High Energy Physics

Overview

The High Energy Physics (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 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 key player 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.

In FY 2024, the Office of Science (SC) made a strategic move by realigning the Accelerator R&D and Production (ARDAP) program activities into a new division under the HEP program. This shift aims to consolidate expertise and capabilities in accelerator research and development (R&D), fostering efficiency and effectiveness in SC investments in this crucial field. The establishment of the HEP Accelerator and Technology (AT) Division represents a significant step forward, encompassing not only traditional accelerator technologies but also cutting-edge areas such as artificial intelligence/machine learning (AI/ML) and quantum information science (QIS). This integration of critical and innovative technologies will undoubtedly propel advancements in accelerator R&D, shaping the future of scientific innovation.

The HEP program enables scientific discovery and supports cutting edge R&D in five focused subprograms:

- Energy Frontier Experimental Physics accelerates particles to the highest energies ever made by humanity and collide them to produce and study the fundamental constituents of matter.
- Intensity Frontier Experimental Physics uses a combination of intense particle beams and highly sensitive detectors to make extremely precise measurements of particle properties, to study some of the rarest interactions predicted by the Standard Model, and to search for new physics.
- Cosmic Frontier Experimental Physics uses naturally occurring cosmic particles and phenomena to reveal the nature of dark matter, understand the cosmic acceleration caused by dark energy and inflation, infer certain neutrino properties, and explore the unknown.
- Theoretical and Interdisciplinary Physics provides the framework to explain experimental observations and gain a deeper understanding of nature.
- Accelerator and Technology R&D fosters innovative research methods and enabling technologies that emerge from AI/ML, QIS, microelectronics, accelerators, and instrumentation that will advance scientific knowledge in HEP and in a broad range of related fields, advancing DOE's strategic goals for science.

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

Highlights of the FY 2026 Request

The HEP FY 2026 Request of $1,112.8 million is a decrease of $111.7 million below the FY 2025 Enacted level.[b] This funding will prioritize fundamental research, operation and maintenance of scientific user facilities, facility upgrades, and projects outlined in the 2023 P5 report.

Research

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

- AI/ML: 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-development of quantum information experiment, theory, and technology aligned with HEP science drivers and exploring new capabilities in quantum sensing and computing. HEP will support the Superconducting Quantum Materials and Systems (SQMS) National QIS Research Center, led by Fermi National Accelerator Laboratory (FNAL).
- Microelectronics: Accelerate R&D into sensor materials, detector devices, advances in front-end electronics; provide adaptation to high-radiation, cryogenic temperature, or low radioactive background environments.

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 4,480, 2,880, and 2,947 hours, respectively. BeamNetUS will provide user access to beam test facilities at nine U.S. 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; Vera C. Rubin Observatory in Chile; and Dark Energy Spectroscopic Instrument (DESI) at the Mayall telescope in Kitt Peak, 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.

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[b] In FY 2025, HEP and ARDAP enacted amounts total $1,225 million and $27 million, respectively. In comparison to the sum of the FY 2025 HEP and ARDAP Enacted budgets, the FY 2026 Request represents a decrease of $138.7 million.

High Energy Physics
Funding

	(dollars in thousands)			
	FY 2024 Enacted	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
High Energy Physics				
Energy Frontier, Research	69,848	66,835	31,450	-35,385
Energy Frontier, Facility Operations and Experimental Support	52,800	51,750	52,000	+250
Energy Frontier, Projects	35,700	33,700	28,400	-5,300
Total, Energy Frontier Experimental Physics	**158,348**	**152,285**	**111,850**	**-40,435**
Intensity Frontier, Research	65,394	58,103	33,902	-24,201
Intensity Frontier, Facility Operations and Experimental Support	190,411	221,000	234,000	+13,000
Intensity Frontier, Projects	5,000	10,000	10,000	–
Total, Intensity Frontier Experimental Physics	**260,805**	**289,103**	**277,902**	**-11,201**
Cosmic Frontier, Research	47,727	47,409	24,184	-23,225
Cosmic Frontier, Facility Operations and Experimental Support	57,056	56,500	54,900	-1,600
Cosmic Frontier, Projects	4,500	4,500	–	-4,500
Total, Cosmic Frontier Experimental Physics	**109,283**	**108,409**	**79,084**	**-29,325**
Theoretical, Computational, and Interdisciplinary Physics, Research	166,584	169,042	–	-169,042
Theoretical,Comp,&InterPhy,Facility Operations and Experimental Supp	–	8,845	–	-8,845
Total, Theoretical, Computational, and Interdisciplinary Physics	**166,584**	**177,887**	**–**	**-177,887**
Theoretical and Interdisciplinary Physics, Research	–	–	26,103	+26,103
Total, Theoretical and Interdisciplinary Physics	**–**	**–**	**26,103**	**+26,103**
Advanced Technology R&D, Research	74,361	72,886	–	-72,886
Advanced Technology R&D, Facility Operations and Experimental Support	54,619	48,000	–	-48,000
Total, Advanced Technology R&D	**128,980**	**120,886**	**–**	**-120,886**
Accelerator & Technology R&D, Research	–	–	186,521	+186,521
Accel & Tech R&D, Facility Operations & Experimental Support	–	–	66,376	+66,376
Total, Accelerator & Technology R&D	**–**	**–**	**252,897**	**+252,897**

(dollars in thousands)	FY 2024 Enacted	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
Subtotal, High Energy Physics	824,000	848,570	747,836	-100,734
Construction				
18-SC-42 Proton Improvement Plan II (PIP-II), FNAL	125,000	125,000	114,000	-11,000
11-SC-40 Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment	251,000	251,000	251,000	–
Subtotal, Construction	376,000	376,000	365,000	-11,000
Total, High Energy Physics	1,200,000	1,224,570	1,112,836	-111,734

SBIR/STTR funding:

- FY 2024 Enacted: SBIR $13,385,000 and STTR $1,882,000
- FY 2025 Enacted: SBIR $13,241,000 and STTR $1,862,000
- FY 2026 Request: SBIR $9,496,000 and STTR $1,335,000

High Energy Physics
Explanation of Major Changes

	(dollars in thousands) FY 2026 Request vs FY 2025 Enacted
Energy Frontier Experimental Physics The Request will decrease due in part to the HL-LHC ATLAS and CMS Detector Upgrade Projects planned reduction in accordance with the baselined funding profiles. The Request will strategically focus research on the highest impact areas.	-40,435
Intensity Frontier Experimental Physics The Request includes a net decrease with increased support for SURF and the Fermilab Accelerator Complex to operate 4,480 hours and support a new GPP, which will replace a critical 345kV substation transformer that provides power to the accelerators. Funding for research decreases and is redirected to administration priorities. Research will focus on maximizing scientific return from ongoing experiments and making critical contributions to the LBNF/DUNE project.	-11,201
Cosmic Frontier Experimental Physics The Request includes a pause for the CMB-S4 project as it reassesses its approach to achieving the science goals without the South Pole site access. Research funding will strategically focus on researchers and collaborations focused on maximizing scientific return from leading dark energy and dark matter experiments.	-29,325
Theoretical, Computational, and Interdisciplinary Physics This subprogram will conclude in FY 2025. Beginning with the FY 2026 Request, Theoretical Physics and Broadening Engagement in HEP, will move to the Theoretical and Interdisciplinary Physics subprogram, and the technology activities of Computational HEP, QIS, and AI/ML will move to the Accelerator & Technology R&D subprogram.	-177,887
Theoretical and Interdisciplinary Physics While this is a new subprogram in FY 2026, the Request will enhance HEP research capacity, workforce training, and career pathways for individuals and institutions while strategically supporting key theoretical research groups to sustain momentum in the most promising areas of high energy physics.	+26,103
Advanced Technology R&D This subprogram will conclude in FY 2025. Beginning with the FY 2026 Request, the HEP accelerator R&D and detector R&D activities will move to the Accelerator & Technology R&D subprogram.	-120,886

	(dollars in thousands)
	FY 2026 Request vs FY 2025 Enacted
Accelerator & Technology R&D[c]	+252,897
The Request will increase support to 1) highly targeted AI/ML methods to identify phenomena, improve fundamental tests, and measure with precision; and 2) QIS to enable expanded work in quantum sensing and computing at the national laboratories, strengthening the contribution of QIS techniques and expertise to the HEP mission. The Request will support FACET-II and ATF to operate 2,880 and 2,947 hours, respectively and support BeamNetUS. Research funding will strategically focus on supporting world-leading accelerator R&D, advanced particle detector technology, and computationally advanced tools and methods to maximize HEP discovery science. The increase also represents the shift of funds from the Theoretical, Computational, and Interdisciplinary Physics and Advanced Technology R&D subprograms, and the ARDAP program activities.	
Construction	-11,000
The Request will decrease support for PIP-II in accordance with the baselined funding profile.	
Total, High Energy Physics	-111,734

[c] This new subprogram will begin with the FY 2026 Request, comprised of activities: HEP General Accelerator R&D, Accelerator Stewardship, Accelerator Development, Detector R&D, Computational HEP, AI/ML, QIS, and Microelectronics.

