquisition Strategy, approved as part of CD-1-RR, documents the acquisition approach. DOE is acquiring design, construction, fabrication, and operation of LBNF through the Fermi Forward Discovery Group, LLC (FFDG), the M&O contractor responsible for FNAL. FFDG and FNAL, through the LBNF Project based at FNAL, are responsible to DOE to manage and complete construction of LBNF at both the near and remote site locations. FFDG and FNAL are assigned oversight and management responsibility for execution of the international DUNE research program, to include management of the DOE contributions to DUNE. Key reasons for this approach include:

- FNAL is the site of the only existing neutrino beam facility in the U.S. and, in addition to these facilities, provides a source of existing staff and expertise to be utilized for beamline and detector construction.
- FNAL can best ensure that effective and efficient coordination of LBNF and DUNE component design, construction, and installation with other FNAL research activities.
- FNAL possesses a DOE-approved procurement system with established processes and acquisition personnel necessary to acquire the components and services for the scientific hardware, equipment, conventional facilities, accelerator beamline, and detectors for LBNF and DUNE.
- FNAL has established a close working relationship with SURF and the SDSTA, the organization that manages and operates the remote site for the far detector in Lead, South Dakota.
- FNAL has extensive experience in managing complex construction, fabrication, and installation projects, both domestic (on-site and remote off-site) and international. This includes its deep involvement with multi-institutional collaborations, such as LHC and CMS projects at CERN, and the increasingly international neutrino experiments and program.

Given its federal, state, private, and international partnership structure, the LBNF/DUNE-US project’s acquisition approach is designed to effectively integrate contributions from all partners. Leading the

LBNF/DUNE-US Project, FNAL will collaborate and work with many institutions, including other DOE national laboratories (e.g. BNL, LBNL and SLAC), dozens of universities, foreign research institutions, and the SDSTA. FNAL will be responsible for overall project management, Near Site conventional facilities, and the beamline. FNAL will work with SDSTA to complete the conventional facilities construction at the SURF needed to house and outfit the DUNE far detector. With the DUNE collaboration, FNAL is also responsible for technical and resource coordination to support the DUNE far and near detector design and construction. DOE will provide in-kind contributions for DUNE detector systems, as agreed upon with the international DUNE collaboration.

International participation in the design, construction, and operation of LBNF and DUNE is essential. This is due to the inherently international nature of High Energy Physics, the global distribution of necessary talent and expertise, and DOE's lack of sufficient procurement or technical resources to perform all required construction and fabrication work. Contributions from other nations will be predominantly through the delivery of components built in their own countries by their own researchers. DOE negotiates agreements in cooperation with the Department of State on a bilateral basis with all contributing nations to specify their expected contributions and the working relationships during the construction and operation of the experiment.

DOE provides funding for the LBNF/DUNE-US Project directly to FNAL and collaborating DOE national laboratories via approved financial plans, and under management control of the LBNF/DUNE-US Project Office at FNAL, which will also manage and control DOE funding to the combination of university subcontracts and direct vendor procurements that are anticipated for the design, fabrication, and installation of LBNF and DUNE technical components. All actions will be performed in accordance with DOE approved procurement policies and procedures.

FNAL staff, or temporary staff working directly with FNAL personnel via subcontract, will perform much of the neutrino beamline component design, fabrication, assembly, and installation. The acquisition approach includes both new procurements based on existing designs, and re-purposed equipment from the Fermilab Accelerator Complex. For highly specialized components, FNAL will engage the Rutherford Appleton Laboratory (RAL) in the United Kingdom to design and fabricate them. RAL is a long-standing FNAL collaborator with proven experience in such components.

FNAL has adopted the Construction Manager/General Contractor (CM/GC) model for LBNF conventional facilities at the SURF Far Site. The Laboratory contracted with an architect/engineer (A/E) firm for design and a CM/GC subcontractor to manage the construction of these facilities. FNAL selected this strategy to reduce risk, enhance quality and safety performance, foster a more collaborative approach to construction, and enable reduced cost and shortened construction schedules through CM/GC options for self-performance or competitively bid subcontract award packages. FNAL determined that excavation scope should be openly competed as provided by the subcontract. An excavation subcontract was awarded within budget, and underground excavation was completed in FY 2024.

For the LBNF Near Site conventional facilities at FNAL, the laboratory will subcontract with an A/E firm for design and plans to utilize a traditional design-bid-build construction method, supported by additional procurements for preconstruction and construction phase services from a professional construction management firm.

The DOE and SDSTA entered a land lease for the LBNF Far Site conventional facilities on May 20, 2016, covering the area on which the DOE-funded facilities housing and supporting the LBNF and DUNE detector will be built. The lease and related realty actions provide the framework for DOE and FNAL to construct federally-funded buildings and facilities on non-federal land, and to establish a long-term (multi-decade) arrangement for DOE and FNAL to use SDSTA space to host the DUNE experiment. Modifications and improvements to the SDSTA infrastructure that directly support the LBNF/DUNE-US project are costed to the project. A cooperative agreement between HEP and SDSTA covers the costs of general facility operations, including repairs and improvements for the overall SURF site. Protections for DOE's real property interests in these infrastructure investments are acquired through the lease with SDSTA, contracts, and other agreements (e.g., easements). such as easements. DOE plans for FNAL to have responsibility for managing and operating the LBNF and DUNE far detector and facilities for a useful lifetime of 20 years and may contract with SDSTA for certain day-to-day management and maintenance services. At the end of useful life, federal regulations permit transfer of ownership to SDSTA, which is willing to accept ownership as a condition for the lease. FNAL developed an appropriate decommissioning before lease signing.