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.[d] Cross-cutting accelerator R&D is closely coordinated within SC[e] and with partner agencies[f] 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 a U.S. company 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)[g] 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[h]. 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 (e.g., SC AI Roundtables[i]), data capture, and Basic Research Needs workshops[j] 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. The SC National QIS Research Center (NQISRC) efforts engage industry to connect both use-inspired research with development efforts, and it utilizes partnerships to improve technology for superconducting quantum computing.

Program Accomplishments

Excavation completes on colossal caverns for underground neutrino laboratory (Construction)

On August 15, 2024, a ribbon-cutting event was held at the Sanford Underground Research Facility (SURF) in Lead, S.D. to mark the completion of excavation work for the Long-Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE), an international project led by the U.S. Department of Energy's Fermi National Accelerator Laboratory (FNAL). The "Into the Depths of Discovery" event, hosted by FNAL and the South Dakota Science and Technology Authority (SDSTA), was attended by supporters of the three-year excavation of the caverns, including state and federal leaders as well as DOE officials. Engineering, construction and excavation teams have worked 4,850 feet below the surface since 2021 at SURF to prepare the space needed for the experiment. Over 800,000 tons of rock were excavated and moved from underground to an expansive former surface mining area known as the Open Cut, a testament to the scale of the project. To accomplish this feat, construction crews dismantled heavy mining equipment and, piece by piece, transported it underground. Workers then reassembled the machinery and have since been diligently blasting and relocating rock. To house the gigantic LBNF/DUNE particle detector modules, two colossal caverns were completed, each

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[d] https://www.osti.gov/servlets/purl/1863553

[e] Specifically, with the Basic Energy Sciences, Fusion Energy Sciences, Nuclear Physics, and Isotope R&D and Production programs.

[f] 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), and the National Science Foundation/Mathematical and Physical Sciences (NSF/MPS) Division.

[g] Supercharging Research: Harnessing Artificial Intelligence to Meet Global Challenges https://www.whitehouse.gov/wp-content/uploads/2024/04/AI-Report_Upload_29APRIL2024_SEND-2.pdf

[h] Roadmap Workshop reports may be found at https://science.osti.gov/hep/Community-Resources/Reports

[i] HEP participation was concentrated in the roundtables on Facilities, High Energy and Nuclear Physics, and Microelectronics.

[j] Basic Research Needs workshop reports may be found at https://science.osti.gov/ardap/Resources

more than 500 feet long and seven stories tall. The two detectors will each be filled with 17,000 tons of liquid argon cooled to minus 184 degrees Celsius to record and study the rare interactions of neutrinos.

First results from DESI make the most precise measurement of our expanding universe (Cosmic Frontier Experimental Physics)
With 5,000 tiny robots in a mountaintop telescope, researchers using the Dark Energy Spectroscopic Instrument (DESI) have peered 11 billion years into the past, creating an unprecedented view of the early universe. This innovative technology allows us to map the cosmos as it was in its youth and track its growth to the present day. Understanding the evolution of our universe is crucial in unraveling the mysteries of dark energy, the force propelling the universe to expand at an accelerated pace. DESI has crafted the most extensive 3D map of our cosmos to date, showcasing the universe's evolution over the past 11 billion years with unprecedented precision. By measuring the expansion history of the early universe with over 1 percent accuracy, scientists have gained unparalleled insights into its evolution, revolutionizing our understanding of its composition. The leading model of the universe, Lamda CDM, incorporating cold dark matter and dark energy, has provided a framework for understanding the cosmos. However, DESI's findings, when combined with data from other studies, reveal subtle deviations from the model's predictions. As DESI continues its five-year survey, more refined results will shed light on potential new explanations or modifications required to enhance our model. DESI's ongoing research will not only refine our understanding of dark energy effects but also provide insights into crucial aspects like the Hubble constant and the mass of neutrinos. The pursuit of knowledge through DESI's groundbreaking work promises to deepen our comprehension of the cosmos and its intricate workings.

SLAC completes construction of the largest digital camera ever built for astronomy (Cosmic Frontier Experimental Physics)
After two decades of dedicated work, scientists and engineers at the DOE's SLAC National Accelerator Laboratory (SLAC) and partners mark the completion of the groundbreaking Legacy Survey of Space and Time (LSST) Camera. The 3,200-megapixel camera, at the core of the Vera C. Rubin Observatory, promises unparalleled insights into our universe. Over ten years, this camera will amass a vast amount of data on the southern night sky, powering the pursuit of understanding dark energy and dark matter, fundamental to the universe's workings. The SLAC team and collaborators have crafted the most extensive digital camera for astronomy, akin to a small car in size and weighing over 3.3 tons. Featuring a front lens over five feet across, the camera boasts a three-foot-wide lens essential for maintaining optical clarity and sealing the vacuum chamber. Its focal plane, composed of 201 custom-designed CCD sensors, ensures precision with pixels only 10 microns wide. Following rigorous testing at SLAC, the LSST Camera heads to Chile, destined for the Simonyi Survey Telescope atop 8,900-foot-high Cerro Pachón in the Andes. Once operational, this camera will meticulously map celestial objects, offering valuable insights such as weak gravitational lensing, shedding light on the universe's mass distribution and the impact of dark energy on cosmic expansion. Exciting times lie ahead for cosmologists and researchers as the LSST Camera gears up to unravel the mysteries of the cosmos.

FNAL delivers new capabilities in quantum information processing using accelerator technology (QIS)
Fermilab leads the Superconducting Quantum Materials and Systems Center (SQMS), one of DOE's five National QIS Research Centers. This center works to leverage the decades of expertise Fermilab has developed in superconducting technology and the operation of world-class large-scale scientific facilities to realize the potential of quantum computing. This year, the FNAL team unveiled a groundbreaking quantum device with world-record coherence time using superconducting radiofrequency (SRF) cavities. These SRF cavities, originally developed to enable high-power accelerator beams, are now repurposed to precisely manipulate quantum states of light to enable high-density, scalable quantum information processing. In a field where devices can often only be operated for microseconds before encountering a fatal error, SRF cavities can store quantum information for up to two seconds, while enabling gates with error rates of less than 0.1%. Additionally, these multi-level devices, called "qudits," dramatically pack large amounts of information into a single device, allowing more complicated computations to be run on less hardware. In the future, Fermilab will work with industry partners to realize a scaled-up version of this new model of computing while co-developing the required control and refrigeration technology. As these technologies advance, they can also enable new modes of quantum sensing that could be used to detect dark matter, gravitational waves, or other new physics targets.

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% 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 to determine if it behaves as predicted by the Standard Model and to search for new physics.
- *Search for direct evidence of new particles*
  Direct searches at the LHC are looking for new particles, leveraging increased collision rates for more precise studies. Over a decade of LHC searches has yielded vast datasets and 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 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. This "indirect" detection complements direct detection experiments in the Cosmic and Intensity Frontiers.

Research

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

- **Analyzing Higgs boson decay patterns:** Revealing subtle deviations from the Standard Model and providing insights into new physics.
- **Processing LHC data:** Identifying new particle signatures, suppressing background noise, and optimizing search strategies.
- **Investigating complex collision events:** 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.

Facility Operations and Experimental Support

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

Projects

CERN is upgrading the LHC to the High-Luminosity LHC (HL-LHC), increasing the collision rate to explore new physics. HEP contributed by 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 2025 Enacted		FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
Energy Frontier Experimental Physics	**$152,285**	**$111,850**	**-$40,435**
Research	$66,835	$31,450	-$35,385
This funding supports researchers who are actively involved in the ATLAS and CMS experiments, leveraging AI/ML techniques across various activities to accelerate discoveries and enhance our understanding of fundamental physics.		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.	Research funding will strategically focus on the highest impact areas: exploring new physics at the LHC and making critical contributions to the HL-LHC detector upgrades.
Facility Operations and Experimental Support	$51,750	$52,000	+$250
This funding supports ongoing ATLAS and CMS detector maintenance and operations activities at CERN, and data taking using the U.S.-based computing infrastructure and resources.		The Request will continue 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.	Increased funding will prioritize the essential upgrades to U.S.-based computing infrastructure, ensuring efficient analysis of the large datasets from the LHC. This is partially offset by a reduction in ongoing ATLAS and CMS detector maintenance activities as integration efforts for the HL-LHC detector upgrades progress.
Projects	$33,700	$28,400	-$5,300
This funding supports fabrication activities for the HL-LHC ATLAS and the HL-LHC CMS Detector Upgrades.		The Request will support fabrication activities for the HL-LHC ATLAS and the HL-LHC CMS Detector Upgrades.	Funding will decrease as planned, according to the established funding profile for each HL-LHC detector upgrade project, as they continue through their respective fabrication activities.

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

Description

The 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 they occur at much higher energies 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*
  Intense proton beams can reveal quantum imprints of new phenomena beyond the reach 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.

Research

This activity supports scientists at research institutions and DOE national laboratories who work on neutrino and rare decay experiments in many roles – from designing equipment to analyzing data. A major focus is accelerator-based neutrino physics at Fermi National Accelerator Laboratory (FNAL), including the Short-Baseline Neutrino (SBN) program, which searches for neutrino types beyond the three currently described in the Standard Model, and the LBNF/DUNE, a 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.

Facility Operations and Experimental Support

The key component of this activity is support for facility operations and experimental activities, including the Fermilab Accelerator Complex User Facility. This includes the operations of all accelerators and beamlines at FNAL; the operation of detectors; computing support; and scientific collaboration support. Accelerator Improvement Project (AIP) and General Plant Project (GPP) funding supports facility improvements. From data analysis and accelerator control, AI/ML is being widely applied in HEP to enhance efficiency, improve accuracy, and unlock new insights from complex datasets.

This subprogram supports the South Dakota Science and Technology Authority (SDSTA) cooperative agreement which supports basic services and critical infrastructure upgrades at the Sanford Underground Research Facility (SURF) in South Dakota. SURF hosts experiments including the HEP-supported LZ experiment, and will be the home of the DUNE far site detectors.

Projects
FNAL is upgrading its outdated accelerator control system with a modern system capable of utilizing advances in AI/ML to create a high-performance accelerator. The Accelerator Controls Operations Research Network (ACORN) MIE is critical for initiating particle beam production, controlling beam parameters; steering beams, and monitoring beam transport throughout the Fermilab Accelerator Complex.

Activities and Explanation of Changes

(dollars in thousands)

FY 2025 Enacted		FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
Intensity Frontier Experimental Physics	**$289,103**	**$277,902**	**-$11,201**
Research	$58,103	$33,902	-$24,201
This funding drives progress in understanding neutrino properties and rare processes by supporting key experiments like SBN and DUNE, with AI/ML playing a crucial role in data analysis, signal identification, and experimental optimization.		The Request will maintain support for researchers actively involved in the ongoing experiments and future projects, prioritizing the use of AI/ML techniques to sustain progress in fundamental physics discovery.	Research funding will strategically focus on maximizing scientific return from ongoing experiments and making critical contributions to the LBNF/DUNE project. Prioritization of AI/ML-driven data analysis and experimental optimization will ensure efficient progress towards unlocking fundamental insights.
Facility Operations and Experimental Support	$221,000	$234,000	+$13,000
This funding supports HEP facility operations, experimental activities, and critical infrastructure at FNAL and SURF, including the incorporation of AI/ML to enhance efficiency and facilitate scientific discovery.		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 and to advance modernization efforts, such as AI/ML upgrades.	Increased funding will support a new GPP, which will replace a critical 345kV substation transformer that provides power to the accelerators. It will also support new infrastructure at the Helen Edwards Engineering Research Center at FNAL, as well as ongoing modernization efforts at SURF.
Projects	$10,000	$10,000	$ —
This funding supports the ACORN MIE system design and other related engineering activities required to reach CD-1.		The Request will support the ACORN MIE system design and other related engineering activities required to reach CD-1 in FY 2026.	No change.

Note:

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

Description

The Cosmic Frontier Experimental Physics subprogram uses measurements and observations to probe fundamental physics questions about dark matter, dark energy, neutrino properties, and new phenomena. Experiments are typically 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*
  Surveys of galaxies will determine the nature of dark energy. Measurements of the cosmic microwave background (CMB) signal and light from distant galaxies map cosmic acceleration and inform researchers about 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 US. 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 to simulate different experimental configurations and identify the most efficient and effective designs.
- **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 the Vera C. Rubin Observatory are driving progress in understanding dark energy. This subprogram 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, data handling, and dissemination. The DOE conducts reviews to ensure readiness and assess ongoing operations. DESI is located on the NSF's Mayall Telescope in Arizona, managed by LBNL. DOE and NSF jointly operate the Vera C. 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[k].

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

Projects
The DOE was a partner in the CMB-S4 project (CD-0 issued July 25, 2019) seeking to detect primordial gravitational waves and search for relic particles. However, because the NSF has put the South Pole component of CMB-S4 on hold, the DOE is pausing its involvement to reassess its approach.

Activities and Explanation of Changes

(dollars in thousands)

FY 2025 Enacted		FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
Cosmic Frontier Experimental Physics	**$108,409**	**$79,084**	**-$29,325**
Research	$47,409	$24,184	-$23,225
This funding drives progress in understanding dark energy and dark matter by supporting key experiments like DESI, Vera Rubin, LZ, and SuperCDMS-SNOLAB, with AI/ML playing a crucial role in data analysis, signal identification, and experimental optimization.		The Request will continue 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.	Research funding will strategically focus on researchers and collaborations focused on maximizing scientific return from leading dark energy and dark matter experiments. Prioritization of AI/ML-driven data analysis and experimental optimization will ensure efficient progress towards unlocking fundamental insights.
Facility Operations and Experimental Support	$56,500	$54,900	-$1,600
This funding ensures the smooth operation of key Cosmic Frontier experiments like DESI, Vera Rubin, LZ, and SuperCDMS-SNOLAB.		The Request will continue to support the collection, processing, and analysis of data from leading Cosmic Frontier experiments.	Funding will prioritize the efficient operation of key Cosmic Frontier experiments, particularly the Vera C. Rubin Observatory and SuperCDMS-SNOLAB, utilizing AI/ML to improve efficiency and accelerate discoveries in dark energy and dark matter research.
Projects	$4,500	$ —	-$4,500
This funding supports continued engineering and design efforts for the CMB-S4 project, including a site study for a Chile-only deployment.		No funding will be requested for this activity.	The DOE will pause the CMB-S4 project and will reassess its approach to achieving the science goals.

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

Description

The Theoretical and Interdisciplinary Physics subprogram (formerly the Theoretical, Computational, 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 for 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.

Theory

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 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.

Broadening Engagement in HEP

This activity expands participation in HEP research by reaching new communities and institutions. Supported initiatives include:

- **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:** Provides hands-on research experiences for students and early-career professionals at DOE national laboratories.
- **Veteran Applied Laboratory Occupational Retraining (VALOR)**: Offers training and career placement at DOE national laboratories for Junior Reserve Officer Training Corps (JROTC) cadets and veterans transitioning to civilian careers.

Activities and Explanation of Changes

(dollars in thousands)

FY 2025 Enacted		FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
Theoretical, Computational, and Interdisciplinary Physics	**$177,887**	**$ —**	**-$177,887**
Research	$169,042	$ —	-$169,042
Theory	*$42,564*	*$ —*	*-$42,564*
This funding supports world-leading theoretical research groups focused on key areas in high energy physics, leveraging AI/ML for accelerating calculations and building new models, and QIS for exploring novel theoretical frameworks and simulating complex quantum systems.		N/A	Funding for FY 2026 is requested in the Theoretical and Interdisciplinary Physics subprogram.
Computational HEP	*$20,236*	*$ —*	*-$20,236*
This funding supports the multi-laboratory HEP and ASCR SciDAC partnerships, and a dedicated Traineeship Program.		N/A	Funding for FY 2026 is requested in the Accelerator and Technology R&D subprogram.
Quantum Information Science	*$50,566*	*$ —*	*-$50,566*
This funding brings together experts in HEP and QIS to work on joint research projects. It also supports the Superconducting Quantum Materials and Systems Center (SQMS), which is one of the national centers for QIS research.		N/A	Funding for FY 2026 is requested in the Accelerator and Technology R&D subprogram.

(dollars in thousands)

FY 2025 Enacted	FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
Artificial Intelligence and Machine Learning *$52,877*	*$ —*	*-$52,877*
This funding advances the HEP mission by investing in AI/ML research and development, promoting innovative solutions to cross-cutting challenges and building a strong AI/ML community within the field.	N/A	Funding for FY 2026 is requested in the Accelerator and Technology R&D subprogram.
Broadening Engagement in HEP *$2,799*	*$ —*	*-$2,799*
This funding broadens participation in HEP by providing research and training opportunities at DOE national labs through initiatives like EPSCoR, SAGE, and VALOR.	N/A	Funding for FY 2026 is requested in the Theoretical and Interdisciplinary Physics subprogram.
Facility Operations and Experimental Support *$8,845*	*$ —*	*-$8,845*
This funding supports AI enhanced faciltities from optimizing accelerator control systems and detector performance to enabling the processing of very large datasets and accelerating the pace of scientific discovery.	N/A	Funding for FY 2026 is requested in the Accelerator and Technology R&D subprogram
Theoretical and Interdisciplinary Physics **$ —**	**$26,103**	**+$26,103**
Research $ —	$26,103	+$26,103
Theory *$ —*	*$23,103*	*+$23,103*
The Theory activity was requested as part of the Theoretical, Computational, and Interdisciplinary Physics subprogram in FY 2025 with a funding level of $42,564,000.	The Request will continue to support world-leading theoretical particle physics research.	This funding will strategically support key theoretical research groups, emphasizing the innovative application of AI/ML and QIS to sustain momentum in the most promising areas of high energy physics.
Broadening Engagement in HEP *$ —*	*$3,000*	+$3,000
The Broadening Engagement in HEP activity was requested as	The Request will continue to support HEP awards through	Funding will enhance HEP research capacity, workforce training, and

(dollars in thousands)

FY 2025 Enacted	FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
part of the Theoretical, Computational, and Interdisciplinary Physics subprogram in FY 2025 with a funding level of $2,799,000.	EPSCoR, and internships through SAGE Journey and VALOR.	career pathways for individuals and institutions.

Note:

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

High Energy Physics
Accelerator & Technology R&D

Description

The Accelerator and Technology R&D subprogram (formerly the Advanced Technology R&D subprogram and Accelerator R&D and Production program) supports the cutting-edge basic research necessary to develop 21st century tools of science, such as advanced particle accelerators and detectors. The subprogram supports research and development (R&D) in a wide range of areas, including: the physics of particle beams, accelerator technology, particle and radiation detection, computational methods for High Energy Physics (HEP), quantum information science (QIS), artificial intelligence/machine learning (AI/ML), and microelectronics. It also funds world-leading scientific facilities at five DOE national laboratories. These activities directly contribute to all six P5 science drivers and support the Energy, Intensity, and Cosmic Frontier Experimental Physics subprograms, as well as Theoretical Physics. Furthermore, the subprogram develops technologies with broad benefits for science and society, and provides advanced training to develop a highly skilled workforce in scientific and technical fields. This subprogram achieves its goals through targeted efforts in General Accelerator R&D, Accelerator Stewardship, Accelerator Development, Detector R&D, Computational HEP, AI/ML, QIS, and Microelectronics.

General Accelerator R&D

The GARD activity supports the science underlying the technologies used in particle accelerators, colliders, and storage rings, as well as the fundamental physics of charged particle beams to enable future discoveries in HEP. Long-term research goals include developing technologies to dramatically improve particle accelerator performance by optimizing beam energy, intensity, quality, and control, while reducing cost and size. This supports scientists and engineers at research institutions and DOE national laboratories, focusing on five key areas: accelerator and beam physics, advanced acceleration concepts, particle sources and targetry, radio-frequency (RF) acceleration technology, and superconducting magnets and materials. In 2023, DOE published a technology report, developed through a community study, to guide future research in accelerator and beam physics.[i] This activity supports the graduate Traineeship Program for Accelerator Science and Engineering. This program aims to revitalize education, training, and innovation in accelerator physics, benefiting HEP, other Office of Science programs, and various DOE initiatives that rely on the aforementioned technologies. This activity also supports curiosity driven accelerator R&D, investing in Office of Science facilities to maintain U.S. leadership and develop a skilled workforce for future facilities.

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 facilitates access to unique state-of-the-art superconducting accelerator R&D infrastructure for the private sector and other users through BeamNetUS. This activity also supports the development of software and material properties databases that are essential for accelerator design. Research activities in cross-cutting accelerator technologies encompass a wide range of areas: superconducting magnets and accelerators, beam physics, new particle sources, advanced high-intensity laser technology, and high-efficiency RF power sources. These efforts also include developing science-based accelerator controls and advanced simulation software.

Accelerator Development

This activity fosters partnerships between industry, academia, and DOE national laboratories. These collaborations address critical supply chain vulnerabilities for scientific facilities supported by the Office of Science. Strengthening domestic accelerator technology suppliers enhance their ability to produce advanced components and drive innovation, ultimately supporting the Office of Science mission to conduct world-leading scientific research. Focus areas include advanced superconducting wire and cable, superconducting RF cavities, novel materials, and high efficiency RF power sources for accelerators.

[i] https://science.osti.gov/hep/-/media/hep/pdf/2022/ABP_Roadmap_2023_final.pdf

Detector R&D
This activity supports the development of the next generation instrumentation, particle detectors, and radiation-hardened devices. This is essential for maintaining U.S. scientific leadership that is expanding into new research areas and leveraging state-of-the-art technologies such as quantum sensors, advanced microelectronics, and 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
This activity supports advanced computing R&D to address challenges in high energy physics, enabling scientific discoveries that are otherwise inaccessible through experiments, observations, or traditional theoretical methods. This activity also supports the multi-laboratory HEP Center for Computational Excellence (CCE), which advances HEP computing by developing common software tools and adapting HEP applications to the latest high performance computing platforms, including exascale systems. Computational HEP partners with the Office of Science's Advanced Scientific Computing Research (ASCR) program to support Scientific Discovery through Advanced Computing (SciDAC), to ensure optimized HEP computing ecosystems for the near- and long-term future. This activity also supports the graduate Traineeship Program in Computational High Energy Physics, training scientists in critical skills, including AI/ML and software development supporting exascale systems.

Artificial Intelligence and Machine Learning
The AI/ML activity supports the development and application of cutting edge artificial intelligence and machine learning techniques to significantly enhance high energy physics research driving discoveries in this data-intensive science. AI is integrated in all aspects of the HEP program, from research and theoretical modeling to experiment design, facility operations, and enhanced AI-ready infrastructure like particle accelerators. This activity focuses on specific AI challenges that advance our scientific agenda and develop scientists with the AI expertise necessary to lead future flagship experiments.

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 were re-competed in 2024 and focus on topics in fundamental Quantum Theory, advancing Quantum Sensing, 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 of the overall Office of Science mission.

Microelectronics
This activity supports sensor materials R&D, advances in front-end electronics, and integrated sensor/processor architectures. HEP applications typically need to operate with exquisite energy efficiency and in extreme temperature or radiation environments. To address these requirements, HEP participates in a multi-program effort to conduct basic research in microelectronics technologies for computing, communication, sensing, and power, seeking transformative advances in energy efficiency and resilience when operating in extreme environments.

Facility Operations and Experimental Support
This activity supports the maintenance and operation of two Office of Science user facilities: FACET-II (a 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 the 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 nine 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 2025 Enacted		FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
Advanced Technology R&D	**$120,886**	**$ —**	**-$120,886**
Research	$72,886	$ —	-$72,886
General Accelerator R&D	*$48,360*	*$ —*	*-$48,360*
This funding supports researchers to advance particle accelerator technology in key areas such as high-field magnets and high-power lasers. The Traineeship Program for Accelerator Science and Engineering is also supported.		N/A	Funding for FY 2026 is requested in the Accelerator and Technology R&D subprogram.
Detector R&D	*$24,526*	*$ —*	*-$24,526*
This funding supports researchers to advance particle detector technology in key areas such as novel devices and new modalities for calorimetry, tracking, and timing. The Traineeship Program in HEP Instrumentation is also supported.		N/A	Funding for FY 2026 is requested in the Accelerator and Technology R&D subprogram.
Facility Operations and Experimental Support	$48,000	$ —	-$48,000
This funding provides access to and supports the operation of FACET-II at SLAC, as well as key accelerator and detector test facilities at DOE national laboratories, enabling cutting-edge high energy physics research.		N/A	Funding for FY 2026 is requested in the Accelerator and Technology R&D subprogram.
Accelerator & Technology R&D	**$ —**	**$252,897**	**+$252,897**
Research	$ —	$186,521	+$186,521
General Accelerator R&D	*$ —*	*$19,082*	*+$19,082*
The General Accelerator R&D activity was requested as part of the Advanced Technology R&D subprogram in FY 2025 with a funding level of $48,360,000.		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.	Research funding will strategically focus on supporting world-leading accelerator R&D, particularly in high-priority areas like high-field magnets and high-power lasers.

(dollars in thousands)

FY 2025 Enacted	FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
HEP Accelerator Stewardship *$ —*	*$9,373*	*+$9,373*
The Accelerator Stewardship research activity was requested as part of the Accelerator R&D and Production program in FY 2025 with a funding level of $13,713,000.	The Request will maintain targeted support for key research activities, emphasizing advancements in superconducting magnets, beam physics, and data analytics-based accelerator controls across various research sectors.	Research funding will focus its resources on supporting high-impact cross-cutting research in technologies with use in science, medicine, security, and industry; with the goal of strengthening U.S. competitiveness in research for the future.
Accelerator Development *$ —*	*$2,990*	*+$2,990*
The Accelerator Development research activity was requested as part of the Accelerator R&D and Production program in FY 2025 with a funding level of $5,522,000.	The Request will continue to support efforts to work with and strengthen domestic suppliers for critical accelerator technologies and ongoing business sector studies to inform future collaborations and strategic insights.	Research funding will strategically focus on its most effective public-private partnerships and collaborative R&D efforts aimed at strengthening domestic suppliers of critical accelerator technologies, such as high-efficiency RF power sources and advanced superconducting wire and cable.
Detector R&D *$ —*	*$12,254*	*+$12,254*
The Detector R&D activity was requested as part of the Advanced Technology R&D subprogram in FY 2025 with a comparatively adjusted funding level of $14,070,000[m].	The Request will maintain support for key expertise while sustaining essential aspects of Detector R&D, including the Traineeship Program in HEP Instrumentation.	Research funding will strategically focus on advanced particle detector technology in key areas such as novel devices and new modalities for calorimetry, tracking, and timing.
Computational HEP *$ —*	*$10,630*	*+$10,630*
The Computational HEP research activity was requested as part of the Theoretical, Computational, and Interdisciplinary Physics subprogram in FY 2025 with a funding level of $20,236,000.	The Request will maintain support for key expertise while sustaining essential aspects of Computational HEP, including the Traineeship Program in Computational HEP.	Research funding will prioritize computationally advanced tools and methods to maximize HEP discovery science, while continuing support for critical expertise in AI/ML and exascale computing.
Artificial Intelligence and Machine Learning *$ —*	*$64,670*	*+$64,670*
The AI/ML research activity was requested as part of the Theoretical, Computational, and Interdisciplinary Physics	The Request will support key advances from the use of AI/ML, enabling the management and analysis of vast datasets, the	Increased funding will support highly targeted AI/ML methods to identify phenomena, improve fundamental tests, and measure

[m] The funding total referenced is comparatively adjusted by removing the funding requested for Microelectronics as that funding is now being requested as an independent activity in FY 2026 in the Accelerator Technology R&D subprogram.

(dollars in thousands)

FY 2025 Enacted	FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
subprogram in FY 2025 with a funding level of $52,877,000.	optimization of complex detector and particle beam systems, and the acceleration of scientific discovery through identification of subtle patterns and anomalies.	precision. This includes innovative methods for subtle signals in unprecedented data sets from current and upcoming experiments (e.g., LHC, Vera Rubin, DUNE), techniques for dark matter, novel dimensions, and searches for broken areas of symmetry.
Quantum Information Science *$ —*	*$57,066*	*+$57,066*
The QIS research activity was requested as part of the Theoretical, Computational, and Interdisciplinary Physics subprogram in FY 2025 with a funding level of $50,566,000.	The Request will support interdisciplinary HEP QIS efforts through individual research grants and the National QIS Research Centers.	Increased funding will enable expanded work in quantum sensing and computing at the national laboratories, strengthening the contribution of QIS techniques and expertise to the HEP mission.
Microelectronics *$ —*	*$10,456*	*+$10,456*
The Microelectronics research activity was requested within the Detector R&D activity in FY 2025 with a funding level of $10,456,000.	The Request will continue supporting microelectronics development at multiple national laboratories and universities as well as support for the Microelectronics Science Research Center projects.	No changes.
Facility Operations and Experimental Support $ —	$66,376	+$66,376
Funding for the BNL-ATF operations was requested as part of the Accelerator R&D and Production program and all other operations within the Advanced Technology R&D subprogram in FY 2025 with a combined comparatively adjusted funding level of $64,610,000.	The Request will continue 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 also support AI/ML to optimize the performance of HEP facilities, by automating control systems, predicting potential failures, and improving resource allocation.	Increased funding will support enhanced user access to accelerator facilities and user access to test facilities through BeamNetUS.

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

Description

This subprogram supports 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 project is enhancing the Fermilab Accelerator Complex to enable higher-power proton beams for neutrino production, facilitating groundbreaking neutrino physics discoveries. Construction includes an 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 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 2025 Enacted		FY 2026 Request	Explanation of Changes FY 2026 Request vs FY 2025 Enacted
Construction	**$376,000**	**$365,000**	**-$11,000**
18-SC-42, Proton Improvement Plan II (PIP-II), FNAL	$125,000	$114,000	-$11,000
This funding enables the construction of the linac building, as well as the fabrication and testing of production RF cavities, cryomodules, and related technical systems.		The Request will support ongoing construction of the linac building and the fabrication and testing of production RF cavities, cryomodules, and related technical systems.	The funding decrease is consistent with the baselined funding profile.
11-SC-40, Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment, FNAL	$251,000	$251,000	$ —
This funding supports both ongoing activities and the recently completed EXC subproject. Ongoing activities include construction of FSCF-BSI, long-lead procurements for FDC and NSCF+B subprojects, preparations for installation of far detector components for FDC, preparations for construction subcontracts for the Near Site facilities, and continue design and other planning efforts for NSCF+B and ND.		The Request will support ongoing construction of FSCF-BSI, begin installation of far detector components at FDC, and the design and prototyping activities for NSCF+B and ND.	Funding will remain constant and will be allocated to the subprojects.

High Energy Physics
Capital Summary

(dollars in thousands)

	Total	Prior Years	FY 2024 Enacted	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
Capital Operating Expenses						
Capital Equipment	N/A	N/A	46,200	58,924	37,800	-21,124
Minor Construction Activities						
General Plant Projects	N/A	N/A	171	5,000	9,000	+4,000
Accelerator Improvement Projects	N/A	N/A	900	–	–	–
Total, Capital Operating Expenses	**N/A**	**N/A**	**47,271**	**63,924**	**46,800**	**-17,124**

High Energy Physics
Capital Equipment

	(dollars in thousands)					
	Total	Prior Years	FY 2024 Enacted	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
Capital Equipment						
Energy Frontier Experimental Physics						
High Luminosity Large Hadron Collider ATLAS Upgrade Project	183,485	130,785	16,200	16,200	15,300	-900
High Luminosity Large Hadron Collider CMS Upgrade Project	158,550	112,838	19,500	17,500	7,500	-10,000
Intensity Frontier Experimental Physics						
Accelerator Controls Operations Research Network	102,301	–	500	1,000	10,000	+9,000
Total, Non-MIE Capital Equipment	N/A	N/A	10,000	24,224	5,000	-19,224
Total, Capital Equipment	**N/A**	**N/A**	**46,200**	**58,924**	**37,800**	**-21,124**

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 2024 Enacted	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
General Plant Projects (GPP)						
GPPs (greater than $5M and $34M or less)						
High Voltage Transformer Replacement	7,100	–	–	–	7,100	+7,100
Total GPPs (greater than $5M and $34M or less)	N/A	N/A	–	–	7,100	+7,100
Total GPPs $5M or less	N/A	N/A	171	5,000	1,900	-3,100
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**171**	**5,000**	**9,000**	**+4,000**
Accelerator Improvement Projects (AIP)						
Total AIPs $5M or less	N/A	N/A	900	–	–	–
Total, Accelerator Improvement Projects (AIP)	**N/A**	**N/A**	**900**	**–**	**–**	**–**
Total, Minor Construction Activities	**N/A**	**N/A**	**1,071**	**5,000**	**9,000**	**+4,000**

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 integrate a higher amount of data by at least a factor of ten. To operate the ATLAS detector for an additional decade at such intense physical conditions, the silicon pixel and strip tracker, muon, and calorimeter detectors, and the trigger and data acquisition systems will be upgraded.[n] The FY 2026 Request for TEC funding of $15,300,000 will be in accordance with the project's baselined funding profile and focuses on continuing fabrication activities of U.S.-built deliverables for the project.

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 integrate a higher amount of data by at least a factor of ten. To operate the CMS detector for an additional decade at such intense physical conditions, the silicon pixel tracker and outer tracker, muon, and calorimeter detectors, and the trigger and data acquisition systems will be upgraded,[a] and a novel timing detector will be added.[o] The FY 2026 Request for TEC funding of $7,500,000 is in accordance with the project's baselined funding profile and will focus on continuing fabrication activities of U.S.-built deliverables for the project.

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. This project will replace FNAL's outdated accelerator control system with a modern system compatible with PIP-II and capable of utilizing advances in AI/ML to create a high-performance accelerator 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 project is expected to receive CD-1 approval in FY 2026. The FY 2026 Request for TEC funding of $10,000,000 will fund system design and other related engineering activities.

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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.

High Energy Physics
Minor Construction Description(s)

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

High Voltage Transformer Replacement
General Plant Project Details

Project Name:	High Voltage Transfer Replacement
Location/Site:	Fermilab Accelerator Complex
Type:	GPP
Total Estimated Cost:	$7,100,000
Construction Design:	$0
Project Description:	The 345kV substations on site are beyond end of life and 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 2024 Enacted	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
18-SC-42, Proton Improvement Plan II (PIP-II), FNAL						
Total Estimated Cost (TEC)	891,200	380,000	125,000	125,000	114,000	-11,000
Other Project Cost (OPC)	86,800	73,594	-	-	-	-
Total Project Cost (TPC)	**978,000**	**453,594**	**125,000**	**125,000**	**114,000**	**-11,000**
11-SC-40, Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment						
Total Estimated Cost (TEC)	3,169,955	1,155,781	251,000	251,000	251,000	-
Other Project Cost (OPC)	107,045	105,625	-	-	-	-
Total Project Cost (TPC)	**3,277,000**	**1,261,406**	**251,000**	**251,000**	**251,000**	**-**
Total, Construction						
Total Estimated Cost (TEC)	N/A	N/A	376,000	376,000	365,000	-11,000
Other Project Cost (OPC)	N/A	N/A	-	-	-	-
Total Project Cost (TPC)	N/A	N/A	376,000	376,000	365,000	-11,000

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 2024 Enacted	FY 2024 Current	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
Scientific User Facilities - Type A					
Fermilab Accelerator Complex	**141,571**	**150,663**	**181,500**	**191,500**	**+10,000**
Number of Users	2,200	2,230	1,020	1,561	+541
Achieved Operating Hours	–	1,940	–	–	–
Planned Operating Hours	2,240	2,240	5,376	4,480	-896
Unscheduled Down Time Hours	–	1,014	–	–	–
Accelerator Test Facility	**–**	**–**	**–**	**8,980**	**+8,980**
Number of Users	–	–	–	88	+88
Planned Operating Hours	–	–	–	2,947	+2,947
Facility for Advanced Accelerator Experimental Tests II (FACET II)	**16,500**	**16,500**	**13,000**	**16,000**	**+3,000**
Number of Users	144	152	152	135	-17
Achieved Operating Hours	–	3,678	–	–	–
Planned Operating Hours	3,120	3,120	2,640	2,880	+240
Unscheduled Down Time Hours	–	580	–	–	–
Total, Facilities	**158,071**	**167,163**	**194,500**	**216,480**	**+21,980**
Number of Users	2,344	2,382	1,172	1,784	+612
Achieved Operating Hours	–	5,618	–	–	–
Planned Operating Hours	5,360	5,360	8,016	10,307	+2,291
Unscheduled Down Time Hours	–	1,594	–	–	–

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 2024 and FY 2025, funding, hours, and users for the Accelerator Test Facility were requested within the Accelerator R&D and Production program. For FY 2024 Enacted, $8,169,000, was planned to support 2,100 hours, and 112 users. In FY 2024 Current, $8,340,000 achieved 2,531 hours, 83 users, with 376 unscheduled downtime hours. In FY 2025 Enacted, $7,765,000 supports 480 planned hours, and 32 users.*
- *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 substation transformer repairs are completed.*

High Energy Physics
Scientific Employment

	FY 2024 Enacted	FY 2025 Enacted	FY 2026 Request	FY 2026 Request vs FY 2025 Enacted
Number of Permanent Ph.Ds (FTEs)	753	722	520	-202
Number of Postdoctoral Associates (FTEs)	364	349	250	-99
Number of Graduate Students (FTEs)	514	489	365	-124
Number of Other Scientific Employment (FTEs)	1,508	1,477	1,475	-2
Total Scientific Employment (FTEs)	**3,139**	**3,037**	**2,610**	**-427**

Note:

- *Other Scientific Employment (FTEs) includes technicians, engineers, computer professionals, and other support staff.*
- *The FY 2026 numbers represent a net decrease, which factors in both the addition of the FTEs from the merger of ARDAP program into HEP and the impact of the FY 2026 President's Budget Request funding level.*

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 2026 Request for the Proton Improvement Project II (PIP-II) is $114,000,000 of Total Estimated Cost (TEC) funding. The project has an approved Total Project Cost (TPC) of $978,000,000.

The PIP-II project will enhance the Fermilab Accelerator Complex to enable it to deliver higher-power proton beams to the neutrino-generating target for groundbreaking discovery in neutrino physics. The project will design and construct an 800 megaelectronvolt (MeV) superconducting radio frequency (SRF) proton linear accelerator and beam transfer line. The PIP-II project also will modify the existing Fermi National Accelerator Laboratory (FNAL) Booster, Recycler, and Main Injector synchrotrons downstream from the new linear accelerator to accept the increased beam intensity. Some of the new components and the cryo-plant will be provided through international, in-kind contributions.

Significant Changes

This project was initiated in FY 2018. The most recent DOE Order 413.3B Critical Decision (CD) is CD-3 (Approve Construction), approved on April 18, 2022. The planned date for CD-4, Project Completion, is 1Q FY 2033.

Anticipated in-kind technical contributions from international partners total $330,000,000 (equivalent to DOE costing). Legally binding agreements with all partnering countries, (except for the French Atomic Energy Commission [CEA]) have been signed to cover the planned in-kind contributions. The legally binding agreement with France for CEA has been drafted and signatures are expected in 2026. Non-binding Project Planning Documents (PPDs) that provide additional technical details beyond those provided in the legally binding agreements are being signed by the international partners. As of January 2022, PPDs were signed with the Italian, Polish, and UK partner institutions. The PPD with India's Department of Atomic Energy laboratories is expected to be signed in 2025.

The FY 2024 Appropriation supports the completion of the cryogenic plant building, continuation of the linac building civil construction, and continued development and testing of prototypes of the superconducting RF cavities and the cryomodules that hold them.

Significant usage of project cost contingency through 3Q FY 2024 was in response to a number of factors including: civil construction contract cost in excess of the baseline estimate due to market conditions; project-wide costs of the seven-month delay for recovery from the civil construction accident and restarting construction with augmented safety processes and management oversight; increased Fermilab overhead charge rates in FY 2024; procurement costs for mitigating schedule delays for delivery of critical in-kind contributions; electrical system design modifications for the cryoplant and linac to significantly improve personnel safety by reducing the risk of arc flash events (based on recently learned lessons at other DOE laboratories); and costs for management implementation of an overall schedule recovery plan.

The FY 2025 Enacted will support continuation of the linac building civil construction, continuing development and testing of prototypes of the superconducting RF cavities and cryomodules, as well as testing of the initial production cryomodules delivered by international partners as in-kind contributions.

The FY 2026 Request will support completion of linac building civil construction, and the fabrication and testing of production RF cavities, cryomodules, and other technical systems.

A Federal Project Director (FPD) has been assigned to this project and has approved this construction project datasheet. The FPD has a Level III certification.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2026	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 2026	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 2025	135,895	755,305	891,200	86,800	86,800	978,000
FY 2026	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, FNAL
SSR1 Cryomodule	2	325	16	U.S. DOE (FNAL), India DAE Labs	U.S. DOE (FNAL)	India DAE Labs	India DAE Labs, Poland WUST, FNAL
SSR2 Cryomodule	7	325	35	France CNRS (IN2P3 Lab)	U.S. DOE (FNAL)	India DAE Labs	India DAE Labs, Poland WUST, FNAL
LB-650 Cryomodule	9	650	36	Italy INFN (LASA)	France CEA (Saclay Lab)	India DAE Labs	India DAE Labs, Poland WUST, FNAL
HB-650 Cryomodule	4	650	24	UK STFC Labs	UK STFC Labs, U.S. DOE (FNAL)	India DAE Labs	India DAE Labs, Poland WUST, FNAL

[p] See Section 8.

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 1.3×10^{12} particles per pulse at 20 Hz pulse-repetition rate will be delivered to the Beam Transfer Line absorber.
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)				

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

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Prior Years	234,105	234,105	95,966	1,293
Prior Years - IRA Supp.	10,000	10,000	—	—
FY 2024	125,000	125,000	86,997	6,728
FY 2025	125,000	125,000	125,000	1,979
FY 2026	114,000	114,000	114,000	—
Outyears	147,200	147,200	323,342	—
Total, Construction (TEC)	**755,305**	**755,305**	**745,305**	**10,000**
Total Estimated Cost (TEC)				
Prior Years	370,000	370,000	231,861	1,293
Prior Years - IRA Supp.	10,000	10,000	—	—
FY 2024	125,000	125,000	86,997	6,728
FY 2025	125,000	125,000	125,000	1,979
FY 2026	114,000	114,000	114,000	—
Outyears	147,200	147,200	323,342	—
Total, Total Estimated Cost (TEC)	**891,200**	**891,200**	**881,200**	**10,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
Prior Years	73,594	73,594	73,420
FY 2024	–	–	1
FY 2025	–	–	173
Outyears	13,206	13,206	13,206
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	443,594	443,594	305,281	1,293
Prior Years - IRA Supp.	10,000	10,000	–	–
FY 2024	125,000	125,000	86,998	6,728
FY 2025	125,000	125,000	125,173	1,979

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
FY 2026	114,000	114,000	114,000	–
Outyears	160,406	160,406	336,548	–
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	182,000	177,000	124,009
Site Preparation	13,000	13,000	12,783
Equipment	455,305	403,760	378,705
Construction - Contingency	105,000	161,545	198,703
Total, Construction (TEC)	**755,305**	**755,305**	**714,200**
Total, TEC	**891,200**	**891,200**	**891,200**
Contingency, TEC	*105,000*	*161,545*	*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
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)	*113,504*	*170,049*	*237,893*

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2024	FY 2025	FY 2026	Outyears	Total
FY 2025	TEC	380,000	125,000	125,000	—	261,200	891,200
	OPC	73,594	—	—	—	13,206	86,800
	TPC	453,594	125,000	125,000	—	274,406	978,000
FY 2026	TEC	380,000	125,000	125,000	114,000	147,200	891,200
	OPC	73,594	—	—	—	13,206	86,800
	TPC	453,594	125,000	125,000	114,000	160,406	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 Research Alliance (FRA), the Management and Operating (M&O) contractor responsible for FNAL, rather than have the DOE compete a contract for fabrication to a third party. FRA 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 FRA, 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; 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 is putting 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 FRA's plans and performance. Project performance metrics for FRA are 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 will potentially transform our understanding about the nature of matter and the evolution of the universe. Department of Energy's Fermilab is the host laboratory for DUNE, in partnership with funding agencies and more than 1,400 scientists and engineers[r] from all over the globe. 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 2026 Request for Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE-US) project is $251,000,000 of Total Estimated Cost (TEC) funding.

The LBNF/DUNE-US scope is organized into five subprojects for improved planning and management control. The CD-1 Reaffirmation (CD-1RR) was approved on February 16, 2023. It established the subproject strategy and a cost range of $3,160,000,000 to $3,677,000,000. At the time of CD-1RR approval, the Total Project Cost (TPC) Point Estimate was $3,277,000,000. This TPC Point Estimate was for planning purposes and will be refined as the project matures and each subproject is baselined. The aggregate of the new baselined subproject TPCs must be below the upper end of the approved cost range. 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. As the project matures, the distribution of project engineering and design (PED) and construction are refined for accuracy. In addition, earlier investments with PED, like prototyping, have reduced risks and costs for the outyear 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

Since the previous project datasheet, the FDC subproject obtained CD-3c approval on February 21, 2025.

The FY 2024 funding supported completion of excavation of the far detector caverns, long-lead procurement items for FDC and NSCF+B, and site preparation activities for NSCF+B; initiated procurements of FSCF-BSI infrastructure including HVAC, electric, plumbing, etc.; and funded design, prototyping, and other planning efforts for FDC, NSCF+B, and ND in preparation for baseline and approval of construction.

The FY 2025 funding supports construction of FSCF-BSI; continue long-lead procurements for FDC and NSCF+B subprojects, preparations for installation of far detector components for FDC; preparations for construction subcontracts for the Near Site facilities, and continue design and other planning efforts for NSCF+B and ND.

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

The FY 2026 Request will continue to support the construction of FSCF-BSI, beginning the installation of far detector components at FDC, and the design and prototyping activities for NSCF+B and ND. NSCF+B activities will also to the potential award of construction subcontracts for the facilities.

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	1Q FY 2027	1Q FY 2027	3Q FY 2028	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	–	–	–	2Q FY 2026	8/10/23	2Q FY 2026	1Q FY 2033
Near Site Conventional Facilities and Beamline	–	–	–	3Q FY 2026	1Q FY 2027	3Q FY 2026	2Q FY 2034
Near Detector	–	–	–	1Q FY 2027	1Q FY 2027	3Q FY 2028	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	1Q 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	2Q FY 2026	—	2/16/23	2/21/23	2/28/24	2/21/25
Near Site Conventional Facilities and Beamline	3Q FY 2026	—	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 in order 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 in order 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 in order 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.

<u>Project Cost History</u>

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2025	569,694	2,593,641	3,163,335	113,665	113,665	3,277,000
FY 2026	705,838	2,464,117	3,169,955	107,045	107,045	3,277,000

Notes:
- *The project is Pre-CD-2 for some subprojects. 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

<u>Scope</u>
The LBNF/DUNE-US construction project is a federal, state, private, and international partnership developing and implementing the technologies of particle accelerators and detectors to enable world-leading research into the fundamental physics of neutrinos, which are the most ubiquitous and among the most 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, which occur as muon neutrinos travel to large detectors in South Dakota, 800 miles away from FNAL, where they are produced in a high-energy beam. The experiment will analyze the rare transformations of neutrinos in flight which are expected to help explain the fundamental physics of neutrinos and the puzzling matter-antimatter asymmetry that enables our existence in a matter-dominated universe.

LBNF/DUNE will be composed of a neutrino beam created by new construction as well as modifications to the existing Fermilab Accelerator Complex, massive neutrino detectors and associated cryogenics infrastructure located in large underground caverns to be excavated 800 miles "downstream" from the neutrino source at the Sanford Underground Research Facility (SURF). A much smaller neutrino detector will be installed at FNAL for monitoring the neutrino beam near its source. A primary beam of protons will produce a neutrino beam directed into a target for converting the protons into a secondary beam of particles (pions and muons) that decay into neutrinos, followed by a decay tunnel hundreds of meters long where the decay neutrinos will emerge and travel through the earth to the massive detector. The Neutrinos at the Main Injector (NuMI) beam at FNAL is an existing example of this type of configuration for a neutrino beam facility. The new LBNF beam line will provide a neutrino beam of greater intensity than the NuMI beam and would point to far detector modules at a greater distance than is used with NuMI experiments.

For the LBNF/DUNE-US project, FNAL will be responsible for design, construction, and operation of the major components of facilities 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.

Justification

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 the beamline and other experimental and civil infrastructure at FNAL and at SURF in South Dakota. SURF is currently operated by the South Dakota Science and Technology Authority (SDSTA), an agency of the State of South Dakota, and 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. DOE and FNAL host the international DUNE research program.

DOE's High Energy Physics program manages the DOE contributions to both 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. DUNE has international leadership and participation of over 1,400 scientists and engineers from over 200 institutions in over 30 countries. DOE will fund approximately one half of the DUNE detectors. This excludes the cryostats that hold the detectors. The cryostats will be provided by CERN. The project continues to refine the development of the design and cost estimates as the U.S. DOE contributions to the multinational effort now are 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*.

Key Performance Parameters (KPPs)
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 Infrastructure (FSCF-BSI)	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 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 ton (5.6 MW) chilled water capacity installed to support two detectors and all general cooling loads at the 4850L.	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 transformers/power distribution specific to detectors 3 and 4.
Far Detector – Horizontal Drift Detector Components (FDC)	Fabricate, deliver to SURF, and install the deliverables as specified in the detailed FDC subproject Threshold KPPs for the Horizontal Drift detector providing coverage for at least 95 percent of the detector volume.	Fabricate, deliver to SURF, and install the deliverables as specified in the detailed FDC subproject Objective KPPs for the Horizontal

Performance Measure	Threshold	Objective
	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.	Drift Detector providing full (100 percent) coverage.
Far Detector – Vertical Drift Detector Components (FDC)	Fabricate, deliver to SURF, and install the deliverables as specified in the detailed FDC subproject threshold KPPs 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 specified in the detailed FDC subproject Objective KPPs 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 the surface receiving facilities for the cryogenic liquids. 3) Install and commission the Argon purification, circulation, regeneration and Argon condensers system for two cryostat detectors. 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. Commit funds for the procurement of 30 percent of the LAr for each of the two far detectors.	In addition to the threshold KPPs: 1) Commit the funds for the procurement of the remaining 70 percent of the LAr for the two Far detectors. 2) Procure the required Liquid Xenon (10 ppm) required to improve light collection efficiency for the Vertical Drift Detector.

Performance Measure	Threshold	Objective
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 the final closure of the cryostat, 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 50 percent and a minimum of 95 percent fully functional electronic readout channels. 2) Close both cryostats in preparation for purging/filling Purge and fill both cryostats to 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) Purge and fill both cryostats to maximum level (100 percent) 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. Perform measurements of the electron lifetime in LAr using the purity monitors for each of the two cryostats.

Performance Measure	Threshold	Objective
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 absorber 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 • Cooling infrastructure includes a minimum of 650 tons of chiller capacity	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
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.	Using parts and components provided by both the project and in-kind by international partners: 1) Deliver a LAr Time Projection Chamber (TPC) detector system capable of measuring neutrino interactions in argon at the near site with similar performance as specified for the Far Detector to directly support long-baseline physics measurements in the DUNE FD 2) Ability to move the LAr TPC near detector system to an off-axis location 3) Ability to monitor the on-axis neutrino beam when the LAr TPC near detector system is off-axis

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	555,684	555,684	452,692	—
FY 2024	76,734	76,734	39,087	—
FY 2025	36,260	36,260	170,278	—
FY 2026	29,910	29,910	32,650	—
Outyears	7,250	7,250	11,131	—
Total, Design (TEC)	**705,838**	**705,838**	**705,838**	**—**
Construction (TEC)				
Prior Years	475,097	475,097	374,056	2,563
Prior Years - IRA Supp.	125,000	125,000	—	—
FY 2024	174,266	174,266	118,458	17,339
FY 2025	214,740	214,740	310,986	93,698
FY 2026	221,090	221,090	221,830	11,400
Outyears	1,253,924	1,253,924	1,313,787	—
Total, Construction (TEC)	**2,464,117**	**2,464,117**	**2,339,117**	**125,000**
Total Estimated Cost (TEC)				

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Prior Years	1,030,781	1,030,781	826,748	2,563
Prior Years - IRA Supp.	125,000	125,000	—	—
FY 2024	251,000	251,000	157,545	17,339
FY 2025	251,000	251,000	481,264	93,698
FY 2026	251,000	251,000	254,480	11,400
Outyears	1,261,174	1,261,174	1,324,918	—
Total, Total Estimated Cost (TEC)	**3,169,955**	**3,169,955**	**3,044,955**	**125,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
Prior Years	105,625	105,625	93,474
FY 2024	–	–	1,005
FY 2025	–	–	4,438
FY 2026	–	–	2,941
Outyears	1,420	1,420	5,187
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	1,136,406	1,136,406	920,222	2,563
Prior Years - IRA Supp.	125,000	125,000	–	–
FY 2024	251,000	251,000	158,550	17,339
FY 2025	251,000	251,000	485,702	93,698
FY 2026	251,000	251,000	257,421	11,400
Outyears	1,262,594	1,262,594	1,330,105	–
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	691,246	555,102	N/A
Design - Contingency	14,592	14,592	N/A
Total, Design (TEC)	**705,838**	**569,694**	N/A
Construction	1,369,163	1,362,798	N/A
Equipment	594,984	571,488	N/A
Construction - Contingency	499,970	659,355	N/A
Total, Construction (TEC)	**2,464,117**	**2,593,641**	N/A
Total, TEC	**3,169,955**	**3,163,335**	N/A
Contingency, TEC	*514,562*	*673,947*	*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	17,840	N/A
OPC - Contingency	2,890	2,890	N/A
Total, Except D&D (OPC)	**107,045**	**113,665**	N/A
Total, OPC	**107,045**	**113,665**	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*	*676,837*	*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 2024	FY 2025	FY 2026	Outyears	Total
FY 2025	TEC	1,155,781	251,000	280,000	—	1,476,554	3,163,335
	OPC	105,625	4,000	—	—	4,040	113,665
	TPC	1,261,406	255,000	280,000	—	1,480,594	3,277,000
FY 2026	TEC	1,155,781	251,000	251,000	251,000	1,261,174	3,169,955
	OPC	105,625	—	—	—	1,420	107,045
	TPC	1,261,406	251,000	251,000	251,000	1,262,594	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 become part of 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 being constructed in this project is replacing 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. The basis for this choice and strategy is that:

- 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 the design, construction, and installation of key LBNF and DUNE components are coordinated effectively and efficiently with other research activities at FNAL.
- FNAL has a DOE-approved procurement system with established processes and acquisition personnel needed to obtain the necessary components and services to build the scientific hardware, equipment and conventional facilities for the accelerator beamline, and detectors for LBNF and DUNE.
- FNAL has extensive experience in managing complex construction, fabrication, and installation projects involving multiple national laboratories, universities, and other partner institutions, building facilities both on-site and at remote off-site locations.
- 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 with management and participation in international projects and international collaborations, including most recently the LHC and CMS projects at CERN, as well as in the increasingly international neutrino experiments and program.

The LBNF/DUNE-US construction project is a federal, state, private and international partnership. 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 be providing in-kind contributions to the DUNE collaboration for detector systems, as agreed upon with the international DUNE collaboration.

International participation in the design, construction, and operation of LBNF and DUNE will be essential because the field of High Energy Physics is international by nature; necessary talent and expertise are globally distributed, and DOE does not have the procurement or technical resources to perform all of the 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 perform in accordance with DOE approved procurement policies and procedures.

FNAL staff, or by subcontract, temporary staff working directly with FNAL personnel, 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 some highly specialized components, FNAL will have the Rutherford Appleton Laboratory (RAL) in the United Kingdom design and fabricate the components. RAL is a long-standing FNAL collaborator who has proven experience with such components.

FNAL has chosen the Construction Manager/General Contractor (CM/GC) model to execute the delivery of LBNF conventional facilities at the SURF Far Site. The Laboratory contracted with an architect/engineer (A/E) firm for design of LBNF Far Site conventional facilities at SURF and with a CM/GC subcontractor to manage the construction of LBNF Far Site facilities. FNAL selected this strategy to reduce risk, enhance quality and safety performance, provide a more collaborative approach to construction, and offer the opportunity for reduced cost and shortened construction schedules, via options for the CM/GC to self-perform 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 the 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 plan 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.

For the LBNF Far Site conventional facilities at SURF, DOE entered into a land lease with SDSTA 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 to directly support the LBNF/DUNE-US project are costed to the project. Repairs and improvements for the overall facility are costed to a cooperative agreement between HEP and SDSTA for general operation of the facility. Protections for DOE's real property interests in these infrastructure investments are acquired through the lease with SDSTA, contracts, and other agreements 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 plan prior to lease signing.